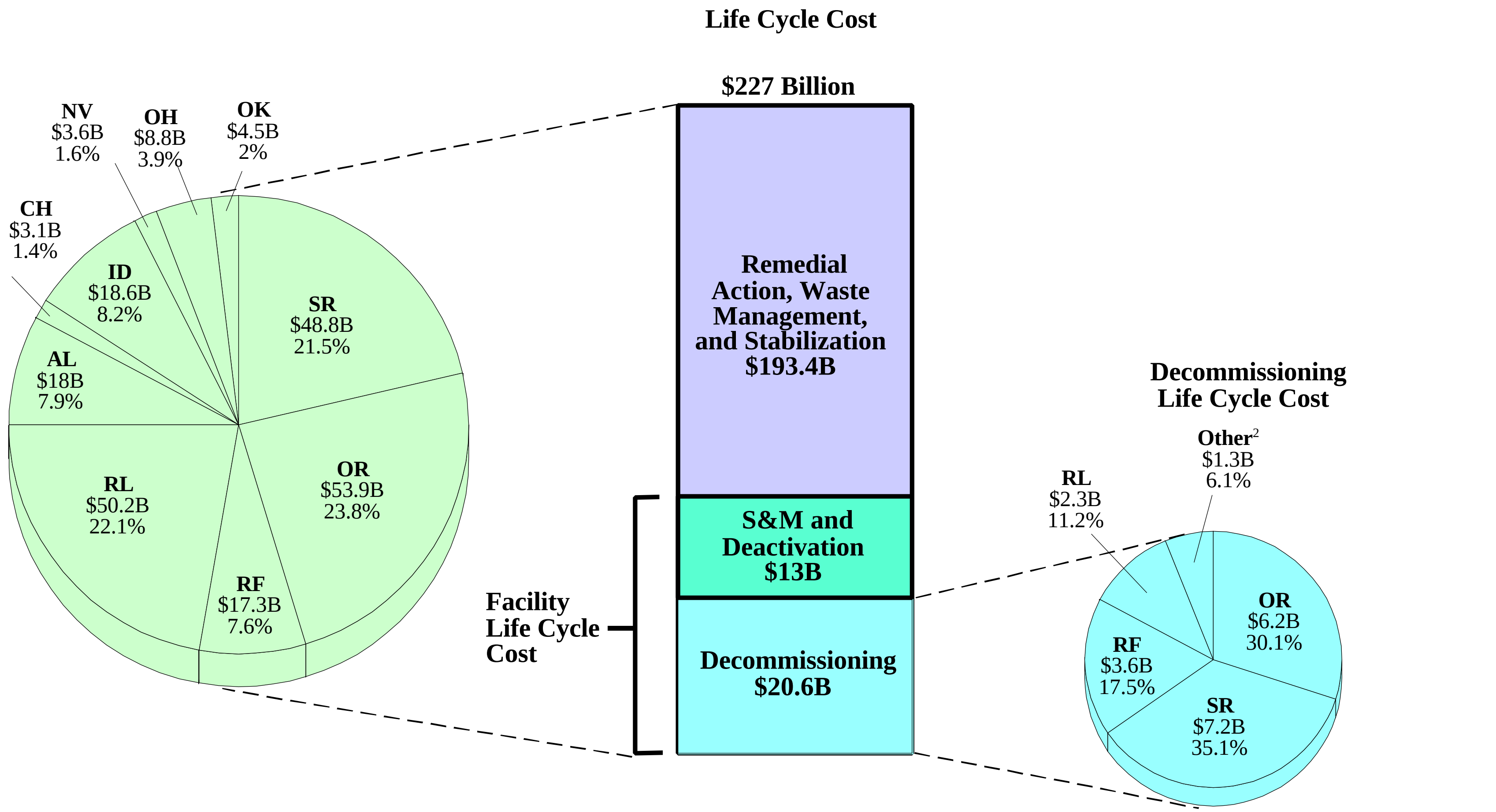
DOE HAS MORE THAN 7,000[1] SURPLUS CONTAMINATED FACILITIES THAT MAY REQUIRE DECOMMISSIONING, COSTING THE DEPARTMENT MORE THAN $20 BILLION, OR ABOUT 10% OF ITS TOTAL ENVIRONMENTAL CLEANUP LIABILITY.

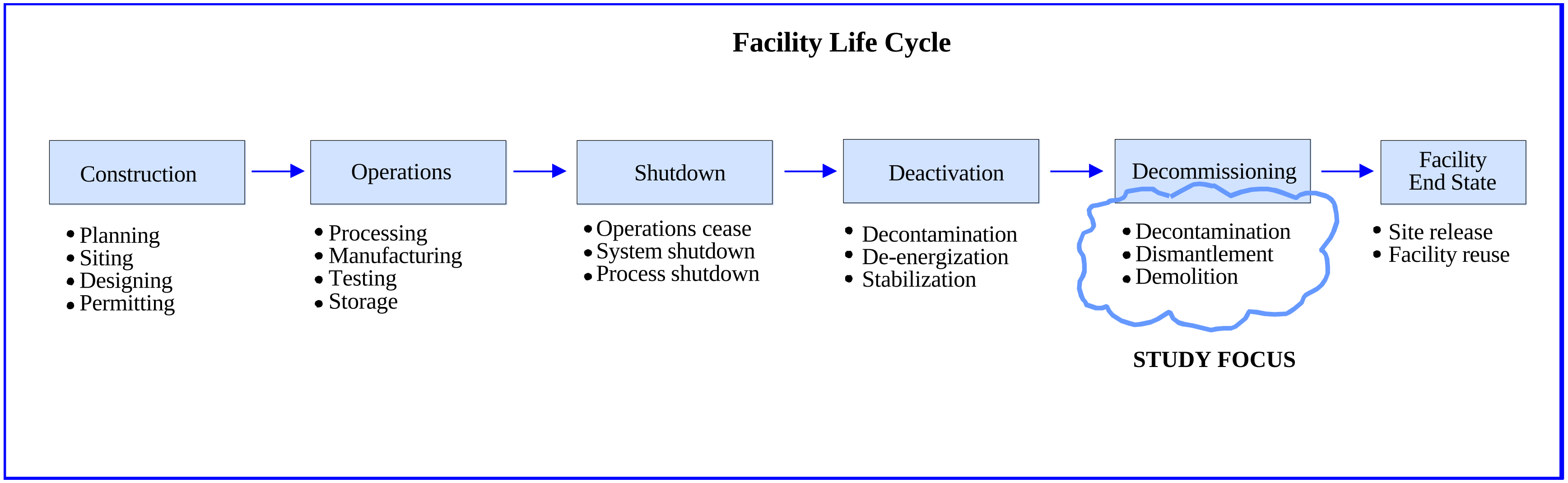


Source: 1996 BEMR Report, Volumes II and III. The term "life cycle cost" refers to the cost to complete the mission of the Environmental Management program. The Ten Year Plan was not finalized at the time of report publication.

1 DOE EM-40 "Decommissioning of Facilities" Web Page (http://www.em.doe.gov/dd/), October 4, 1996.

2 Fernald and Weldon Spring decommissioning cost estimates are included under remedial actions.

THE PURPOSE OF THIS STUDY IS TO ANALYZE PHYSICAL ACTIVITIES IN FACILITY DECOMMISSIONING AND TO DETERMINE APPROACHES TO IMPROVE THE DECOMMISSIONING PROCESS IN DOE'S ENVIRONMENTAL RESTORATION PROGRAM.

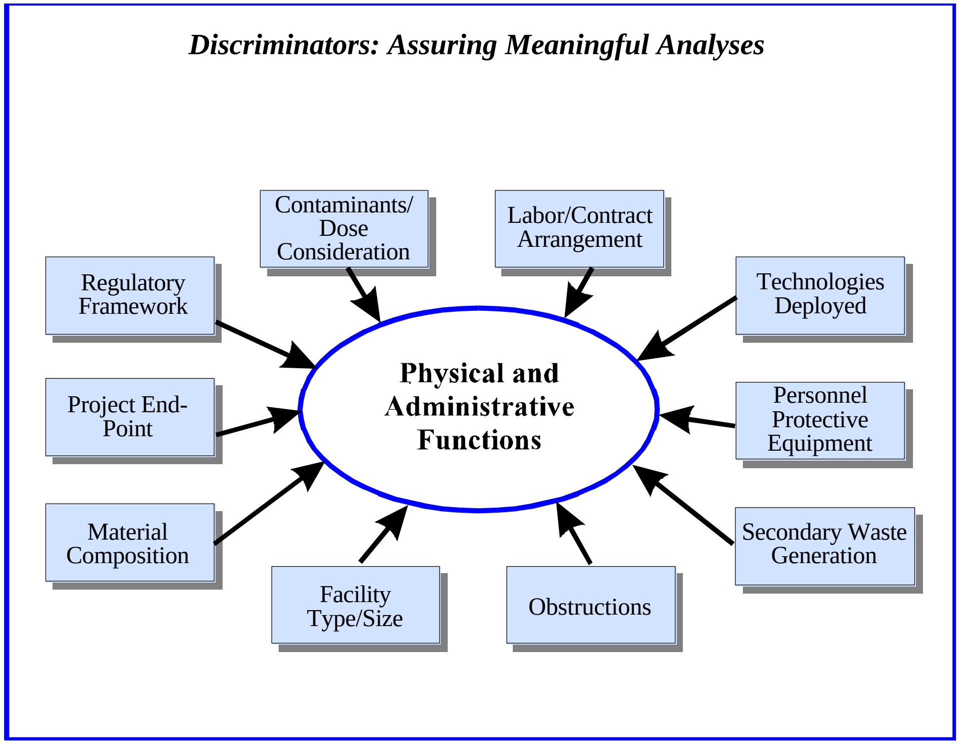


DOE's Office of Environmental Restoration is currently responsible for more than 1,000 facilities and accepts deactivated facilities for decommissioning.
Note: DOE decommissioning normally excludes: high level waste tanks, spent nuclear fuel, soil and groundwater remediation, and waste transportation and disposal.

THE STUDY FOCUSED ON QUANTIFYING PRODUCTIVITY OF DECOMMISSIONING PHYSICAL ACTIVITIES AND IDENTIFYING HOW PRODUCTIVITY IS AFFECTED BY SPECIFIC WORKING CONDITIONS.

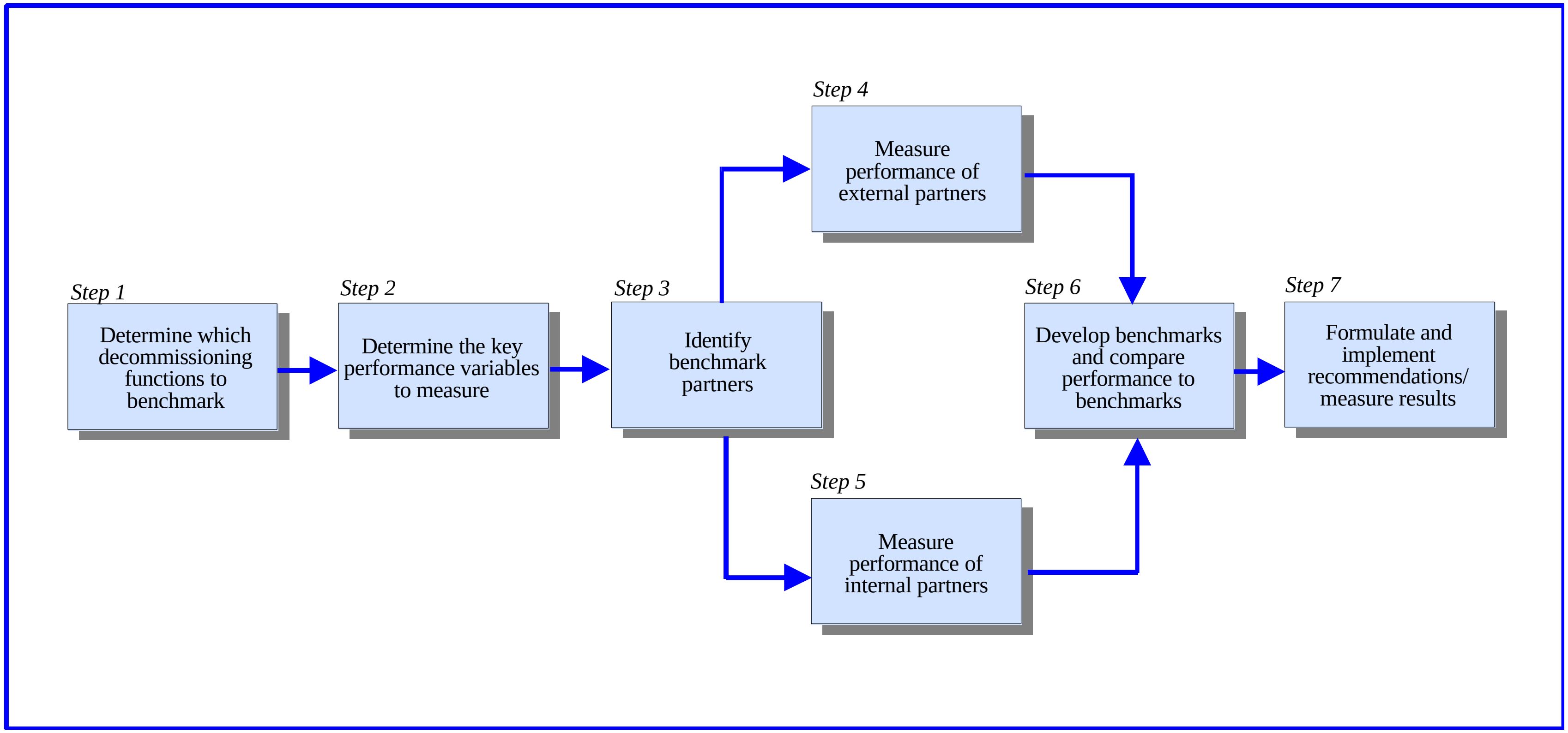
Physical Functions	Unit of Measure
Concrete Surface Decontamination	manhours/ft^2
Concrete Demolition	manhours/ft^3
Steel Surface Decontamiantion	technology hours/ft^2
Structural Steel Demolition	manhours/ton
Steel Component Cutting/Sizing	manhours/ton
ACM Tile and Siding Removal	manhours/ft^2
ACM Pipe Insulation Removal	manhours/ft^3
Equipment Removal	manhours/ton or item
Pipe Removal	manhours/ft
General Demolition	manhours/ft^3

Administrative Functions	Unit of Measure
Project Management	%total hours or cost
Engineering/Planning/Design	%total hours or cost
Support Services	%total hours or cost
Health and Safety Documentation	%total hours or cost
Security Surveillance & Maint.	%total hours or cost



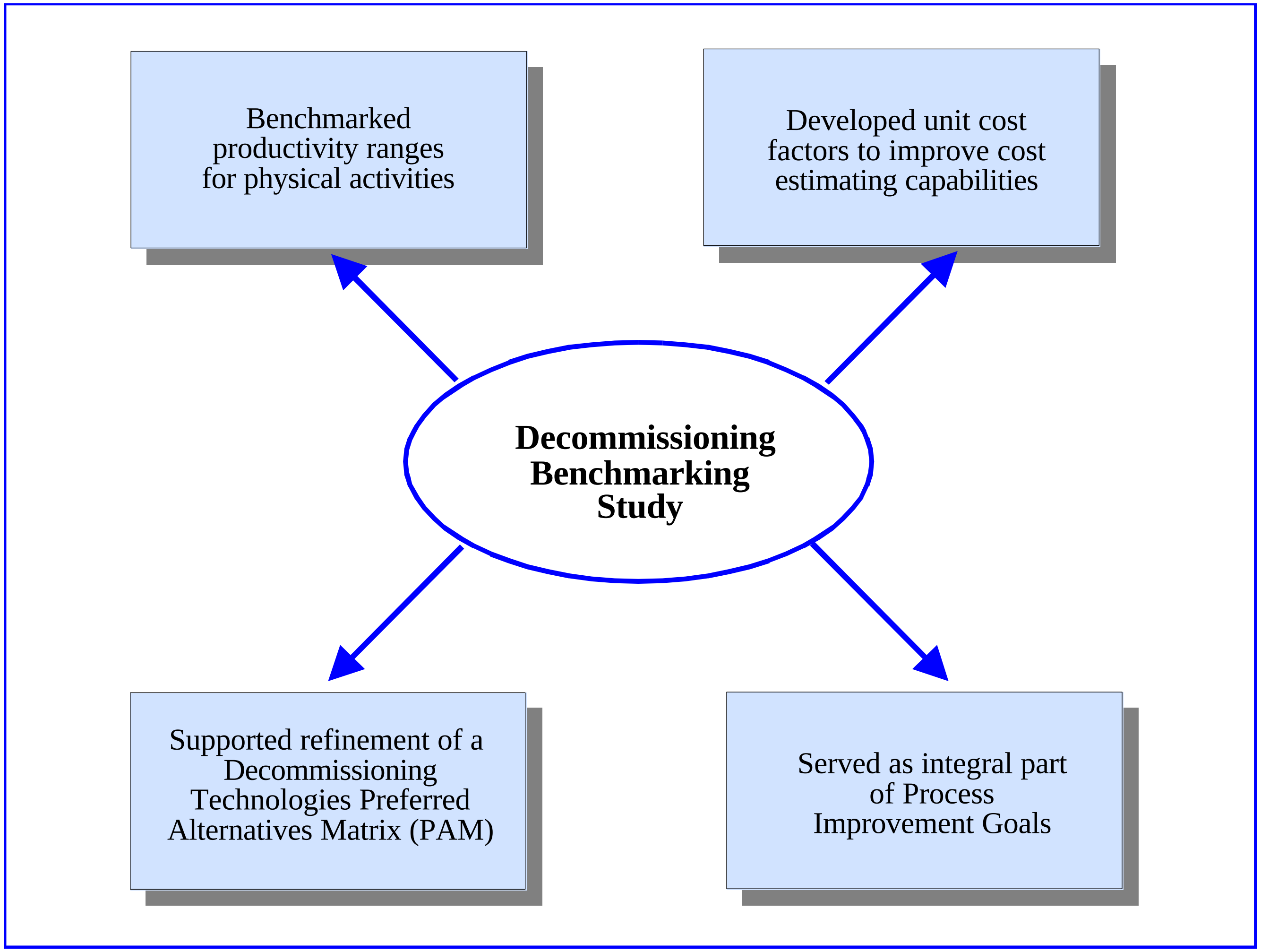
Since the study focused primarily on hourly productivity as opposed to costs, the data was collected at the task level (e.g., manhours to decontaminate "x" ft^2 of floor space in building "y").

THE DECOMMISSIONING BENCHMARKING TEAM FOLLOWED A SEVEN STEP BENCHMARKING PROCESS.



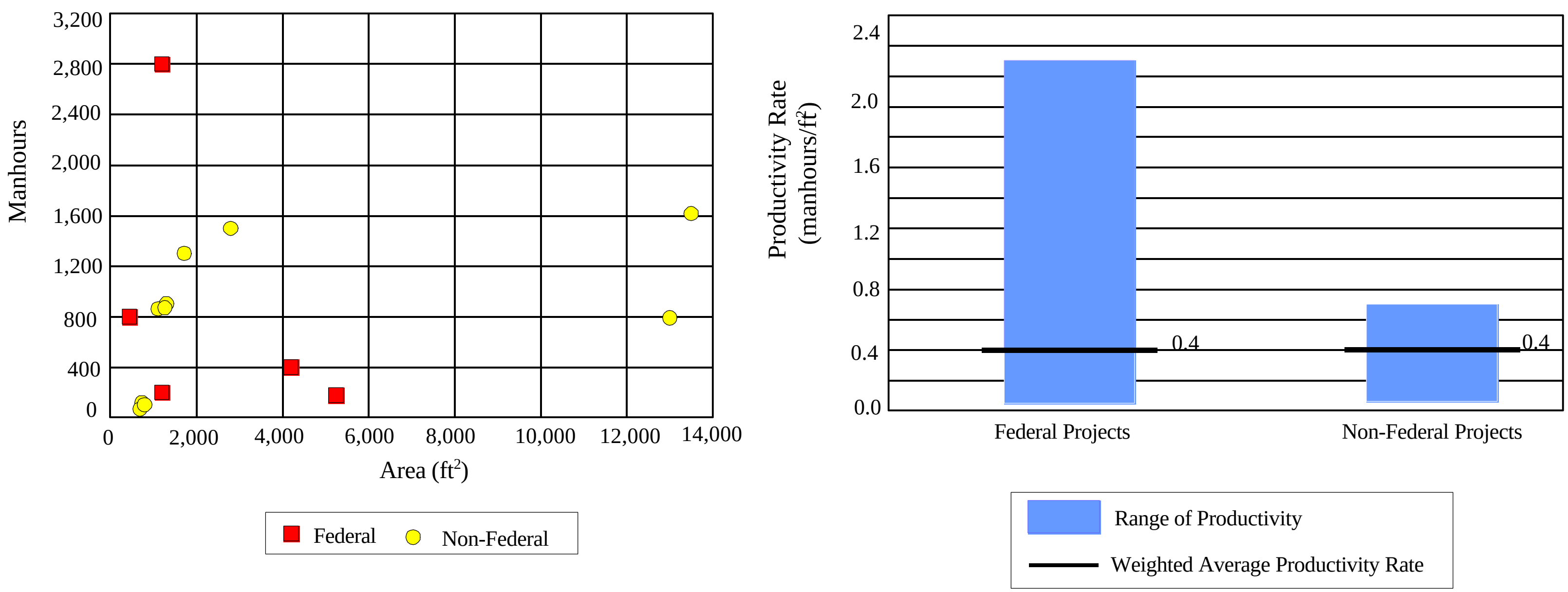
Note: An Implementation Plan was developed in late 1995 to initiate the Decommissioning Benchmarking Study Steps 1 and 2 were conducted as part of the Implementation Plan development.

THE DECOMMISSIONING BENCHMARKING RESULTS ARE THE FOUNDATION FOR SEVERAL DISTINCT PRODUCTS.

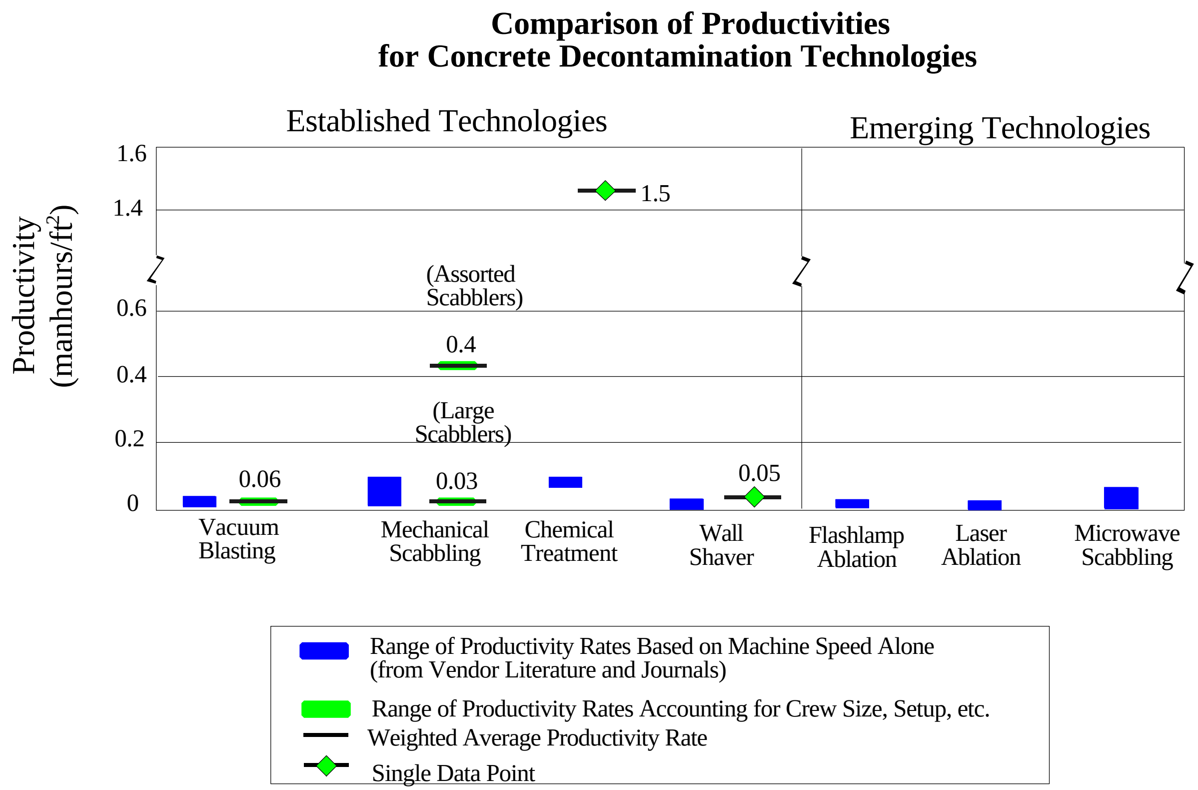


AT THE TASK LEVEL AVAILABLE DATA SHOWS THAT THERE ARE NO PRODUCTIVITY DIFFERENCES BETWEEN FEDERAL AND NON-FEDERAL DECOMMISSIONING PROJECTS.

Concrete Decontamination Productivity for Federal and Non-Federal Projects



SINCE EXISTING DECOMMISSIONING TECHNOLOGIES ARE WELL SUITED FOR MOST DECOMMISSIONING TASKS NOT REQUIRING REMOTE OPERATION, THE AVAILABILITY OF TECHNOLOGIES SHOULD NOT IMPEDE PROGRESS OF DECOMMISSIONING ACTIVITIES.



PRODUCTIVITY RATES AND RELATED UNIT COST FACTORS CAN BE USED BY DECOMMISSIONING MANAGERS IN DEVELOPING ESTIMATES TO SUPPORT BUDGETS AND PROPOSAL REQUESTS AND IN EVALUATING COST TRADE-OFFS BETWEEN DECOMMISSIONING END STATES.

Task	Weighted Average Productivity Rate
Concrete Decontamination	0.12 hours/ft^2
Concrete Removal	0.03 hours/ft^3
Remot Concrete Removal	2.0 hours/ft^3
Structural Steel Removal	3.6 hours/ton
Asbestos Siding Removal	0.09 hours/ft^2
Asbestos Insulation Removal	0.65 hours/ft^3
Asbestos Tile Removal	0.28 hours/ft^2
Equipment Removal	25 hours/ton
Pipe Removal	0.27 hours/ft

Derived Benchmarks

MEANS® productivity rates for concrete removal, structural steel removal, and piping removal tasks are consistently lower than study productivity rates. MEANS® productivity rates are based on tasks conducted in a non-contaminated environment.

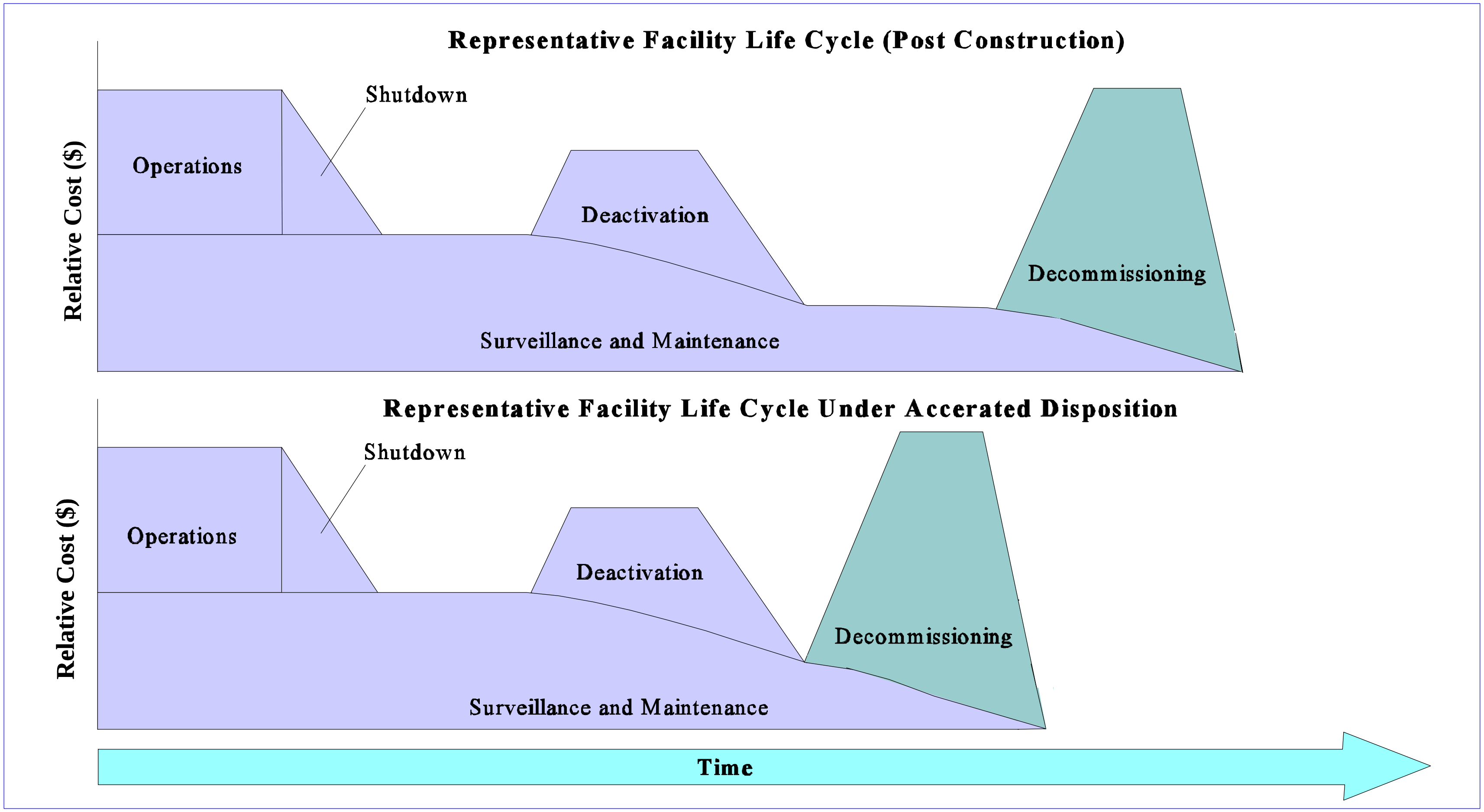
DECOMMISSIONING PROGRAM MANAGERS MAY USE THE DECOMMISSIONING PREFERRED ALTERNATIVES MATRIX TO ASSIST IN THE DETERMINATION OF TECHNOLOGIES FOR USE ON A DECOMMISSIONING PROJECT.

Sample Matrix Rating Demolition Technologies

	Concrete				Brick/Cinder Block	
	Reinforced Structure (>2' thick)	Lightly Reinforced Structure (<2' thick)	Non-reinforced Structure (<2' thick)	Stack	Structure	Stack
HEAVY EQUIPMENT						
Backhoe Mounted Pulverizer	◑	◑	◑	◑	◕	◑
Backhoe Mounted Ram	◕	◕	●	◑	◕	◕
Backhoe Mounted Shears	◑	◕	◑	⊗	◑	⊗
Wrecking Ball/Slab	◔	◕	◕	◑	●	●
TOOLS						
Jackhammer	◑	◑	◑	⊗	◕	⊗
Rock Splitter	◑	◕	◕	◑	⊗	⊗
Wall and Floor Saws	◔	◑	◑	⊗	⊗	⊗
MISCELLANEOUS EQUIPMENT/METHODS						
Controlled Blasting/Explosive Cutting	◑	◑	◑	◑	◑	◑
Diamond Wire	◑	◕	◕	⊗	⊗	⊗
Expansive Grout/Demolition Compounds	◔	◕	◕	◕	◕	◕
Grapple	◑	◕	◕	⊗	●	⊗

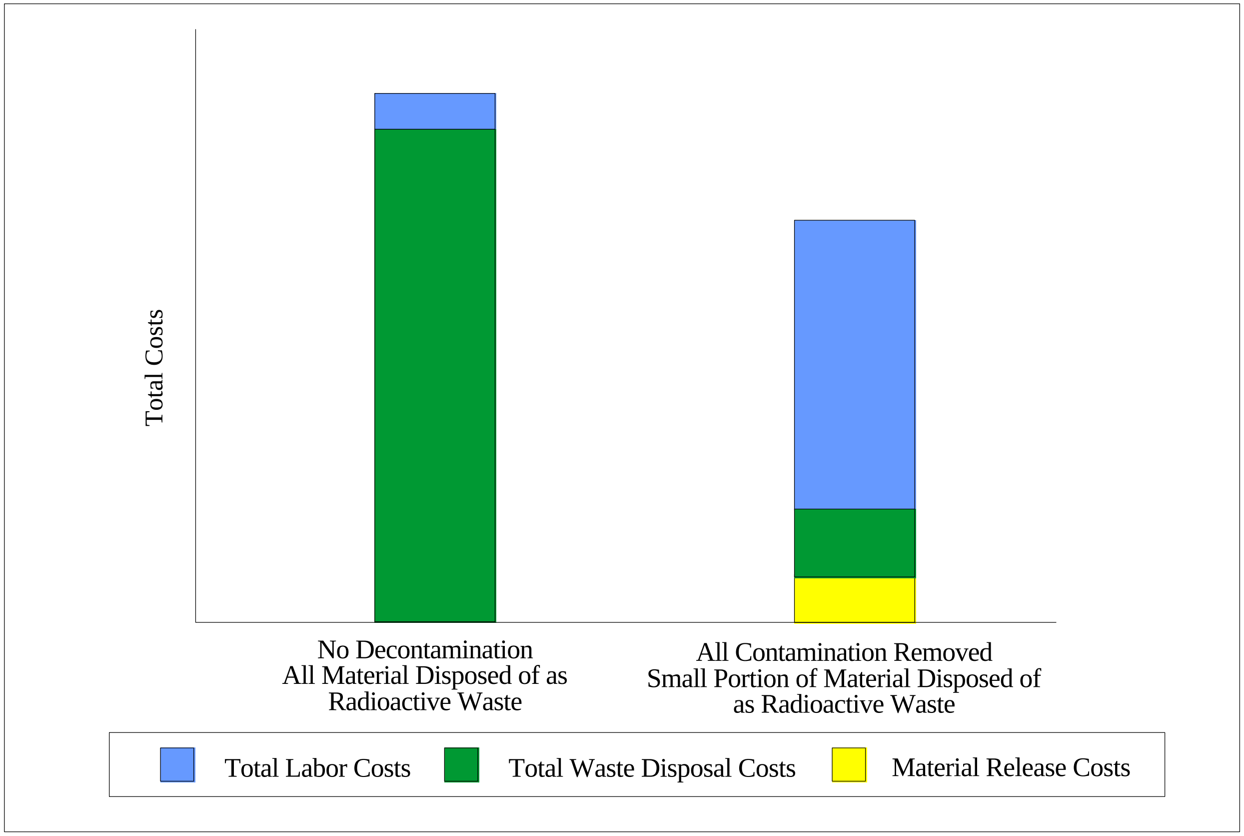
PAM Legend					
● Preferred Alternative (lowest cost, best performance, and low risk)	◕ Probable Alternative (low cost, good performance, and low risk)	◑ Potential Alternative (acceptable performance, but medium cost or risk)	◔ Possible Alternative (high cost or high risk)	○ Unlikely (limited performance or high cost or risk)	⊗ Not Applicable

FACILITY LIFE CYCLE COSTS CAN BE REDUCED BY PERFORMING DECOMMISSIONING AS SOON AFTER DEACTIVATION AS POSSIBLE.



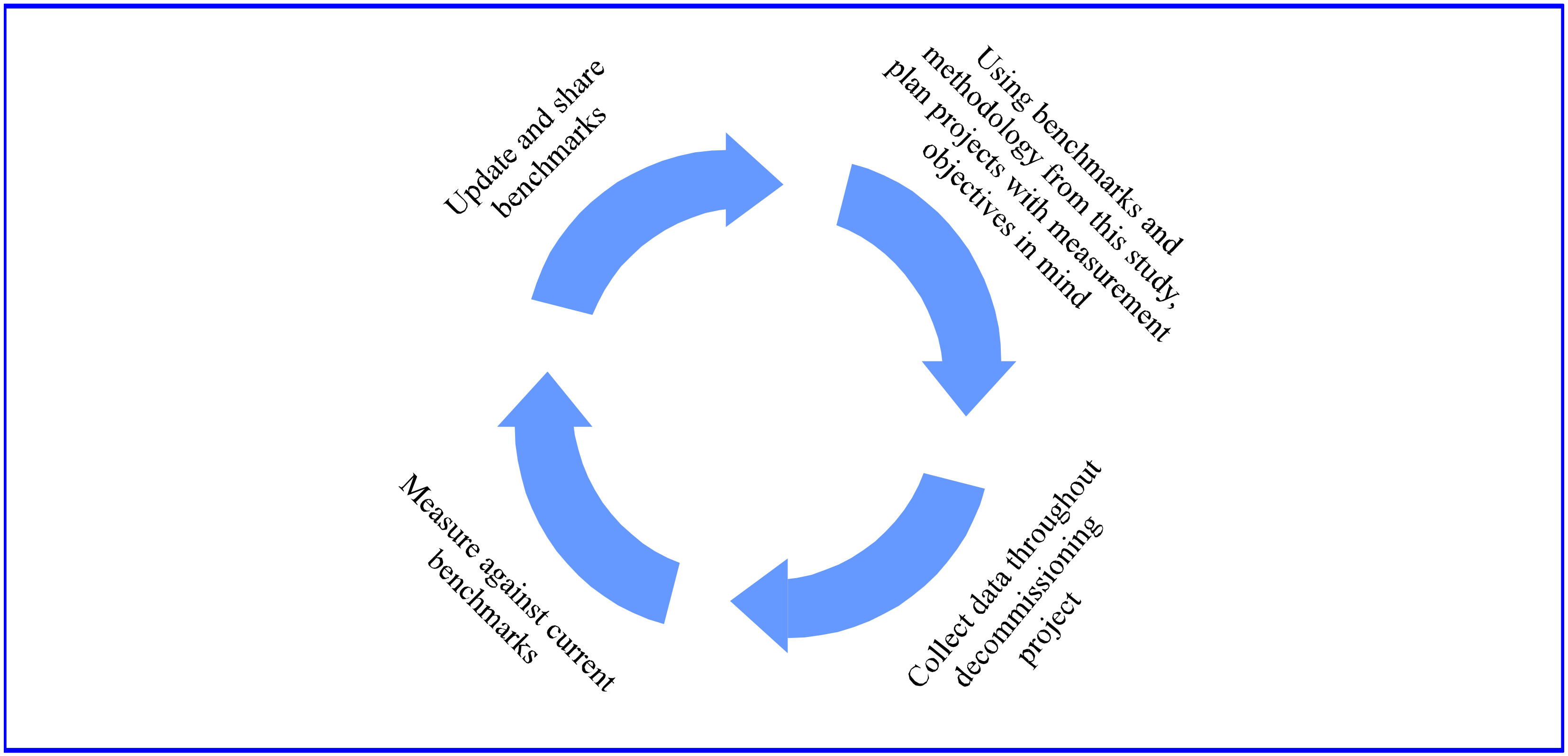
Graphs above are not to scale. The DOE Office of Environmental Management will spend approximately $750 million for surveillance and maintenance in FY 1997; the 1996 BEMR projects a life cycle cost of $14.3 billion for surveillance and maintenance.

FOR RADIOACTIVE DECOMMISSIONING ACTIVITIES, DOE SHOULD CONSIDER WASTE DISPOSAL COSTS INCURRED IN DECOMMISSIONING ACTIVITIES TO ENSURE APPROPRIATE TRADE-OFFS BETWEEN LABOR COSTS (DECONTAMINATION ACTIVITIES) AND DISPOSAL COSTS (VOLUME OF MATERIAL DISPOSED).



Graphs above are not to scale.

DOE SHOULD CONTINUE THE DECOMMISSIONING COMMITTEE ACTIVITIES AND INCREASE EMPHASIS ON COLLECTING DATA, MEASURING PROGRESS, AND SHARING DECOMMISSIONING RESULTS WITH DOD, EPA, AND INTERNATIONAL PARTNERS.



Decommissioning projects should be planned with measurement objectives in mind to achieve the ability to measure performance. DOE should establish a data collection and reporting protocol for DOE and contractors similar to the functions covered in the benchmark, periodically update average and "best-in-class" productivity rates, and continue to seek input from external partners.

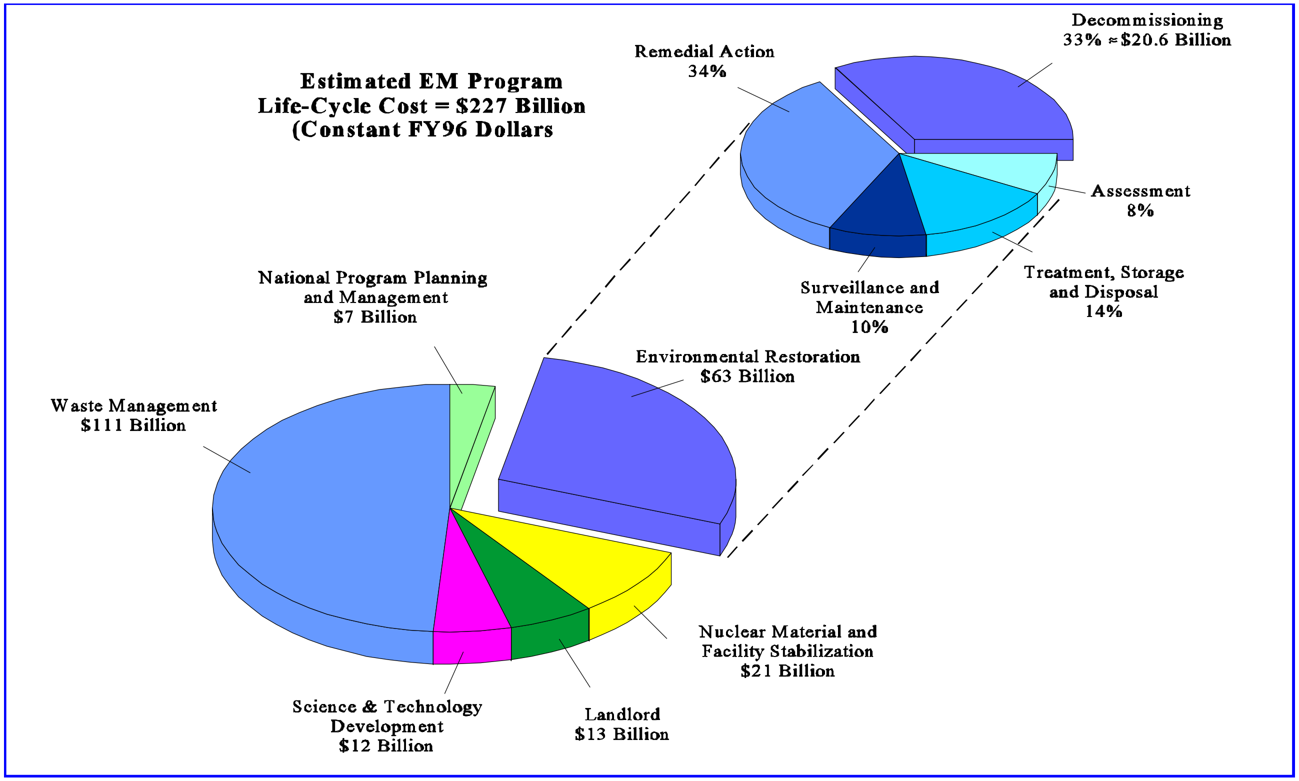
For more information, please contact:

Telephone: Stephen Warren, DOE (301) 903-7673
Internet: stephen.warren@em.doe.gov

The Final Report will be available February 1997 on the DOE Decommissioning Home Page on the World Wide Web:

http://www.em.doe.gov/dd

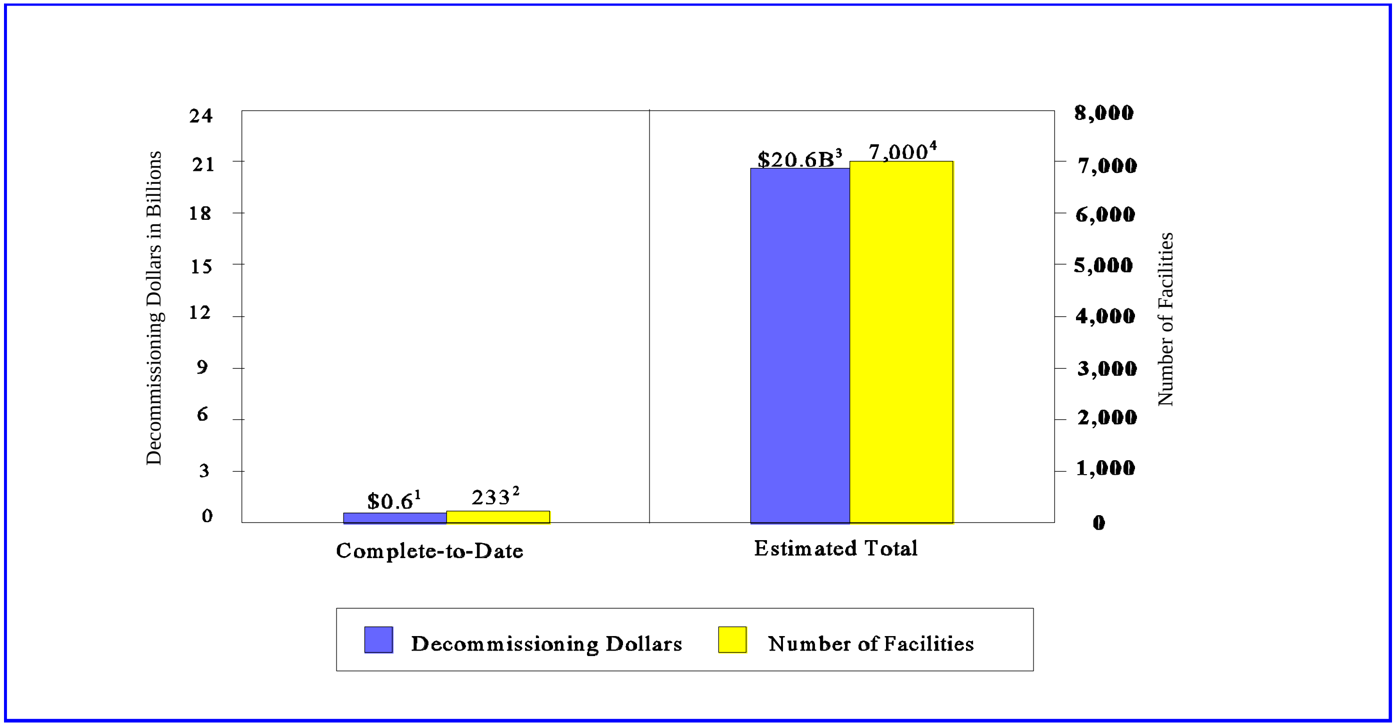
THE U.S. DOE ENVIRONMENTAL MANAGEMENT PROGRAM FACES A LIABILITY OF APPROXIMATELY $20.6 BILLION[1] TO DECOMMISSION 7,000[2] SURPLUS CONTAMINATED FACILITIES.



Source: [1]1996 BEMR, Volume I, p. 4-17. The Ten Year Plan was not finalized at the time of report publication.
[2]DOE EM-40 "Decommissioning of Facilities" Web Page (http://www.em.gov/dd/), October 4, 1996.

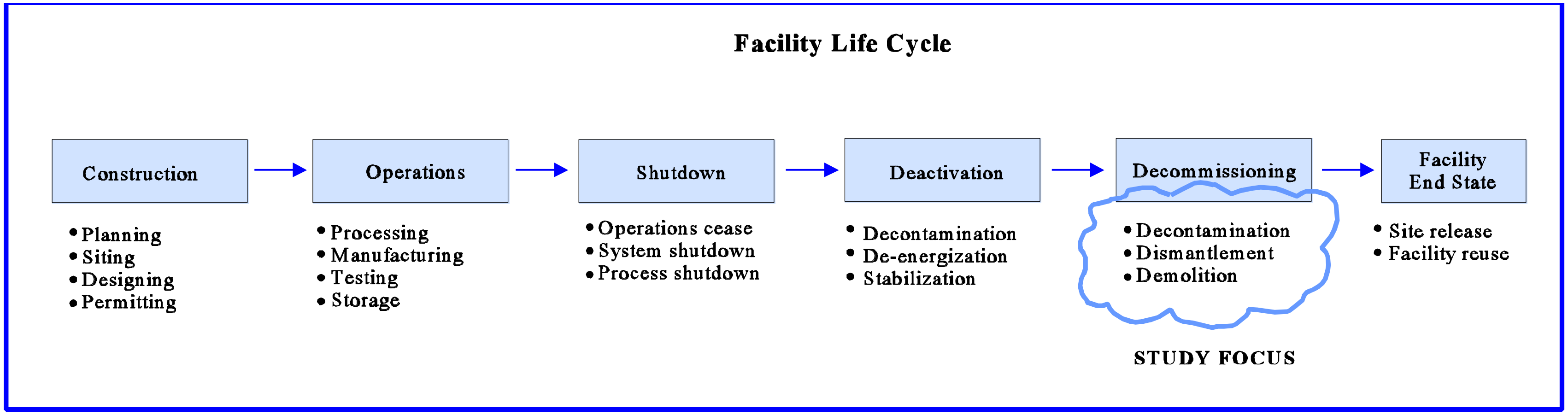
SINCE MOST OF THE 233 DOE FACILITIES DECOMMISSIONED TO DATE HAVE BEEN RELATIVELY SIMPLE STRUCTURES, DECOMMISSIONING COSTS PER FACILITY ARE EXPECTED TO GROW.

DOE Decommissioning Projects
Complete-to-Date vs. Total



Source: [1]DOE Financial Information System Year End Reports (FY91 - 96).
[2]EM-40 Core Database, dated October 29, 1996.
[3]1996 BEMR, Volume I, p. 4-17. The Ten Year Plan was not finalized at the time of report publication.
[4]DOE EM-40 “Decommissioning of Facilities” Web Page (http://www.em.gov/dd/), October 4, 1996.

THE PURPOSE OF THIS STUDY IS TO ANALYZE PHYSICAL ACTIVITIES IN FACILITY DECOMMISSIONING AND DETERMINE APPROACHES TO IMPROVE THE DECOMMISSIONING PROCESS IN DOE'S ENVIRONMENTAL RESTORATION PROGRAM.



This study focused on:

- Quantifying and analyzing the differences in scope, schedule, and cost associated with decommissioning activities as determined from recent decommissioning experiences from DOE, commercial enterprises, other government agencies, and international sources.
- Quantifying ranges of decommissioning costs and productivity rates and developing recommendations for improving DOE's decommissioning performance.
- Determining approaches to improve the decommissioning process and reduce costs.
- Providing additional support for refined cost estimates for decommissioning projects.

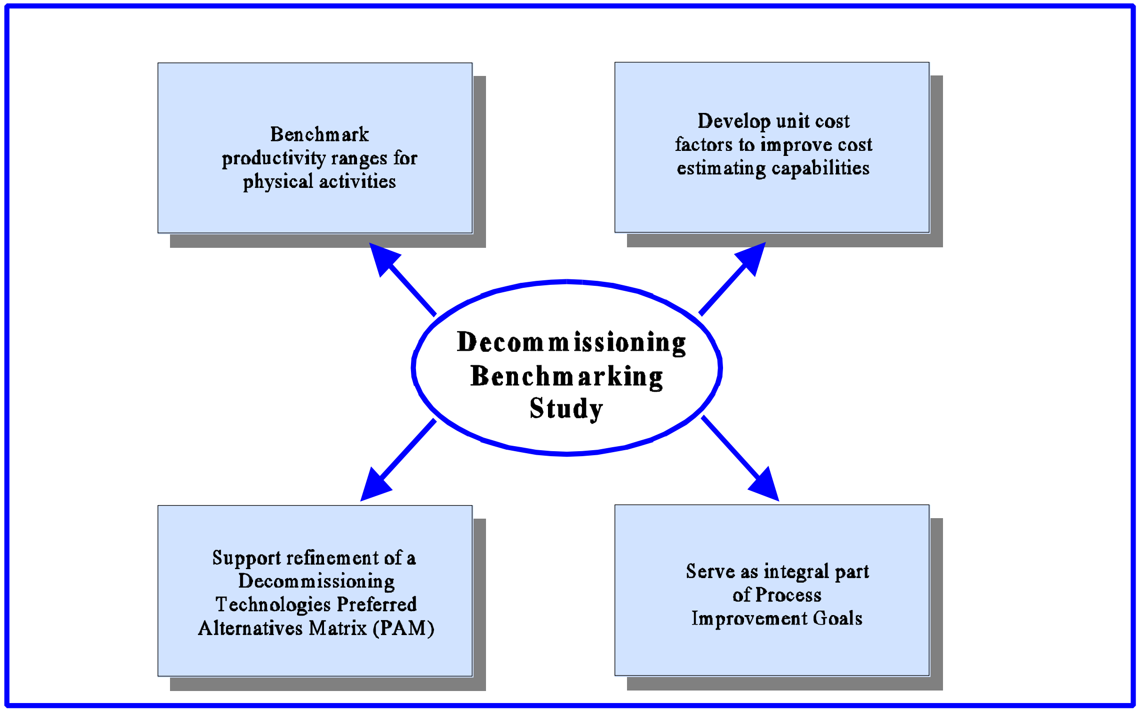
Note: DOE's Office of Environmental Restoration is currently responsible for more than 1,000 facilities and accepts deactivated facilities for decommissioning. DOE decommissioning normally excludes: high level waste tanks, spent nuclear fuel, soil and groundwater remediation, and waste transportation and disposal.

THE STUDY TEAM IDENTIFIED SEVERAL USES FOR THE RESULTS OF THIS STUDY.

- Identify best practices and technology applications.

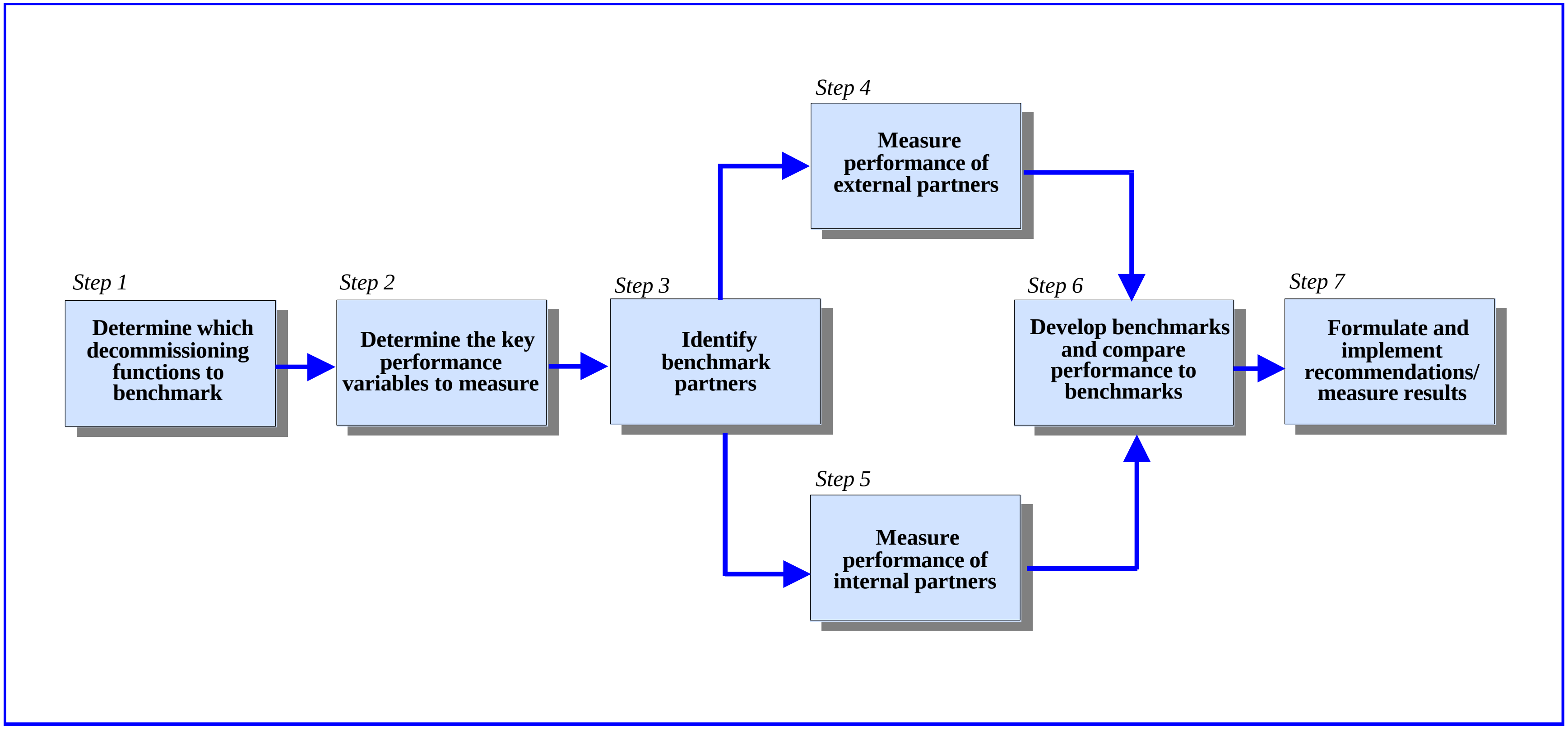
  - Identify preferred technologies for future decommissioning tasks.
  - Identify situations where contaminants, protective gear, and other working conditions may impact productivity.
  - Identify areas where technology enhancement would be beneficial

- Support improved long-range cost estimates and program planning.



Analysis Approach

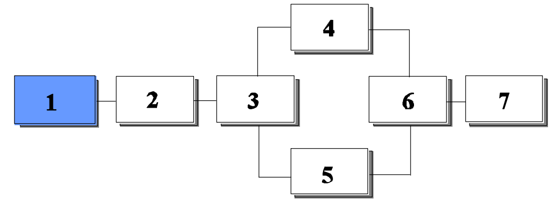
THE DECOMMISSIONING BENCHMARKING TEAM FOLLOWED A SEVEN STEP BENCHMARKING PROCESS.

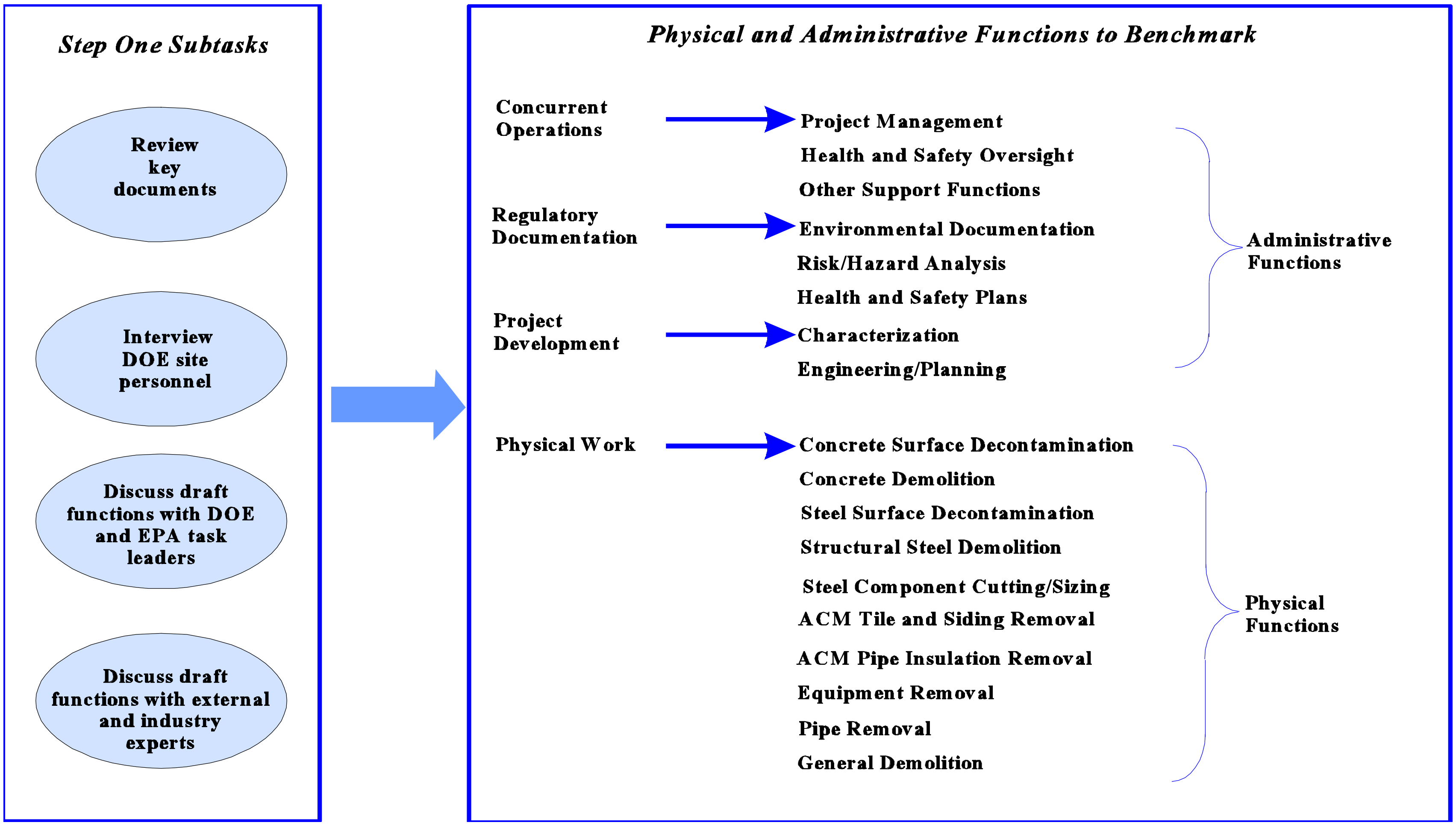


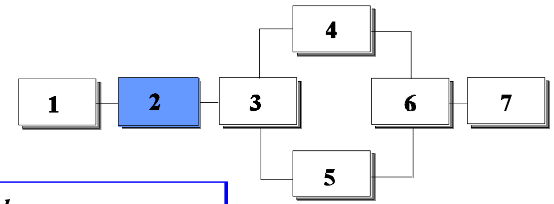
Note: An Implementation Plan was developed in late 1995 to initiate the Decommissioning Benchmarking Study. Steps 1 and 2 were conducted as part of the Implementation Plan development.

Analysis Approach - Step One - Determine Functions

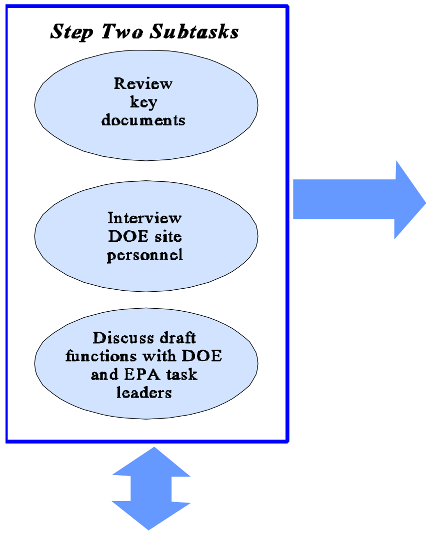
THIS BENCHMARKING STUDY FOCUSED ON THE PHYSICAL ACTIVITIES COMMON TO MOST DECOMMISSIONING PROJECTS.

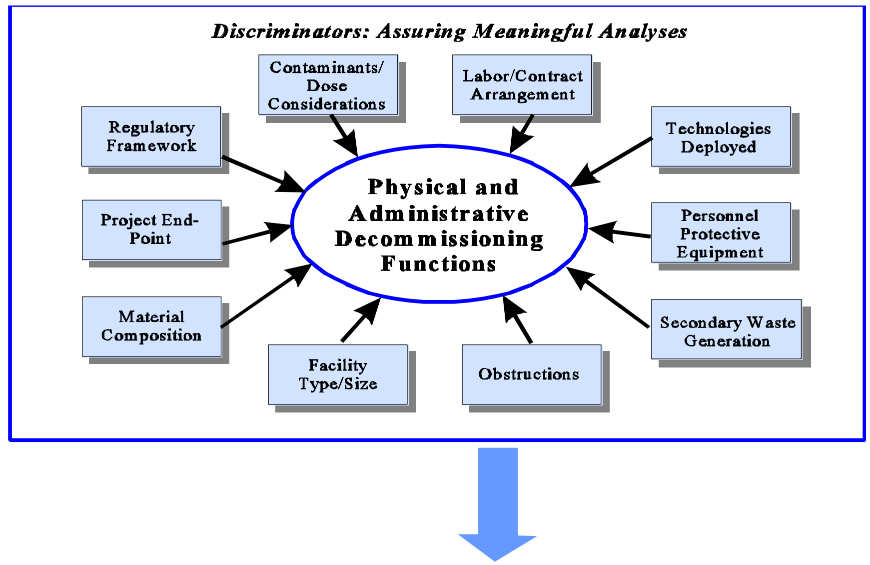






IDENTIFICATION OF KEY PERFORMANCE METRICS FOCUSED DATA COLLECTION ACTIVITIES AND ENSURED "APPLES-TO-APPLES" COMPARISONS.



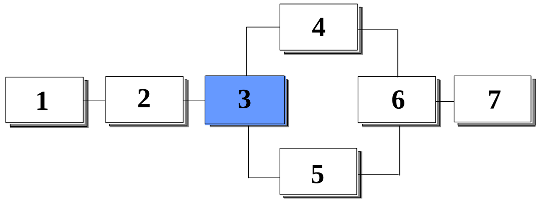


Physical Functions	Unit of Measure
Concrete Surface Decontamination	manhours/ft^2
Concrete Demolition	manhours/ft^3
Steel Surface Decontamination	technology hours/ft^2
Structural Steel Demolition	manhours/ton
Steel Component Cutting/Sizing	manhours/ton
ACM Tile and Siding Removal	manhours/ft^2
ACM Pipe Insulation Removal	manhours/ft^3
Equipment Removal	manhours/ton or item
Pipe Removal	manhours/ft
General Demolition	manhours/ft^3

Develop Initial Hypotheses

- Does DOE perform decommissioning as efficiently as the provate sector?
- Are existing technologies adequate to conduct decommissioning?

Analysis Approach - Step Three - Identify Benchmarking Partners



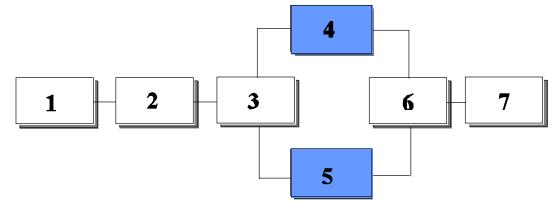
SOLICITING PARTICIPATION FROM A TARGETED MIX OF FEDERAL AND NON-FEDERAL PROJECTS ENSURED THAT DATA WOULD BE MOST APPLICABLE TO FUTURE PROJECTS.

- The primary data for the study was collected from ongoing or completed projects within DOE, EPA, the commercial industry, and international programs.
- The study team contacted more than 80 potential internal and external partners, including commercial utilities, vendors, decommissioning subcontractors, and international organizations, to invite their participation in the study.
- Seventeen partners participated in the study.

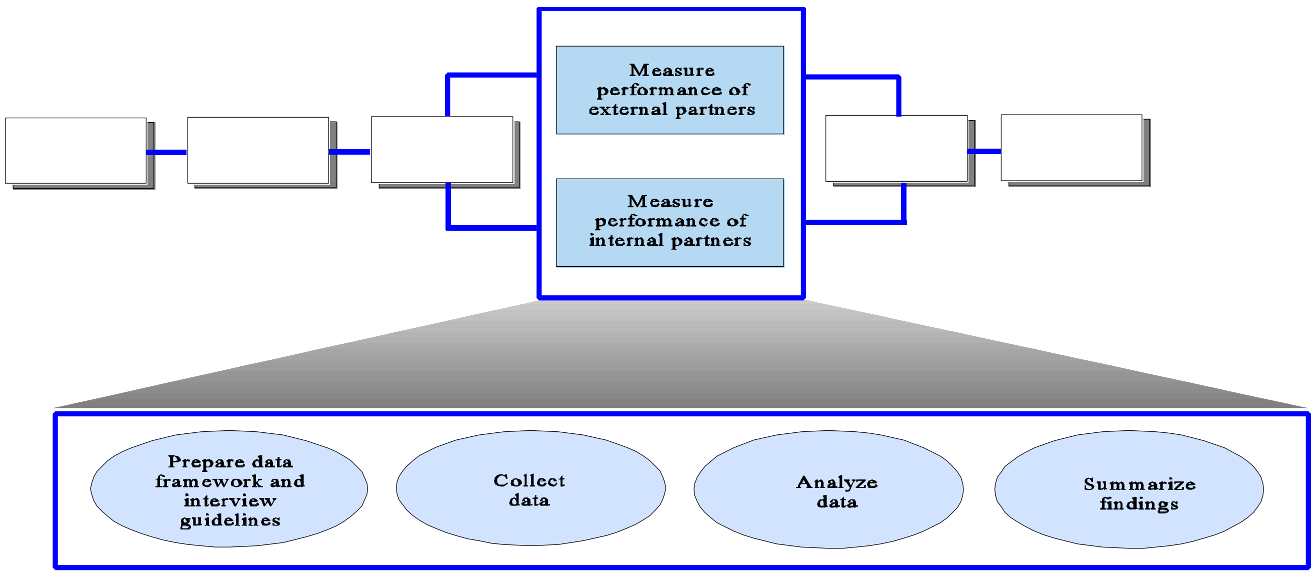
Internal Partners	External Partners
Department of Energy: • Argonne National Laboratory • Battelle Columbus Laboratory • Energy Technology Engineering Center • Fernald • Grand Junction • Hanford • Idaho National Engineering Laboratory • Mound • Oak Ridge Environmental Protection Agency: • Eastern Environmental Radiation Facility	• Alaron, Inc. • Atomic Energy of Canada, Inc. • Belgoprocess • Forschungszentrum Karlsruhe GmbH • Japan Atomic Energy Research Institute • MELE Associates • Pentek Inc. • Shippingport Decommissioning Demonstration Project

- Potential partners declined to participate in this study for several reasons:
  - Many potential participants lacked detailed records of their decommissioning activities and costs.
  - Although all potential partners were assured that the owner of the data would not be identified in the analysis section, some potential participants were not willing to release their data.
  - Several potential participants were initiating decommissioning projects and did not have complete data available.
  - Several potential participants requested compensation for their data.

Analysis Approach - Steps Four and Five - Measure Internal and External Performance



ONCE THE FUNCTIONS AND PERFORMANCE VARIABLES WERE SELECTED, ACTUAL PERFORMANCE (INTERNAL AND EXTERNAL) WAS MEASURED.

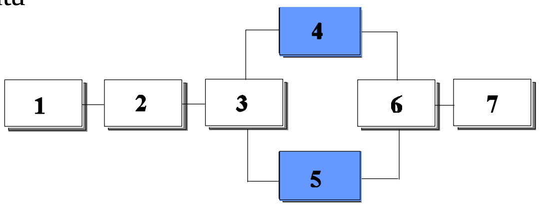


- Create/finalize data survey
- Develop interview guidelines
- Finalize primary data requirements (physical and non-physical parameters)

- Brief participants
- Identify discriminators (levels of control and variances)
- Collect data

- Analyze data
- Validate data
- Refine goals/ framework as appropriate
- Clarify major discrepancies

- Develop rollups of data analyzed

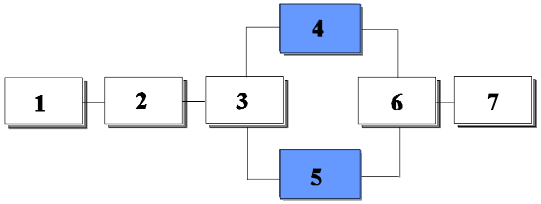


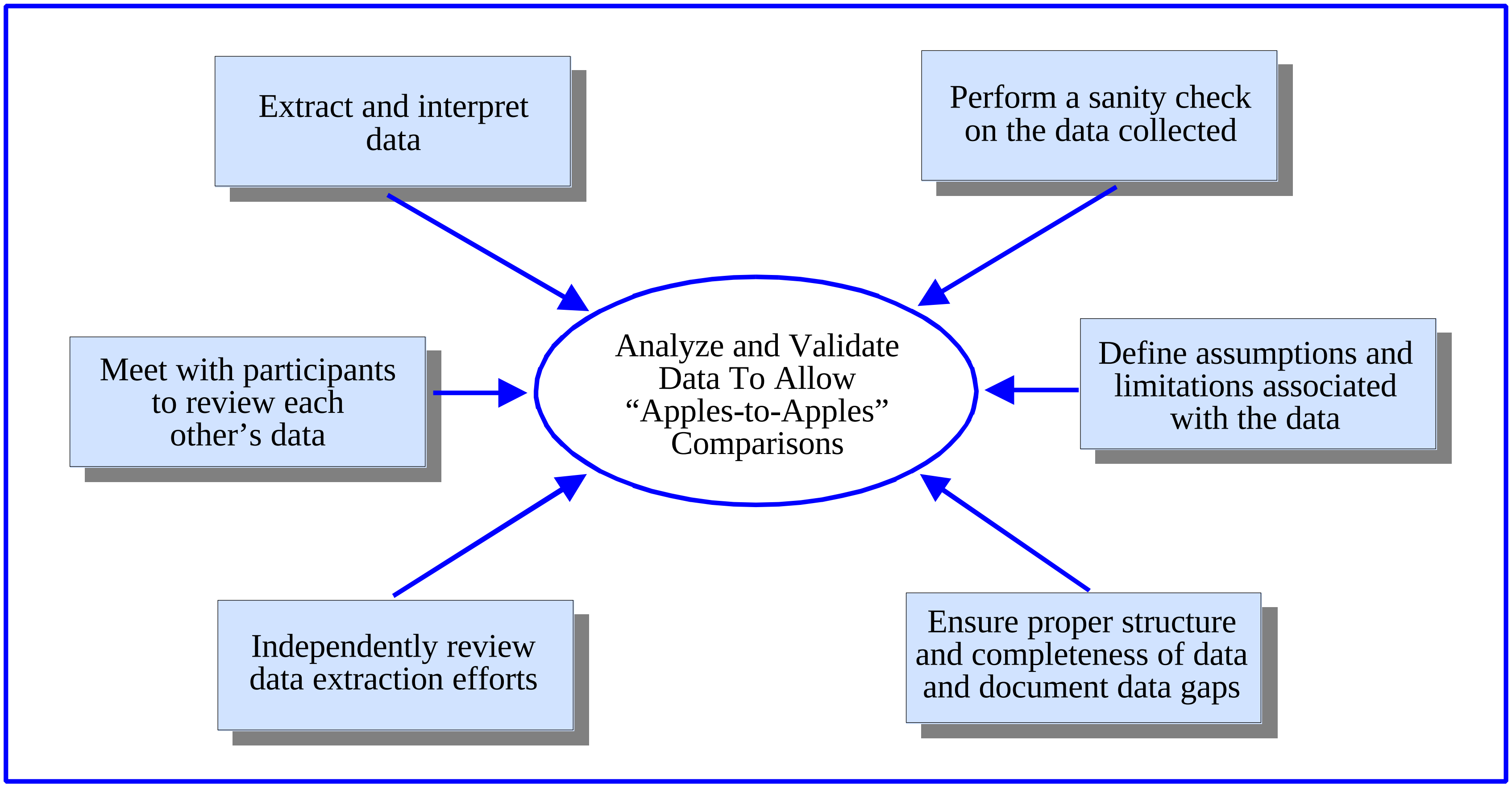
THE STUDY TEAM USED A VARIETY OF DATA COLLECTION METHODS.

Internal Partners	External Partners
• Six internal partners were visited by the team. These visits included: – Reviewing project-specific documents, such as monthly reports, final project reports, and photographs taken during the actual work – Interviewing site financial and project personnel. • Four internal partners provided data via data collection forms.	• Two external partners were visited by the team. These visits included: – Reviewing project-specific documents, such as monthly reports and final project reports – Interviewing site financial and project personnel. • Three external partners indirectly provided data from literature obtained from relevant publications on decontamination and decommissioning as archived or sponsored by DOE's Remedial Action Program Information Center (RAPIC). • Three external partners provided data via data collection forms.

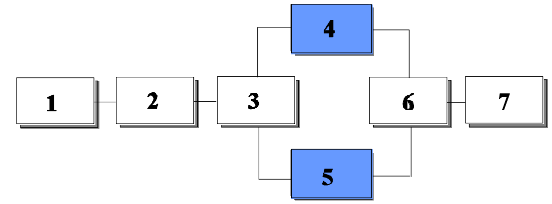
Note: Conference calls were held on an as-needed basis to clarify the data collected. In addition to the information obtained from benchmarking partners, the project team contacted sources including the American Nuclear Society, the Electric Power Research Institute, and the Nuclear Energy Institute and used construction handbooks, such as MEANS® Heavy Construction Cost Data, to establish appropriate productivity rates for demolition work in a non-contaminated environment.

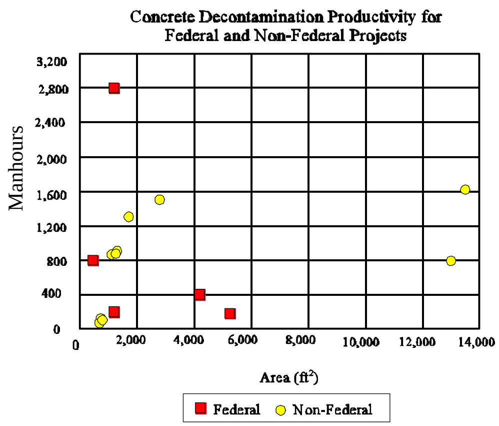
THE DATA WAS ANALYZED TO BUILD AN UNDERSTANDING OF DIFFERENCES AMONG THE INTERNAL AND EXTERNAL PARTNERS.

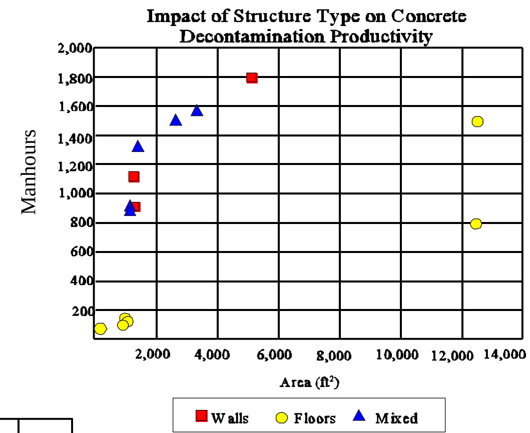


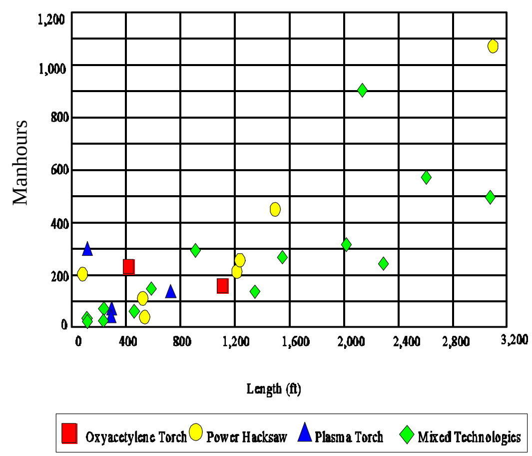


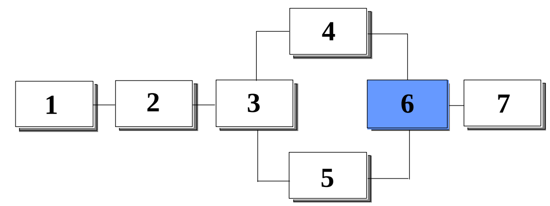
PERFORMANCE MEASUREMENT FOCUSED ON SUMMARIZING AND GRAPHICALLY DEPICTING INTERNAL, EXTERNAL, AND REFERENCE LEVEL DECOMMISSIONING PERFORMANCE TO DATE.



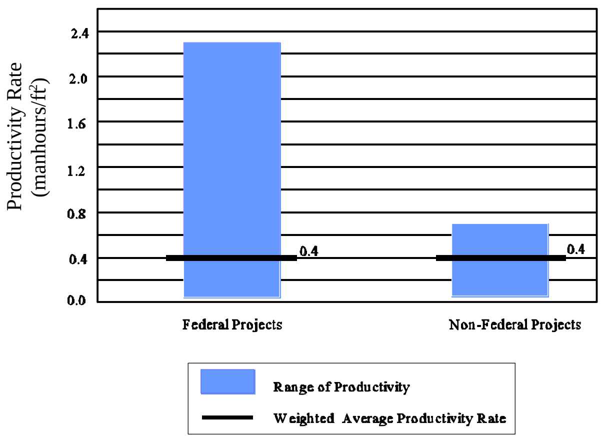


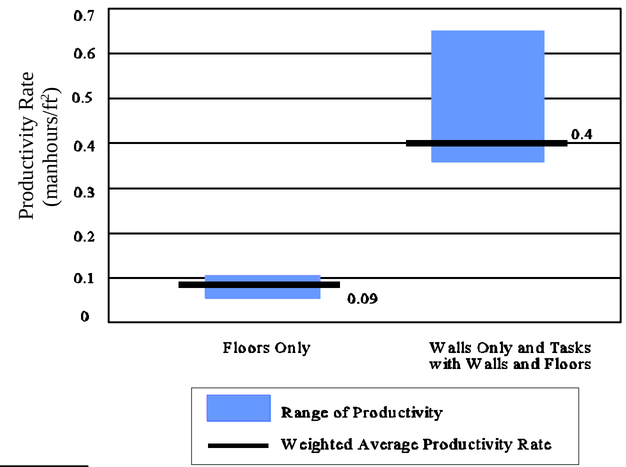


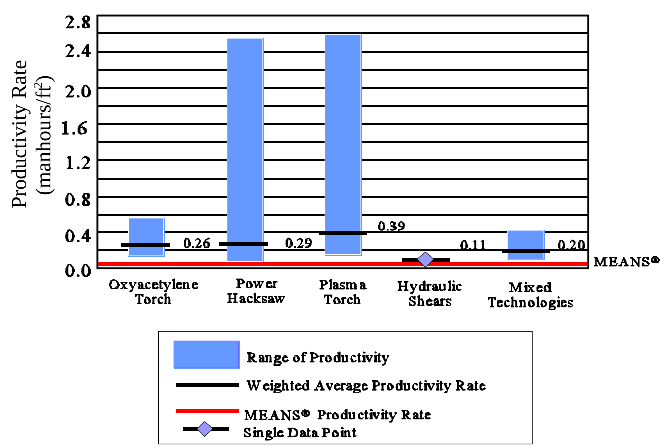




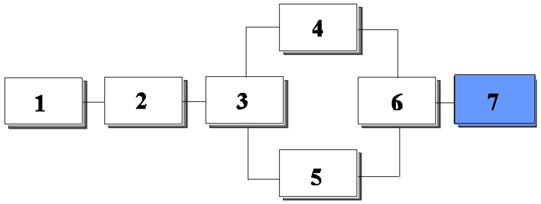
THE STUDY TEAM THEN COMPARED INTERNAL DECOMMISSIONING PERFORMANCE TO EXTERNAL PERFORMANCE AND REFERENCE BENCHMARKS (E.G., MEANS®) AND IDENTIFIED PRELIMINARY CAUSE-EFFECT HYPOTHESES.







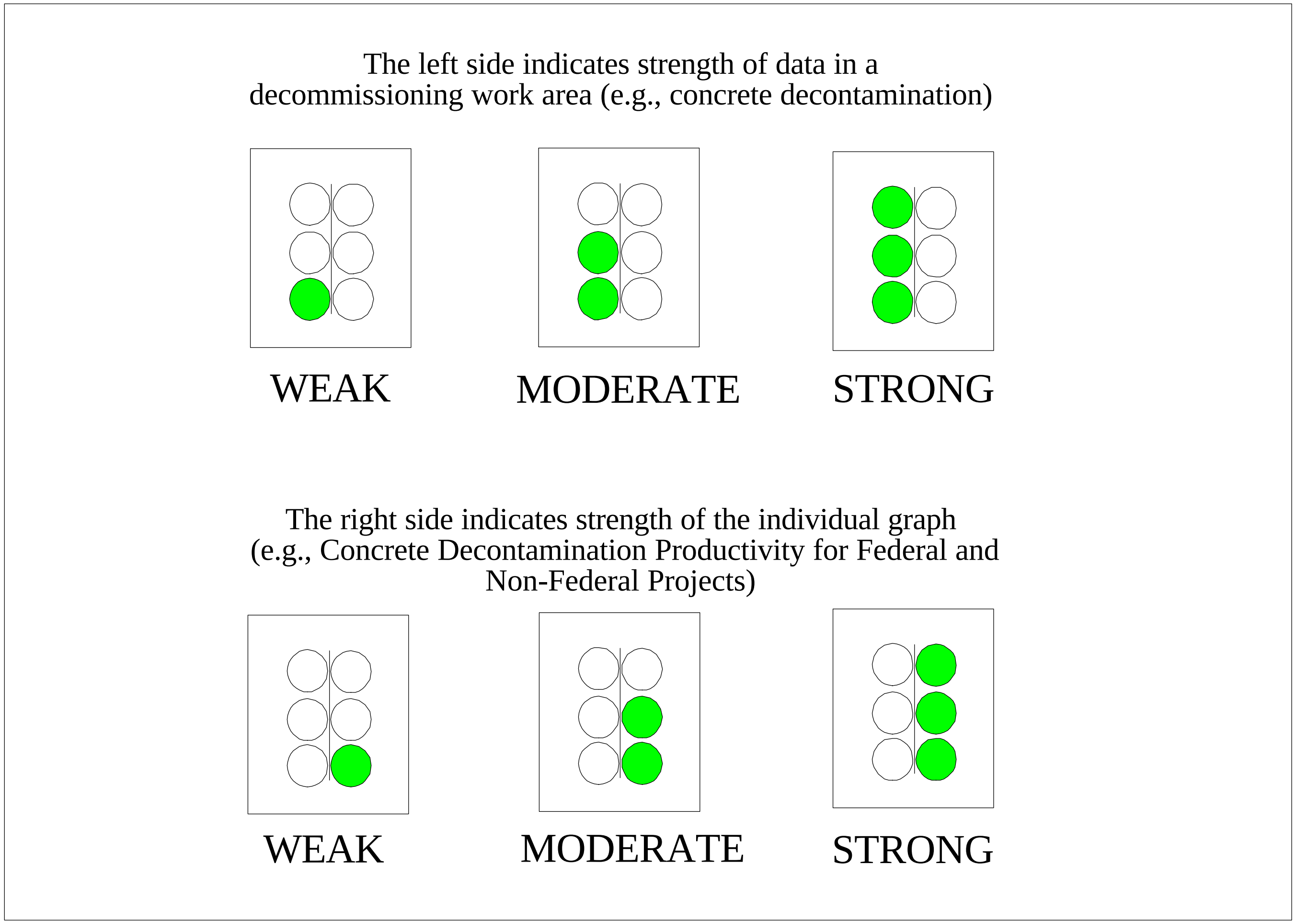
Analysis Approach - Step Seven - Formulate Recommendations and Measure Results



THE FINAL STEP IN THIS STUDY WAS TO FORMULATE RECOMMENDATIONS FOR PROCESS IMPROVEMENTS.

- Since existing decommissioning technologies are well suited for most decommissioning tasks not requiring remote operation, the availability of technologies should not impede progress of decommissioning activities.
- Productivity rates and related unit cost factors can be used by decommissioning managers in developing estimates to support budgets and proposal requests and evaluating cost trade-offs between decommissioning end-states.
- Decommissioning Program Managers may use the Decommissioning Preferred Alternatives Matrix to assist in the determination of technologies for use on a decommissioning project.
- Facility life cycle costs can be reduced by performing decommissioning as soon after deactivation as possible.
- For radioactive decommissioning activities, DOE should consider waste disposal costs incurred in decommissioning activities to ensure appropriate trade-offs between labor costs (decontamination activities) and disposal costs (volume of material disposed).
- DOE should continue the decommissioning committee activities and increase emphasis on collecting data, measuring progress, and sharing decommissioning results with DOE, EPA, and international partners.

ALL GRAPHS HAVE BEEN CODED WITH A DATA CONFIDENCE INDICATOR TO IDENTIFY THE STRENGTH OF THE DATA COLLECTED FOR EACH WORK AREA AND FOR THE INDIVIDUAL GRAPH.



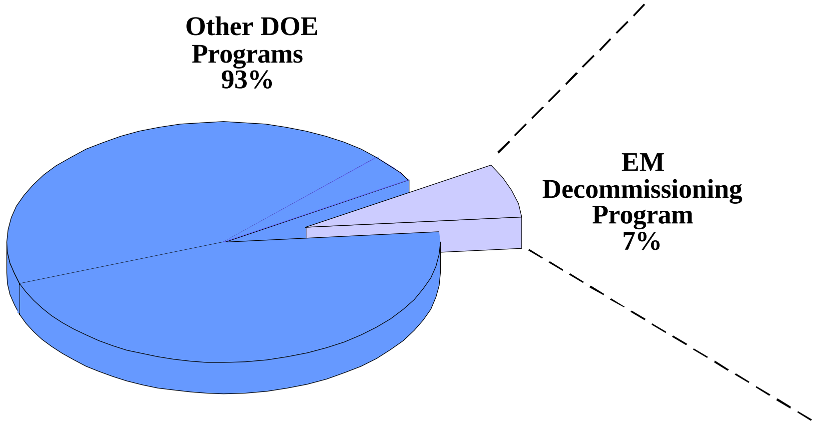
Program/Project Overview

- The Decommissioning Program Overview summarizes DOE's decommissioning liability.
- Data depicting total project costs categorized by physical labor, support, and white collar costs are in the Total Project Summaries.
- Benchmarks and unit cost factors are used to develop sample facility decommissioning costs.
  - Unit cost factors accounting for removal action only were determined by multiplying the productivity rate by a labor rate of $40/hr. Unit cost factors accounting for waste disposal and removal action include additional costs determined by one of five waste disposal scenarios:
    - Recycle/reuse - No additional costs; no credit.
    - Local disposal @ $0.26/ft^3 - This is based on MEANS® productivity rates for short range hauling and dumping of demolition debris.
    - Sanitary asbestos disposal @$20/ft^3 - This is comparable to asbestos disposal rates at federal installations.
    - DOE low-level waste disposal @$43/ft^3 - This is typical of what DOE generators may pay for disposal.
    - Commercial disposal of low-level radioactive waste @ $300/ft^3 - This is comparable to the highest rates commercial generators may pay and is intended to demonstrate the relative impact of high waste disposal costs on decommissioning.
  - Disposed volumes were determined by applying a factor to the quantity of material removed. For all waste disposal scenarios it is assumed that the waste meets all criteria concerning hazardous constituents.
  - The next page summarizes the waste disposal options that were considered for each physical task.

Waste Disposal Options Considered for Each Physical Task					
Decommissioning Activity Resulting in Waste Stream	Waste Disposal Options Considered				
	Recycle/ Reuse	Sanitary Debris	Sanitary ACM	DOE Low Level Waste	Commercial Low Level Waste
Concrete Decontamination				✔	✔
Concrete Demolition		✔		✔	✔
Structural Steel Demolition	✔			✔	✔
ACM Tile and Siding Removal			✔	✔	✔
ACM Pipe Insulation Removal			✔	✔	✔
Equipment Removal	✔			✔	✔
Pipe Removal	✔			✔	✔

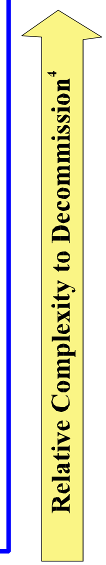
CURRENTLY, DOE HAS 15,024[1] FACILITIES IN INVENTORY, OF WHICH 7,000[2] ARE SURPLUS CONTAMINATED FACILITIES IN THE ENVIRONMENTAL MANAGEMENT PROGRAM.

DOE FACILITIES INVENTORY
Total = 15,024



DECOMMISSIONING PROGRAM INVENTORY

Type	Number
Uranium Enrichment	5
Fuel Reprocessing	2
Production, Test, and Research Reactors	25
Plutonium and Uranium Production Manufacturing Facility	8
Laboratories	29
Accelerator	1
Equipment and Physical Plant	154
Other Buildings	486
Tanks, Landfills, Sumps, etc.	172
Security Buildings, Warehouses, and Trailers	133
Administrative Buildings and Trailers	71
Total	**1,086[3]**

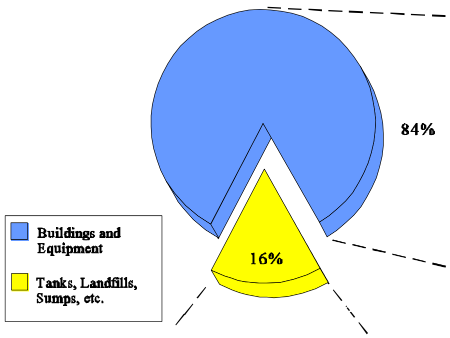


To date, only 1,086 of the surplus contaminated facilities are the responsibility of the Environmental Restoration Decommissioning Program. Forty of these facilities are large, highly complex facilities.
EPA has a very limited set of facilities surplus to its needs.

Source: 1 DOE Real Property Report for FY 94.
2 DOE EM-40 "Decommissioning of Facilities" Web Page (http://www.em.doe.gov/dd/), October 4, 1996.
3 EM-40 Core Database, dated October 29, 1996. (Note: Only one facility is included in this database for Savannah River).
4 Booz Allen & Hamilton Inc. analysis.

THE EM DECOMMISSIONING PROGRAM CURRENTLY HAS 1,086 FACILITIES TO BE DECOMMISSIONED, 914 OF WHICH ARE BUILDINGS AND EQUIPMENT.

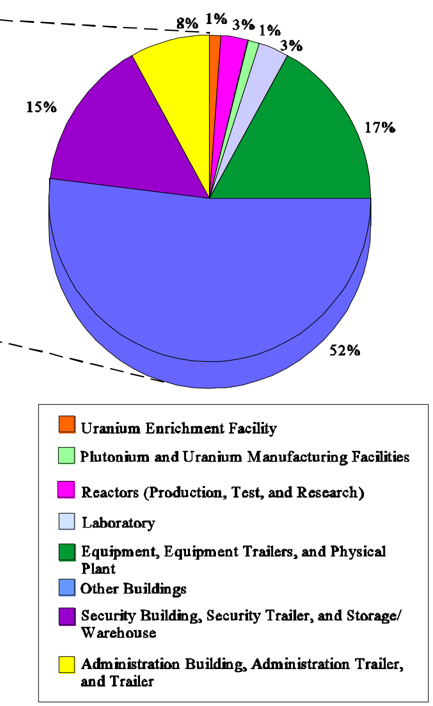
Types of Facilities to be Decommissioned



Detailed Breakout of Tanks, Landfills, Sumps, etc.

Other Categories	Number	Percent
Tanks Above Ground	104	61
Material/Waste Liquid Surface	43	25
Impoundments	10	6
Miscellaneous	5	3
Waste	4	2
Spills and Leaks Dispersed Surface	4	2
Contamination	2	1
Total	172	100% of 16%

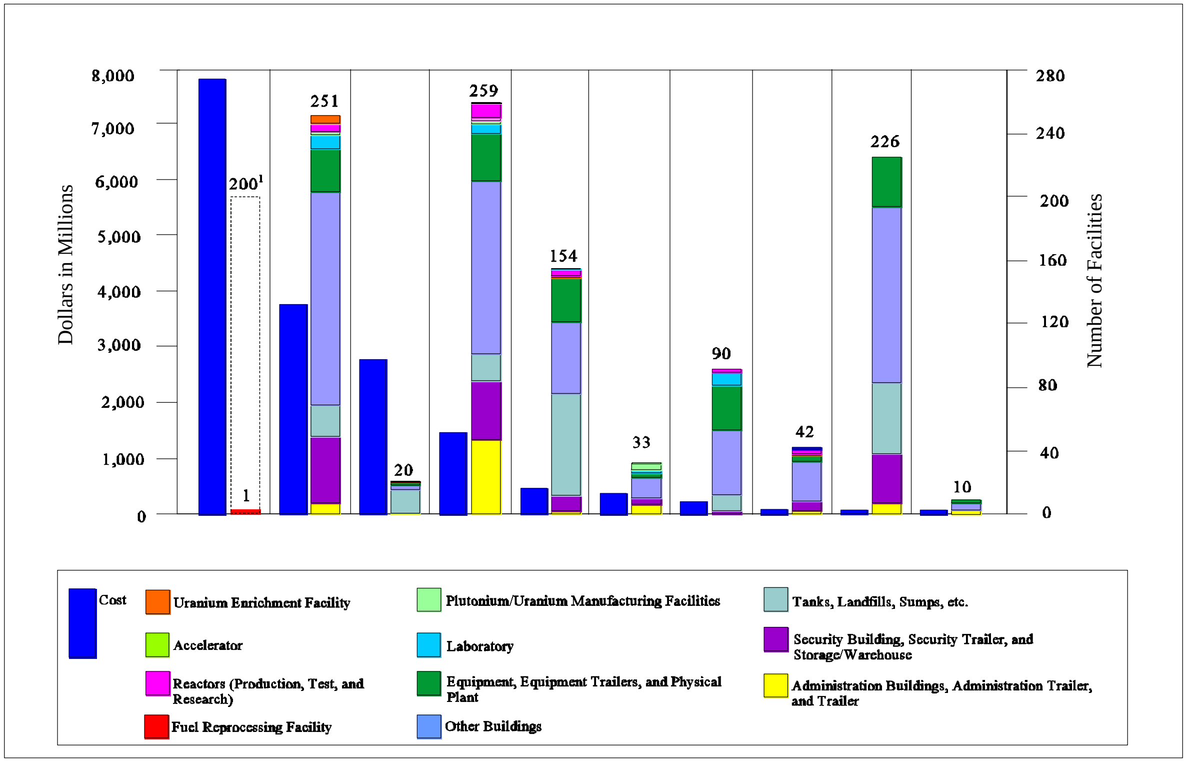
Detailed Breakout of Buildings and Equipment[1]



Source: EM-40 Core Database, dated October 29, 1996.

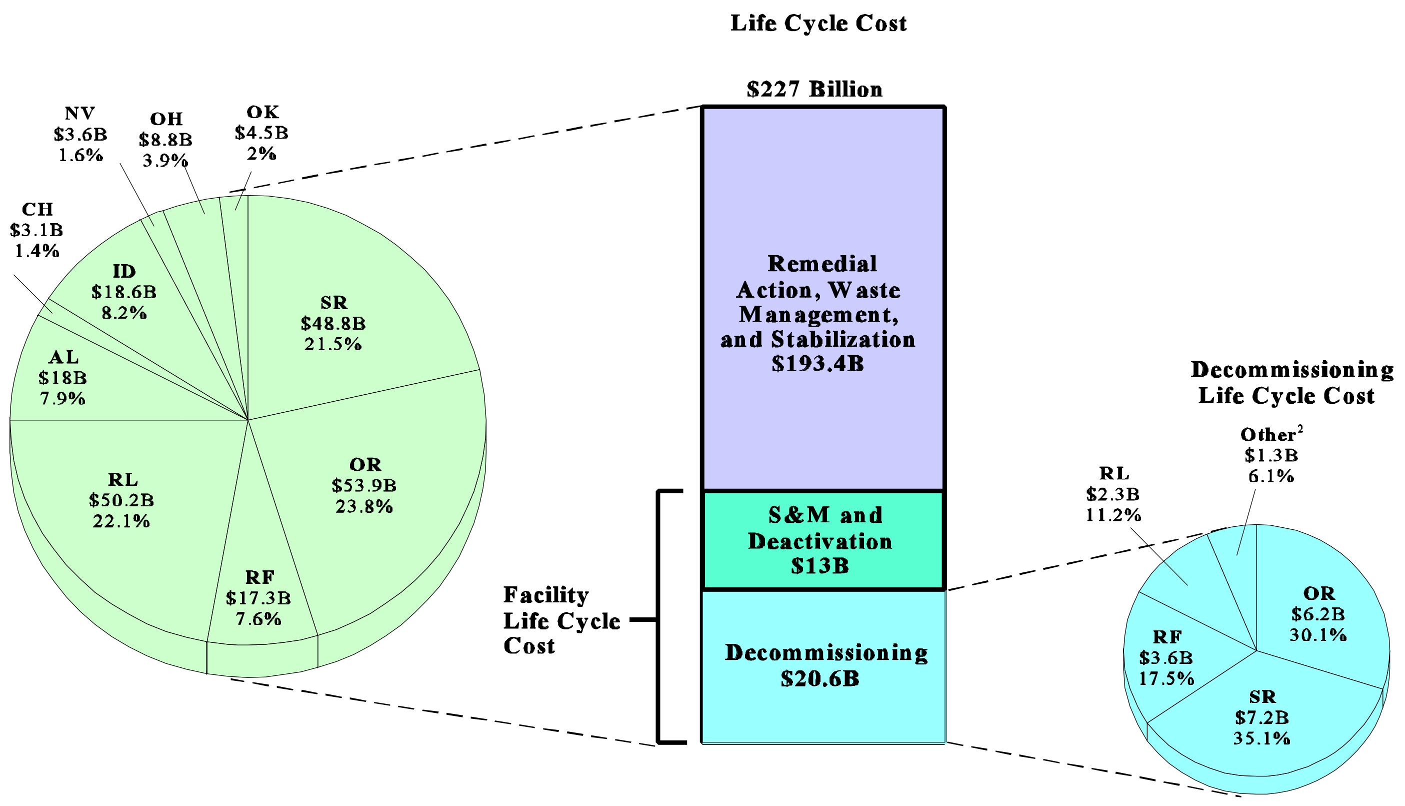
[1]The fuel processing facilities and the accelerator do not appear on the pie chart since they represent less than 1% of the total.

EM'S MOST SIGNIFICANT DECOMMISSIONING LIABILITIES ARE AT SAVANNAH RIVER, OAK RIDGE, ROCKY FLATS, AND IDAHO; 63% OF THE 1,086 FACILITIES TO BE DECOMMISSIONED ARE LOCATED AT IDAHO, OAK RIDGE, ROCKY FLATS, AND RICHLAND.



[1]While only one facility for decommissioning was listed in the EM-40 Core Database, dated October 29, 1996, the Savannah River Operations Office Web Page (http://www.srs.gov/general/news-notes/newspress/decom_facilities.html) indicates approximately 200 buildings to be decommissioned with approximately 660 more buildings being assessed.

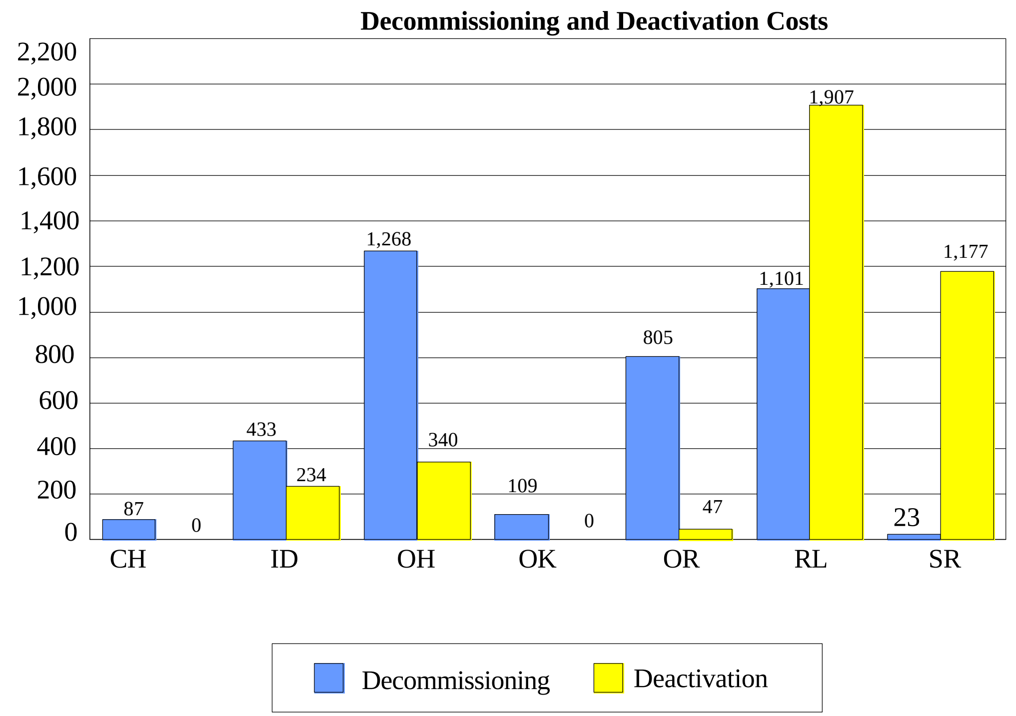
OF THE TOTAL $227 BILLION LIABILITY, DECOMMISSIONING IS PROJECTED TO REQUIRE APPROXIMATELY $20.6 BILLION - 94% OF WHICH WILL BE ALLOCATED TO DECOMMISSIONING PROJECT AT SAVANNAH RIVER, OAK RIDGE, ROCKY FLATS, AND RICHLAND.



Source: 1996 BEMR Report, Volumes II and III. The term "life cycle cost" refers to the cost to complete the mission of the Environmental Management program. The Ten Year Plan was not finalized at the time of report publication.

[1] Fernald and Weldon Spring decommissioning cost estimates are included under remedial actions.

EM'S TEN YEAR PLANS REVEAL SUBSTANTIALLY LESS DECOMMISSIONING AND DEACTIVATION COSTS ($7.5B) THAN THE 1996 BEMR LIFE CYCLE COSTS ($33.6B).



Source: The Ten Year Plan data is from the draft submission dated July 1996. The Ten Year Plan is currently being completed. Seven out of ten Operations Offices provided decommissioning/deactivation costs for the Ten Year Plan utilized. Ten Year Plan totals are \$3.8B for decommissioning and \$3.7B for deactivation for a combined total of \$7.5B. The total decommissioning cost does not include decommissioning the facilities deactivated in the ten year window since subsequent decommissioning occurs after the ten year period.

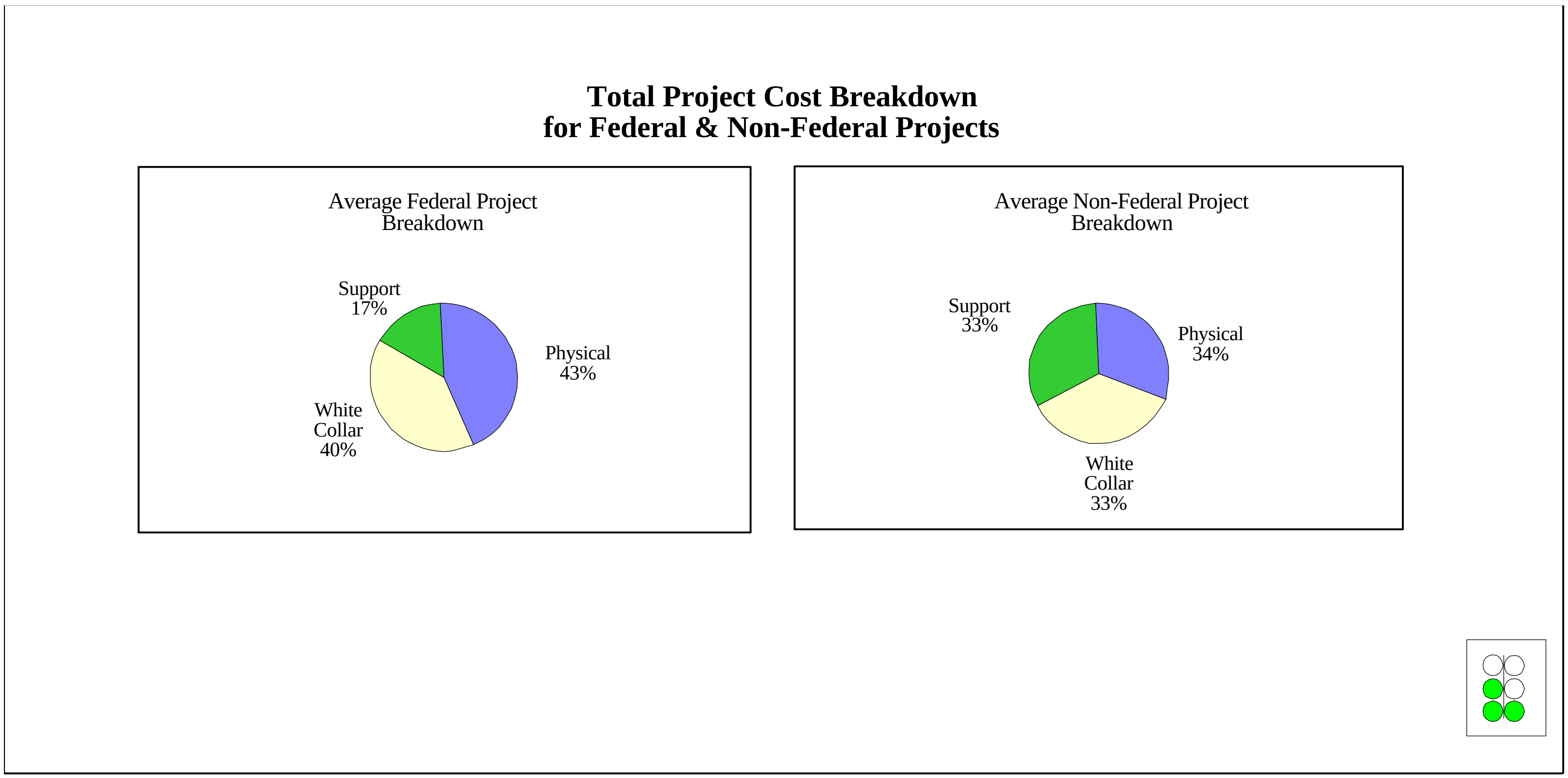
Total Project Summaries

Total Project Cost Breakdown for Federal and Non-Federal Projects	
Data sources	Federal and non-federal
Structures	Small prototype reactors, fuel reprocessing facilities, laboratories, and other contaminated buildings
Contaminants	Radioactively contaminated, several contained asbestos
Scope	Setup, removal, and waste packaging included. Some of the projects involved complete demolition of the facility, while others focused on facility reuse.
Assumptions	For projects where only subcontractor data was available an additional 20% of the total subcontractor cost was added as white collar labor to the total project cost to account for estimated Federal contractor oversight, project management, and engineering. The 20% estimate was based on empirical observation of other projects and engineering judgment.

Discussion:

- Initial data indicates that federal projects use a slightly greater percentage of white collar labor than non-federal projects. Note that the non-federal average is generated from a limited data set.
- **Physical labor** includes all craftsmen and foremen cost (or hours) expended on a job; **white collar** labor includes all project management, engineering, safety and health documentation, and procurement organization costs (or hours); and **support** includes costs (or hours) for health physics (HP) technicians, site characterization, setting up utilities, security, surveillance, and maintenance.
- Due to some differences in how data was collected at various projects, some of the support costs may be lumped with physical labor data. Therefore, the most significant difference shown by these graphs is that a slightly greater percentage of white collar labor is utilized on federal projects than on non-federal projects.
- Waste costs were not included in these calculations. Data indicated that waste disposal costs generally accounted for 5% to 15% of the total project cost. Waste disposal costs will vary greatly, however, depending on the types and quantities of waste generated, as well as the availability of disposal facilities.

WHITE COLLAR LABOR ACCOUNTS FOR GREATER THAN ONE THIRD OF TOTAL DECOMMISSIONING PROJECT COST.



Labor Cost Distribution vs. Total Project Cost	
Data sources	Federal and non-federal
Structures	Small prototype reactors, fuel reprocessing facilities, laboratories, and other contaminated buildings
Contaminants	Radioactively contaminated, several contained asbestos
Scope	Setup, removal, and waste packaging included. Some of the projects involved complete demolition of the facility, while others focused on facility reuse.
Assumptions	For projects where only subcontractor data was available an additional 20% of the total subcontractor cost was added as white collar labor to the total project cost to account for estimated Federal contractor oversight, project management, and engineering. The 20% estimate was based on empirical observation of other projects and engineering judgment.

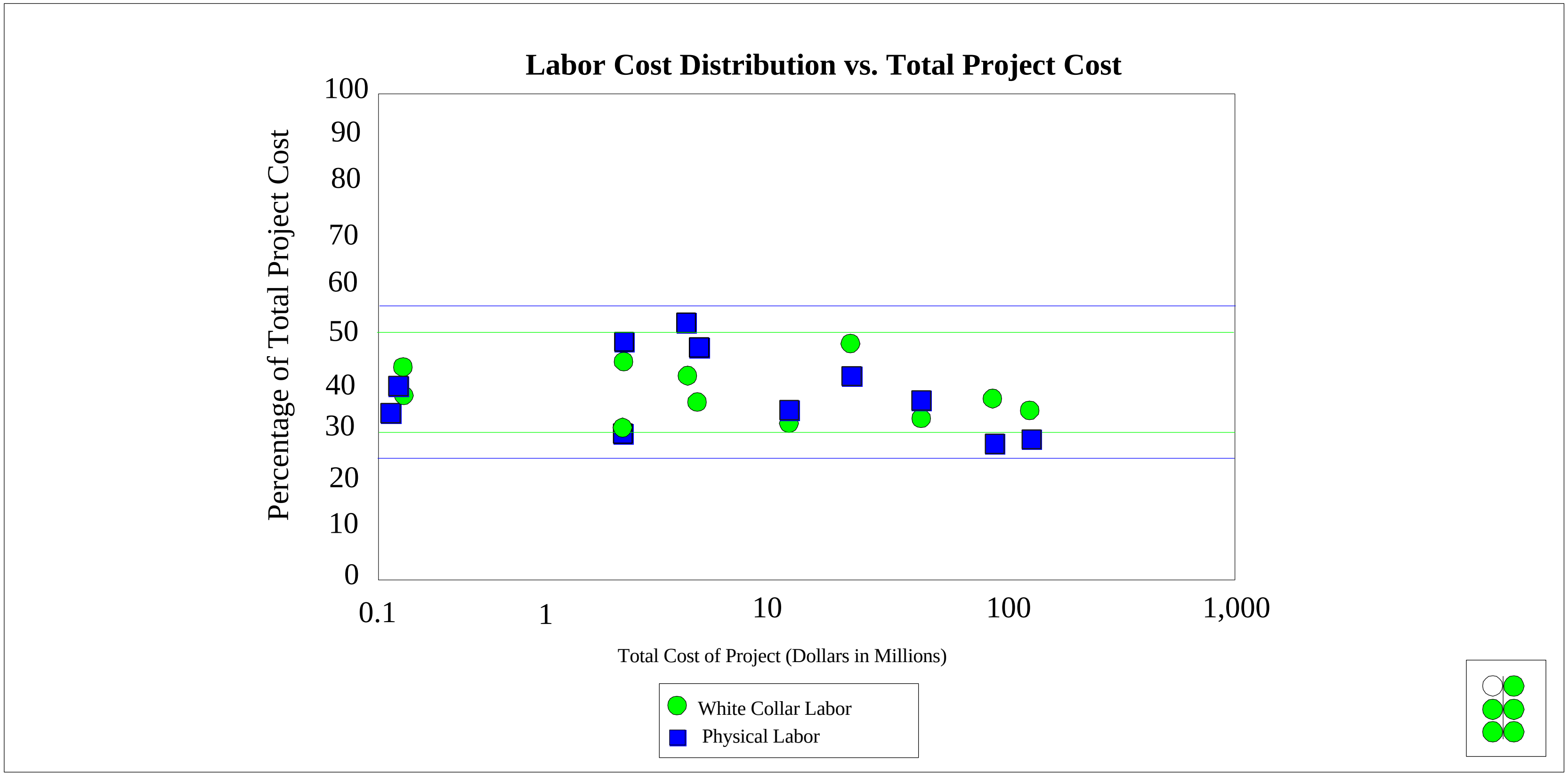
Discussion:

- **Physical labor** includes all craftsmen and foremen cost (or hours) expended on a job; **white collar** labor includes all project management, engineering, safety and health documentation, and procurement organization costs (or hours); and **support** includes costs (or hours) for health physics (HP) technicians, site characterization, setting up utilities, security, surveillance, and maintenance.

- The lines are provided on the graph to highlight ranges of physical and white collar labor.

- Although an increase in the percentage of physical labor versus white collar labor may be anticipated as projects increase in size, the graph shows no economy of scale in decommissioning projects. This may be due to larger decommissioning projects actually being thought of as a series of many smaller tasks that each require an appropriate amount of engineering and project management. Alternatively, this may reflect a practice of assigning personnel to a project for the duration of the job.

PERCENTAGE OF TOTAL PROJECT COST SPENT ON WHITE COLLAR AND PHYSICAL LABOR ARE INDEPENDENT OF TOTAL PROJECT SIZE.



SAMPLE APPLICATIONS OF DECOMMISSIONING BENCHMARKING RESULTS: DECOMMISSIONING COST ESTIMATES FOR REPRESENTATIVE 50 MWt RESEARCH REACTOR AND HOT CELL FACILITY.

Unit cost factors developed from benchmarking results can be used to develop decommissioning cost estimates for any facility.

Terms:

Quantity: Amount of a specific material that is part of the facility, e.g., 100 cubic feet of concrete or 6 tons of structural steel
Costs for removal and local disposal: Quantity multiplied by unit cost factor for removal and local disposal
Costs for removal and commercial disposal: Quantity multiplied by unit cost factor for removal and commercial disposal

Methodology:

Calculate the cost of each decommissioning task (material quantity multiplied by unit cost factor)
Sum the costs of all decommissioning tasks
Total project costs, accounting for administrative and support costs is equal to 2.5 times the costs for physical tasks.

Major Assumptions:

Facilities are completely deactivated.
Quantities and facility conditions are comparable to respective DOE research reactor and hot cell facilities.
Structure is in sound condition.
20% of equipment, structural steel, and piping is assumed removed and disposed of as radioactive waste.
5% of concrete and ACM is assumed contaminated and/or activated such that decontamination is not feasible.
No new contamination is encountered once surfaces are decontaminated.
All equipment required for decommissioning is available on-site (i.e., no new purchases).
Radiological controls remain in place until the site is released.
Pressure vessel and internals removal is only work requiring remote operation.
Demolition is to grade with minimal soil remediation.
Uncontaminated equipment, piping, and steel is released as scrap.
Labor force is comprised of maintenance and operation personnel.

Decommissioning Unit Cost Factors Used for Sample Facility Cost Estimates					
Decommissioning Activity Resulting in Waste Stream	**Waste Disposal Options**				
	Removal Only or Recycle/ Reuse	**Sanitary Debris**	**Sanitary ACM**	**DOE Low Level Waste**	**Commercial Low Level Waste**
Concrete Decontamination (1/16" depth)	$4.8/ft^2$	N/A	N/A	$5.2/ft^2$	$7.9/ft^2$
Concrete Removal (Contact)	$1.2/ft^3$	$1.6/ft^3$	N/A	$65.7/ft^3$	$451/ft^3$
Concrete Removal (Remote)	$80/ft^3$	N/A	N/A	$145/ft^3$	$530/ft^3$
Structural Steel Removal (Clean)	$144/ton	N/A	N/A	N/A	N/A
Structural Steel Removal (Contaminated; 7ft^3/ton)	$440/ton	N/A	N/A	$741/ton	$2540/ton
Asbestos Siding Removal	$3.6/ft^2$	N/A	$5.6/ft^2$	$9.6/ft^2$	$33.6/ft^2$
Asbestos Tile Removal	$11.2/ft^2$	N/A	$13.2/ft^2$	$15.3/ft^2$	$41.2/ft^2$
Asbestos Insulation Removal (Tasks > 1,000 ft^3)	$26/ft^3$	N/A	$56/ft^3$	$91/ft^3$	$476/ft^3$
Equipment Removal (Mixed equipment @ 25 manhours/ton, 21 ft^3/ton)	$1,000/ton	N/A	N/A	$1,903/ton	$7,300/ton
Pipe Removal (Removal based on 2"-6" diameter; disposal based on 6" diameter)	$10.5/ft	N/A	N/A	$18.9/ft	$69/ft
Activated Component Cutting (Remote - e.g., reactor pressure vessel internals)	N/A	N/A	N/A	$1M/job	$2M/job

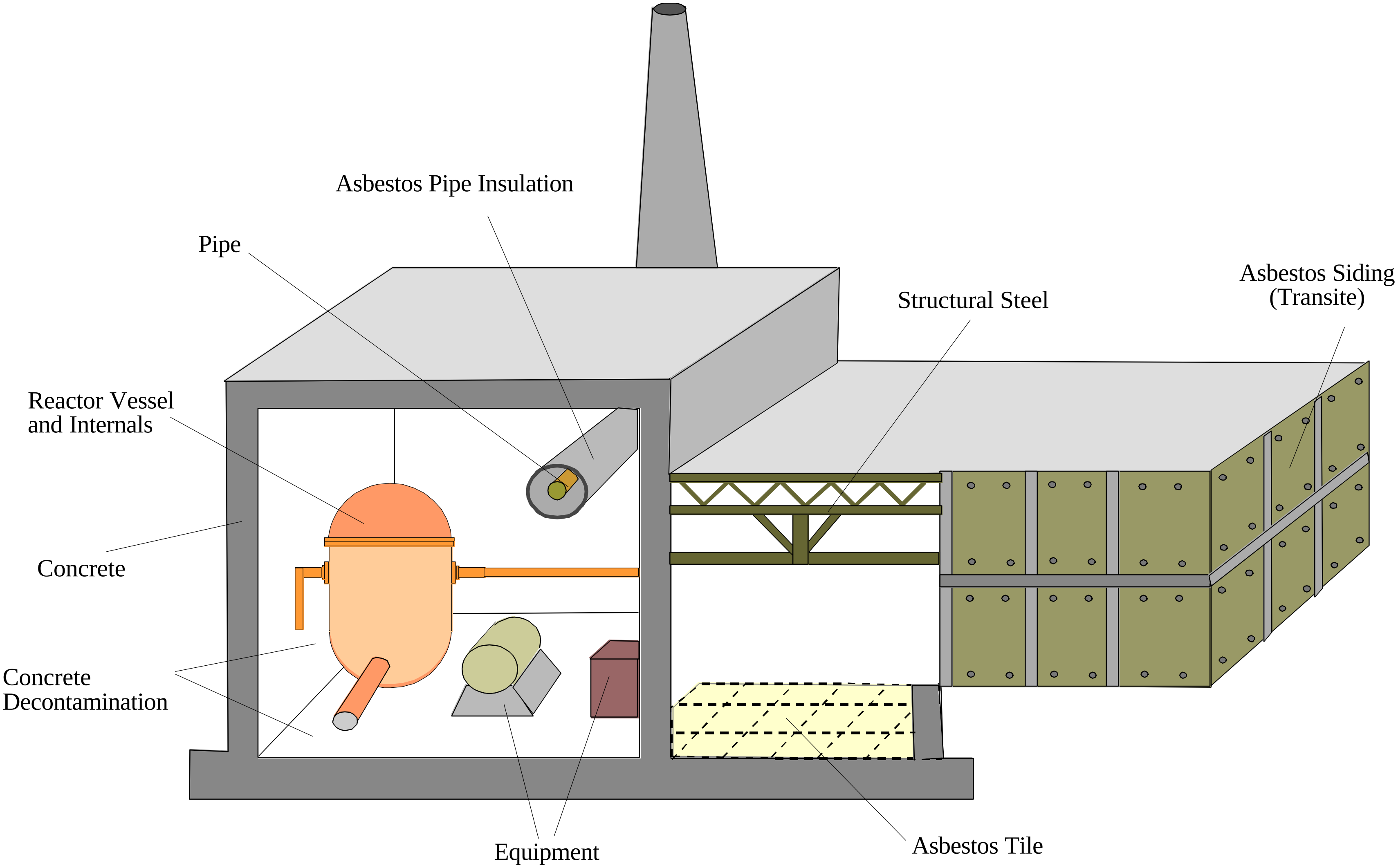
A more in-depth treatment of the unit cost factors is presented in the analysis of each physical function.

Example Decommissioning Cost Estimate for a Representative 50MWt Research Reactor			
Task Name	**Quantity**	**Removal & DOE Disposal Cost Estimate**	**Removal & Commercial Cost Estimate**
Concrete Decontamination	93,000 ft^2	$483,600	$734,700
Concrete Removal (Contact)	180,920 ft^3	$869,330	$4,354,744
Structural Steel Removal	458 ton	$120,637	$285,425
Asbestos Siding (Transite) Removal	31,450 ft^2	$267,325	$305,065
Asbestos Insulation Removal	53,000 ft^3	$3,060,750	$4,081,000
Asbestos Floor Tile Removal	45,000 ft^2	$261,000	$315,000
Equipment Removal	304 ton	$358,902	$687,040
Piping Removal	36,865 ft	$449,016	$818,403
Reactor Vessel & Core Internals Removal	N/A	$1,000,000	$2,000,000
Subtotal of Physical Labor	N/A	$6,870,560	$13,581,377
Total (including physical labor, white collar, and support)	**N/A**	**$17,176,400**	**$33,953,443**

Discussion:

- Quantities based on published data and Booz·Allen & Hamilton Inc. analysis.

REPRESENTATIVE 50 MWt RESEARCH REACTOR

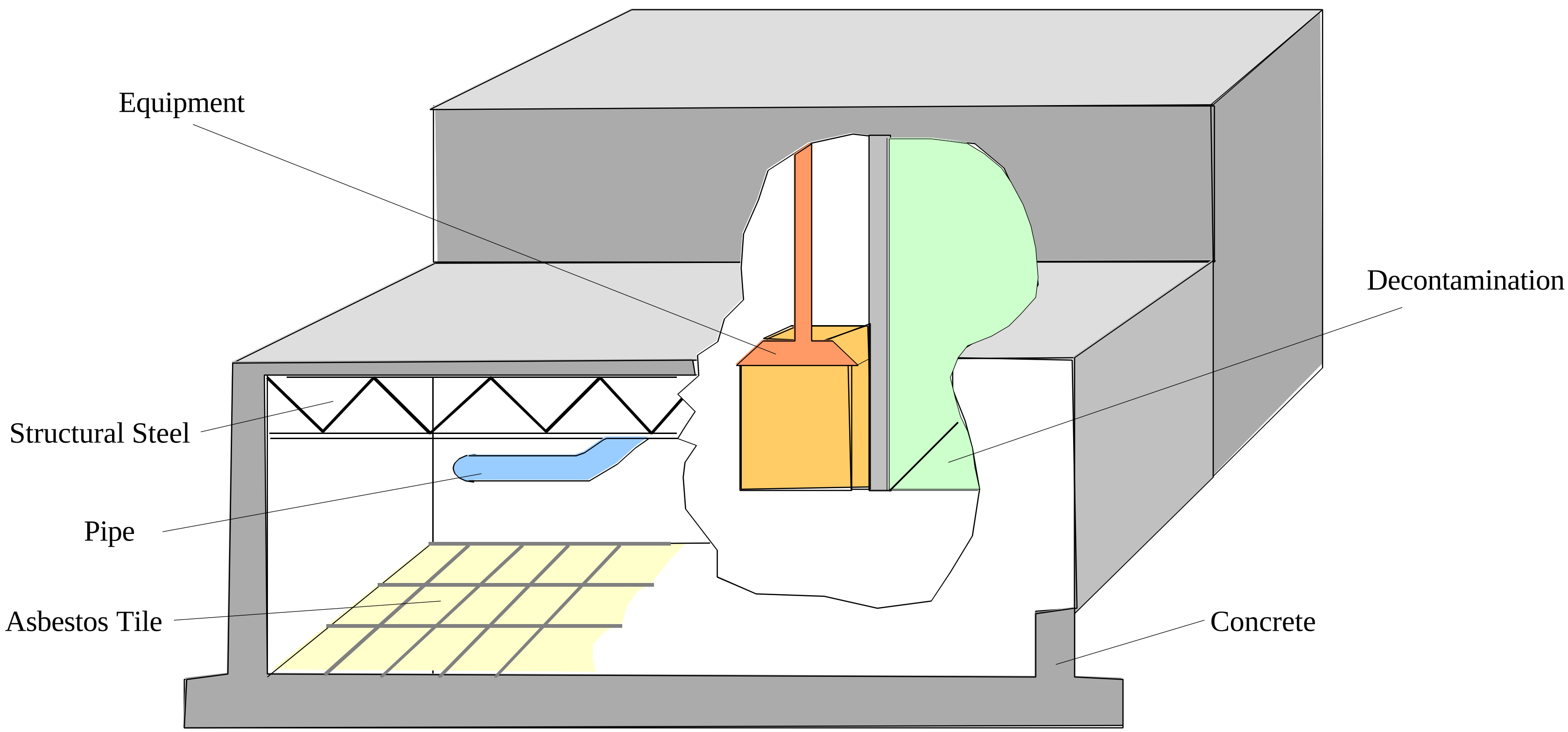


Example Decommissioning Cost Estimate for a Representative Hot Cell Facility (Five Cell)			
Task Name	**Quantity**	**Removal & DOE Disposal Cost Estimate**	**Removal & Commercial Cost Estimate**
Concrete Decontamination	22,200 ft^2	$115,440	$175,380
Concrete Removal (Contact)	24,000 ft^3	$115,320	$577,680
Structural Steel Removal	300 ton	$79,020	$189,960
Asbestos Siding (Transite) Removal	0 ft^2	$0	$0
Asbestos Insulation Removal	0 ft^3	$0	$0
Asbestos Floor Tile Removal	5,000 ft^2	$66,525	$73,000
Equipment Removal	9 ton	$10,625	$20,340
Piping Removal	9,450 ft	$115,101	$209,790
Subtotal of Physical Labor	N/A	$502,031	$1,246,150
Total (including physical labor, white collar, and support)	**N/A**	**$1,255,078**	**$3,115,375**

Discussion:

- Quantities based on published data and Booz·Allen & Hamilton Inc. analysis.

REPRESENTATIVE HOT CELL FACILITY (FIVE CELL)



Process/Labor Productivity Efficiencies
• Study data is shown for ten physical activity categories. • Data is displayed and analyzed with data ranges, weighted averages, and unit cost factors calculated. - Weighted average for productivity rates were determined by the sum of manhours worked divided by the sum of the physical quantity removed (e.g., tons or ft^3). The weighted average places more emphasis on tasks where larger quantities were involved and is a more appropriate comparison than the total range of data. - Productivity rates for tasks performed in a non-contaminated environment as published in the 1996 MEANS® Construction Handbook are presented, where applicable, along with rates developed from the data collected for comparative purposes.

Concrete Surface Decontamination

Concrete Decontamination Productivity for Federal and Non-Federal Projects	
Data sources	Federal and non-federal
Structures	Mostly horizontal surfaces
Contaminants	Radionuclides and PCBs
Technologies	Scabbling and vacuum blasting technologies
Depth of material removed	Varied within each project from 1/32" to 1/4"; usually 1/16"
Labor crew	Operators and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	Setup, decontamination and waste packaging operations, spot maintenance, and takedown is included. Orientation and transportation to job not included.

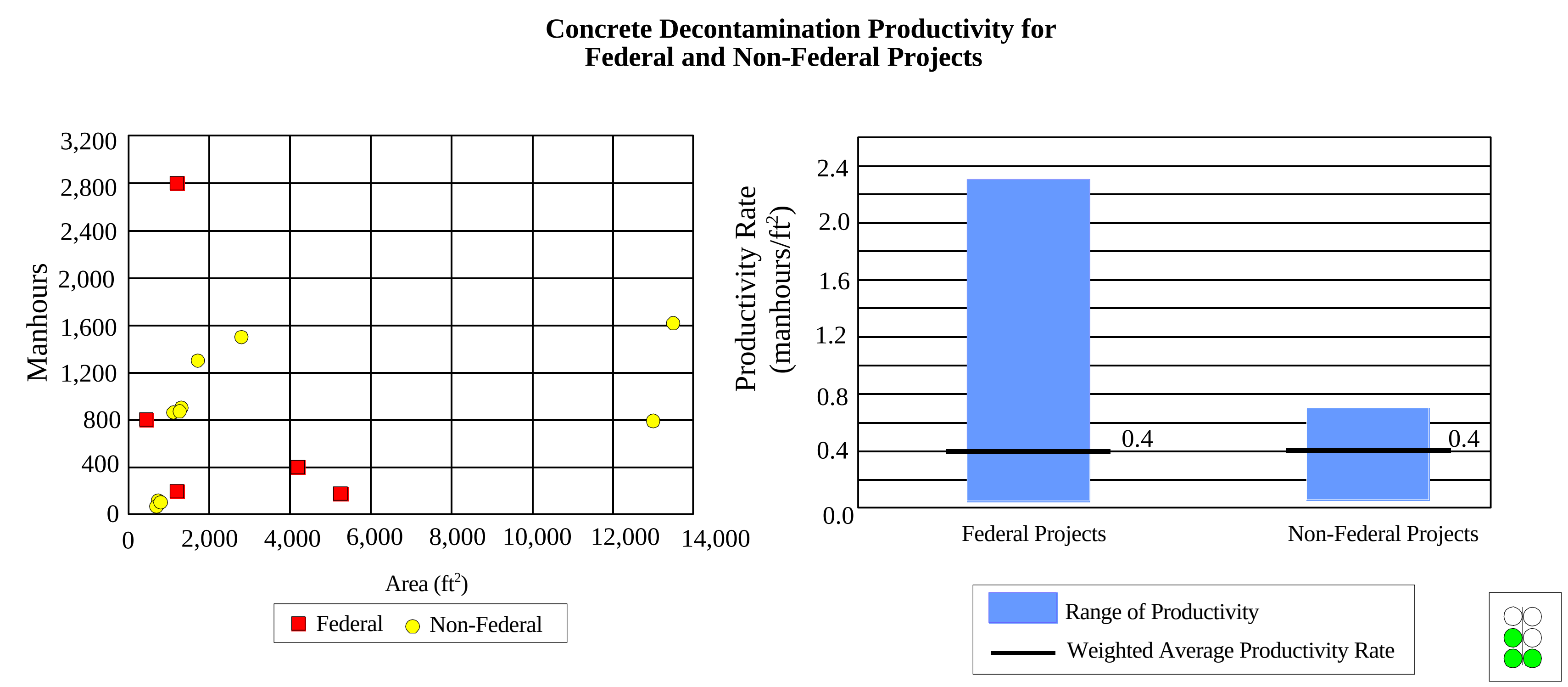
Discussion:

- Trends in decontamination productivity at the worker level between federal and non-federal projects were not observable.

- Significant ranges in productivity were observed for both federal and non-federal projects.

- Differences between federal and non-federal projects in regulatory and management approaches for decontamination may lead to cost advantages of one system over the other. For example, onerous documentation requirements increase project costs without impacting productivity. Additionally, strict release criteria can increase the scope of decontamination required but not affect productivity.

CONCRETE DECONTAMINATION PRODUCTIVITY EXPERIENCED AT FEDERAL PROJECTS IS COMPARABLE TO THAT EXPERIENCED AT NON-FEDERAL PROJECTS.



Comparison of Concrete Decontamination Productivity for Different Technologies	
Data sources	Federal and non-federal
Structures	Mostly horizontal surfaces
Contaminants	Radionuclides and PCBs
Technologies	Scabbling, vacuum blasting, and chemical extraction technologies
Depth of material removed	Varied within each project from 1/32" to 1/4"; usually 1/16"
Labor crew	Operators and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	Setup, decontamination and waste packaging operations, spot maintenance, and takedown is included. Orientation and transportation to job not included.

Discussion:

- For decontamination tasks including corners, baseboards, and incidental vertical surfaces, a productivity rate of 0.4 manhours/ft^2 may be expected from using scabblers of all sizes.

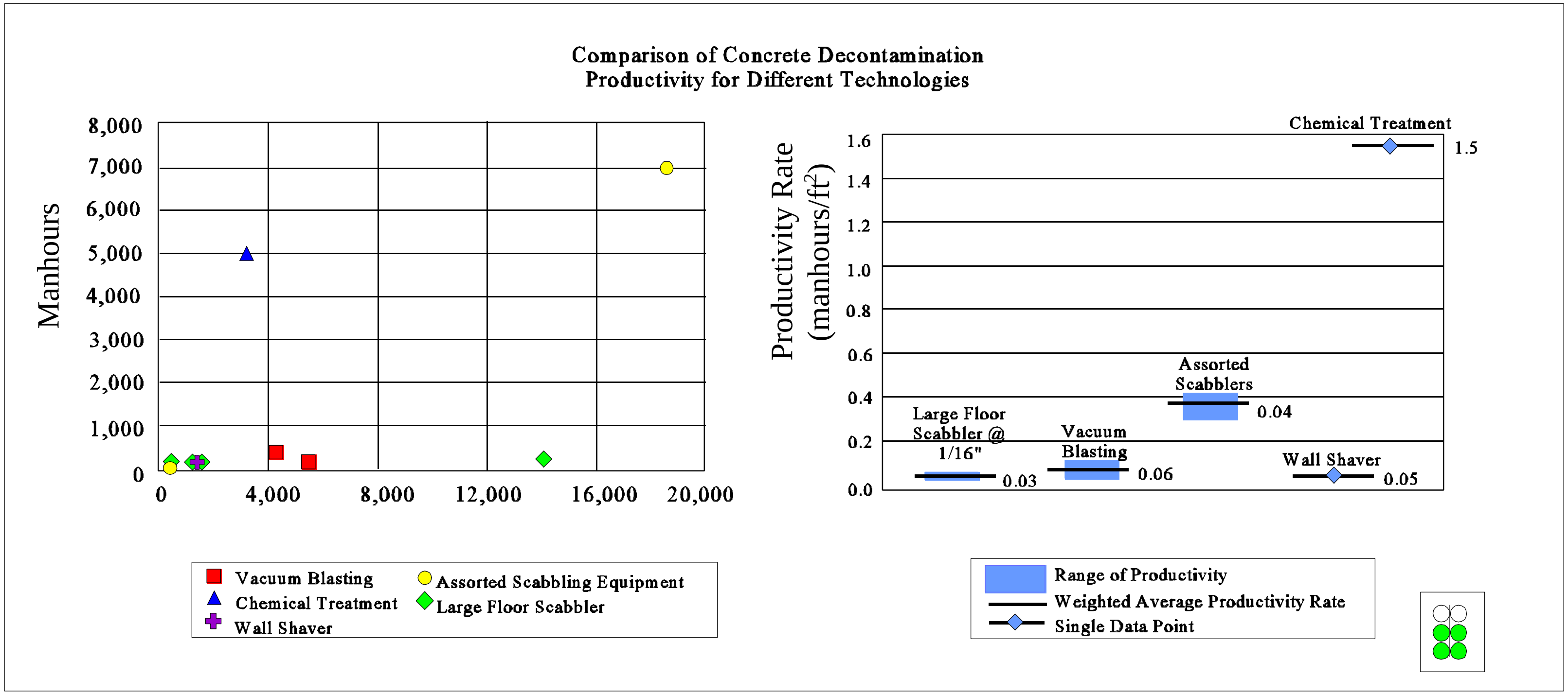
- Chemical extraction does not appear to have any advantage in terms of productivity over mechanical decontamination; however, it makes decontamination possible in areas inaccessible to conventional equipment.

- Different models types and ages of the same base technology may experience different productivities. Obstructions, periodic maintenance, and the size of the job may greatly influence productivity.

- Contaminant type did not appear to have any impact on productivity.

VACUUM BLASTING TECHNIQUES AND LARGE FLOOR SCABBLERS OFFER THE BEST CONCRETE

DECONTAMINATION PRODUCTIVITY RATES (0.06 MANHOURS/FT^2 AND 0.03 MANHOURS/FT^2 RESPECTIVELY) FOR UNOBSTRUCTED HORIZONTAL SURFACES.



Analysis Findings - Process/Labor Productivity Efficiencies - Concrete Surface Decontamination

Impact of Structure Type on Concrete Decontamination Productivity	
Data sources	Federal and non-federal
Structures	Horizontal, vertical, and tasks with both horizontal and vertical surfaces
Contaminants	Radionuclides and PCBs
Technologies	Scabbling and vacuum blasting technologies
Depth of material removed	Varied within each project from 1/32" to 1/4"; usually 1/16"
Labor crew	Operators and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	Setup, decontamination and waste packaging operations, spot maintenance, and takedown is included. Orientation and transportation to job not included.

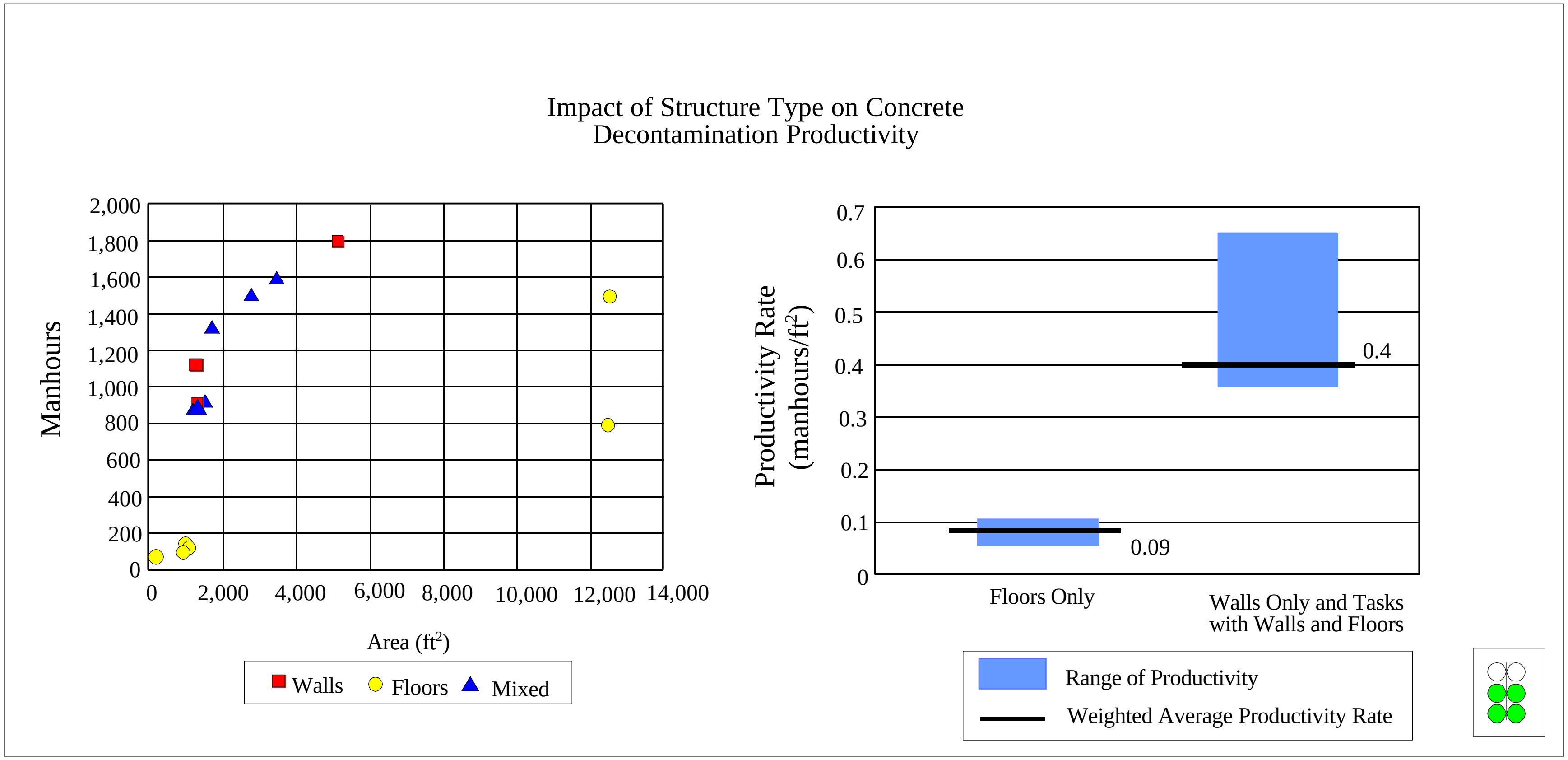
Discussion:

- Vacuum blasting technologies may be best suited for vertical surfaces. These technologies are lighter and more controllable than scabbling technologies and can navigate obstacles more easily.

- Although vacuum blasting cannot remove the same depth of material in a single pass as a scabbler, contaminants are less likely to penetrate deep into a vertical surface than a horizontal surface.

- Scabbling systems for vertical surfaces have been developed but have not yet been used extensively in the field.

TIME REQUIRED FOR DECONTAMINATION TASKS WITH BOTH VERTICAL AND HORIZONTAL SURFACES IS MORE THAN THREE TIMES THAT REQUIRED FOR TASKS WITH HORIZONTAL SURFACES ALONE.



Analysis Findings - Process/Labor Productivity Efficiencies - Concrete Surface Decontamination

Comparison of Productivities for Concrete Decontamination Technologies	
Data sources	Federal and non-federal
Structures	Mostly horizontal surfaces
Contaminants	Radionuclides and PCBs
Technologies	Scabbling, vacuum blasting, chemical, and emerging thermal technologies
Depth of material removed	Varied within each project from 1/32" to 1/4"; usually 1/16"
Labor crew	Operators and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	Setup, decontamination and waste packaging operations, spot maintenance, and takedown are included. Orientation and transportation to job not included. Process speed data based solely on rate at which equipment decontaminates a unit of area; crew size, setup, spot maintenance, and takedown are not included.

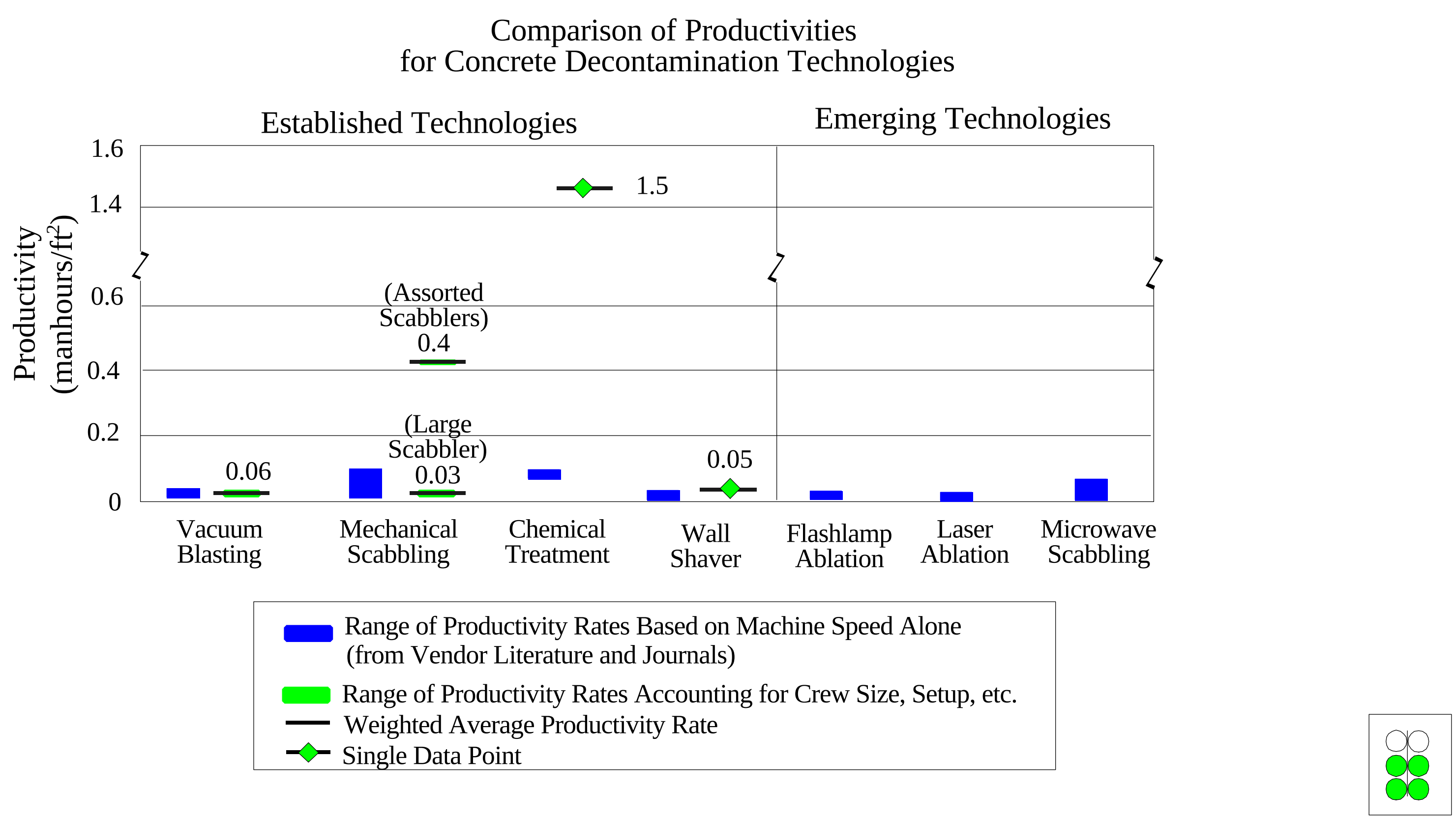
Discussion:

- Crew size, set-up, spot maintenance, etc. reduce optimum productivity of machine alone.

- Emerging technologies do not offer a productivity advantage over developed technologies, although they may address other issues such as waste minimization or worker safety. For example, emerging technologies that rely on rapidly heating the surface of the concrete to induce spalling may offer dose avoidance advantages in high radiation areas.

- Production scale units for emerging technologies have been developed, but are currently not widely deployed.

PRELIMINARY TESTS INDICATE EMERGING TECHNOLOGIES HOLD NO CLEAR ADVANTAGE OVER ESTABLISHED TECHNOLOGIES IN TERMS OF PRODUCTIVITY.

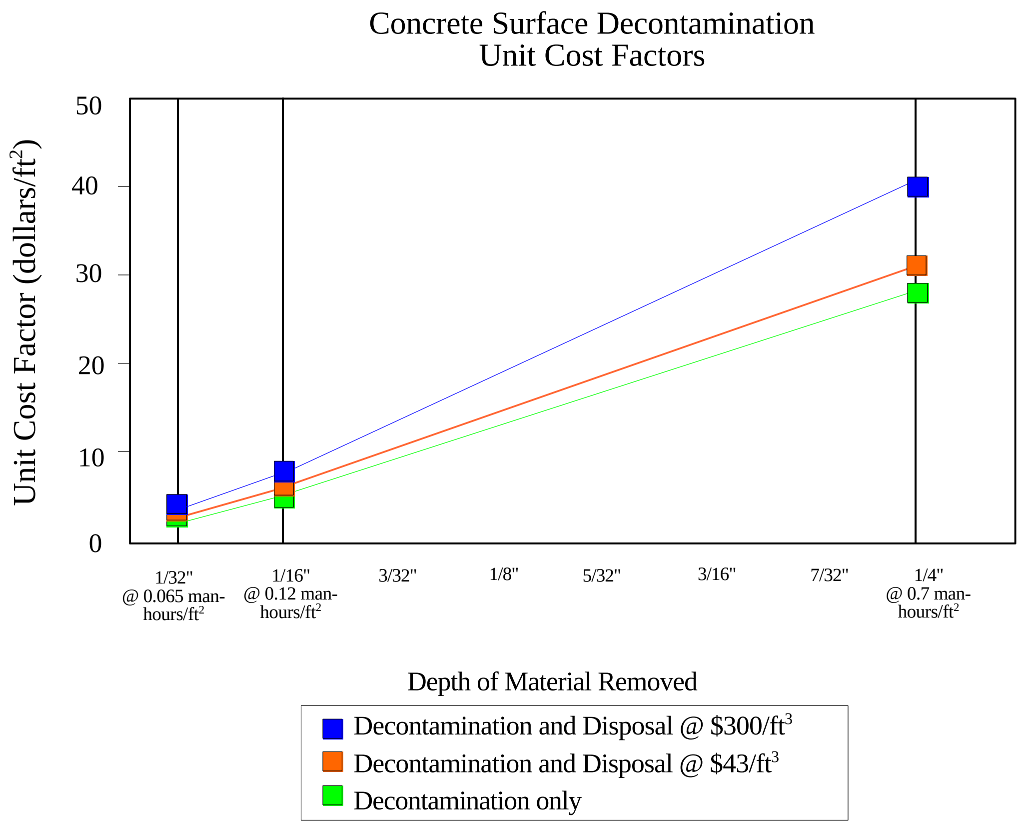


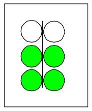
Concrete Surface Decontamination Unit Cost Factors	
Data sources	Federal and non-federal
Structures	Mostly horizontal surfaces
Contaminants	Radionuclides and PCBs
Technologies	Scabbling and vacuum blasting technologies
Depth of material removed	1/32" to 1/4"
Labor crew	Operators and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	Setup, decontamination and waste packaging operations, spot maintenance, and takedown included; orientation and transportation to job not included.
Productivity rates	0.065 manhours/ft^2 for 1/32"; 0.12 manhours/ft^2 for 1/16"; 0.7 manhours/ft^2 for 1/4"
Assumed labor rate	$40/hr; weighted fully burdened rate accounts for skilled operator and fraction of a foreman
Adjustment for disposed volume	Disposed volume equals two times volume removed to account for the disposal of filters, personnel protective equipment, and miscellaneous items.
Waste disposal rate	$43/$ft^3$; representative of the rate DOE low level waste generators may pay for disposal $300/$ft^3$; representative of the rate commercial low level waste generators may pay for disposal

Discussion:

- Productivity rates chosen to develop unit cost factors were typical rates experienced for decontaminating concrete at various depths. Variations in productivity may be experienced at any depth.

UNIT COST FACTORS FOR CONCRETE DECONTAMINATION ARE BASED PRIMARILY ON LABOR COSTS RATHER THAN WASTE DISPOSAL COSTS.





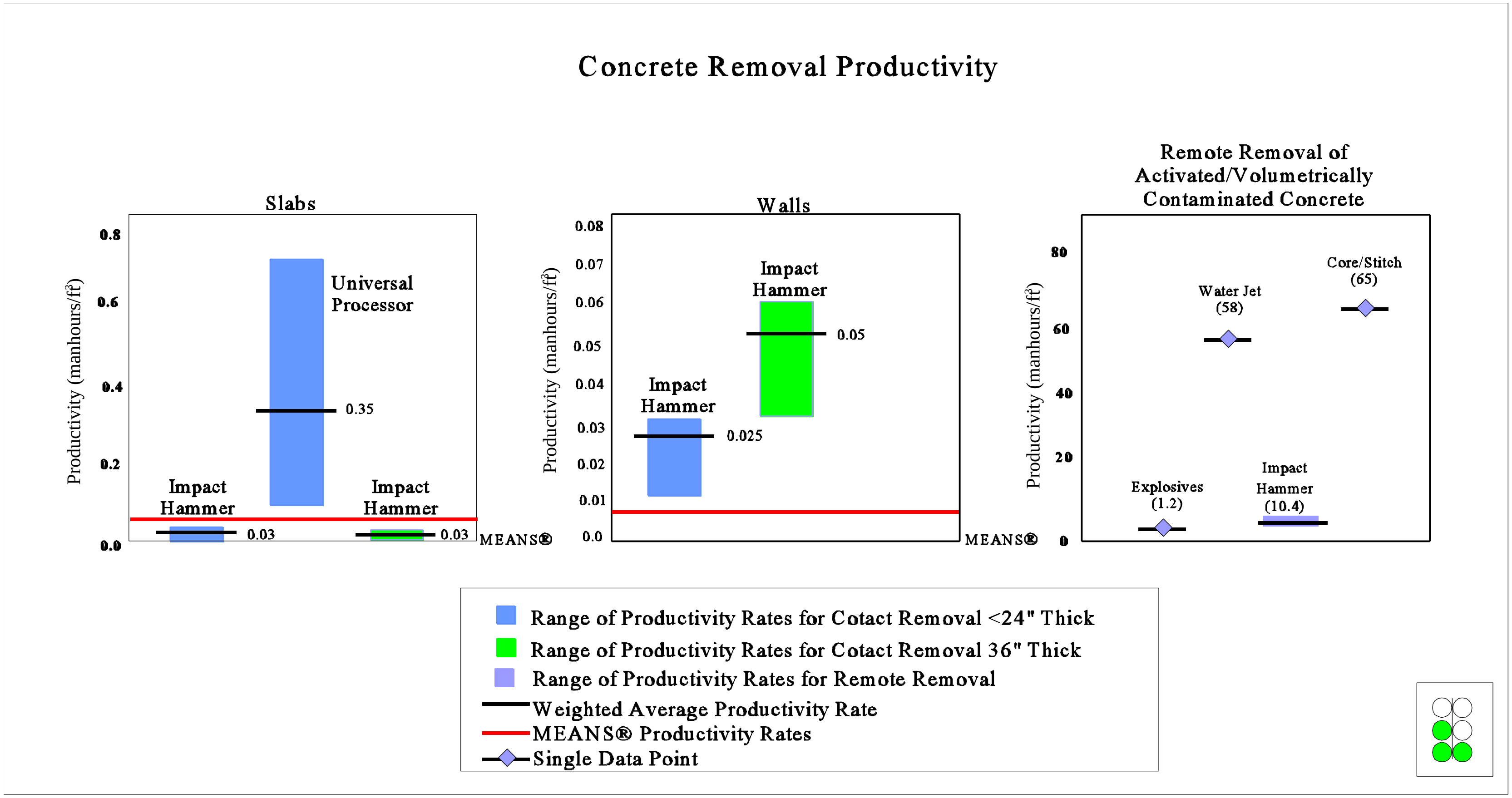
Concrete Demolition

Concrete Removal Productivity	
Data sources	Federal and non-federal
Structures	Walls and slabs
Contaminants	Clean, contaminated, and activated
Technologies	Track mounted crushers/shears, impact hammers; remotely operated booms for water jet, impact hammer and core/stitch drilling; other heavy equipment for moving rubble
Thickness of concrete	Up to 24" and greater than 36" for clean and contaminated concrete and more than 60" for activated concrete
Labor crew	Operators and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	Setup, removal operations, spot maintenance, and takedown are included. Orientation and transportation to job not included.

Discussion:

- Remote removal of concrete may take up to two orders of magnitude longer than contact removal.
- Productivity rates account for additional heavy equipment required to remove concrete and rebar from the work area.
- Project reports consistently indicated that impact hammers were more effective than other methods, while wrecking balls/slabs were less effective.
- Slab saws were required to “prime” concrete more than 36" thick prior to impact hammer use.
- Diamond wire cutting may be the most suitable method when the integrity of the remaining structures must be maintained and/or a smooth, straight cutting surface is required.

IMPACT HAMMERS OFFER EXCELLENT PRODUCTIVITY FOR A WIDE RANGE OF CONCRETE DEMOLITION TASKS.



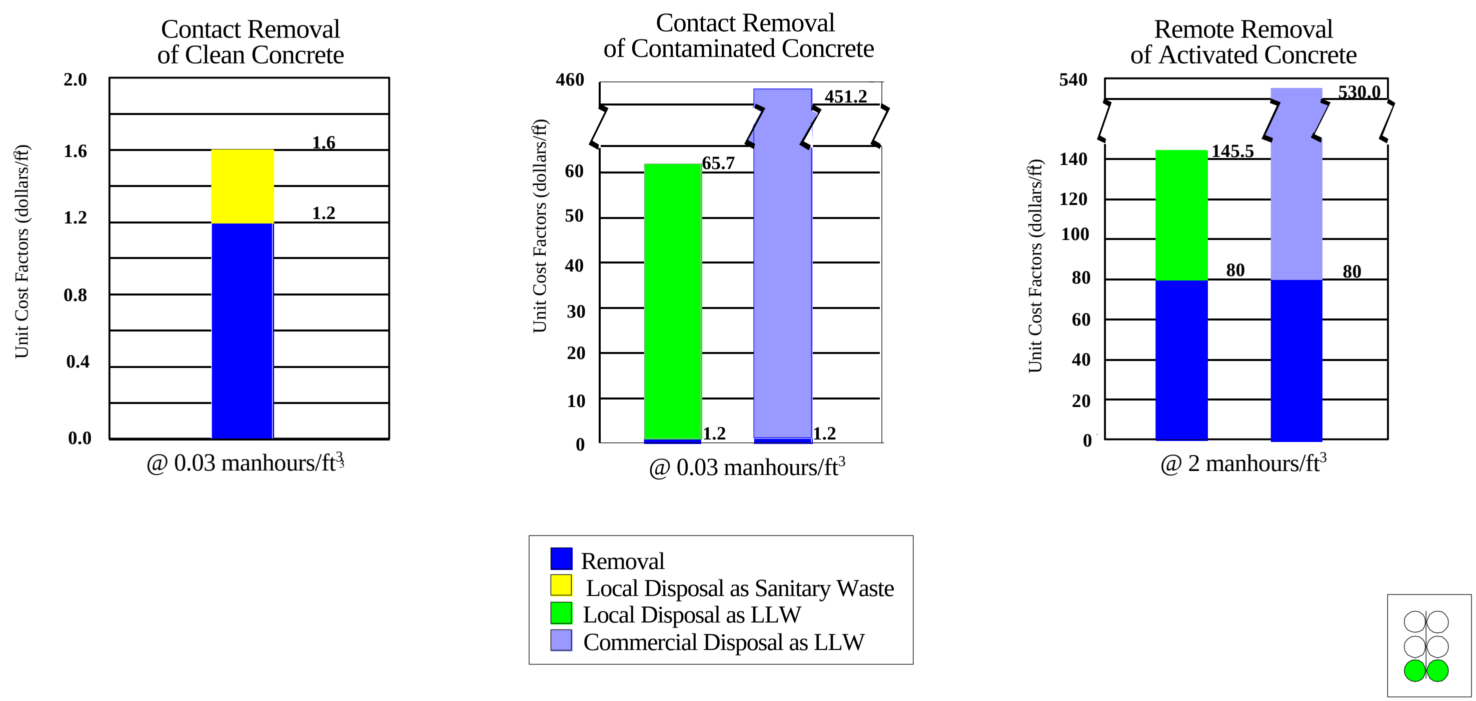
Concrete Removal Unit Cost Factors	
Data sources	Federal and non-federal
Structures	Walls and floors
Contaminants	Clean and contaminated structures
Technologies	Track mounted impact hammers and other heavy equipment for moving rubble
Thickness of concrete	Up to 100"
Labor crew	Operators and (occasionally) foremen; HP technicians and other support personnel not included
Scope	Setup, removal operations, spot maintenance, and takedown; orientation and transportation to job not included. Clean rubble used as fill or hauled off and disposed.
Productivity rates	0.03 manhours/ft^3 for contact removal of concrete; 2 manhours/ft^3 for remote removal of activated concrete
Assumed labor rate	$40/hr; weighted fully burdened rate for all heavy equipment operators and fraction of foreman
Adjustment for disposed volume	Hauled and disposed volume assumed 1.5 times demolished volume to account for void spaces and other debris
Hauling and disposal rates for sanitary waste	0.00256 hrs/ft^3 for on-site disposal, 0.00404 hrs/ft^3 for 5 mile haul (from MEANS®, 1996); this may be comparable to on-site disposal at federal installations
Waste disposal rate	$43/$ft^3$; representative of the rate DOE low level waste generators may pay for disposal $300/$ft^3$; representative of the rate commercial low level waste generators may pay for disposal

Discussion:

- Waste disposal charges can greatly increase the unit cost factor for remote removal of concrete. The unit cost factors for contact removal of concrete are dominated by labor as opposed to transportation and disposal.

CONCRETE REMOVAL UNIT COST FACTORS ARE HIGHLY SENSITIVE TO WASTE DISPOSAL RATES AND THE NEED FOR REMOTE REMOVAL.

Concrete Removal Unit Cost Factors



Steel Surface Decontamination

Analysis Findings - Process/Labor Productivity Efficiencies - Steel Surface Decontamination

Painted Steel Decontamination Productivity vs. Volume of Secondary Waste Generated	
Data sources	Federal
Structures	Steel plates and I-beams
Contaminants	Paint
Technologies	Blasting: CO_2, high pressure H_2O, plastic, soda, sponge, steel grit, ultra high pressure H_2O, wet ice
Depth of material removed	Most technologies removed 80% of finish coat, 80% of sub-primer/sub-coat, and 80% of red oxide primer. Steel Grit achieved superior results, cleaning to a near white condition, and sponge also performed slightly better, cleaning to a commercial grade surface. High pressure H_2O and wet ice did not perform as well as the others as they did not remove 80% of the red oxide primer in all cases.
Scope of productivity measure	The productivity measure only includes the time the technology was in use. Set up time and crew size are not accounted for in the measurements.

Discussion:

- All data comes from FEMP/SUB-098, UC-706, "Analysis of Potential Surface Blasting Decontamination Technologies for Structural Steel," M.A. Ebadian, L.E. Lagos, J.F. Boudreaux, T.R. Clark, and L.K. Miller, August 1995. The study was performed at Florida International University.

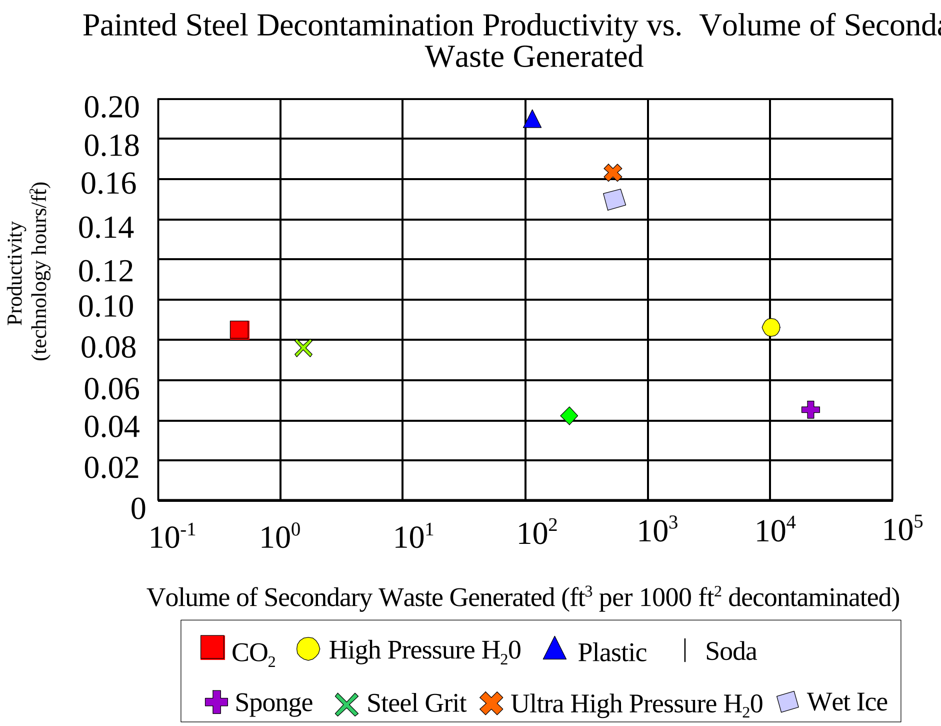
- CO_2 and steel grit blasting achieved superior ratings in terms of minimizing secondary waste produced.

- Sponge and soda were the most productive technologies.

- The graph does not indicate crew size required to operate the technology, personnel protective equipment (PPE) required while operating, or whether containment is necessary while operating the technology. The referenced study contains that information, as well as all the testing details from which these results were generated.

- The Data Confidence Indicator is not included because the data displayed is from a single, previously published study.

STUDIES INDICATE THAT ALTHOUGH SODA AND SPONGE TECHNOLOGIES HAVE GOOD PAINT REMOVAL PRODUCTIVITY FOR STEEL, CO2 AND STEEL GRIT BLASTING POSSESS ADVANTAGES IN MINIMIZING SECONDARY WASTE GENERATION.



Analysis Findings - Process/Labor Productivity Efficiencies - Steel Surface Decontamination

Rusted Steel Decontamination Productivity vs. Volume of Secondary Waste Generated	
Data sources	Federal
Structures	Steel plates and I-beams
Contaminants	Rust
Technologies	CO_2, high pressure H_2O, plastic, soda, sponge, steel grit, ultra high pressure H_2O, wet ice
Depth of material removed	Most technologies removed 80% of the loose rust from the surface. Steel grit achieved superior results, cleaning to a near white condition; and sponge also performed slightly better, cleaning to a commercial grade surface.
Scope of productivity measure	The productivity measure only includes the time the technology was in use. Set up time and crew size are not accounted for in the measurements.

Discussion:

- All data comes from FEMP/SUB-098, UC-706, "Analysis of Potential Surface Blasting Decontamination Technologies for Structural Steel," M.A. Ebadian, L.E. Lagos, J.F. Boudreaux, T.R. Clark, and L.K. Miller, August 1995. The study was performed at Florida International University.

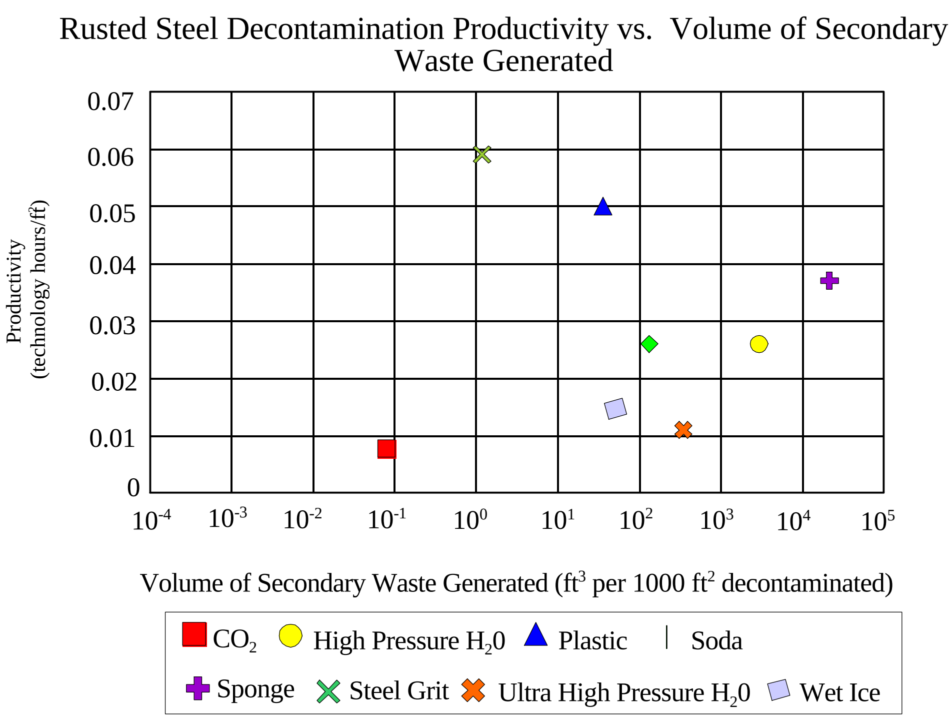
- CO_2 and steel grit achieved superior ratings in terms of minimizing secondary waste produced.

- CO_2, ultra high pressure H_2O, and wet ice were the most productive technologies.

- The graph does not indicate crew size required to operate the technology, personnel protective equipment (PPE) required while operating, or whether containment is necessary while operating the technology. The referenced study contains that information, as well as all the testing details from which these results were generated.

- The Data Confidence Indicator is not included because the data displayed is from a single, previously published study.

STUDIES ON DECONTAMINATION OF RUSTED STEEL INDICATE CO2 BLASTING IS MORE PRODUCTIVE AND GENERATES LESS SECONDARY WASTE THAN COMPETING TECHNOLOGIES.



Structural Steel Demolition

Structural Steel Demolition Productivity Rates vs. Mass of Steel	
Data sources	Federal
Structures	Structural steel from steel girder frames of large buildings that have been stripped of equipment, interior walls and siding.
Contaminants	Clean and radioactively contaminated with some lead based paint
Technologies	Explosives, large shears, universal processors, grapples, thermal cutting equipment
Labor Crews	Heavy equipment operators and foremen; HP technicians were not included in the three largest data points. A few HP technician hours may have been included in the smallest tonnage data point (i.e., 7 tons contaminated) to survey steel prior to recycle/disposal.
Scope	Setup, removal, and waste packaging is included.

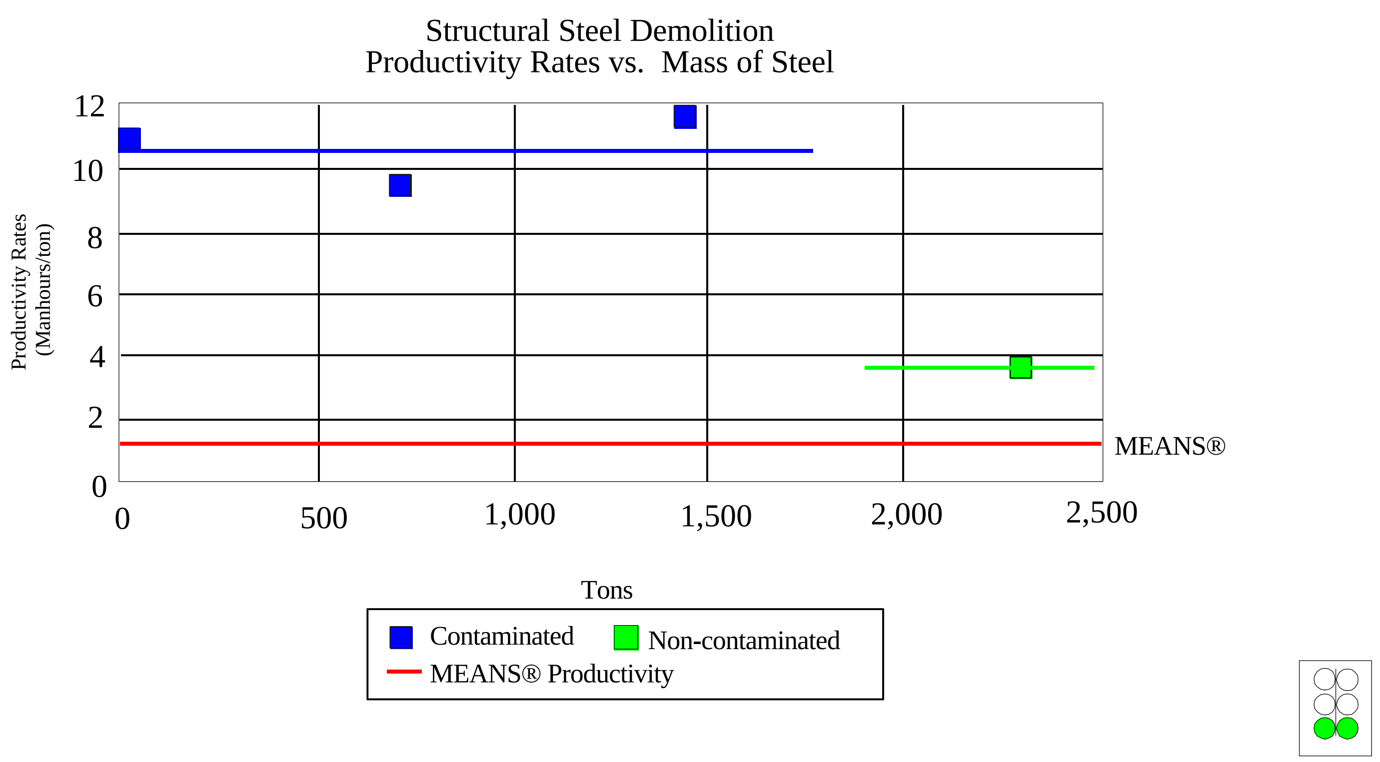
Discussion:

- For the purpose of this study, structural steel was considered to be the steel girder frames of buildings. Steel siding, steel lining, and large steel components were excluded from this portion of the study. Some data sets included steel decking.

- For at least two of the data points (700 tons and 1,400 tons), presence of lead based paint on the structural steel further reduced productivity due to the need to perform limited decontamination before size reducing with any thermal cutting equipment.

- The MEANS® productivity line indicating 1.2 hours/ton on the graph was generated from productivity rates for structural steel removal presented in the MEANS® Construction Handbook. Productivity rates in the MEANS® Handbook assume simple, non-contaminated structures.

SIZE OF JOB APPEARS TO HAVE LITTLE IMPACT ON PRODUCTIVITY RATE FOR STRUCTURAL STEEL DEMOLITION.



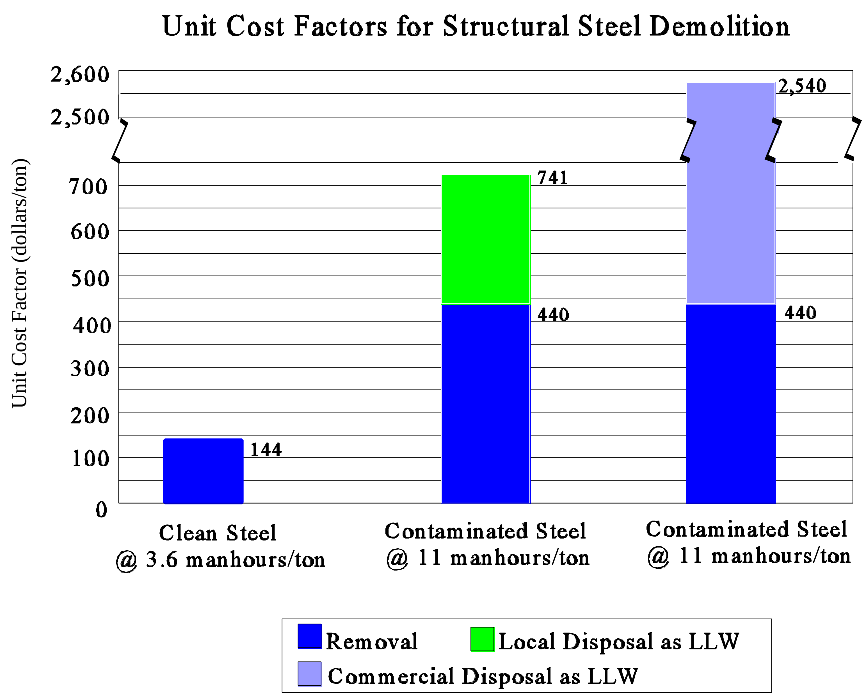
Analysis Findings - Process/Labor Productivity Efficiencies - Structural Steel Demolition

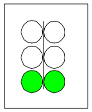
Structural Steel Removal Unit Cost Factors	
Data sources	Federal
Structures	Structural steel from steel girder frames of large buildings that have been stripped of equipment, interior walls and siding.
Contaminants	Clean and radioactively contaminated with some lead based paint
Technologies	Explosives, large shears, universal processors, grapples, thermal cutting equipment
Labor Crew	Heavy equipment operators and foremen; no HP technicians included
Scope	Setup, removal, and waste packaging
Productivity rates	11 manhours/ton for contaminated steel; 3.6 manhours/ton for clean steel
Labor rates	$40/hr; weighted fully burdened rate for all heavy equipment operators and fraction of foreman
Adjustment for disposed volume	Assumed disposal volume is 7 ft^3/ton to account for void fractions and other debris.
Hauling and disposal productivity rates for sanitary waste	0.00256 hrs/ft^3 for on-site disposal, 0.00404 hrs/ft^3 for 5 mile haul (from MEANS®, 1996)
Waste disposal rate	$43/$ft^3$; representative of the rate DOE low level waste generators may pay for disposal $300/$ft^3$; representative of the rate commercial low level waste generators may pay for disposal

Discussion:

- Productivity rates chosen to develop unit cost factors were typical of rates experienced for demolishing structural steel.
- The hauling and clean disposal productivities are based on short hauling and dumping; this may be comparable to on site disposal at federal installations. Note that clean steel may be recycled rather than disposed.

CONTAMINATION STATUS SIGNIFICANTLY INCREASES REMOVAL AND DISPOSAL COSTS OF STRUCTURAL STEEL.





Steel Component Cutting/Sizing

Analysis Findings - Process/Labor Productivity Efficiencies - Steel Component Cutting/Sizing

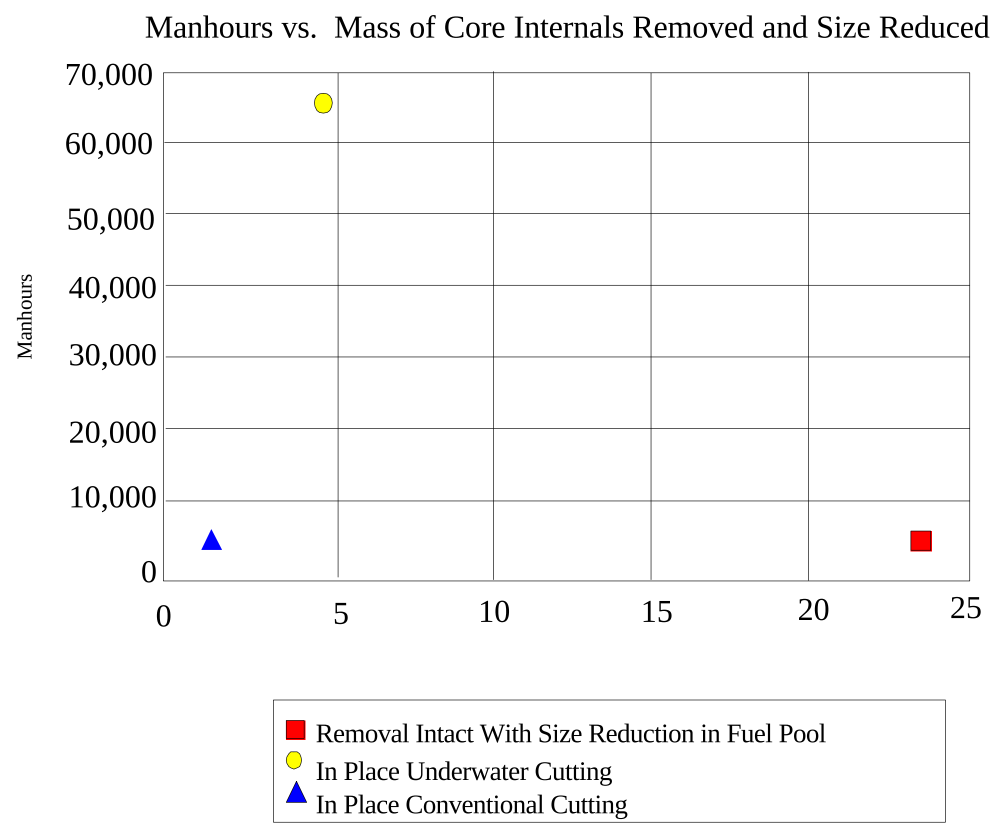
Manhours vs. Mass of Core Internals Removed and Size Reduced	
Data sources	Federal and non-federal
Structures	Reactor pressure vessels (RPVs) and all reactor core internal components
Contaminants	Activated metal (steel) in very high radiation fields
Technologies	Specialized mechanical cutting equipment, underwater plasma cutting, and large cranes for transport of vessel or internals
Labor crews	Craftsmen, foremen, and HP technicians
Scope	Setup, cutting, size reduction, and packaging are included.

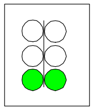
Discussion:

- Project documentation indicates that the total exposure per ton of RPV and core internals removed from the projects included in this portion of the study were comparable.

- The data collected for this section included only smaller prototype/research reactors, and thus, the productivity rates may not be applicable to larger reactor vessels, and their associated core internals.

USE OF EXISTING FUEL POOL TO PERFORM SIZE REDUCTION GREATLY INCREASES PRODUCTIVITY OVER CONSTRUCTING A TANK AROUND THE REACTOR VESSEL.





Analysis Findings - Process/Labor Productivity Efficiencies - Steel Component Cutting/Sizing

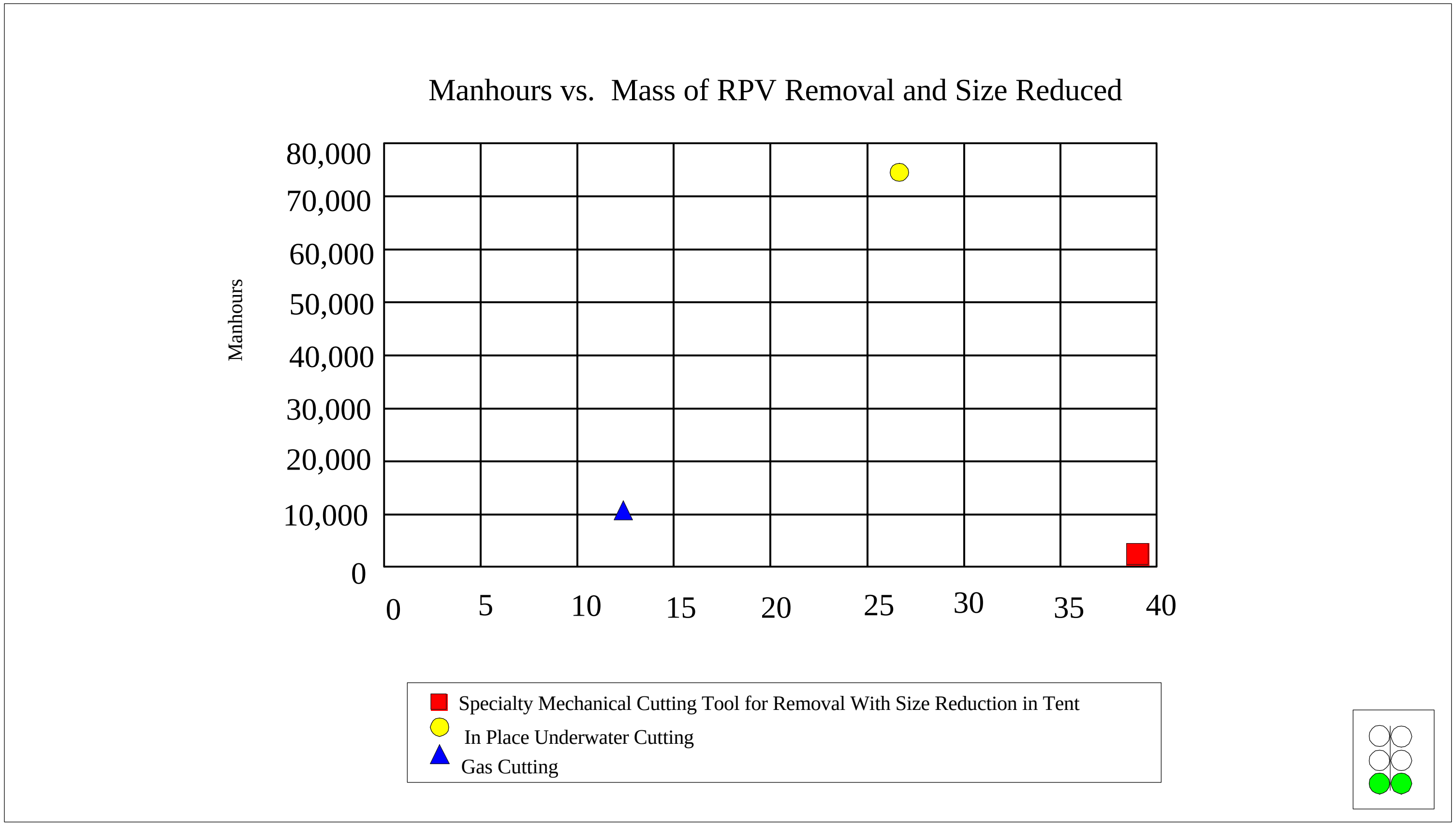
Manhours vs. Mass of RPV Removed and Size Reduced	
Data sources	Federal and non-federal
Structures	Reactor pressure vessels and all reactor core internal components
Contaminants	Activated metal (steel) in very high radiation fields
Technologies	Specialized mechanical cutting equipment, underwater plasma cutting, and large cranes for transport of vessel or internals
Labor crews	Craftsmen, foremen, and HP technicians
Scope	Setup, cutting, size reduction, and packaging are included.

Discussion:

- For smaller reactor vessels, mechanical cutting of the reactor pressure vessel (RPV) can be more productive than underwater thermal techniques.
- Project documentation indicates that the total exposure per ton of RPV and core internals removed from the projects included in this portion of the study were comparable.
- The data collected for this section included only smaller prototype/research reactors, and thus, the productivity rates may not be applicable to thicker reactor vessels.

Analysis Findings - Process/Labor Productivity Efficiencies - Steel Component Cutting/Sizing

SPECIALTY TOOLS, WHERE AVAILABLE, CAN INCREASE THE PRODUCTIVITY OF REACTOR PRESSURE VESSEL (RPV) REMOVAL.



Asbestos Containing Material Tile and Siding Removal

Analysis Findings - Process/Labor Productivity Efficiencies - Asbestos Containing Material (ACM) Tile and Siding Removal

Asbestos Tile and Siding Removal Productivity	
Data sources	Federal and non-federal
Structures	Floor tile and siding
Contaminants	Asbestos and radioactively contaminated asbestos
Technologies	Cranes, man-lifts, hand tools, scaffolding, external elevator
Labor crew	Laborers and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	Setup, removal and waste packaging operations, and takedown included. Orientation and transportation to job not included.

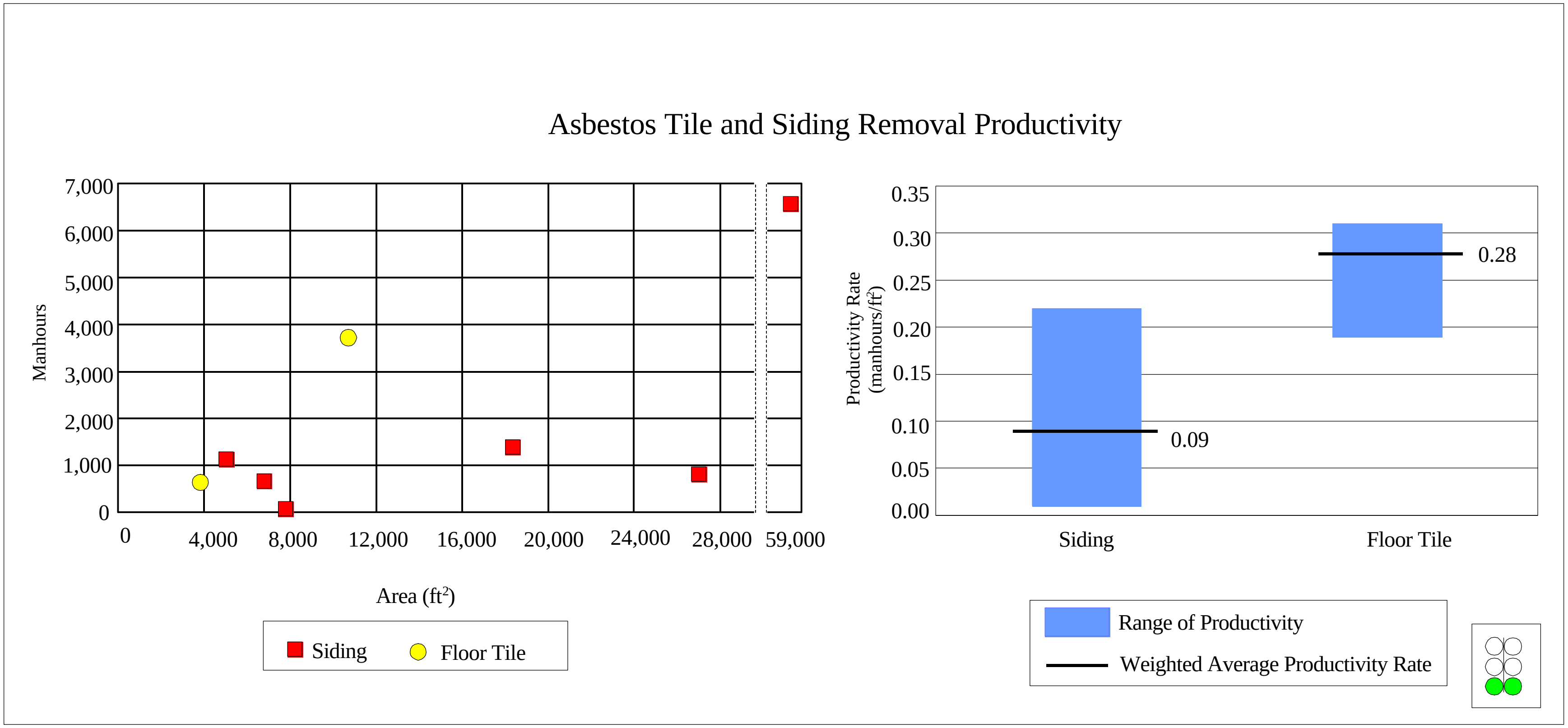
Discussion:

- External siding removal can be greatly affected by weather, height of structure, and existence of airborne asbestos exposure hazards.

- The use of an external elevator can maximize external siding removal productivity on multi-story structures.

- Removal of internal siding is affected by the existence of airborne asbestos exposure hazards and obstructions.

EXPECTED ASBESTOS FLOOR TILE REMOVAL PRODUCTIVITY RATE IS 0.28 MANHOURS/FT^2; EXPECTED ASBESTOS SIDING REMOVAL PRODUCTIVITY IS 0.09 MANHOURS/FT^2.

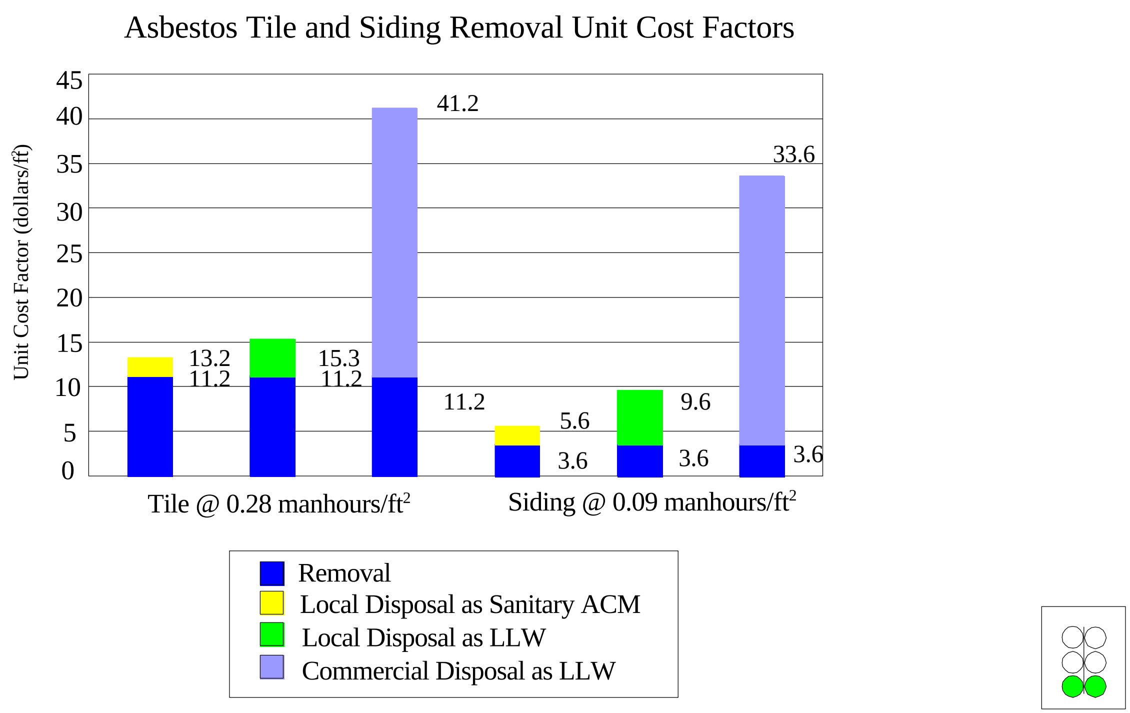


Asbestos Tile and Siding Removal Unit Cost Factors	
Data sources	Federal and non-federal
Structures	Floor tile and siding
Contaminants	Asbestos only
Technologies	Cranes, man-lifts, hand tools, scaffolding
Labor crew	Laborers and (occasionally) foremen; HP technicians and other support personnel not included
Scope	Setup, removal and waste packaging operations, and takedown; orientation and transportation to job not included.
Assumed labor rate	$40/hr; weighted fully burdened rate for all heavy equipment operators and fraction of foreman
Productivity Rate	0.09 manhours/ft^2 for siding; 0.28 manhours/ft^2 for floor tile
Adjustment for disposed volume	Disposed volume assumed equal to removed area times 0.1 ft^3/ft^2 based on the thickness of the tile and siding being approximately one inch thick. Disposed volume includes tyvek suits, bags, and miscellaneous items.
Waste disposal	$20/$ft^3$; based on on-site disposal of sanitary ACM at federal installations $43/$ft^3$; representative of the rate DOE low level waste generators may pay for disposal $300/$ft^3$; representative of the rate commercial low level waste generators may pay for disposal

Discussion:

- Productivity rates chosen to develop unit cost factors were typical of rates experienced for asbestos siding and floor tile removal.

WHEN WASTE DISPOSAL COSTS ARE LOW, ASBESTOS TILE AND SIDING REMOVAL UNIT COST FACTORS ARE DRIVEN PRIMARILY BY LABOR.



Asbestos Containing Material Insulation Removal

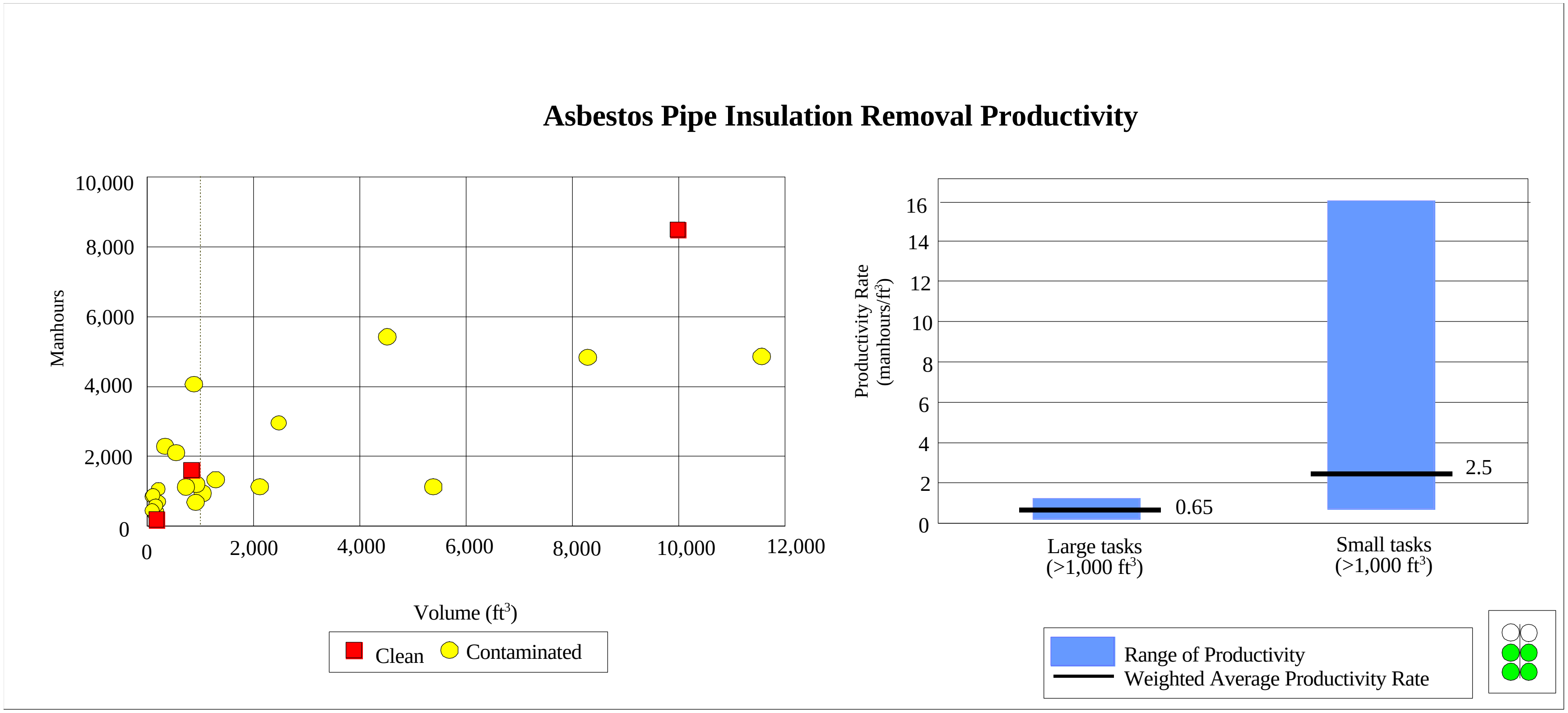
Analysis Findings - Process/Labor Productivity Efficiencies - ACM Insulation Removal

Asbestos Pipe Insulation Removal Productivity	
Data sources	Non-federal
Structures	Pipes with diameters ranging from 2" to more than 12"
Contaminants	Clean asbestos and radioactively contaminated asbestos
Technologies	Hand tools, wetting agents, and scaffolding
Labor crew	Laborers and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	Setup, removal and waste packaging operations, and takedown included. Orientation and transportation to job not included.

Discussion:

- Large asbestos pipe insulation removal tasks minimize the relative time spent for setup and interim encapsulation.
- Productivity based on removing insulation from the pipe. Removing the pipe altogether may improve productivity at the expense of greater waste volumes.
- Contamination status does not seem to affect productivity.

REMOVAL OF ASBESTOS PIPE INSULATION DOES NOT APPEAR TO BE IMPACTED BY RADIOACTIVE CONTAMINATION STATUS.



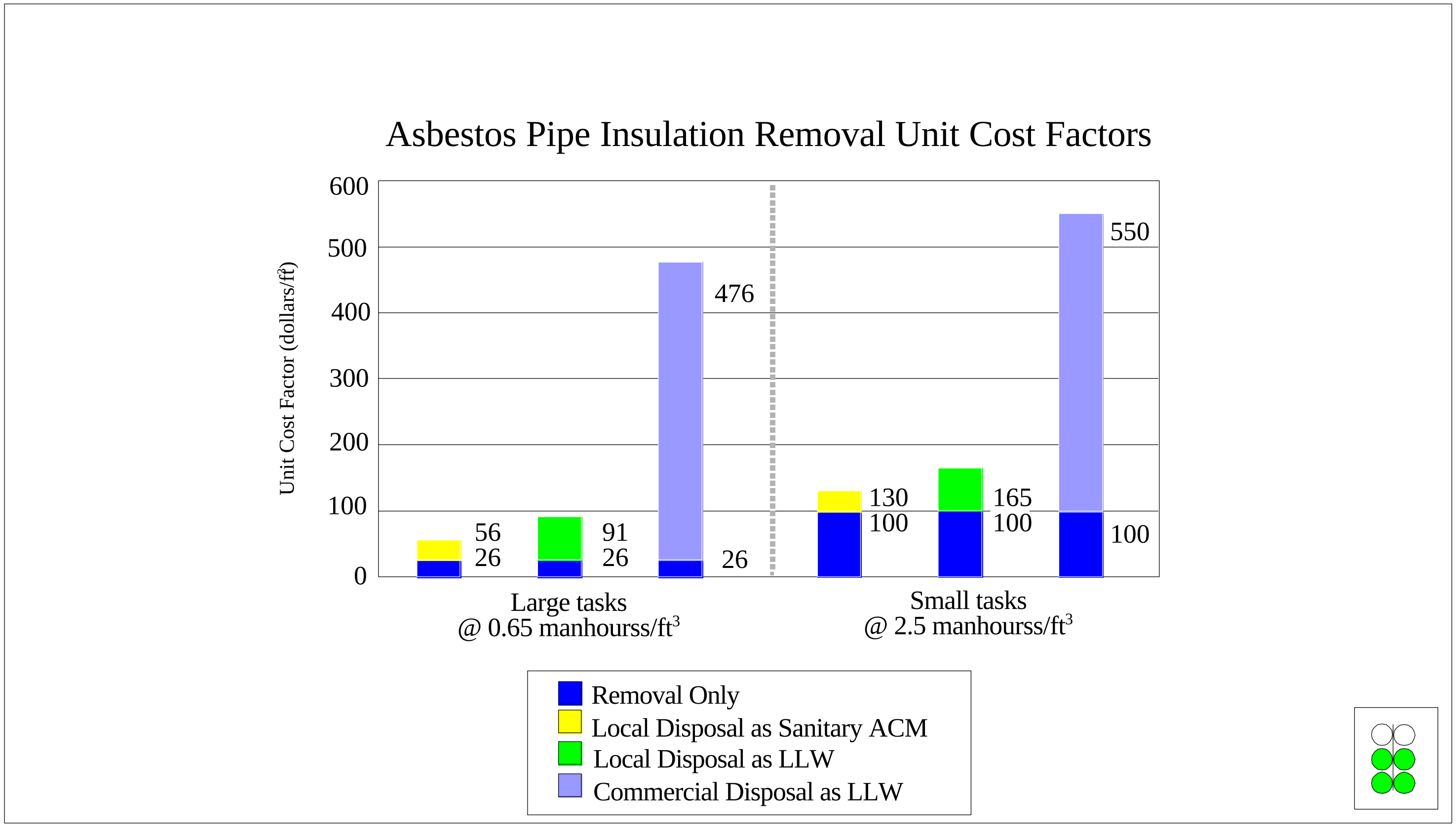
Analysis Findings - Process/Labor Productivity Efficiencies - ACM Insulation Removal

Asbestos Pipe Insulation Removal Unit Cost Factors	
Data sources	Non-federal
Structures	Pipes with diameters ranging from 2" to more than 12"
Contaminants	Clean and contaminated asbestos
Technologies	Hand tools, wetting agents, and scaffolding
Labor crew	Laborers and (occasionally) foremen; HP technicians and other support personnel not included
Scope	Setup, removal and waste packaging operations, and takedown; orientation and transportation to job not included.
Productivity rate	0.65 manhours/ft^3 for large tasks; 2.5 manhours/ft^3 for small tasks
Assumed labor rate	$40/hr; weighted fully burdened rate for all heavy equipment operators and fraction of foreman
Adjustment for disposed volume	Disposed volume assumed equal to removed volume times 1.5 to account for tyvek suits, bags, and miscellaneous items.
Waste disposal rate	$20/$ft^3$; based on on-site asbestos disposal at federal installations $43/$ft^3$; representative of the rate DOE low level waste generators may pay for disposal $300/$ft^3$; representative of the rate commercial low level waste generators may pay for disposal

Discussion:

- Productivity rates chosen to develop unit cost factors were typical of rates experienced for asbestos pipe insulation removal.
- The hauling productivities are based on short hauling of generic rubble; this may be comparable to hauling for on-site disposal at federal installations.

ASBESTOS PIPE INSULATION REMOVAL UNIT COST FACTORS ARE DOMINATED BY LABOR WHEN WASTE DISPOSAL COSTS ARE LOW.



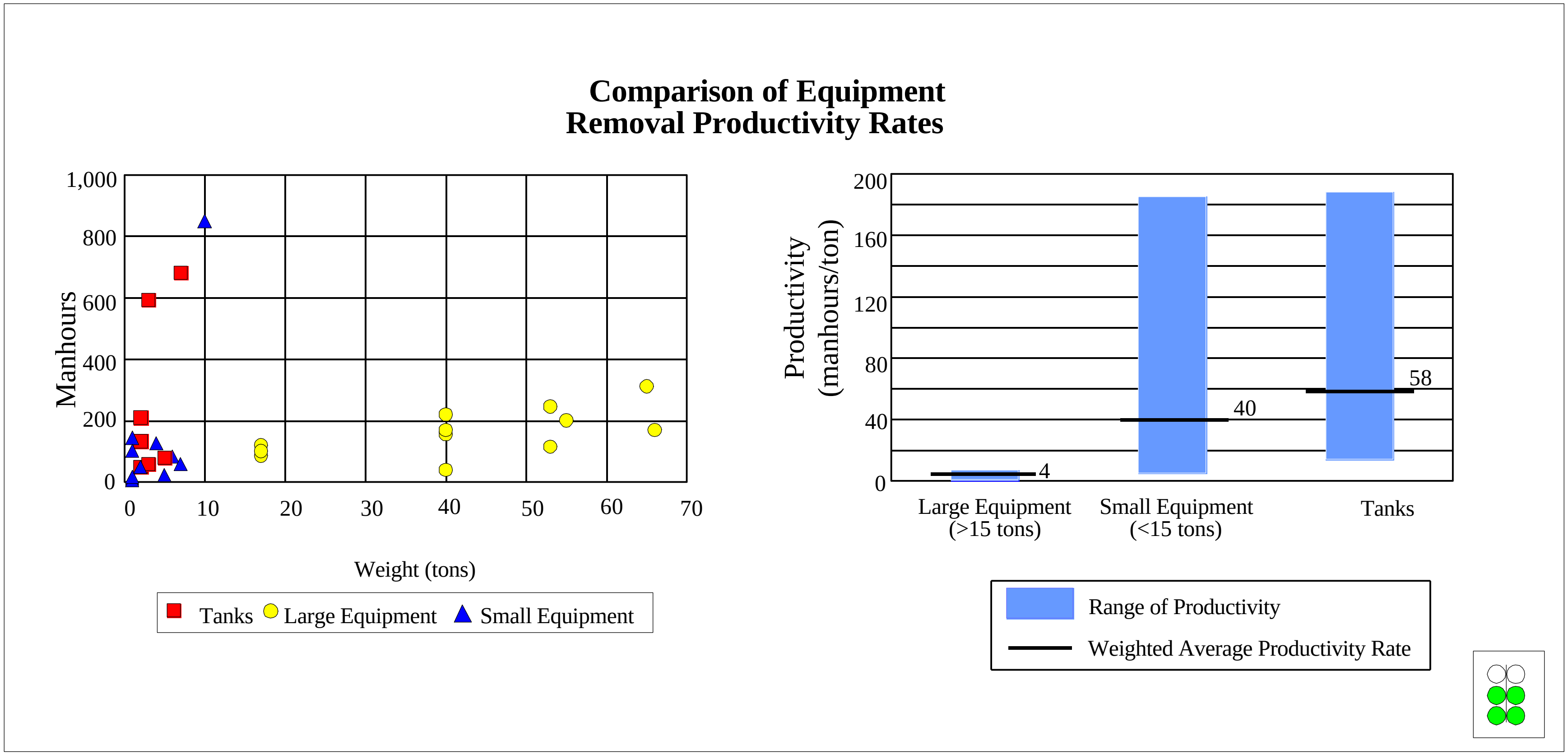
Equipment Removal

Comparison of Equipment Removal Productivity Rates	
Data sources	Non-federal
Structures	Large components (e.g., heat exchangers), small components (e.g., motors), and tanks
Contaminants	Clean and contaminated
Technologies	Cranes/rigging, hand tools, hand held torches
Labor crew	Laborers and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	Setup, removal and packaging operations, and takedown included. Orientation and transportation to job not included. Removal includes severing fasteners and penetrations and removing as one piece with equipment usually conditioned as its own package.

Discussion:

- Based on project documentation, contamination status had no observable impact on removal productivity.
- Obstructions, available crane capacity, effective volume, and other task specific conditions impacted large equipment removal productivity to the point where weight is not the critical parameter.
- Tank capacity (volume) may be a better parameter to measure removal productivity than weight; however, available data did not permit analysis on this basis.

REMOVAL OF LARGE COMPONENTS IS LESS SENSITIVE TO WEIGHT THAN THE REMOVAL OF SMALL COMPONENTS.



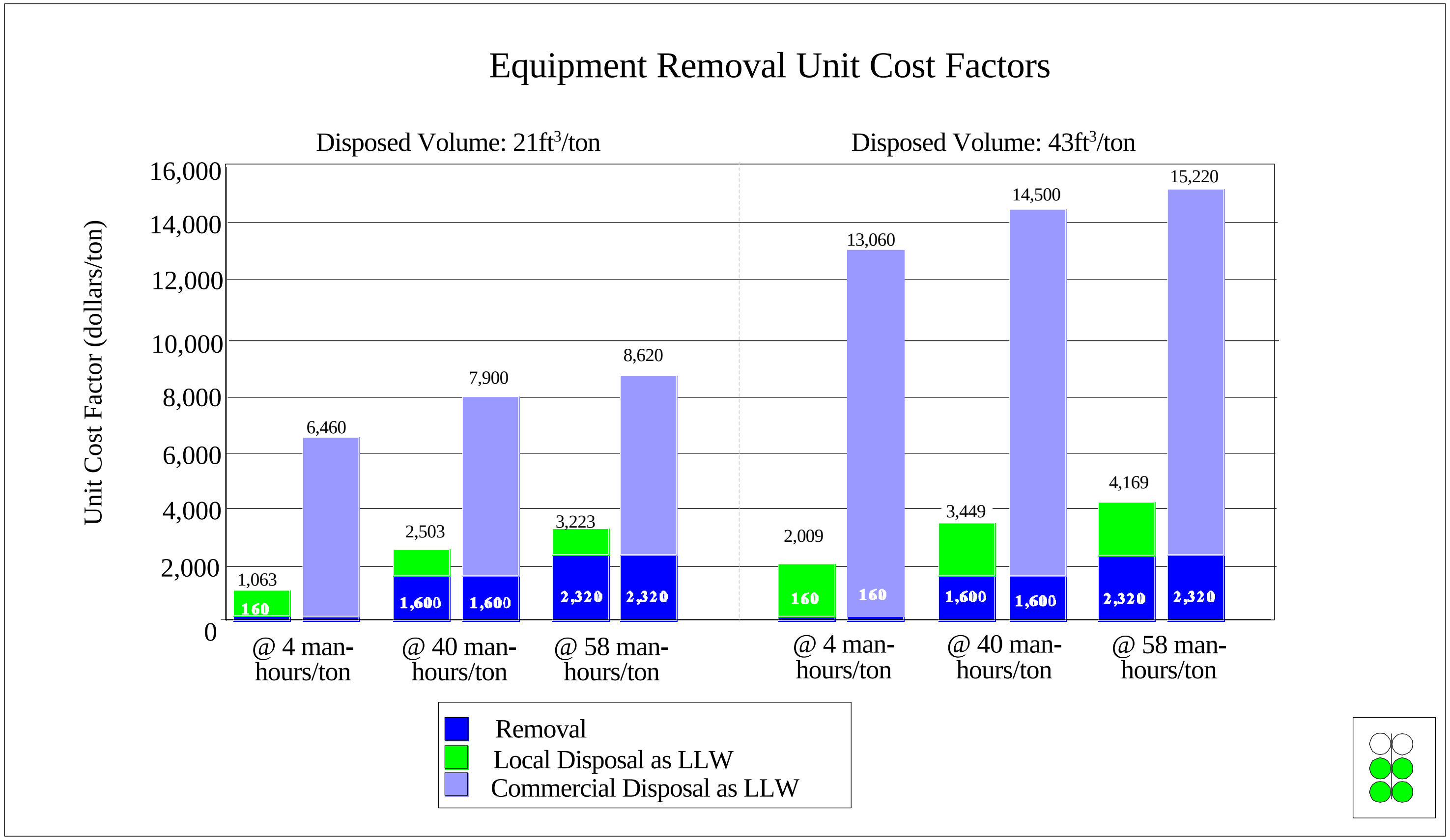
Analysis Findings - Process/Labor Productivity Efficiencies - Equipment Removal

Equipment Removal Unit Cost Factors	
Data sources	Non-federal
Structures	Large components (e.g., heat exchangers), small components (e.g., motors), and tanks
Contaminants	Clean and contaminated
Technologies	Cranes/rigging, hand tools, hand held torches
Labor crew	Laborers and (occasionally) foremen; HP technicians and other support personnel not included
Scope	Setup, removal and packaging operations, and takedown included. Orientation and transportation to job not included. Removal includes severing fasteners and penetrations and removing as one piece with equipment usually conditioned as its own package.
Productivity	4, 40, and 58 manhours/ton based on productivity rates for large equipment, small equipment, and tanks, respectively
Assumed labor rate	$40/hr; weighted fully burdened rate for all heavy equipment operators and fraction of foreman
Waste disposal rate	$43/ft^3; representative of the rate DOE low level waste generators may pay for disposal $300/ft^3; representative of the rate commercial low level waste generators may pay for disposal
Adjustment for disposed volume	Disposed volume is 21 ft^3/ton or 43 ft^3/ton to account for void fractions and other debris.

Discussion:

- Productivity rates chosen to develop unit cost factors were typical of rates experienced for removing equipment.
- Disposed volume and disposal fee greatly impact equipment removal unit cost factor.
- Clean equipment may be recycled rather than disposed.

EQUIPMENT REMOVAL UNIT COST FACTORS ARE HIGHLY SENSITIVE TO DISPOSED VOLUME.



Pipe Removal

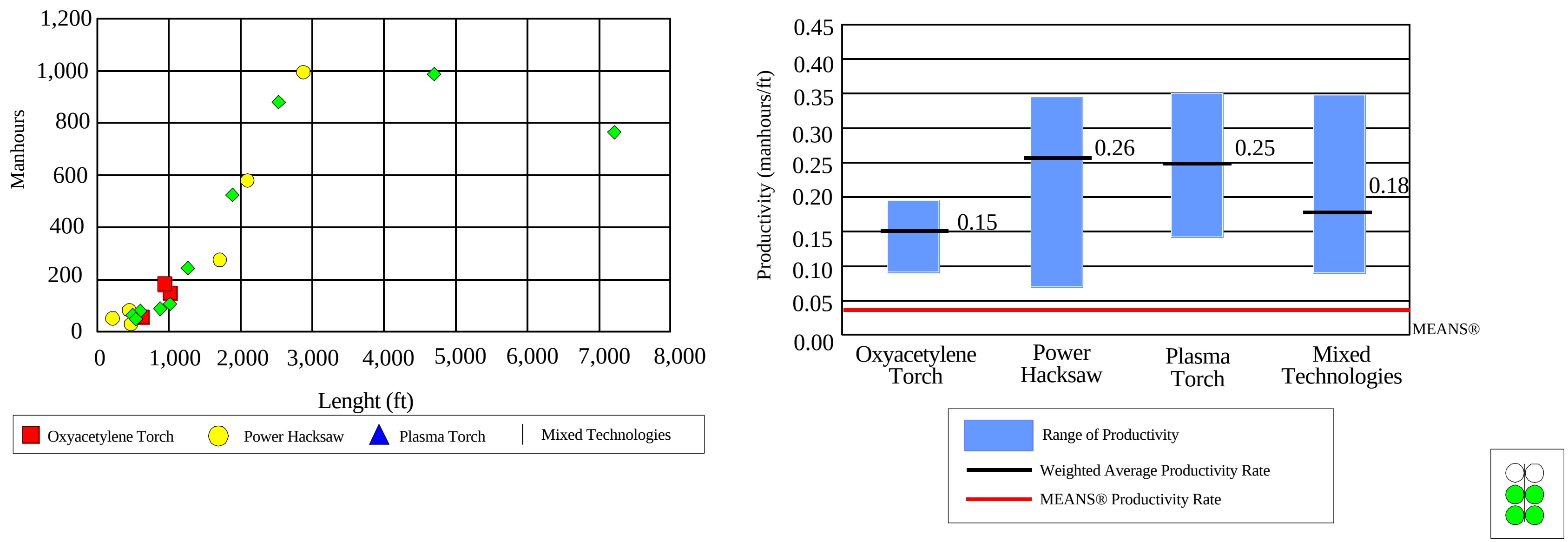
Comparison of <2" Diameter Pipe Removal Productivity Rates	
Data sources	Non-federal
Structures	Carbon steel, stainless steel, and aluminum <2" diameter linear pipe
Contaminants	Although some piping systems were designated as “clean”, all piping systems were considered contaminated since they were located in a radiological designated area.
Technologies	Oxyacetylene torch, plasma torch, power hacksaw, and mixed technologies
Labor crew	Laborers and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	All data points include pipe removal, handling, and initial packaging, while most data points did not include preparatory work such as erection of scaffolding.

Discussion:

- Mixed technologies data include tasks where several technologies were used and the quantities removed and manhours were not separated per technology.
- Where appropriate, using a mixed set of technologies also showed a slight increase in productivity.
- The MEANS® productivity line indicating 0.04 manhours/ft on the graph was generated from productivity rates for piping removal presented in the MEANS® Construction Handbook. Productivity rates in the MEANS® Handbook assume non-contaminated piping.

THERE IS NO SIGNIFICANT DIFFERENCE IN TECHNOLOGY PRODUCTIVITY, ALTHOUGH PRODUCTIVITY INCREASES SLIGHTLY USING AN OXYACETYLENE TORCH FOR <2" DIAMETER PIPE.

Comparison of <2" Diameter Pipe Removal Productivity Rates



Comparison of 2"-6" Diameter Pipe Removal	
Data sources	Non-federal
Structures	Carbon steel, stainless steel, and aluminum 2" - 6" diameter linear pipe
Contaminants	Although some piping systems were designated as "clean", all piping systems were considered contaminated since they were located in a radiological designated area.
Technologies	Oxyacetylene torch, hydraulic shears, power hacksaw, plasma torch, and mixed technologies
Labor crew	Laborers and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	All data points include pipe removal, handling, and initial packaging, while most data points did not include preparatory work such as erection of scaffolding.

Discussion:

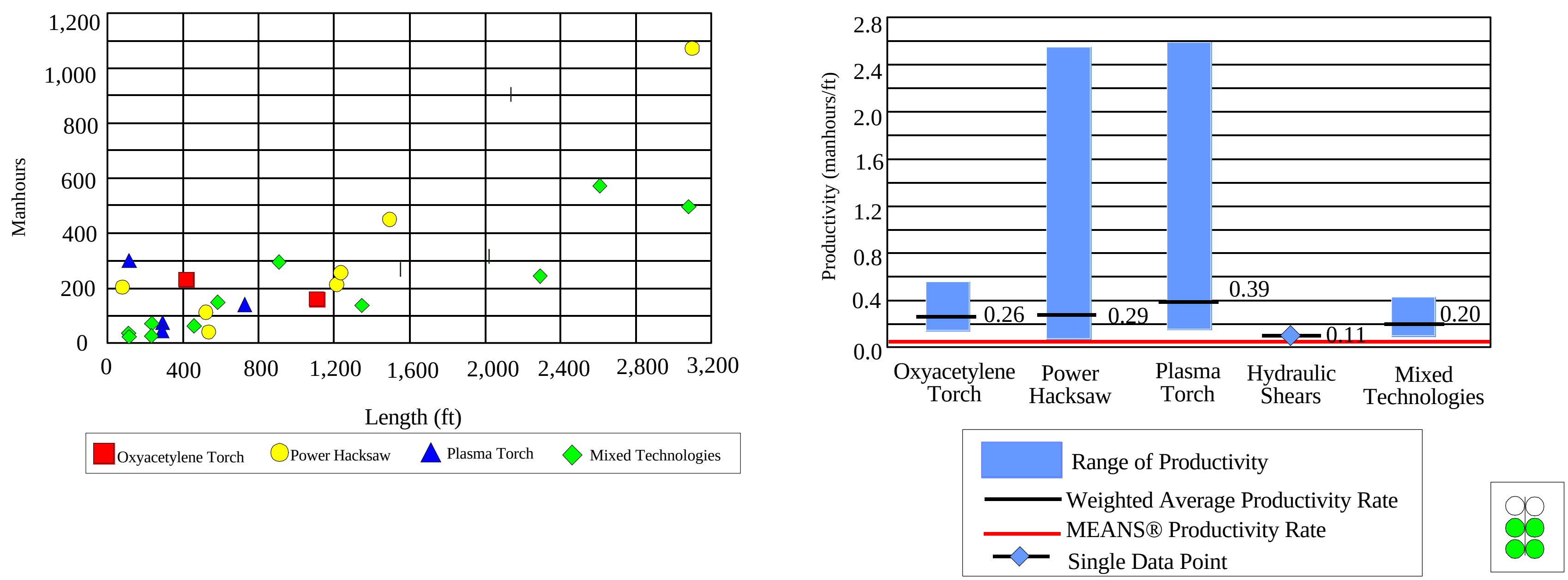
- Hydraulic Shear productivity was excellent; however, the data set only included one point.

- Mixed technologies data include tasks where several technologies were used and the quantities removed and manhours were not separated per technology.

- The MEANS® productivity line indicating 0.053 manhours/ft on the graph was generated from productivity rates for piping removal presented in the MEANS® Construction Handbook. Productivity rates in the MEANS® Handbook assume non-contaminated piping.

THE OXYACETYLENE TORCH AND THE POWER HACKSAW HAVE COMPARABLE PRODUCTIVITY RATES FOR 2"-6" DIAMETER PIPE; ALTHOUGH PRODUCTIVITY INCREASES SLIGHTLY AS DIFFERENT TECHNOLOGIES ARE UTILIZED ON A PARTICULAR PROJECT.

Comparison of 2"-6" Diameter Pipe Removal Productivity Rates



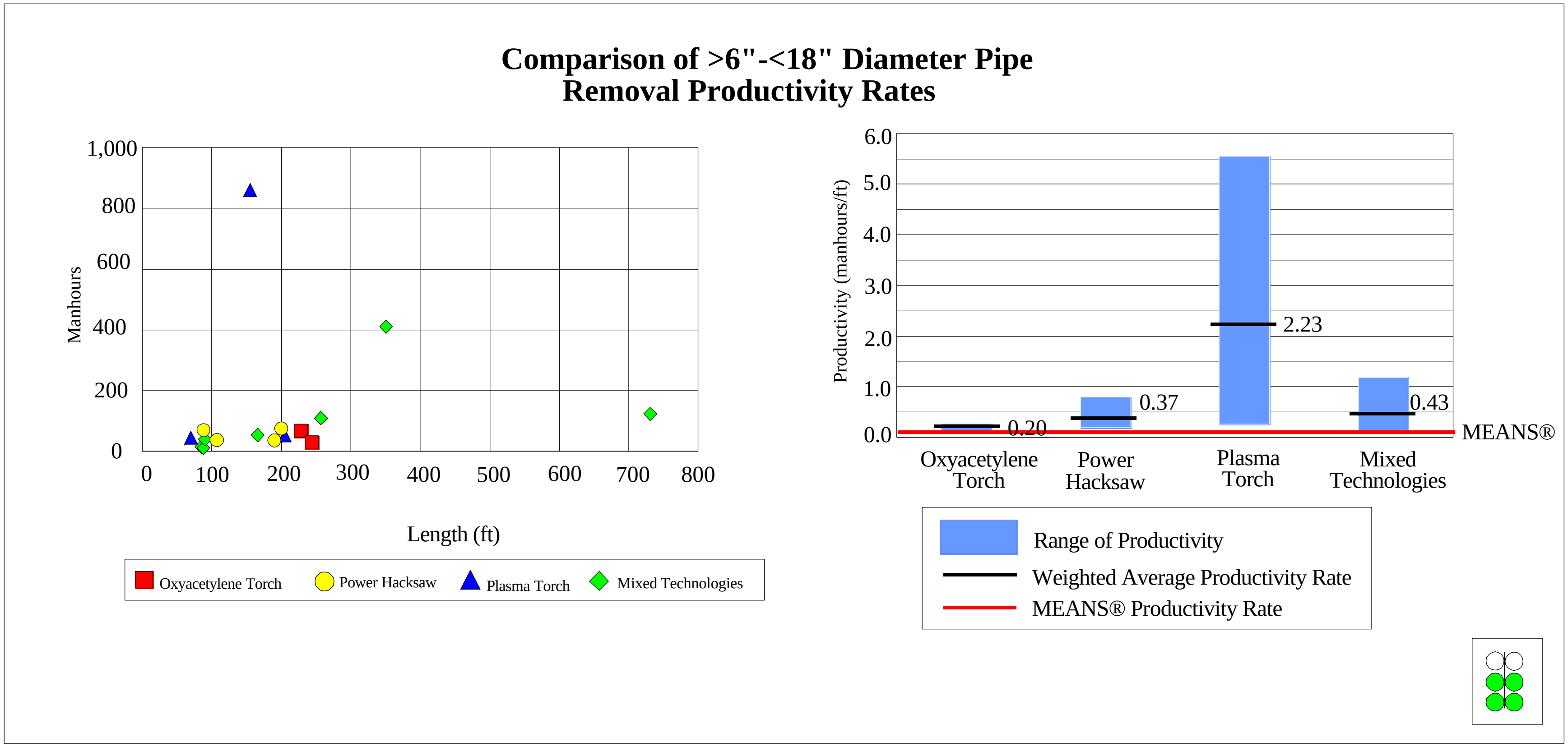
Comparison of >6"-<18" Diameter Pipe Removal Productivity Rates	
Data sources	Federal and non-federal
Structures	Carbon steel, stainless steel, and aluminum >6"-<18" diameter linear pipe
Contaminants	Although some piping systems were designated as “clean”, all piping systems were considered contaminated since they were located in a radiological designated area.
Technologies	Oxyacetylene torch, power hacksaw, plasma torch, and mixed technologies
Labor crew	Laborers and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	All data points include pipe removal, handling, and initial packaging.

Discussion:

- Mixed technologies data include tasks where several technologies were used and the quantities removed and manhours were not separated per technology.

- The MEANS® productivity line indicating 0.16 manhours/ft on the graph was generated from productivity rates for piping removal presented in the MEANS® Construction Handbook. Productivity rates in the MEANS® Handbook assume non-contaminated piping.

PLASMA TORCH IS LESS PRODUCTIVE THAN POWER HACKSAW AND OXYACETYLENE TORCH FOR >6" - <18" DIAMETER PIPE.

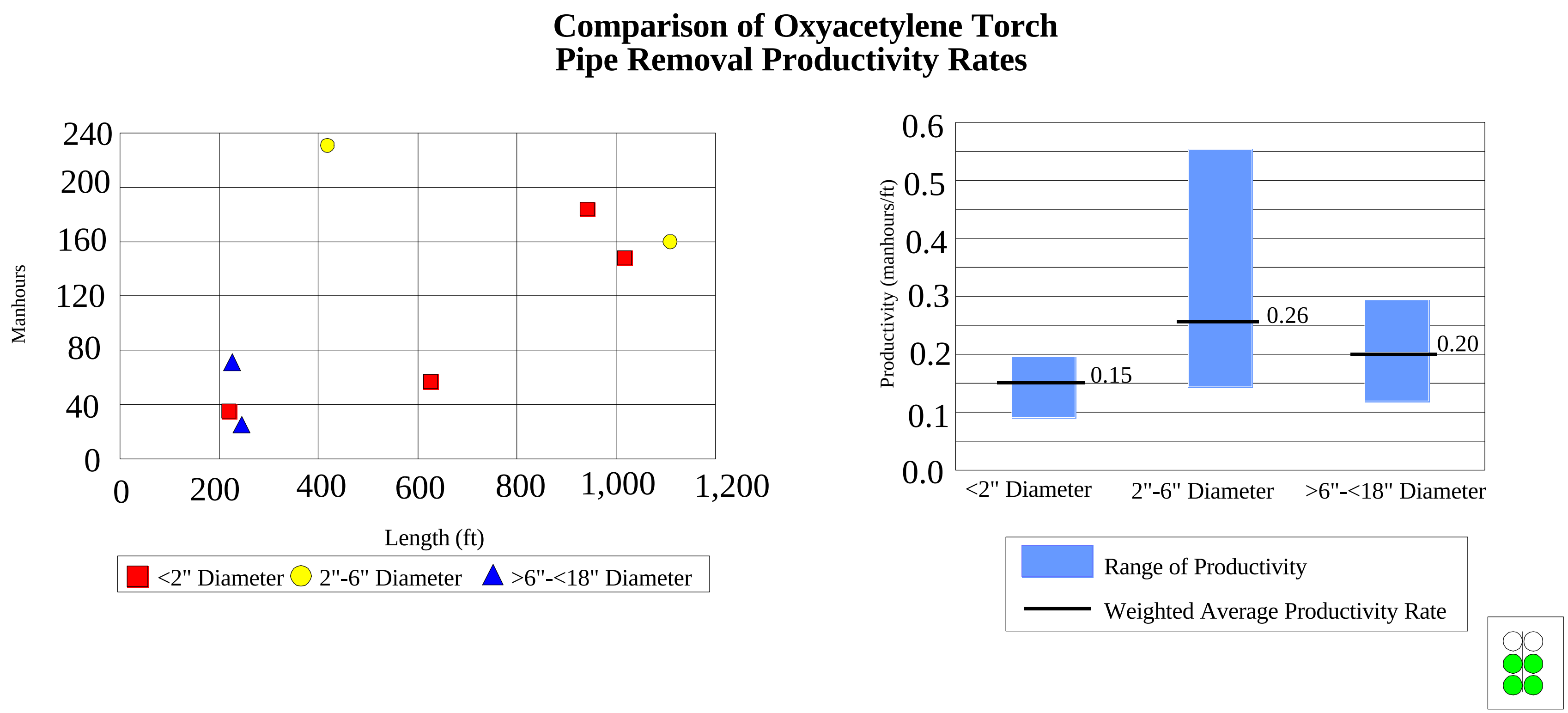


Comparison of Oxyacetylene Torch Pipe Removal Productivity Rates	
Data sources	Non-federal
Structures	Carbon steel piping ranging in three sizes: <2" diameter, 2" - 6" diameter, and >6" diameter linear pipe
Contaminants	Although some piping systems were designated as “clean”, all piping systems were considered contaminated since they were located in a radiological designated area.
Technologies	Oxyacetylene torch
Labor crew	Laborers and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	All data points include pipe removal, handling, and initial packaging, while most data points did not include preparatory work such as erection of scaffolding. The trench piping included removal of the trench covers.

Discussion:

- The outlying 2"-6" diameter data point is due to piping located in trenches that required jack hammering.

OXYACETYLENE TORCHES PRODUCTIVITY RANGES FROM 0.15 TO 0.26 MANHOURS/FT.

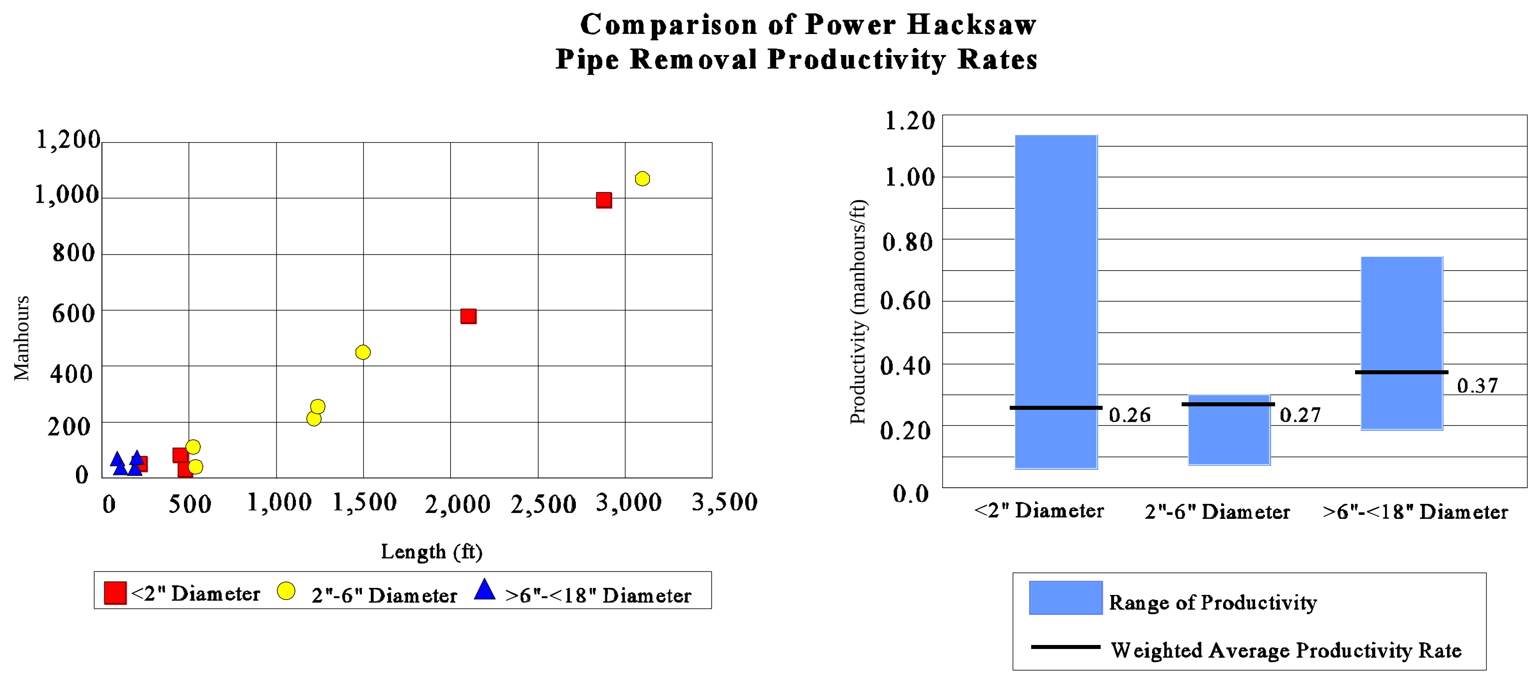


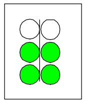
Comparison of Power Hacksaw Pipe Removal Productivity Rates	
Data sources	Non-federal
Structures	Carbon steel piping ranging in three sizes: <2" diameter, 2" - 6" diameter, and >6" diameter linear pipe Stainless steel piping ranging in two sizes: <2" diameter, and 2" - 6" diameter Aluminum piping ranging in three sizes: <2" diameter, 2" - 6" diameter, and >6" diameter linear pipe
Contaminants	All piping systems contained radioactive contamination. Three data points also contained hazardous and ACM contamination.
Technologies	Power hacksaw
Labor crew	Laborers and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	All data points include pipe removal, handling, and initial packaging.

Discussion:

- Some piping systems were hard to reach and required scaffolding, which was already on the site due to prior asbestos removal. The remaining piping systems required no special location requirements.

PIPE DIAMETER SIZE DOES NOT SIGNIFICANTLY AFFECT THE PRODUCTIVITY OF POWER HACKSAWS.



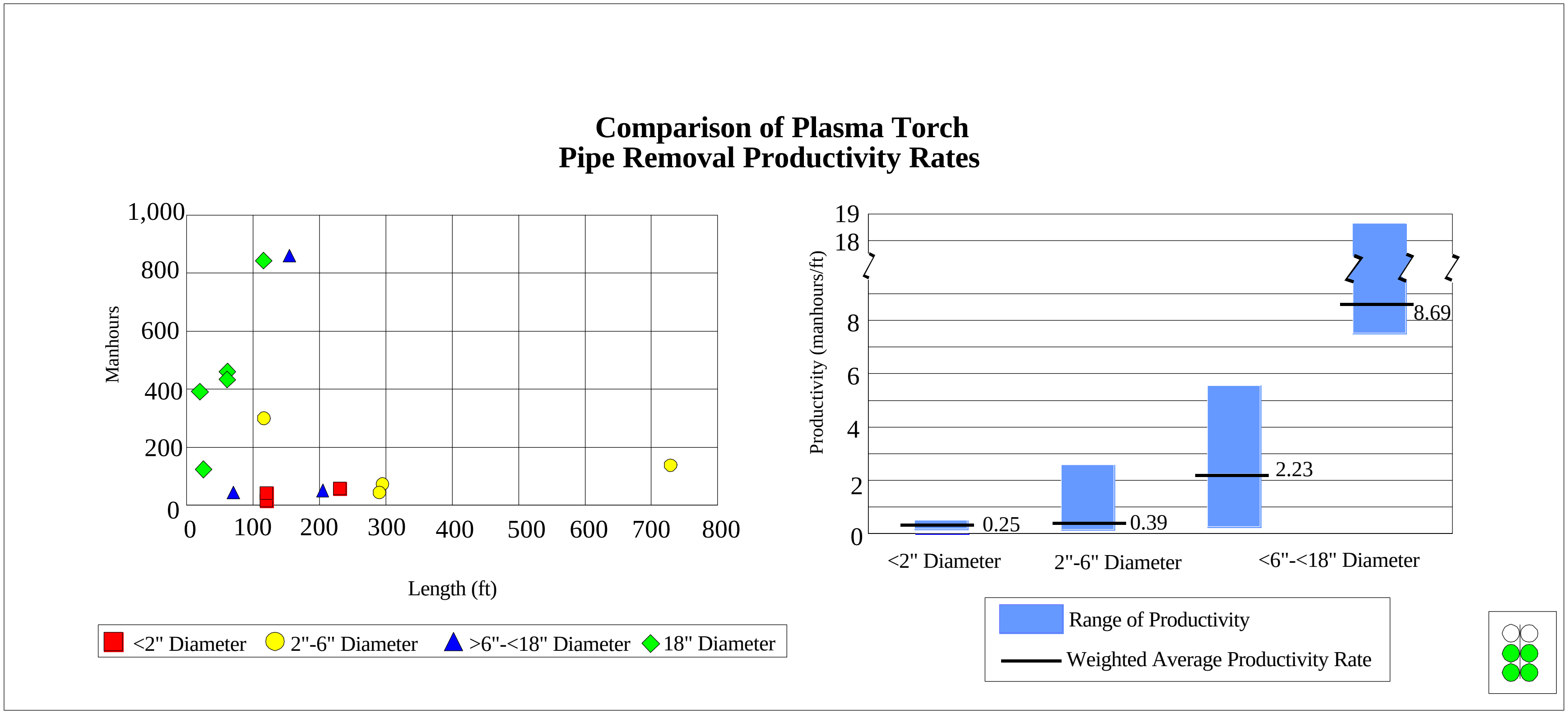


Comparison of Plasma Torch Pipe Removal Productivity Rates	
Data sources	Non-federal
Structures	Carbon steel piping ranging in three sizes: <2" diameter, 2" - 6" diameter, and >6" diameter linear pipe Stainless steel piping ranging in four sizes: <2" diameter, 2" - 6" diameter, >6" - <18" diameter, and 18" diameter linear pipe Aluminum piping ranging in one size: >6" diameter linear pipe
Contaminants	All piping systems contained radiological contamination.
Technologies	Plasma torch
Labor crew	Laborers and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	All data points include pipe removal, handling, and initial packaging, while most data points did not include preparatory work such as erection of scaffolding.

Discussion:

- The decrease in productivity was more noticeable in the larger diameter pipe.

PRODUCTIVITY DECREASES AS PIPE DIAMETER INCREASES FOR THE PLASMA TORCH.



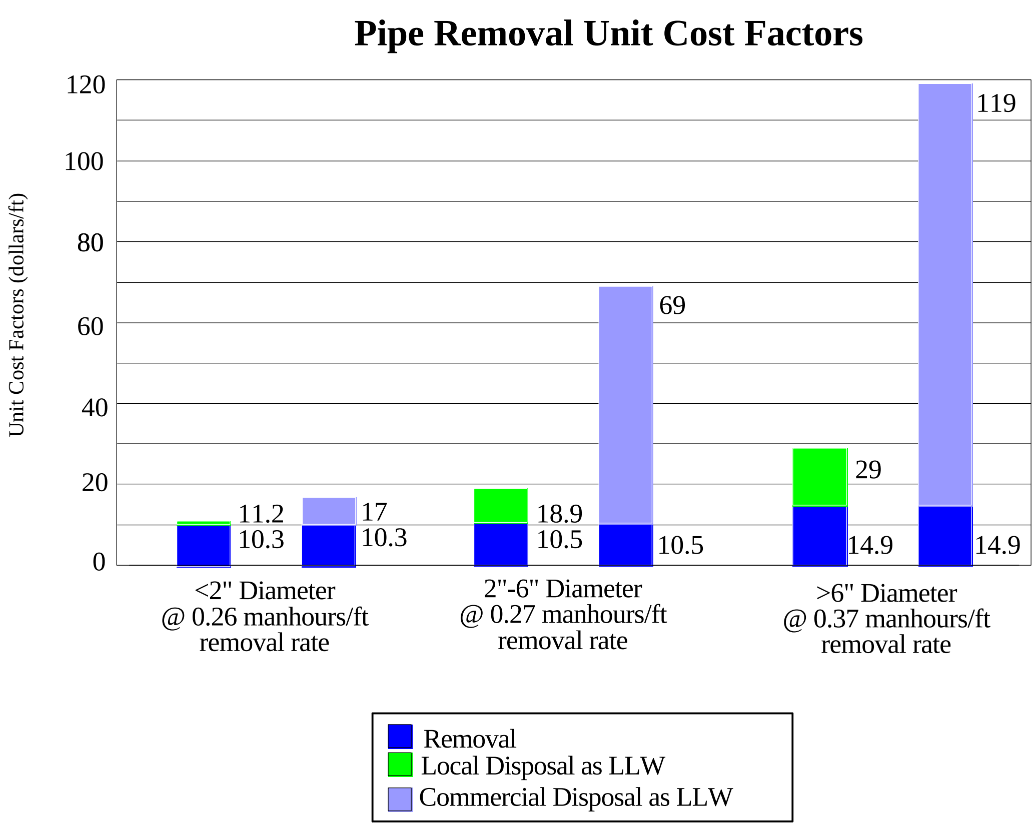
Analysis Findings - Process/Labor Productivity Efficiencies - Pipe Removal

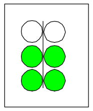
Pipe Removal Unit Cost Factors	
Data sources	Non-federal
Structures	Piping
Contaminants	All piping systems contained radiological contamination.
Labor crew	Laborers and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	All data points include pipe removal, handling, and initial packaging.
Productivity rates	0.26 manhours/ft for <2" diameter pipe; 0.27 manhours/ft for 2"-6" diameter pipe; 0.37 manhours/ft for >6" pipe
Adjustment for disposed volume	Disposed volume assumed exactly length times area.
Assumed labor rate	$40/hr; weighted fully burdened rate for all heavy equipment operators and fraction of foreman
Waste disposal rate	$43/ft^3; representative of the rate DOE low level waste generators may pay for disposal $300/ft^3; representative of the rate commercial low level waste generators may pay for disposal

Discussion:

- All productivity rates are based on representative power hacksaw data.
- Clean pipe may be recycled rather than disposed.

UNIT COST FACTORS FOR PIPE REMOVAL ARE AFFECTED MORE BY WASTE DISPOSAL RATHER THAN REMOVAL PRODUCTIVITY.





General Demolition

Analysis Findings - Process/Labor Productivity Efficiencies - General Demolition

General Demolition Productivity	
Data sources	Federal
Structures	One- and two-story structures with concrete and steel construction
Contaminants	Radionuclides, PCBs, and/or ACM
Technologies	Track mounted crushers/shears and impact hammers, slab saws, explosives, and additional heavy equipment for moving rubble
Labor crew	Operators and (occasionally) foremen included. HP technicians and other support personnel not included.
Scope	Setup, removal operations, spot maintenance, and takedown included. Clean debris used as fill or recycled; contaminated debris removed as radioactive waste.

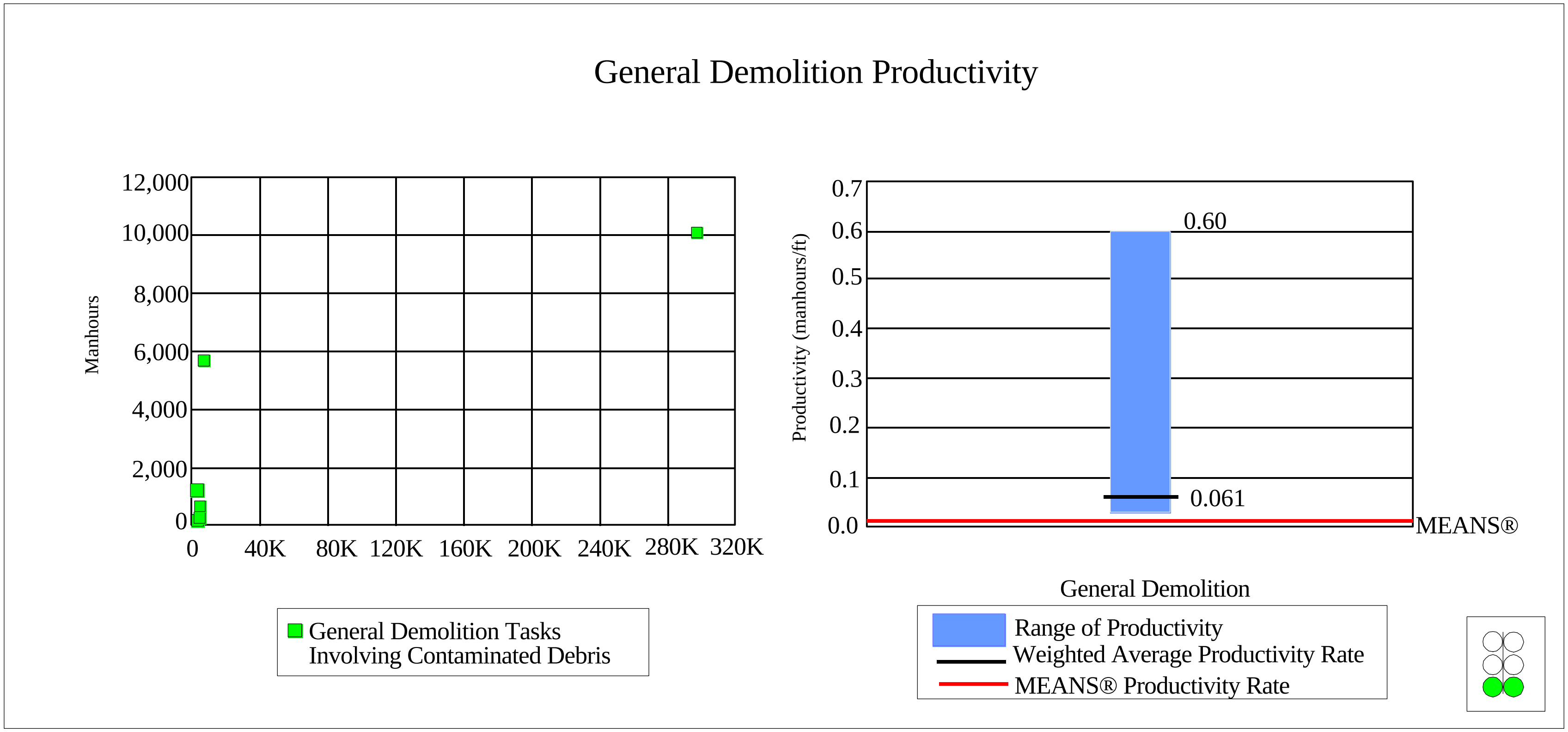
Discussion:

- According to MEANS®, demolition of simple non-contaminated structures (e.g., no radioactive or ACM contamination) is 0.0035 manhours/ft^3.

- The data displayed is from data sets that were not reported at the task level (i.e., gross project demolition data).

- The data displayed is from data sets that were not reported at the task level (i.e., gross project demolition data). An attempt was made to supplement this data set with projects where data was reported at the task level and summed; however, uncertainties existed over whether all tasks were captured for these projects. Therefore, only projects that supplied gross demolition data were included.

PRESENCE OF RADIOACTIVE AND HAZARDOUS MATERIALS (E.G., ACM AND PCBS) INCREASE TIME REQUIRED TO DEMOLISH SMALL STRUCTURES BY UP TO TWO ORDERS OF MAGNITUDE.



WEIGHTED AVERAGE PRODUCTIVITY RATES ARE ESTABLISHED AS BENCHMARKS.

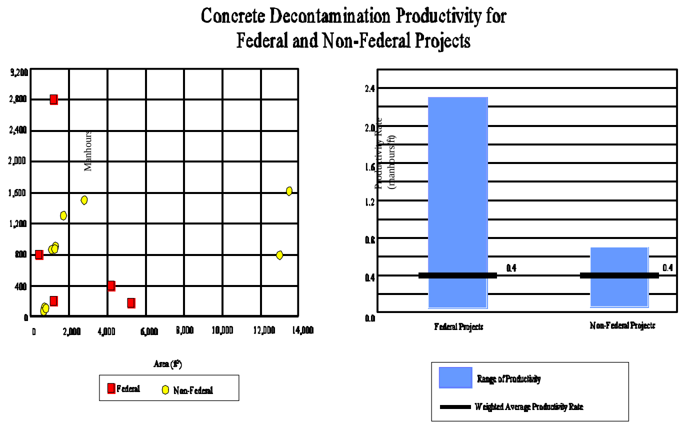
Task	Weighted Average Productivity Rate
Concrete Decontamination	0.12 hours/ft^2
Concrete Removal	0.03 hours/ft^3
Remote Concrete Removal	2.0 hours/ft^3
Structural Steel Removal	3.6 hours/ton
Asbestos Siding Removal	0.09 hours/ft^2
Asbestos Insulation Removal	0.65 hours/ft^3
Asbestos Tile Removal	0.28 hours/ft^2
Equipment Removal	25 hours/ton
Pipe Removal	0.27 hours/ft

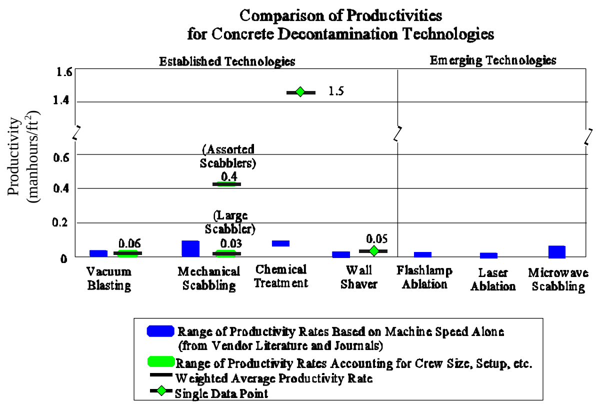
Derived Benchmarks

MEANS® productivity rates for concrete removal, structural steel removal, and piping removal tasks are consistently lower than study productivity rates. MEANS® productivity rates are based on tasks conducted in a noncontaminated environment.

ANALYSIS OF STUDY DATA YIELDED IMPORTANT CONCLUSIONS ABOUT DECOMMISSIONING. . .

At the task level available data shows that there are no productivity difference between federal and non-federal decommissioning projects.

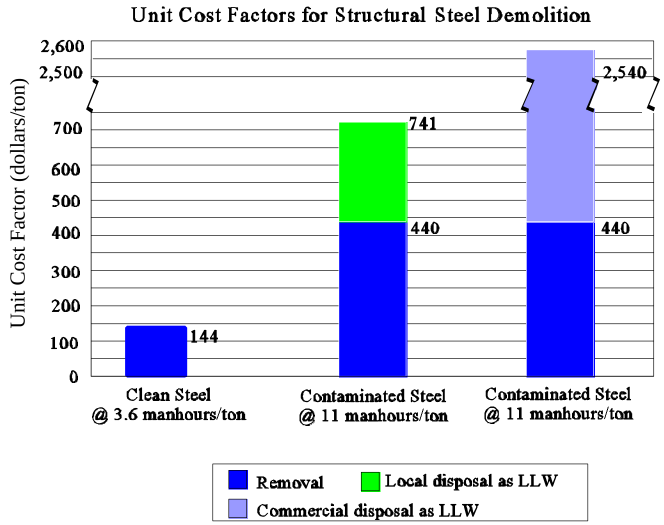


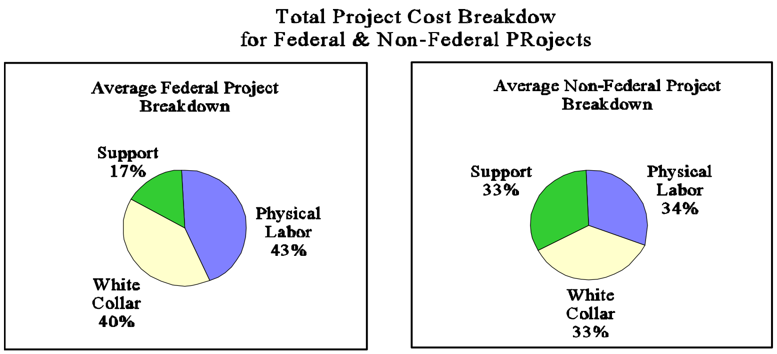


Existing decommissioning technologies are well suited for most decommissioning tasks not requiring remote operation.

. . . THAT CAN HELP DOE MINIMIZE COSTS OF FUTURE DECOMMISSIONING PROJECTS.

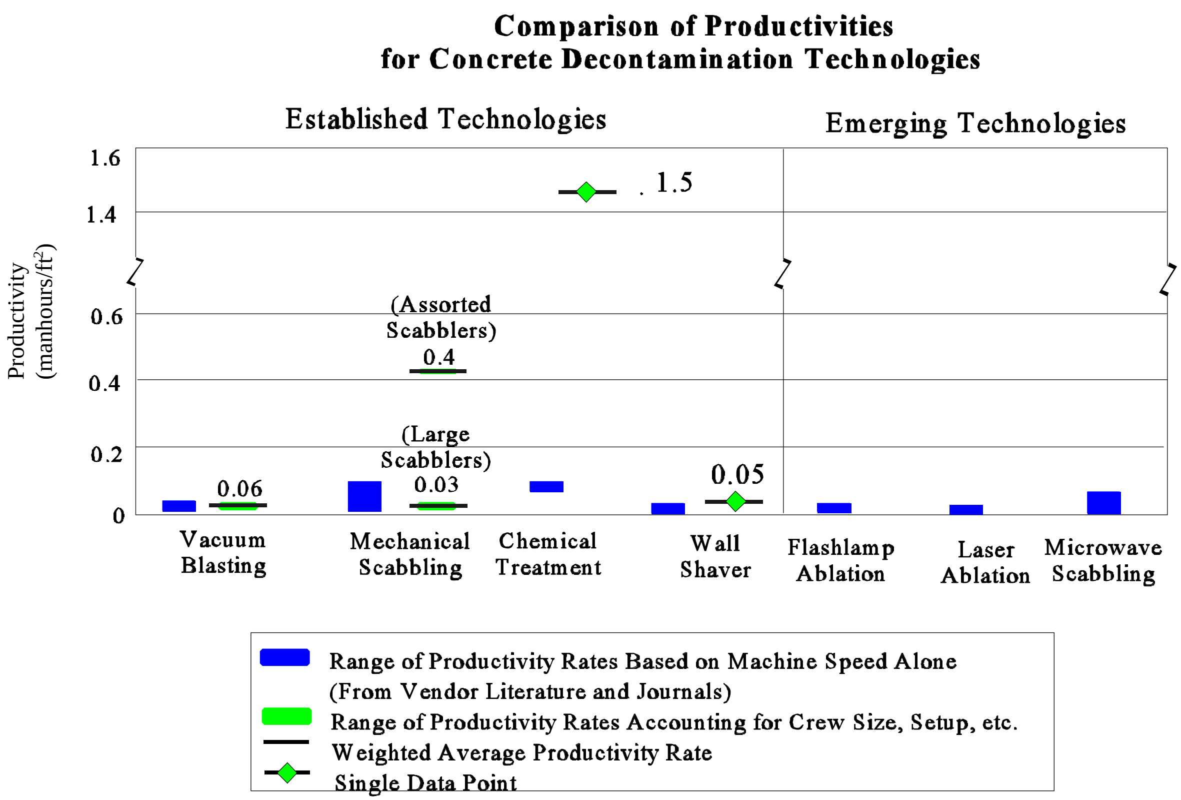
Radioactive waste disposal costs can dramatically impact the scope of decommissioning projects.





Physical costs (activity dependent) account for 35% to 45% of total decommissioning costs.

SINCE EXISTING DECOMMISSIONING TECHNOLOGIES ARE WELL SUITED FOR MOST DECOMMISSIONING TASKS NOT REQUIRING REMOTE OPERATION, THE AVAILABILITY OF TECHNOLOGIES SHOULD NOT IMPEDE PROGRESS OF DECOMMISSIONING ACTIVITIES.



PRODUCTIVITY RATES AND RELATED UNIT COST FACTORS CAN BE USED BY DECOMMISSIONING MANAGERS IN DEVELOPING ESTIMATES TO SUPPORT BUDGETS AND PROPOSAL REQUESTS AND IN EVALUATING COST TRADE-OFFS BETWEEN DECOMMISSIONING END STATES.

Task	Weighted Average Productivity Rate
Concrete Decontamination	0.12 hours/ft^2
Concrete Removal	0.03 hours/ft^3
Remote Concrete Removal	2.0 hours/ft^3
Structural Steel Removal	3.6 hours/ton
Asbestos Siding Removal	0.09 hours/ft^2
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Equipment Removal	25 hours/ton
Pipe Removal	0.27 hours/ft

Derived Benchmarks

MEANS® productivity rates for concrete removal, structural steel removal, and piping removal tasks are consistently lower than study productivity rates. MEANS® productivity rates are based on tasks conducted in a non-contaminated environment.

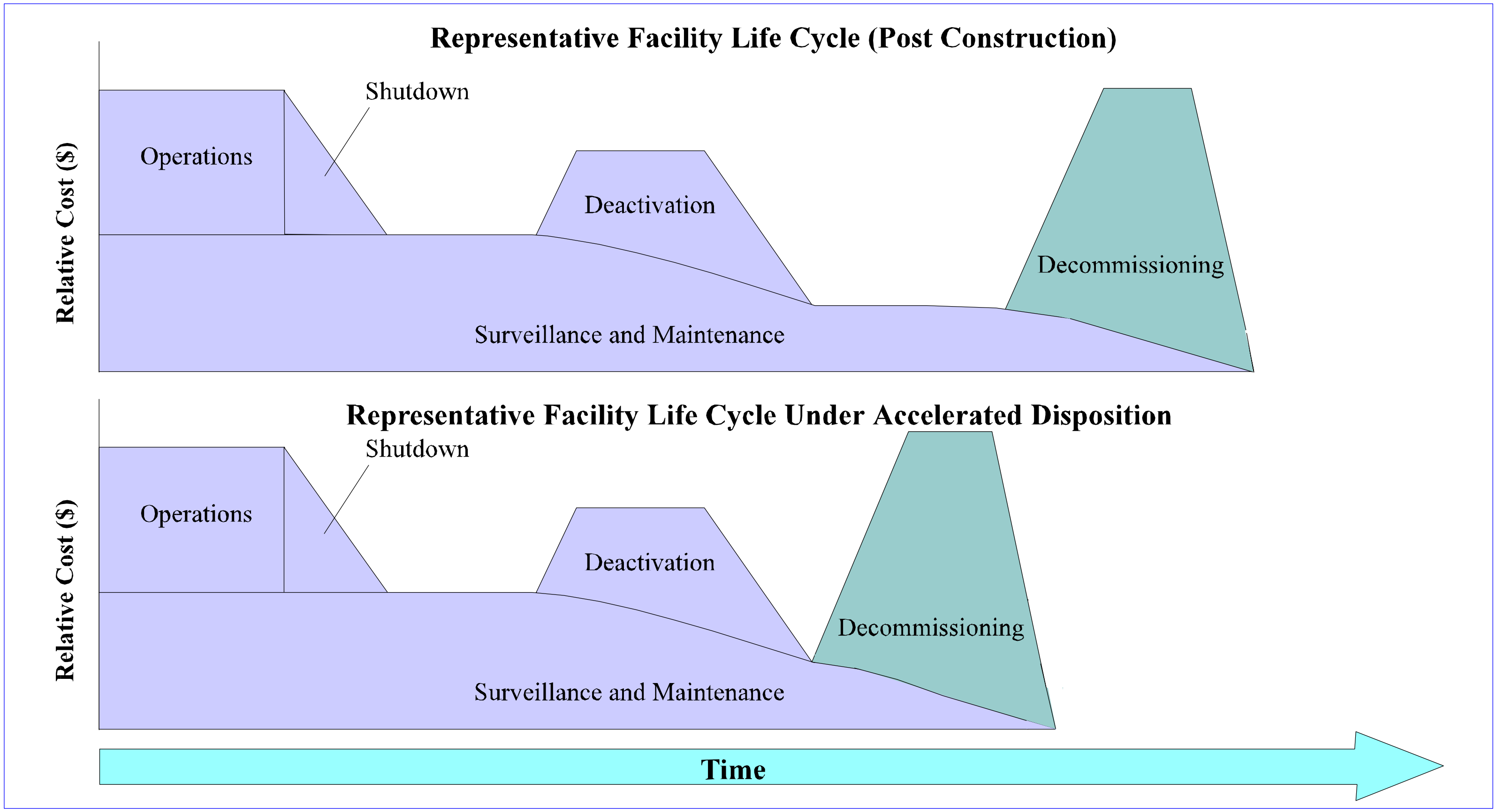
DECOMMISSIONING **PROGRAM MANAGERS MAY USE THE DECOMMISSIONING PREFERRED ALTERNATIVES MATRIX TO ASSIST IN THE DETERMINATION OF TECHNOLOGIES FOR USE ON A COMMISSIONING PROJECT.**

Sample Matrix Rating Demolition Technologies

	Concrete				Brick/Cinder Block	
	Reinforced Structure (>2' thick)	Lightly Reinforced Structure (<2' thick)	Non-reinforced Structure (<2' thick)	Stack	Structure	Stack
HEAVY EQUIPMENT						
Backhoe Mounted Pulverizer	◑	◑	◑	◑	◕	◑
Backhoe Mounted Ram	◕	◕	●	◑	◕	◕
Backhoe Mounted Shears	◑	◕	◑	⊗	◑	⊗
Wrecking Ball/Slab	◔	◕	◕	◑	●	●
TOOLS						
Jackhammer	◑	◑	◑	⊗	◕	⊗
Rock Splitter	◑	◕	◕	◑	⊗	⊗
Wall and Floor Saws	◔	◑	◑	⊗	⊗	⊗
MISCELLANEOUS EQUIPMENT/METHODS						
Controlled Blasting/Explosive Cutting	◑	◑	◑	◑	◑	◑
Diamond Wire	◑	◕	◕	⊗	⊗	⊗
Expansive Grout/Demolition Compounds	◔	◕	◕	◕	◕	◕
Grapple	◑	◕	◕	⊗	●	⊗

PAM Legend					
● Preferred Alternative (lowest cost, best performance, and low risk)	◕ Probable Alternative (low cost, good performance, and low risk)	◑ Potential Alternative (acceptable performance, but medium cost or risk)	◔ Possible Alternative (high cost or high risk)	○ Unlikely (limited performance or high cost or risk)	⊗ Not Applicable

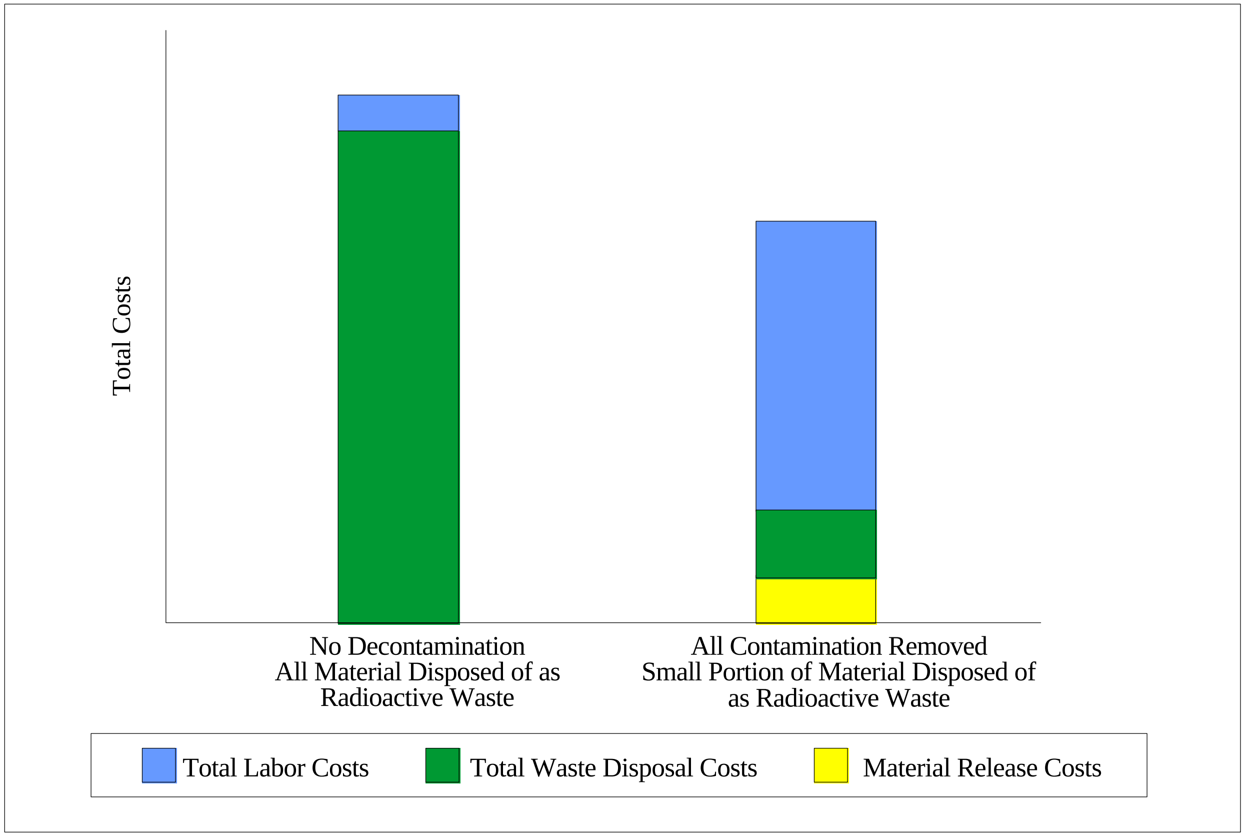
FACILITY LIFE CYCLE COSTS CAN BE REDUCED BY PERFORMING DECOMMISSIONING AS SOON AFTER DEACTIVATION AS POSSIBLE.



The DOE Office of Environmental Management will spend approximately $750 million for surveillance and maintenance in FY 1997; the 1996 BEMR projects a life cycle cost of $14.3 billion for surveillance and maintenance.

Recommendations

FOR RADIOACTIVE DECOMMISSIONING ACTIVITIES, DOE SHOULD CONSIDER WASTE DISPOSAL COSTS INCURRED IN DECOMMISSIONING ACTIVITIES TO ENSURE APPROPRIATE TRADE-OFFS BETWEEN LABOR COSTS (DECONTAMINATION ACTIVITIES) AND DISPOSAL COSTS (VOLUME OF MATERIAL DISPOSED).



The graphs above are not to scale.

DOE CAN REDUCE ESTIMATES FOR MOST CHALLENGING FACILITIES BY CONCENTRATING ON PRODUCTIVITY, WASTE DISPOSAL OPTIONS, RECYCLING, AND ALTERNATIVE END-POINTS.

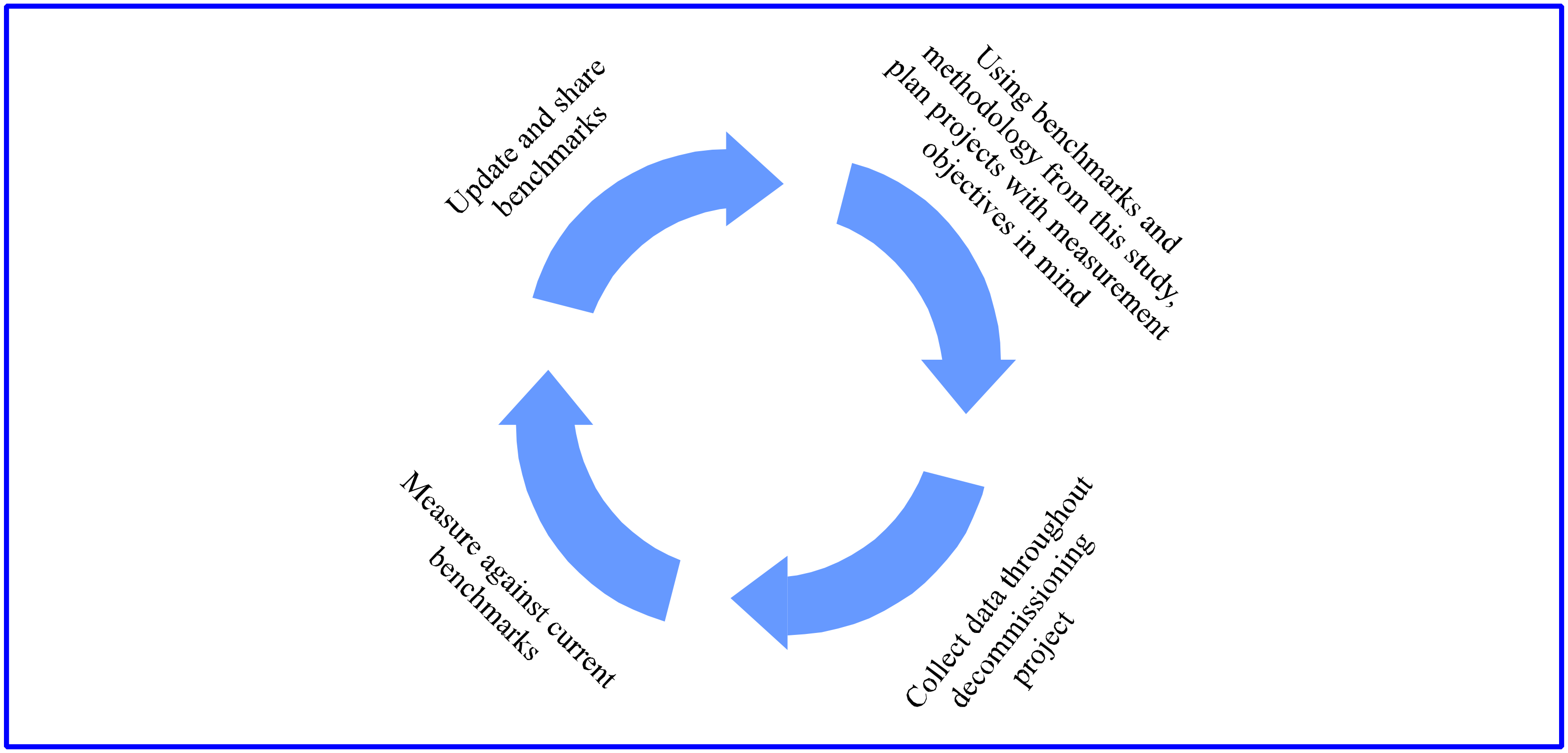
Most Challenging Facilities to Decommission	
Facility Type	**Number of Facilities[1]**
Gaseous Diffusion	101
Reactors	71
Fuel Reprocessing	69
Plutonium and Uranium Manufacturing Facilities	239

TOTAL LIFE CYCLES ESTIMATES: $16 BILLION[2]

Source: [1] Surplus Facility Inventory Assessment (SFIA) database, dated November 8, 1994. Note that the number of facilities reflects all buildings, etc., associated with that facility type, not just the main process facilities.
[2] 1996 BEMR, Volume I and Booz Allen & Hamilton Inc. analyses.

Recommendations

DOE SHOULD CONTINUE THE DECOMMISSIONING COMMITTEE ACTIVITIES AND INCREASE EMPHASIS ON COLLECTING DATA, MEASURING PROGRESS, AND SHARING DECOMMISSIONING RESULTS WITH DOD, EPA, AND INTERNATIONAL PARTNERS.



Decommissioning projects should be planned with measurement objectives in mind to achieve the ability to measure performance. DOE should establish a data collection and reporting protocol for DOE and contractors similar to the functions covered in the benchmark, periodically update average and "best-in-class" productivity rates, and continue to seek input from external partners.

Table of Contents

Glossary

Abrasive Cutter - Cutting tool consisting of a rotating wheel comprised of resin bonded particles of aluminum oxide or silicon carbide.

Abrasive Water/Water Jet - Cutting tool utilizing abrasive particles entrained in a water jet. Used for cutting concrete and metal.

Acid Etching - Acid is sprayed onto a contaminated surface to promote corrosion to remove the surface layer. The resultant debris is neutralized and disposed of.

Acid/Hydrogen Peroxide Dissolution - This is a chemical process that uses acids and hydrogen peroxide to dissolve and remove surface contamination from lead.

ACM - Asbestos Containing Material

Activated - Radionuclides distributed throughout a structure; usually generated by exposure to neutrons.

AL - U.S. Department of Energy, Albuquerque Operations Office

Alkaline Permanganate (AP) - An oxidizing (REDOX) agent used to oxidize chromium in the corrosion film to Cr_2O_3, which can subsequently be dissolved in an alkaline solution. It is used as a pretreatment process in multistep decontamination programs to expose the remaining corrosion film matrix to subsequent chemical dissolution, including AP followed by Ammonium Citrate (AP/AC); AP, AC with Ethylenediaminetetraacetic Acid (APACE); and AP with Citric Acid (AP/CITROX).

Alkaline Permanganate followed by Ammonium Citrate (AP/AC) - This is a two-step process with intermediate water rinsing that has achieved significant decontamination results, specifically on stainless steel and carbon steel. In dilute form, the AC removes residual manganese oxide from the AP solution and neutralizes that solution. In concentrated form, the AC attacks the remaining corrosion film. However, redeposition has been a significant problem with this process.

Glossary

Alkaline Permanganate, Ammonium Citrate with Ethylenediaminetetraacetic Acid (APACE) Process - A two-step process of alkaline permanganate (AP) as an oxidizing pretreatment with an intermediate water rinsing, followed by ammonium citrate (AC) to remove the oxide layer, and the use of Ethylenediaminetetraacetic Acid (EDTA) for chelation of iron oxides in solution to prevent redeposition onto the cleaned surface.

Alkaline Permanganate with Citric Acid (AP/CITROX) - AP with citric acid is a mixture of oxalic acid, citric acid and an inhibitor. It is an effective decontaminant for stainless steel as the second step after AP pretreatment. The citric acid neutralizes any traces of the alkaline solution, dissolves any manganese oxide, and complexes the iron oxides to keep them in solution and retard deposition. This process is highly corrosive to carbon steel and 400 series stainless steels. Accordingly, in decontamination, its use is confined to 300 series stainless steel and Inconel.

Alkaline Salts - Caustic compounds that are used for decontamination both by themselves and in solutions with other compounds, including potassium hydroxide (KOH), sodium hydroxide (NaOH), sodium carbonate (Na_2CO_3) and ammonium carbonate ($(NH_4)_2CO_3$). They are used to remove grease and oil films; to neutralize acids, as surface passivators; and to remove paint and other coatings, as a rust remover for mild steel, as a solvent for species that are soluble at high pH, and as a means of providing the right chemical environment for other agents. As a degreaser, they are normally mixed with detergents, and most commercial detergents contain mild caustic compounds. Alkaline solutions may be used on all nonporous surfaces, except aluminum and magnesium. Advantages: they are cheap, easy to store, have fewer material problems than acids (both strong mineral and organic), and can be applied in the form of gels for ceilings and walls. Disadvantages: their slow reaction time and destructive effect on aluminum; in addition, the bases pose safety hazards (i.e., workers can be burned if they come into contact with them).

Ammonium Carbonate ($(NH_4)_2CO_3$) - An alkaline salt that is frequently mixed in solutions with oxidizing agents and a reducing agent, which are not stable in acid solutions. It is used for milder removal of paints, coatings and films than the strong bases; this softens the paint so that it can be removed by mechanical means, which is often preferable to completely dissolving the paint because that may contaminate the surface under it.

AP/AC - Alkaline Permanganate/Ammonium Citrate (see definition)

Glossary

APACE - Alkaline Permanganate/Ammonium Citrate/Ethylenediaminetetraacetic Acid process (see definition)

AP/CITROX - Alkaline Permanganate/Citric Acid (see definition)

Arc Saw - Metal cutting tool utilizing a high electric current between a rotating metal disc and a piece of metal to be cut.

Assessment/Characterization - Facility or site sampling, monitoring and analysis activities to determine the extent and nature of the release. Characterization provides the basis for acquiring the necessary technical information to develop, screen, analyze and select appropriate cleanup techniques.

Automated Grinding - Abrading target surface, using coarse-grained, water-cooled diamond grinding wheels or tungsten-carbide surfacing discs. Machines to power these abrasives are floor-type grinders, whose grinding heads rotate in a circular fashion parallel to the floor.

BEMR - Baseline Environmental Management Report

Backhoe Mounted Pulverizer - Track-mounted equipment for the demolition of concrete, brick and cinder block. It is capable of separating rebar and steel beams from concrete. Mist is required to control dust.

Backhoe Mounted Ram - Track-mounted equipment with an approximate reach of 23 feet for the demolition of concrete, brick, cinder block, steel and wood structures. Mist is required to control dust. Must section rebar in advance.

Backhoe Mounted Shears - Track-mounted equipment for the demolition of concrete, brick, cinder block, steel and wood structures. Mist required to control dust. It is capable of cutting separated metal and concrete.

Backhoe Ram - See Backhoe Mounted Ram.

Bioshield - A mass of absorbing material placed around a reactor or radioactive source to reduce the radiation to a level that is safe for human beings.

Bulldozer - Heavy equipment for the push/pull demolition of wood structures.

Glossary

$C_2H_2O_4$ - Oxalic Acid (see definition)

CAN-DECON Process - Developed for use in Canadian CANDU (heavy water moderated) reactors. It involves application of dilute reagents (e.g., citric acid, oxalic acid) and EDTA, as a chelating agent.

Caustic Treatment (Detergents) - Essentially cleaning a surface with soap and water scrubbing. Commercial detergents use alkaline salts, a wetting agent (surfactant), a thickening agent, other fillers and, possibly, a complexing agent.

Centrifuge Cryogenic CO_2 Pellet Blasting - A variation on Grit Blasting in which CO_2 pellets are used as the cleaning medium. Small dry ice pellets are accelerated through a nozzle and use a high speed rotating wheel, which is more efficient than Compressed Air Cryogenic CO_2 Pellet Blasting.

CH - U.S. Department of Energy, Chicago Operations Office

Chelation - This involves the use of organic chelating agents to remove contaminants from the surface. Essentially the bonding of the chelant to a metal oxide (contaminant), which solubilizes the oxide for removal from the surface.

Chemical Conditioning - Asbestos containing material (ACM) may be converted into non-friable material through the application of chemical additives currently under development. In-situ and ex-situ processes convert the ACM into a non-regulated material by chemically breaking down asbestos. In instances where the ACM is contaminated with radionuclides, the resulting waste would be considered low level waste; volume reduction is not significant.

Glossary

Chemical Extraction/Treatment - Technique using chemicals that penetrate the surface (typically concrete) and remove contaminants in the substrate, while leaving the substrate intact, primarily used for concrete decontamination. The objective of chemical decontamination in the nuclear industry is to remove fixed contamination on surfaces of piping, components, equipment and facilities. Advantages: it can be used for inaccessible surfaces, requires fewer workhours, can decontaminate process equipment and piping in place, can usually be performed remotely, produces few airborne hazards, uses chemical agents that are readily available, produces wastes that can be handled remotely, and generally allows the recycling of the wash liquors after further processing. Disadvantages: it is not usually effective on porous surfaces; can produce large volumes of waste (although volume may be reduced by a radioactive waste treatment system); may generate mixed wastes; can result in corrosion and safety problems when misapplied; requires different reagents for different surfaces; requires drainage control; for large jobs, generally requires the construction of chemical storage and collecting equipment; and requires addressing criticality concerns, where applicable.

Chemical Foam - Surface decontamination techniques that uses foam, such as produced by detergents, and wetting agents as carriers of chemical decontamination agents. Primarily used as a pre-treatment.

Chemical Gel - Surface decontamination technique that uses a gel as a carrier of chemical decontamination agents. The gel is applied to the surface and then scrubbed, wiped, rinsed or peeled off.

Chemical Oxidation Reduction Decontamination (CORD) - This REDOX process is used to remove oxide films from metal surfaces without needing replacement of fluid contents of a system. It adds permanganic acid as a first step to oxidize the chromium to the hexavalent state. The decontamination solvent, dicarboxylic acid, is added directly, without the fluid contents of the system having to be replaced. Permanganic ions are reduced to manganous ions by an equivalent concentration of the decontamination solvent. Dissolved metals may be removed by ion exchange in real-time application or by subsequent evaporation of the solvent. This procedure is referred to as one cycle and can be applied several times, and may be applied to oxide films. An adequate DF is normally achieved after two cycles.

Chipping Hammer - Powered chisel driven in a reciprocating motion, used for breaking up concrete at the surface (e.g., jackhammer, pneumatic hammer, etc.).

Glossary

Circular Saw - Rotating abrasive wheel used to cut through concrete and occasionally metal.

Citric Acid ($C_6H_8O_6$) - Effective for decontaminating stainless steel when in mixture with oxalic acid.

ClF_3 - Chlorine Triflouride

CITROX - Citric Acid and Oxalic Acid process - Chemical process for cleaning steel surfaces in boiling water reactors. It utilizes citric acid and oxalic acid.

CO_2 - Carbon Dioxide

CO_2 Blasting - See Compressed Air Cryogenic CO_2 Pellet Blasting and Centrifuge Cryogenic CO_2 Pellet Blasting.

Commercial Recycle - This includes all administrative controls, packaging and transportation required for commercial, licensed vendors to take title to contaminated scrap metal and other salvageable building debris and process material. Vendors may employ mechanical or chemical decontamination techniques, smelting or other processes necessary to release material through appropriate channels or produce products from the recycled material. Recycled products and/or waste streams, resulting from the vendor's activity may be returned to DOE depending on prior agreement and/or DOE policy; commercial recycle activities should be consistent with the Office of Environmental Restoration's Recycle 2000 and/or other policy initiatives.

Compaction - Normally, hydraulically-driven systems are designed to compact dry, low density waste. Conventional compactors cannot handle metal and concrete in appreciable quantities; waste is usually pressed in a standard 55 gallon drum. Disc pressures of up to 150 psi can be achieved. The piston may require decontamination, if used on contaminated waste.

Glossary

Complexing Agent - A chemical species that forms a stable complex with a metal ion in two different manners. Those that are preferential form complexes with certain ions and are called *sequestering agents*. *Chelating agents* are complexing agents that bind the metal at two or more locations. The most common complexing agents include EDTA, organic acids, and sodium or ammonium salts of the organic acids. The ability of the agent to sequester metal ions depends on the specific ion, its oxidation state and the solution pH. Advantages: it increases the DF of most decontaminating agents, can perform dual functions (in the case of the organic acids), and are relatively safe and nontoxic. Disadvantages: expense (of chelating agents), the limited range, and effect on some radioactive waste processes (e.g., precipitation and ion exchange).

Compressed Air Cryogenic CO_2 Pellet Blasting - A variation on Grit Blasting in which CO_2 pellets are used as the cleaning medium. Small dry ice pellets are accelerated through the use of compressed air, which is less efficient than Centrifuge Cryogenic CO_2 Pellet Blasting.

Containment - A device used to prevent or minimize the spread of contamination, often a plastic enclosure with HEPA-filtered ventilation.

Contamination - Unwanted radioactive and/or hazardous material which is disbursed on or in equipment, structures, objects, soil or water. Contamination may be either surface or volumetric (i.e., contamination incorporated within a solid material). Surface contamination may be either removable or fixed.

Controlled Blasting/Explosive Cutting - Specialized charges used to cut or sever specific points of a structure.

CORD - Chemical Oxidation Reduction process (see definition)

Core/Stitch Drilling - Forming a continuous cutting line with side-by-side cuts from a drill.

Crushers/Shears - Cutting technique using opposed cutting surfaces that work on the same principle as a conventional pair of scissors. They vary in size and preferred application (metal or concrete).

Glossary

Deactivation - The process of placing a facility in a safe and stable condition to minimize the long-term cost of a surveillance and maintenance program that is protective of workers, the public and the environment until decommissioning is completed. Actions include the removal of fuel, draining and/or de-energizing of nonessential systems, removal of stored radioactive and hazardous materials and related actions. As the bridge between operations and decommissioning, based on facility-specific considerations and final disposition plans, deactivation can accomplish operations-like activities such as final process runs, and also decontamination activities aimed at placing the facility in a safe and stable condition.

Decommissioning - Actions that take place after deactivation and include surveillance and maintenance, decontamination and/or dismantlement. These actions are taken at the end of the life of a facility to retire it from service with adequate regard for the health and safety of workers and the public and for the protection of the environment. The ultimate goal of decommissioning is unrestricted release or restricted use of the site.

Decontamination - The removal or reduction of radioactive or hazardous contamination from facilities, equipment or soils by washing, heating, chemical or thermal action, mechanical cleaning or other techniques to achieve a stated objective or end condition.

Decontamination Factor (DF) - Defined as the original amount of radionuclide divided by the final amount. In some cases, decontamination effectiveness is reported in terms of percent of contamination removed.

DF - Decontamination Factor (see definition)

Diamond Wire - Cutting technology using a metal wire impregnated with diamonds. Tension and direction are maintained by pulleys.

Dismantlement - The disassembly or demolition and removal of any structure, system or component during decommissioning and satisfactory interim or long-term disposal of the residue from all or portions of a facility.

Disposal - Final placement or destruction of toxic, radioactive or other waste, surplus or banned pesticides or other chemicals, polluted soils and drums containing hazardous materials from removal actions or accidental releases. Disposal may be accomplished through use of approved, secure, regulated landfills, surface impoundments, land farming or incineration.

<u>**Glossary**</u>

DOE - U.S. Department of Energy

DOD - U.S. Department of Defense

DOT - U.S. Department of Transportation

DP - U.S. Department of Energy, Office of Defense Programs

Drill and Spall - Technique involves drilling 1-½ inch diameter holes approximately three inches deep into which a hydraulically operated spalling tool is inserted. The spalling tool bit is an expandable tube through which a tapered mandrel is hydraulically forced in to spall off the concrete.

Dry Vacuum Cleaning - The vacuum cleaning method is effective for removal of loose debris and is used for dust/debris collection resulting from decontamination and/or demolition processes.

EDTA - Ethylenediaminetetraacetic Acid (see definition)

Electrochemical Low Oxidation-State Metal Ion Exchange (ELOMIX) - This is a modification of the LOMI process, where the primary objective is to reduce the volume of waste. Currently, the resin resulting from the application of the LOMI process is normally managed by solidification in cement-based matrices for shipment to an appropriate disposal location, but this is not desirable as a long-term solution because of the instability of organic media and the cost of long-term disposal. The principle features include electrodisposition of metals, back-diffusion of nonplating ions, continual resin regeneration, and compatible chemistry and regeneration of the LOMI solution. The key element of the ELOMIX process is an electrochemical cell consisting of three compartments: anode, cathode and resin.

Electropolishing - Item to be decontaminated is placed in a bath containing a decontamination solution (generally phosphoric acid or phosphoric acid/sulfuric acid) to act as the anode of an electrolyte cell. Electric current is passed through the bath, which causes oxidation, and consequent removal, of the contaminated surface.

Glossary

Encapsulation - A process whereby waste is placed in casks, cans or other containers to prevent the material from moving through the environment.

Environmental Remediation - Cleanup and restoration of sites contaminated with hazardous substances during past production or disposal activities.

ELOMIX - Electrochemical Low Oxidation State Metal Ion Exchange process (see definition)

EM - U.S. Department of Energy, Office of Environmental Management

EM-40 - U.S. Department of Energy, Office of Environmental Management, Office of Environmental Restoration

EPA - U.S. Environmental Protection Agency

ER - U.S. Department of Energy, Office of Energy Research

ES&H - Environment, Safety and Health

Ethylenediaminetetraacetic Acid (EDTA) - A complexing (chelating) agent that is most often used with detergent, oxidizing agents or weak acids and is noncorrosive and nontoxic. Wastes containing EDTA may present a disposal problem.

Expansive Grout - See Expansive Grout/Demolition Compounds.

Expansive Grout/Demolition Compounds - Material similar to Portland cement is poured into pre-drilled holes and allowed to cure. The material expands during curing, causing material to crack along planes connecting pre-drilled holes.

Explosive Charges/Explosive Cutting- see Controlled Blasting/Explosive Cutting.

Explosives - The top three to four inches of concrete are removed by detonating carefully placed and timed explosive charges.

Glossary

Facilities - Buildings or other structures, their functional systems and equipment, and other fixed systems and equipment installed therein; outside plant, including site development features such as landscaping, roads, walks, and parking areas; outside lighting and communication systems; central utility plants; utilities supply and distribution systems; and other physical plant features.

Federal Project - U.S. Department of Energy's or U.S. Environmental Protection Agency's decontamination project.

Fixative/Stabilizer Coatings - Various agents can be used as coatings on contaminated residues to fix or stabilize the contaminant in place and decrease or eliminate exposure hazards.

Fiscal Year - A 12-month period for which an organization plans the use of its funds. In the Federal Government, this period extends from October 1 through September 30 of the following calendar year.

Fission Products - The radioactive elements produced from the fission of fissile materials such as U-235.

Flame Cutting - Concrete cutting method using powered iron and aluminum in a directed stream of oxygen.

Flashlamp Ablation - Uses energy absorbed from a high energy xenon flashlamp to cause rapid temperature rises, creating decomposition or evaporation of material to a particulate residue.

Foam/Sponge Blasting - Cleans surface with various grades of foam-cleaning media (i.e., sponges made of water-based urethane).

FP - Fission Products (see definition)

Friable Asbestos - Asbestos insulation that is loose and capable of becoming airborne.

Fuel Reprocessing - The dissolution of spent nuclear fuel and separation of uranium, transuranic elements and fission products.

FY - Fiscal Year (see definition)

Glossary

Gamma Radiation - Electromagnetic radiation of extremely short wavelength similar to X rays. Gamma radiation is highly penetrating; therefore, gamma-emitting nuclides are a hazard both when ingested or inhaled and when external to the body. Heavy materials such as lead (or massive amounts of lighter materials) are effective shields for protection from gamma radiation.

Gas Cutting - Metal cutting method utilizing a combustive gas with an oxygen source.

Gas Phase Fluorination (ClF_3) - A process proposed for removing uranium fluoride deposit from piping and component internals of gaseous diffusion plants.

Grapple - Track mounted "grips" used to hold or remove portions of a structure.

Grinding - See Automated Grinding or Hand Grinding/Honing.

Grit Blasting - This technique uses abrasive materials (e.g., sand, alumina, metal shot, etc.) suspended in a medium that is projected onto the surface being treated, and results in uniform removal of surface contamination. Compressed air, water or some combination can be used to carry the abrasive.

H&S - Health and Safety

Hand Grinding/Honing - Power-driven grinding equipment is used to remove the surface from an contaminated object.

Hazardous Material - A substance or material that has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety and property when transported in commerce and that has been so designated.

Hazardous Waste - As defined in 40 CFR 261, any solid waste; concentration; or physical, chemical or infectious characteristics that may "(1) cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible or incapacitating reversible, illness; or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed...."

HCl - Hydrochloric Acid (see definition)

HEPA - High Efficiency Particulate Air filter (see definition)

HF - Hydrogen Fluoride

High Efficiency Particulate Air (HEPA) Filter - A filter used to remove particulates from dry gaseous effluent streams.

High-Level Waste (HLW) - The highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid, that contains a combination of transuranic waste and fission products in concentrations requiring permanent isolation.

High Pressure Freon Cleaning - High pressure commercial Freon (an organic solvent) is utilized to remove contamination associated with grease, oil, etc.

High-Pressure Water Pressure Blasting - See Hydroblasting.

HLW - High-Level Waste (see definition)

HNO_3 - Nitric Acid (see definition)

Hot Cell - A building that contains shielded rooms, or cells, where remote operations can be performed on radioactive materials.

Hot Water Flushing - This technique involves flooding a surface with hot water, which dissolves contaminants. The resulting wastewater is collected and treated.

HP - Health Physicist

H_3PO_4 - Phosphoric Acid (see definition)

Hydraulic Shears - See Crusher/Shears.

Hydroblasting - This technique uses a high pressure water jet ($\leq$10,000 psi) to remove surface contamination.

Glossary

Hydroblasting - Flexible Lance - This is a modification of the Hydroblasting technique, where small diameter piping/tubing is inserted inside piping to direct the high pressure water jet to internal surfaces.

Hydrochloric Acid (HCl) - Removal of tightly adherent contamination using hydrochloric acid solutions in spray booth, dipping or flushing decontamination processes. It is also a strong mineral acid that is one of the first chemical cleaning agents used for utility boilers. Laboratory data indicated decontamination of stainless steel gave repeatable DFs of approximately 10.

HSO_3NH_2 - Sulfamic Acid (see definition)

Ice Blasting - This is similar to the Grit Blasting technique; the system employs low-pressure air and wet ice for surface cleaning.

ID - U.S. Department of Energy, Idaho Operations Office

Impact Hammer (Ram) - Pneumatic or hydraulic powered chisel, usually track mounted, used for concrete demolition.

Incineration - May be performed on combustible solids and/or PCB electrical components to reduce the volume of the waste and/or destroy hazardous constituents. The process employs ample oxygen, high temperatures and sometimes chemical additives to destroy organic or toxic agents and/or reduce combustible solids to ash. Airborne particulates are trapped by filters, which require eventual disposal. Ash must be disposed of as waste.

Industrial Floor Scrubbers - Commercially available floor polishers are used to clean smearable contamination from floors.

In Place Burial - Solid waste is used to fill basement or excavated areas or exposed subsurface structures, resulting from decommissioning activities. Typically, the waste is not processed except, perhaps, for some in-place compacting with machinery. There may be a potential for authorization to include a specific minor amount of nuclear or chemical material, but the fill will be considered a sanitary landfill.

In-Situ Electropolishing - Techniques developed for the in-situ electropolishing of objects that are too large for immersion. See Electropolishing.

Glossary

In-Situ Underwater Cutting - See Plasma Arc/Arc Torch.

Jackhammer - Type of impact hammer for the demolition of concrete, brick and cinder block structures. Rebar must be sectioned in advance. Its utility is limited to small areas of floors, hard to reach areas and stack foundations.

KOH - Potassium Hydroxide (see definition)

Kerosene - Used in decontamination for removing organic materials, grease, wax, oil and paint from surfaces and for cleaning clothes.

Laser Etching/Ablation - Process uses absorption of laser energy and its conversion to heat (photopyrolysis) to selectively remove surface coatings or contamination. Emerging thermal technology for concrete decontamination.

Life-Cycle Cost - The total cost to complete the mission of the Environmental Management program.

Local Disposition - Includes all administrative controls and storage/disposal packages required to disposition solid waste at a facility prepared locally, rather than at a large central radioactive waste disposal site. The waste remains on DOE property; is not processed except, perhaps, for some degree of in-place compaction with machinery; and will generally be stored or disposed of in an on-site, engineered disposal cell. The waste may be either sanitary, LLW, mixed waste or TRU.

LOMI - Low Oxidation State Metal Ion process (see definition)

Low-Level Waste (LLW) **-** Radioactive waste not classified as high-level waste, transuranic waste or spent nuclear fuel.

Glossary

Low Oxidation-State Metal Ion (LOMI) - This REDOX process is applied in a manner similar to that used for the CAN-DECON process. The reactor coolant is first adjusted to neutral pH and a low dissolved-oxygen level is then brought to a temperature of 80-90°C. The chemical decontamination solution is then injected, and a side stream of circulation coolant is passed through filter and cation exchange resin columns to regenerate the solution on line. Decontamination times are very short (i.e., 1-3 hours). It utilizes the vanadium (+2) ion (as vanadium picolinate) to reduce steel corrosion layers (Fe+3) to a soluble state; formic acid is then added to scavenge solubilized metal ions. Advantages: low corrosion without the use of an inhibitor and reacts rapidly. Disadvantages: the reagent is relatively expensive and creates a relatively larger volume of waste.

LLW - Low-Level Waste (see definition)

M&O - Managing and Operating Contractor (see definition)

M&O Contractor - The management and operations contractor, which is the prime contractor at a DOE site.

Manual Brushing/Wiping/Scrubbing - Simple manual techniques for cleaning contaminated surfaces. It typically includes detergents or solvents, as appropriate.

MEANS® - Heavy Construction Book - Handbook containing cost estimate data.

Mechanical Cutting - Techniques that use mechanical forces (e.g., shear) and/or motions (e.g., reciprocating or circular) to cut various components (e.g., structures or piping) that may be encountered during decommissioning. These techniques are usually driven electrically, pneumatically or hydraulically, resulting in the cutting and/or breaking of the component.

Glossary

Mechanical Decontamination - These methods can be classified as either surface cleaning (e.g., sweeping, wiping or scrubbing) or surface removal (e.g., grit blasting, scarifying or drill and spall), used as an alternative to chemical decontamination, used simultaneously with chemical decontamination, or used in sequence with chemical decontamination. In general, these methods can be used on any surface and achieve superior decontamination; when used in conjunction with chemical methods, an even better result is realized. Disadvantages: the surface of the workpiece must be accessible (i.e., free of crevices and corners), and many methods produce airborne dusts (if contamination is a concern, this requires containment). Surface preparation and safety precautions are required; all surfaces to be treated must be free of obstructions and surfaces should be washed down to minimize the release of airborne contamination during the surface-removal technique.

Mechanical Saw - Metal cutting tool using a reciprocating hardened steel blade.

Mechanical Scabbling - See Scabbling.

Megawatt (electric and thermal) - A unit of power equal to one million watts. Megawatt thermal is commonly used to define heat produced, while megawatt electric defines electricity produced.

Melting - Can be used to reduce the volume of packaging required for a given amount of scrap metal. The metal is simply melted and cast into ingots, which may result in volumetrically contaminated waste. Decontamination of the crucible and mold may be required following melting and casting of contaminated metal.

Mixed Waste - Waste that contains both radiological and hazardous chemical components.

Mobile Shears - See Crusher/Shears.

Moderate - Ranking of physical activity according to strength of data collected per work area and per individual graph.

MWe - Megawatt of electric power

MWt - Megawatt of thermal power

Glossary

Na_2CO_3 - Sodium Carbonate (see definition)

NaOH - Sodium Hydroxide (see definition)

$(NH_4)_2CO_3$ - Ammonium Carbonate (see definition)

Nibblers/Shears - Small version of Shears most commonly used for metal cutting.

Nitric Acid (HNO_3) - A strong mineral acid used for dissolving uranium and its oxides in stainless steel and Inconel systems. It cannot be used on carbon steel because of the high corrosion rate. This strong oxidizing agent can be used alone, or in combination with other chemicals (e.g., sodium hydroxide (NaOH), ammonium permanganate, etc.) and is very effective in removing uranium.

Non-Federal Project - Decontamination project in the private sector.

NV - U.S. Department of Energy, Nevada Operations Office

Off-Site - Beyond the boundary line marking the limits of the plant property.

OH - U.S. Department of Energy, Ohio Operations Office

OK - U.S. Department of Energy, Oklahoma Operations Office

OPP - Oxalic Peroxide (see definition)

On-Site - The same or geographically contiguous property that may be divided by public or private right-of-way, provided the entrance and exit between the properties is at a cross-roads intersection, and access is by crossing as opposed to going along the right-of-way. Noncontiguous properties owned by the same person but connected by a right-of-way that he/she controls and to which the public does not have access is also considered onsite property.

OR - U.S. Department of Energy, Oak Ridge Operations Office

Glossary

Organic/Weak Acids - Acids used for contamination include oxalic acid ($C_2H_2O_4$), citric acid ($C_6H_8O_6$) and sulfamic acid (HSO_3NH_2), particularly as used in oxalate peroxide. It is generally used on metal surfaces and acts by dissolving the metal oxide film and sequestering or solubilizing the metal ion. Advantages: less corrosive (than strong mineral acids), superior safety and handling characteristics, and double role in dissolving oxide films and sequestering the metal contaminant. Disadvantages: more expensive than some of the strong mineral acids; slower reaction time; although less corrosive, still have some material compatibility and personnel considerations; can break down at high temperatures; and require neutralization before treating in a radioactive waste system.

Oxalate Peroxide (OPP) - An oxidizing agent consisting of a mixture of oxalic acid and hydrogen peroxide. It is used for the simultaneous dissolution of UO_2 and the defilming and decontamination of metals. The oxalic acid decontaminates the surface, and the hydrogen peroxide enhances the decontamination and passivates the steel by its oxidative action. However, the peroxide destroys the oxalic acid, preventing reuse of the solvent.

Oxalic Acid ($C_2H_2O_4$) - Used for removal of rust from iron. Excellent complexor for niobium (when present) and fission products in decontamination of reactor systems.

Oxyacetylene Torch - Metal cutting tool using acetylene and pure oxygen.

Oxidizing and Reducing (REDOX) Agents - See REDOX Treatments.

Package As-Is for Storage and/or Shipment - Includes all administrative controls, transportation and/or disposal packages, and packaging equipment required to remove solid waste from the site to appropriate storage and/or disposal cells. The waste is not processed in any way. Packages must meet all DOT and/or disposal cell waste acceptance criteria (WAC). Waste may be either sanitary, LLW, mixed waste or TRU.

Paint Remover - Solvents used with hand scraping, water washing and detergent scrubbing to remove metal-based paints.

PAM - Preferred Alternatives Matrix (see definition)

Partners - refers to study participants.

Glossary

Paving Breaker/Chipping Hammer - Although paving breakers (e.g., jackhammers, pneumatic drills, etc.) and chipping hammers are typically used for demolition, they can be used to remove surface contamination up to six inches thick. Concrete is removed by mechanically fracturing localized sections of the surface.

PCB - Polychlorinated Biphenyl (see definition)

Personnel Protective Equipment (PPE) - Clothing and equipment used to shield or isolate individuals from the chemical, physical and biological hazards that may be encountered at the hazardous site. PPE should protect the respiratory system, skin, eyes, face, hands, feet, head, body and hearing. PPE may also represent personal protective clothing and equipment.

Phosphoric Acid - Rapidly defilms and decontaminates carbon steel surfaces through formation of a ferrous phosphate film. The use of phosphates is not recommended when the waste end product will be glass.

Physical Labor - Includes all craftsmen and foremen costs (or hours) expended on a job.

Piston Scabbler - High-speed, reciprocating, tungsten carbide-tipped pistons are used to pulverize protective coatings and concrete substrate in a single-step process.

Planing - Layers of soft material, such as wood or lead, are shaved off.

Plasma Arc/Arc Torch - Metal cutting technique based on establishing an electric current between an electrode and the metal. The current is facilitated by a stream of gas and water.

Plastic Blasting - This technique directs a high-velocity stream of fine plastic pellets onto a surface to remove contamination.

Polychlorinated Biphenyls (PCBs) - A group of commercially produced organic chemicals used since the 1940s in industrial applications throughout the nuclear weapons complex. PCBs are found in many gaskets and large electrical transformers and capacitors in the uranium enrichment facilities. They have been proven to be toxic to both humans and laboratory animals.

Glossary

Potassium Hydroxide - An alkaline salt that is also a strong base. It is frequently mixed in solutions with oxidizing agents and a reducing agent, which are not stable in acid solutions. It is used for aggressive attacks on paints, coatings and films; this softens the paint so that it can be removed by mechanical means, which is often preferable to completely dissolving the paint because that may contaminate the surface under it.

Power Hacksaw - See Mechanical Saw.

PPE - Personnel Protective Equipment (see definition)

Preferred Alternatives Matrix (PAM) - The PAM could be used as an initial screening tool to assess decommissioning technologies in relationship to media types and broad categories of decommissioning activities. The PAM provides a concise format for accommodating multiple variable that influence the selection of a decommissioning technology. The scoring of individual technologies are the result of the application of the ranking criteria, incorporating a thorough literature review, field experience and professional judgement. Only decommissioning technologies that are state of the art and that are, in general, commercially available from one or more vendors are included. Each technology listed is given a qualitative ranking, indicating its applicability and effectiveness for given decommissioning tasks.

Process Speed - Rate at which equipment decontaminates a unit of area.

Productivity - Rate at which a unit area is decontaminated (includes process speed, crew size, setup, decontamination, waste packaging operations, spot maintenance and takedown).

psi - Pounds per Square Inch

psig - Pounds per Square Inch Gauge

Pu - Plutonium

RA - Remedial Action (see definition)

Glossary

Radioactive - Any material or combination of materials that spontaneously emits ionizing radiation.

Radioactivity - The property of certain nuclides of spontaneously decaying.

Radionuclides - A radioactive species of an atom characterized by the constitution of its nucleus.

RAPIC - DOE's Remedial Action Program Information Center

Reactor Pressure Vessels (RPV) - The device within the reactor that sustains a controlled nuclear fission chain reaction to produce electricity or man-made isotopes (e.g., plutonium or tritium).

Reactor - A facility that contains a device that sustains a controlled nuclear fission chain reaction to produce electricity or man-made isotopes (e.g., plutonium or tritium).

Rebar - Steel reinforcing bars embedded in concrete structures to improve tensile strength.

REDOX - Oxidizing and Reducing Agents

REDOX Treatments - An oxidizing agent increases the oxidation state of another chemical species (e.g., potassium permanganate [$KmnO_4$], potassium dichromate [$K_2Cr_2O_7$], hydrogen peroxide [H_2O_2], etc.) and are used to condition metal oxide films, dissolve fission product debris/various chemical species, and oxidize the metal surface either for protection or corrosion. It could also be used to protect a metal surface or reduce higher oxidation states for sequestering agents. A reducing agent lowers the oxidation state. A change in oxidation state may be beneficial because some oxidation states are more soluble than others. Frequently, these two classes of chemicals are used jointly to maintain a specified oxidation level; some of these agents include alkaline permanganate (AP), low oxidation-state metal ion (LOMI), electrochemical low oxidation-state metal ion exchange (ELOMIX), and chemical oxidation reduction decontamination. Oxidizing agents find extensive application in decontamination by conditioning metal oxide films, dissolving fission product debris, dissolving various chemical species, and oxidizing the metal surface either for protection or corrosion. Most metal surfaces can be treated with oxidizing agents, but conditions must be adjusted to avoid excessive corrosion.

Remedial Action - Cleaning up inactive waste sites, which primarily concerns contaminated soil, surface water and groundwater.

Glossary

Removal - Includes cutting, dismantling and demolishing in preparation for packaging.

Reprocessing - See Fuel Reprocessing.

RF - U.S. Department of Energy, Rocky Flats Operations Office

RL - U.S. Department of Energy, Richland Operations Office

Rock Splitter - Slow, quiet, non-cutting method for cutting and sizing concrete, brick or cinder block structures. Must first clear and section rebar. It is appropriate for confined space usage.

Rotating Brushes/Honing - A device that utilizes cylindrical, mechanically rotated brushes, which are nylon strands attached to abrasive honing stones that are rotated at high speed. The device is inserted into piping to remove fixed contamination/oxide layers from internal surfaces.

Rotating Cavitation Water Jet - A device that is inserted into piping that uses rotating water jets to clean fixed contamination from internal surfaces. The MOLE nozzle uses water pressures at 10,000 psig; the CaviJet uses 7,000 psig water with a specially designed nozzle to produce bubbles for cleaning action.

RPV - Reactor Pressure Vessel (see definition)

Rubblizing - A technique analogous to Shredding applied to brick, block and concrete. Rock Crushers and Universal Processors can be used to reduce the volume of brick, block and concrete through extreme pressure and/or repeated blows. Pressure applying and striking surfaces may require decontamination if used to process contaminated material. Processed material is typically not decontaminated.

S&M - Surveillance and Maintenance (see definition)

Safe Storage - Those actions required to place and maintain a nuclear facility in such a condition that future risk to public safety from the facility is within acceptable bounds and that the facility can be safely stored for as long a time as desired.

Glossary

Sanitary Waste - Waste, such as garbage, that is generated by normal housekeeping activities and is not hazardous or radioactive. The waste is disposed of in sanitary landfills. Sanitary waste also includes liquids which are treated in sewage treatment plants.

Scabbling - Concrete decontamination using the impact of reciprocating pistons to pulverize the surface of the concrete.

Setup - On-site installation and preparation of decommissioning technologies for work.

Shears - See Crushers/Shears.

Shot Blasting - An airless method that strips, cleans and etches a surface simultaneously. Portable units move along the surface that is being treated as the abrasive is fed into the center of a completely enclosed centrifugal blast wheel. As the wheel spins, abrasives are hurled from the blades, blasting the surface. The abrasives and surface debris are bounced back to a separation system for abrasive recycling and dust collection.

Shredding - Achieve volume reduction by tearing metal objects into small strips with counter rotating cutting wheels. It can be either electrically or hydraulically driven. Also, it can be either stationary or mobile units. Cutting surfaces and shredding chamber may require decontamination, if used to shred contaminated metal. Processed metal is typically not decontaminated.

Shrouded, Needle Scalar - Scarifier for removing concrete from outside edges, inside corners and wall surfaces.

Shutdown - The time during which a site is not in productive operation.

Site - The geographic area upon which the facility is located that is subject to controlled public access.

Slab Saws - Large circular saws (a rotating abrasive wheel) used for cutting through floor and wall slabs of concrete.

Smelt Purification - Purifies metals by introducing suitable additives to scrap metals that will react with impurities in the metal when melted. Impurities are then removed in the slag that separates from the molten metal.

Soda Blasting - This technique uses sodium bicarbonate suspended in a medium that is projected onto the surface being treated, and results in uniform removal of surface contamination. Compressed air, water or some combination can be used to carry the sodium bicarbonate.

Sodium Carbonate (Na_2CO_3) - An alkaline salt that is frequently mixed in solutions with oxidizing agents and a reducing agent, which are not stable in acid solutions. It is used for milder removal of paints, coatings and films than the strong bases; this softens the paint so that it can be removed by mechanical means, which is often preferable to completely dissolving the paint because that may contaminate the surface under it.

Sodium Hydroxide (NaOH) - An alkaline salt that is also a strong base. It is frequently mixed in solutions with oxidizing agents and a reducing agent, which are not stable in acid solutions. It is used first as a conditioning step for stainless steel and other metal surfaces. When used in combination with potassium permanganate ($KmnO_4$), it aggressively attacks paints, coatings and films. This softens the paint so that it can be removed by mechanical means, which is often preferable to completely dissolving the paint because that may contaminate the surface under it.

Spalling - See Drill and Spall.

Spent Nuclear Fuel - Irradiated nuclear reactor fuel before reprocessing. It contains uranium, transuranic elements and fission products.

Sponge Blasting - This technique blasts surfaces with various grades of foam-cleaning media (i.e., sponges), which are made of water-based urethane. During surface contact, the sponges expand and contract, creating a scrubbing effect.

Spot Maintenance - Any actions performed by an operator on decommissioning technologies that can be accomplished without removing the technology from the work area (e.g., filter change).

SR - U.S. Department of Energy, Savannah River Operations Office

Glossary

Stabilization - The conversion of the active organic matter in sludge into inert, harmless material. Also any activities undertaken to reduce the active management requirements for disposal facilities.

Steam Cleaning - Combination of solvent action of water with the kinetic energy effect of blasting. At relatively high temperatures, the solvent action is increased and required water volume is reduced.

Steam Vacuum - Modification of Steam Cleaning technique that combines the steam cleaning action with a HEPA vacuum system to minimize spread of contamination and "spray-back."

Steel Grit Blasting - See Grit Blasting.

Strippable (and Self-Strippable) Coatings - Application of a polymer mixture to a contaminated surface. As the polymer reacts, contaminants are stabilized, becoming entrained in the polymer. Generally, the contaminated layer is pulled off or, in the case of self-strippable coatings, coating cracks, flakes and falls off, taking loose contamination with it. This contamination can then be vacuumed up.

Strong - Ranking of physical activity data according to the strength of data collected per work area and per individual graph.

Strong Mineral Acids - The acids used for decontamination include hydrochloric acid, nitric acid, sulfuric acid and phosphoric acid. Their main purpose is to attack and dissolve metal oxide films and lower the pH of solutions to increase solubility or ion-exchange of metal ions, and can be used on almost all metal surfaces except reactive metals such as zinc. They can be used alone, as dilute solutions, or in formulation mixtures with acid salts, such as sodium bisulfate ($NaHSO_4$), sodium sulfate (Na_2SO_4), ferric sulfate [$Fe_2(SO_4)_3$], ammonium oxalate ($NH_4C_2O_4$), ammonium citrate [$(NH_4)_2HC_6H_5O_7$], sodium fluoride (NaF) and other compounds with each other (e.g., HNO_3-HCl); includes hydrochloric acid (HCl), nitric acid (HNO_3), sulfuric acid (H_2SO_4) and phosphoric acid (H_3PO_4) Advantages: they are relatively cheap, quick and effective. Disadvantages: they present safety and handling problems, require neutralization before waste treatment, and are incompatible with many materials.

Subcontractor - A contractor to the M&O contractor at a DOE site.

Sulfamic Acid (HSO_3NH_2) - An organic acid used to remove contaminants from carbon steel surfaces.

Supercompaction - Hydraulically driven systems, similar to Compactors, but can achieve disc pressures up to 22,000 psi and, therefore, can handle metal and concrete. The piston may require decontamination, if used on contaminated waste.

Superheated Water - Uses a high velocity stream of superheated water directed onto a surface to remove contamination.

Glossary

Support Labor - Includes all costs (or hours) for health physicists, site characterization, setting up utilities, security, surveillance and maintenance.

Surface Contamination - Radioactive and/or hazardous material adherent to an otherwise non-contaminated surface.

Surface Cleaning - A mechanical decontamination method used when contamination (both building and equipment) is limited to near-surface material. Some techniques may remove thin layers of the surface (less than 1/4 inch), some of which generate contaminated liquids that need to be collected and treated. These techniques differ from surface removal techniques in that the removal of the contaminant from the surface is the goal, rather than the removal of the surface itself. Some surface cleaning techniques can be used as a secondary treatment following surface removal.

Surface Removal - A mechanical decontamination method used when future land-use scenarios include reuse or when it is impractical to demolish the building (e.g., a laboratory within a building). The techniques remove various depths of surface contamination (e.g., floors vs. walls) and may be used to reduce the amount of contaminant to be disposed of. Most of these techniques leave an undesirable surface finish; if a smoothly finished surface is required, a concrete cap or some other surface-smoothing treatment must be applied.

Surplus Facility - Any facility or site (including equipment) that has no identified programmatic use.

Surveillance and Maintenance (S&M) - Those activities necessary to ensure that the site remains in a safe condition, including periodic inspection and monitoring of the site, maintenance of barriers that prevent access to radioactive materials left on the site, and prevention of activities on the site that might impair these barriers.

Survey and Free Release - Includes all administrative controls, real-time surveys and sampling required to certify scrap metal and other salvageable building debris as radiologically clean and suitable for recycle and/or reuse. Material determined to be contaminated must be dispositioned by other means.

Takedown - Removing technologies and any temporary structures/systems from the work vicinity.

Thermal Cutting - There are two types of thermal cutters: flame producers and arc producers, including Plasma Arc/Arc Torch, Flame Cutting, Thermite Lance. The more common are the flame producing techniques where a flame is established by igniting fuel gases. With arc producing techniques, an electrical arc is established between the tool and the workpiece. In either method, the workpiece is literally melted away.

Thermite Lance - High temperature cutting technique utilizing the combustion of iron, aluminum and magnesium wires. Can be used on concrete and metal.

Glossary

Transite Siding - Outside siding of buildings that contains asbestos.

Transuranic Waste (TRU) - Any waste material measured or assumed to contain more than 100 nCi/g of transuranic elements (elements with an atomic number greater than 92) that emit alpha radiation and have a half-life of greater than 20 years.

Treatment/Storage/Disposal - Waste management activities for low-level waste, high-level waste and transuranic waste.

TRU - Transuranic (see definition)

Turbulator - Large tank with propellers that direct the flow of cleaning solution across a component to remove surface contamination.

U - Uranium

UCF - Unit Cost Factor (see definition)

UF_4 - Uranium Tetrafluoride

Ultra-High Pressure Water Blasting - Similar to Hydroblasting, except that the water pressures exceed 10,000 psi (as high as 55,000 psi). The water jet is forced through a small-diameter nozzle that generates a high-velocity water jet with speeds up to 3,000 feet per second. Deeper surface penetration is possible with the addition of abrasives.

Ultrasonic Vibration - Contaminated component is placed into a bath, containing a cleaning solution. Vigorous scrubbing action is produced by means of ultrasonic vibrations to clean component surface.

Underwater Plasma Cutting - See Plasma Arc/Arc Torch.

Unit Cost Factor (UCF) - Price per unit of media to be decommissioned (e.g., dollars per cubic foot of concrete to be demolished).

- UCF for Removal Only: Productivity Rate times Fully Burdened Labor Rate
- UCF for Removal plus Onsite Disposal: Productivity Rate times Fully Burdened Labor Rate plus Volume Adjustment Factor times Onsite Disposal Rate
- UCF for Removal plus Commercial Disposal: Productivity Rate times Fully Burdened Labor Rate plus Volume Adjustment Factor times Commercial Disposal Rate

Universal Processor - See Crusher/Shears.

UO_2 - Uranium Dioxide

Glossary

UO_2F_2 - Uranium Oxyfluoride

Vacuum Blasting - Concrete surface decontamination technique using abrasive particles conducted in a vacuum to reduce the spread of contamination.

Vibratory Finishing - Objects are placed in a basket filled with abrasive media. The basket is then vibrated at a high frequency in a cleaning solution. The vibrating media produce scouring action that removes contamination.

WAC - Waste Acceptance Criteria

Wall and Floor Saw - Mechanical equipment for removing large section of concrete en masse during cutting, demolition and sizing operations on brick, concrete, cinder block and wood structures. It tends to bind if used for long periods.

Wall Shaver - Concrete surface decontamination technique for scraping contamination from vertical surfaces.

Waste Acceptance Criteria (WAC) - The requirements specifying the characteristics of waste and waste packaging acceptable to a waste receiving facility; and the documents and processes the generator needs to certify that waste meets applicable requirements.

Waste Management - Activities that include treating, storing and disposing of low-level waste, high-level waste, transuranic waste, mixed waste and sanitary waste.

Waste Minimization - The reduction, to the extent feasible, of radioactive and hazardous waste that is generated *before* treatment, storage or disposal of the waste. Waste minimization includes any source reduction or recycling activity that results in: (1) reduction of total volume of hazardous waste, (2) reduction of toxicity of hazardous waste, or (3) both.

Waste Packaging - Placing removed structures, equipment, debris, etc. into approved packages for transportation and/or disposal.

Water Jet - See Abrasive Water Jet.

Weak - Ranking of physical activity data according to the strength of data collected per work area and per individual graph.

Wet Ice Blasting - This technique employs low-pressure air and wet ice in a high-velocity stream for cleaning and surface preparation. The contaminated water that is generated by the melting ice particles is the controlling medium for the displaced contamination, which must then be treated for discharge.

White Collar Labor - Includes all project management, engineering, ES&H documentation and procurement organization costs (or hours).

Glossary

Wrecking Ball/Slab - Heavy equipment for cutting, demolition and sizing concrete, brick, cinder block, steel and wood structures. It is not recommended for radiological work or reinforced concrete (rebar requires sectioning). This technique is limited to structures <100 feet in height.

References

1. American Nuclear Society. Nuclear News. Volume 39, Number 4, Mid-March 1996.

2. Bechtel Hanford, Inc. Budget Estimate, 105-C Reactor Long-Term Storage. August 5, 1996.

3. Dickerson KS, Ally MR, Brown CH, et al. Demonstration Recommendations for Accelerated Testing of Concrete Decontamination Methods. ORNL/TM-13098. Oak Ridge National Laboratory for the U.S. Department of Energy, Office of Technology Development, December 1995.

4. Ebadian MA, Lagos LE, Boudreaux JF, et. Al. "Analysis of Potential Surface Blasting Decontamination Technologies for Structural Steel." FEMP/SUB-098, UC-706, August 1995.

5. EQES, Inc. Nuclear Plant Journal. Volume 13, Number 6, November-December 1995.

6. MEANS®. Heavy Construction Cost Data. 10th Annual Edition, 1996.

7. U.S. Department of Energy, Office of Environmental Management. The 1996 Baseline Environmental Management Report. DOE/EM-0290. Executive Summary and Volumes I, II and III. June 1996.

8. U.S. Department of Energy, Office of Environmental Management. Ten Year Plan. July 31, 1996.

9. U.S. Department of Energy, Office of Environmental Management, Office of Environmental Restoration. Decommissioning Benchmarking Study: Implementation Plan. February 1996.

10. U.S. Department of Energy, Office of Environmental Management, Office of Environmental Restoration. Decommissioning Resource Manual. DOE/EM-0246. August 1995.

11. U.S. Department of Energy, Office of Environmental Management, Office of Environmental Restoration. EM-40 Core Database. October 29, 1996.

12. U.S. Department of Energy, Office of Environmental Management, Office of Environmental Restoration. EM-40 National Decommissioning Program, Surplus Facilities Inventory List. November 8, 1994.

13. U.S. Department of Energy, Office of Environmental Management, Office of Environmental Restoration. Preferred Decommissioning Technologies Guide. Environmental Restoration Program. Draft, July 4, 1996.

14. U.S. Department of Energy, Office of Environmental Management, Office of Environmental Restoration. Remedial Action Program Information Center (RAPIC).

15. U.S. Department of Energy, Office of Environmental Management, Office of Environmental Restoration. Decommissioning of Facilities Web Page, (http://www.em.doe.gov/dd/). October 4, 1996.

16. U.S. Department of Energy, Office of Field Management. DOE Real Property, A Yearly Statistical Handbook, Fiscal Year 1994. DOE/FM-0004, pp. 15-18.

17. U.S. Department of Energy, Office of Management and Budget. Financial Information System (FIS), Year End Report. FY 1991, FY 1992, FY 1993, FY 1994, FY 1995 and FY 1996.

18. U.S. Department of Energy, Savannah River Operations Office. News and Notes Web Page, "SRS Pioneers Decommissioning of Unused Facilities," (http://www.srs.gov/general/news-notes/newspress/decom_facilities.html). February 27, 1996.

Note: To protect the identity of the data, actual project reports and other documentation used in Section III graphs are not referenced in this Section.

Data Collection Forms

Improving the accuracy of the productivity rates and unit cost factors developed from this study will improve cost estimating capabilities and end-point alternatives analyses. The following blank forms can be utilized by decommissioning project managers to collect project data and refine productivity rates. The data collected will also be beneficial to the DOE Decommissioning Program.

Additionally, the Interagency Cost Estimating Group, with representation from the Department of Defense, Energy, Interior, and EPA, has developed a hazardous, toxic, radioactive waste (HTRW) work breakdown structure (WBS) for tracking costs for all phases of a facilities lifecycle. In July 1996, DOE EM-40 endorsed the implementation of the HTRW WBS for use in the EM-40 program. The HTRW WBS for decommissioning is also included here.

Data Collection Form for the DOE Decommissioning Benchmarking Study

Overall Project

Instructions:

1) Please provide the total costs and total hours and percentages, as available. The total costs and total hours should reflect the entire decommissioning project, if complete.

2) In some cases, data may not be available for all categories. If this is the case, please place an "NA" for "Not Applicable" in the block and provide any information, as appropriate.

3) Please provide any additional relevant information, either on the data collection form or on another sheet.

General Information (including site name, project name/description, contact person/telephone number, etc.)					
	Total Costs (designate currency)	**Total Hours (man-hours)**	**Total Percent Costs**	**Total Percent Hours**	**Additional Information**
Characterization (including sampling, surveys, analysis, etc.)					
Pre-decommissioning Operations					
Facility Shutdown Activities					
Procurement of General Equipment and Material					
Dismantling Activities (including all Physical Work)					
*** Project Management** (including business management, financial control, progress reporting, meetings, etc.)					
*** Engineering/ Planning/ Design**					
*** Support Services** (including technicians, matrixed engineers, security, training, etc.)					
Regulatory Documentation (including compliance reports, etc.)					
Security, Surveillance, and Maintenance					
Risk/ Hazards Analysis and Health & Safety Documentation					
Waste Treatment and Disposal					
Site Clean-up and Landscaping					
Other (with explanation)					
TOTAL			100%	100%	

* We recognize that based on the OECD Task Group on Decommissioning Costs these three categories are combined into one category - Project Management, Engineering, and Site Support, and that separating the total costs and total hours may be difficult.

Data Collection Form for the DOE Decommissioning Benchmarking Study
Task Level Data

Instructions:

1) Please provide your actual data for the requested areas. At a minimum, actual data must be provided for the "Work Activity", "Dimensions of Initial Structure and/or Material Removed", and the "Crew Duration" fields.

2) Please provide any additional relevant information, either on the data collection form or by attaching additional sheets.

DATA REQUESTED	ACTUAL DATA
**** Work Activity** • Please indicate the work activity type, choices include concrete surface decontamination, concrete demolition, structural steel demolition, asbestos containing material (ACM) tile and siding removal, ACM insulation removal, general ACM removal, equipment removal, material handling, area release surveys, material release surveys, general demolition, pipe removal, or other (with explanation). • Please include the Work Activity Name (for tracking purposes only).	
Equipment Used • Please describe the equipment used during the work activity. • Please indicate the manufacturer and model number of all equipment used. • If vendor information is available, please indicate the vendor and telephone number. • Please indicate any quoted vendor productivity values, if available. • If project quoted productivity rates were calculated, please provide the rates. • If any equipment was modified, please provide a description of the modifications.	
Contamination Present • Please indicate the type of contamination present, including radioactive, hazardous, ACM, clean (no contamination), or a combination of the above. • Please indicate the extent or depth of the contamination. • Please indicate whether or not ALARA considerations were taken. • Please provide the recorded dose after the work activity was completed or during the work.	

DATA REQUESTED	ACTUAL DATA
**** Dimensions of Initial Structure and/or Material Removed** (preferred units) • Please indicate the dimensions of the initial structure including area (ft^2), volume (ft^3), weight (tons), diameter (inches), length (ft), height (ft), width (ft), and/or thickness (inches). Note that not all dimensions apply to each work activity. AND/OR • Please indicate the dimensions of the material removed including area (ft^2), volume (ft^3), weight (tons), diameter (inches), length (ft), height (ft), width (ft), thickness (inches). Note that not all dimensions apply to each work activity.	
Structure • Please indicate the type of structure including ceiling, floor, wall, roof, siding, piping, buildings, frame, equipment, or generic (with explanation).	
Protective Measures • Please indicate the measures taken to protect your workers including industrial safety, HEPA filters, anti-contamination clothing, respirators or air supply, containment, or other (with explanation).	
**** Crew Duration** (in man-hours) • Please indicate the number of man-hours used to complete the work activity. Also, please indicate the composition of the work force.	
Scope included in Crew Duration • Please indicate the scope included in the Crew Duration above, such as mobilization/ demobilization/ training, decontamination, waste packaging/ release, shipping and disposal, or other (with explanation).	
Identified Problems • Please indicate any problems that occurred during the work activity which may have impacted the productivity of the workers.	
Other Relevant Information • Please use this space to include any other relevant information which may have affected the efficiency rates.	

**** In order to use the data, at a minimum, the following three fields must be completed - Work Activity, Dimensions of Initial Structure and/or Material Removed, and Crew Duration.**

HTWR Remedial Action Work Breakdown Structure (RA WBS)

To Fourth Level

WBS Number	Description	Unit of Measure
17	**DECONTAMINATION AND DECOMMISSIONING (D&D)**	
17 01	**Pre-Decommissioning Operations**	Ft^2
17 01 01	Preparation of Decommissioning Plan	Each
17 01 02	Licensing	Each
17 01 03	Radioactivity Surveys	Each
17 01 9x	Other (Use Numbers 90-99)	Each
17 02	**Facility Shutdown Activities**	Ft^2
17 02 01	Plant Shutdown and Inspection	Each
17 02 02	Defueling and Transfer of Fuel to Temporary Spent Fuel Storage	Each
17 02 03	Drainage and Drying or Blowdown of all Systems not in Operation	Each
17 02 04	Samples for Radioactivity Inventory Characterization	Each
17 02 05	Disposal of System Fluids (water oils...)	Gallon
17 02 06	Disposal of special System Fluids (D_20, sodium...)	Gallon
17 02 07	Decontamination of Systems for Dose Reduction	Each
17 02 08	Disposal of Wastes from Decontamination	Ft^3
17 02 09	Disposal of Combustible Material	Ft^3

WBS Number	Description	Unit of Measure
17 02 10	Disposal of Spent Resins	Ft^3
17 02 11	Disposal of Other Wastes from Reactor Operations	Ft^3
17 02 12	Isolation of Power Equipment	Ft^2
17 02 13	Decontamination of Areas and Equipment in all Buildings to Reduce Controlled Area	Ft^2
17 02 14	Mothballing	Ft^2
17 02 15	Entombment	Ft^2
17 02 9x	Other (Use Numbers 90-99)	
17 03	**Procurement of Equipment and Material**	Ft^2
17 03 01	Site Dismantling Equipment	Each
17 03 02	Radiation Protection and Health Physics Equipment	Each
17 03 03	Security and Maintenance Equipment for Long-Term Storage	Each
17 03 9x	Other (Use Numbers 90-99)	
17 04	**Dismantling Activities**	Ft^2
17 04 01	Decontamination of Areas and Equipment in all Buildings to Facilitate Dismantling	Ft^2
17 04 02	Drainage of Spent Fuel Pool and Decontamination of Linings	Ft^2
17 04 03	Zoning for Long-Term Storage	Ft^2
17 04 04	Radioactive Inventory Categorization	Ft^2
17 04 05	Dismantling and Transfer of Contaminated Equipment and Material to Containment for Storage	Ft^2
17 04 06	Isolation and Sealing of Containment Structure	Ft^2

WBS Number	Description	Unit of Measure
17 04 07	Layout of Dormancy Period Control Area	Ft^2
17 04 08	Removal of Fuel Handling Equipment	Ft^2
17 04 09	Design and Procurement of Special Tools for Dismantling	Each
17 04 10	Dismantling Operations on Reactor Vessels and Internals	Each
17 04 11	Removal of Primary and Auxiliary Systems	Ft^2
17 04 12	Removal of Biological Shield	Ft^2
17 04 13	Removal of Other Material and Equipment from Containment Structure	Ft^2
17 04 14	Removal and Disposal of Asbestos	Ft^2
17 04 15	Removal of Pool Linings	Ft^2
17 04 16	Removal of Contamination from Areas and Structures in all Buildings	Ft^2
17 04 17	Radioactive Waste Characterization	Each
17 04 18	Radioactive Waste Characterization for Recycling	Each
17 04 19	Radioactive Waste Characterization for Final Disposal	Each
17 04 20	Personnel Training	Each
17 04 9x	Other (Use Numbers 90-99)	
17 05	**Research and Development (R&D)**	Ft^2
17 05 01	Literature Review	Each
17 05 02	Data Collection	Each
17 05 03	Considerations on Actual and Future Dismantling	Each

WBS Number	Description	Unit of Measure
17 05 04	Decontamination Strategies/Techniques	Each
17 05 05	Status Review	Each
17 05 06	Development of New Dismantling Equipment	Each
17 05 07	Development or Use of New Decontamination Techniques	Each
17 05 08	Development of Adapted Measurement Devices and Calculation Techniques	Each
17 05 09	Development of Adapted Waste Treatment and Disposal Technology	Each
17 05 10	Research and Development on Remotely Operated Systems	Each
17 05 11	Simulation of Complicated Work on Model	Each
17 05 12	Robotics and Manipulators (R&D)	Each
17 05 9x	Other (Use Numbers 90-99)	
17 06	**Spent Fuel Handling**	Ft^2
17 06 01	Transfer of Fuel from Temporary Storage to Intermediate Storage	Each
17 06 02	Intermediate Fuel Storage	Each
17 06 03	Dismantling/Disposal of Temporary Fuel Storage Facility	Ft^2
17 06 04	Transfer of Fuel from Intermediate Storage to Reprocessing	Each
17 06 05	Reprocessing Costs	Each
17 06 06	Transfer and Disposal of Wastes from Reprocessing	Ft^3
17 06 07	Transfer and Conditioning of Spent Fuel	Ft^3
17 06 08	Transfer and Disposal of Spent Fuel	Ft^3

WBS Number	Description	Unit of Measure
17 06 9x	Other (Use Numbers 90-99)	
17 07	**Hot Cell Cleanup**	Ft^2
17 07 01	Radioactivity Survey	Each
17 07 02	Decontamination of Areas and Equipment in Cell to Facilitate Dismantling	Ft^2
17 07 03	Decontamination of Areas and Equipment in Cell to Reduce Contamination Levels	Ft^2
17 07 04	Decontamination of Equipment for Transfer or Disposal	Ft^2
17 07 05	Cell Equipment Modification	Each
17 07 06	Dismantling of Primary and Auxiliary Services to Cell	Ft^2
17 07 07	Dismantling of In-Cell Equipment	Each
17 07 08	Transfer of Material and Equipment to Airlock Services	Each
17 07 09	Packaging and Preparation of Cell Waste in Airlock	Ft^3
17 07 10	Transfer of Material from Airlock to Shipping Dock	Ft^3
17 07 11	Cell Window Maintenance and Cleaning	Each
17 07 12	Cell Window Replacement/Refurbishment	Each
17 07 9x	Other (Use Numbers 90-99)	
17 9x	**Other (Use Numbers 90-99)**	

Appendix B: Decommissioning Preferred Alternatives Matrices

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Background

The Office of Environmental Restoration is developing a set of tools to help decision makers at DOE sites select the most appropriate technologies. This document presents a matrix approach as an initial screening tool to assess decommissioning technologies in relationship to media types and broad categories of decommissioning activity.

Only decommissioning technologies that are state of the art and that are, in general, commercially available from one or more vendors are included. Each technology listed is given a qualitative ranking, indicating its applicability and effectiveness for given decommissioning tasks.

Such a matrix approach provides a concise format for accommodating multiple variables that influence the selection of a decommissioning technology. Each matrix table consists of a Y-axis that lists the decommissioning technologies and an X-axis that describes conditions that affect applicability of decommissioning technologies. The X-axis is different for each broad decommissioning task type. The scoring of individual technologies on the matrix tables is the result of the application of the ranking criteria (see legend), incorporated a thorough literature review, field experience, and professional judgement. The individual technology scores represent a balancing of scores for the following attributes, as they pertain to each technology: Development Status; Capital Cost; Operating Cost; Safety; and Effectiveness. Any technology under consideration that had an “Development Status” attribute rating of “Unlikely” was deemed innovative or emerging and was not incorporated into the matrix. The “Effectiveness” and “Safety” attributes were given the greatest weight. “Capital Cost” and “Operating Cost” attribute ratings could only lower an overall score.

The initial version of the PAMs involves limited incorporation of the results of the decommissioning benchmark study since the two were developed in parallel. Future revisions to the PAMs will include review of the decommissioning benchmark study and its revisions.

PAM Legend

●	1	Preferred Alternative	Technology commercially available in application. Lowest cost, best performance, and low risk.
◕	2	Probable Alternative	Technology commercially available in application. Low cost, good performance, and low risk.
◑	3	Potential Alternative	Technology commercially available in application. Acceptable performance, but medium cost/risk.
◔	4	Possible Alternative	Technology is commercially available. Technology is high cost or high risk (e.g., not proven in this application).
○	5	Unlikely	Technology is commercially available. Limited performance or high cost or risk.
⊗	N/A	Not Applicable	

TABLES B.1 - B.5: Decontamination

Decontamination is divided into the following five broad categories: Concrete; Equipment/Gloveboxes/Dismantled Piping; Sheet Metal/Structural Steel Surfaces/Stainless Steel Liners; Systems Piping/Tank Internals; and Lead Materials with Contamination. Decontamination of Concrete Surfaces (Table B.1) is arranged to score floors separately from walls and ceilings with each of these surfaces evaluated for large and tight (or hard-to-reach) areas, which are further subdivided into surficial (<1/8") and deeper contamination (≥1/8"). Table B.2 (Decontamination - Equipment/Gloveboxes/Dismantled Piping) scores large (requiring in situ techniques) and small components separately. Decontamination of Sheet Metal/Structural Steel Surfaces/Stainless Steel Liners (Table B.3) is constructed similarly to Table B.1, although the differential between surficial and deeper contamination is set at 1/32". Table B.4 (Decontamination of System Piping/Tank Internals) is structured around the type of contaminant (i.e., hard crud/oxide films, organic deposits containing U/TRU/FP, and uranium contamination) with stainless steel and high alloy steels considered separately from carbon/low alloy steels for hard crud/oxide films contamination. Table B.5 captures techniques that can be used to decontaminate Lead materials so that they can be reused or recycled rather than disposed of as hazardous or mixed waste. For each table, methods/technologies are broadly classified under the individual headings of Chemical Extraction, Coatings, Lasers, Physical Methods, Vacuuming/Blasting, and Washing. The following readily available technology options are included in the Preferred Alternatives Matrix:

Acid Etching - Acid is sprayed onto a contaminated surface to promote corrosion to remove the surface layer. The resultant debris is neutralized and disposed of. (B.1)

Acid/Hydrogen Peroxide Dissolution - This is a chemical process that uses acids and hydrogen peroxide to dissolve and remove surface contamination from lead. (B.5)

Alkaline Permanganate Ammonium Citrate with Ethylenediaminetetraacetic Acid (APACE) Process - A two-step process of alkaline permanganate (AP) as an oxidizing pretreatment with an intermediate water rinsing, followed by ammonium citrate (AC) to remove the oxide layer, and the use of Ethylenediaminetetraacetic Acid (EDTA) for chelation of iron oxides in solution to prevent redeposition onto the cleaned surface. (B.4)

TABLES B.1 - B.5: Decontamination

Alkaline Salts - Caustic compounds that are used for decontamination both by themselves and in solutions with other compounds, including potassium hydroxide (KOH), sodium hydroxide (NaOH), sodium carbonate (Na_2CO_3) and ammonium carbonate ($(NH_4)_2CO_3$). They are used to remove grease and oil films; to neutralize acids, as surface passivators; and to remove paint and other coatings, as a rust remover for mild steel, as a solvent for species that are soluble at high pH, and as a means of providing the right chemical environment for other agents. As a degreaser, they are normally mixed with detergents, and most commercial detergents contain mild caustic compounds. Alkaline solutions may be used on all nonporous surfaces, except aluminum and magnesium. Advantages: they are cheap, easy to store, have fewer material problems than acids (both strong mineral and organic), and can be applied in the form of gels for ceilings and walls. Disadvantages: their slow reaction time and destructive effect on aluminum; in addition, the bases pose safety hazards (i.e., workers can be burned if they come into contact with them). (B.1)

Automated Grinding - Abrading target surface, using coarse-grained, water-cooled diamond grinding wheels or tungsten-carbide surfacing discs. Machines to power these abrasives are floor-type grinders, whose grinding heads rotate in a circular fashion parallel to the floor. (B.3)

CAN-DECON Process - Developed for use in Canadian CANDU (heavy water moderated) reactors. It involves application of dilute reagents (e.g., citric acid, oxalic acid) and EDTA, as a chelating agent. (B.4)

Caustic Treatment (Detergents) - Essentially cleaning a surface with soap and water scrubbing. Commercial detergents use alkaline salts, a wetting agent (surfactant), a thickening agent, other fillers and, possibly, a complexing agent. (B.2, B.3)

Centrifuge Cryogenic CO_2 Pellet Blasting - A variation on Grit Blasting in which CO_2 pellets are used as the cleaning medium. Small dry ice pellets are accelerated through a nozzle and use a high speed rotating wheel, which is more efficient than Compressed_Air Cryogenic CO_2 Pellet Blasting. (B.1-B.3, B.5)

Chelation - This involves the use of organic chelating agents to remove contaminants from the surface. Essentially the bonding of the chelant to a metal oxide (contaminant), which solubilizes the oxide for removal from the surface. (B.1-B.2)

TABLES B.1 - B.5: Decontamination

Chemical Extraction - Technique using chemicals that penetrate the surface (typically concrete) and remove contaminants in the substrate, while leaving the substrate intact. The objective of chemical decontamination in the nuclear industry is to remove fixed contamination on surfaces of piping, components, equipment and facilities. Advantages: it can be used for inaccessible surfaces, can decontaminate process equipment and piping in place, can usually be performed remotely, produces few airborne hazards, uses chemical agents that are readily available, produces wastes that can be handled remotely, and generally allows the recycling of the wash liquors after further processing. Disadvantages: it is not usually effective on porous surfaces; can produce large volumes of waste (although volume may be reduced by a radioactive waste treatment system); may generate mixed wastes; can result in corrosion and safety problems when misapplied; requires different reagents for different surfaces; requires drainage control; for large jobs, generally requires the construction of chemical storage and collecting equipment; and requires addressing criticality concerns, where applicable. (B.1, B.3)

Chemical Foam - Surface decontamination technique that uses foam, such as produced by detergents, and wetting agents as carriers of chemical decontamination agents. Primarily used as a pretreatment. (B.1, B.2)

Chemical Gel - Surface decontamination technique that uses a gel as a carrier of chemical decontamination agents. The gel is applied to the surface and then scrubbed, wiped, rinsed or peeled off. (B.2)

Chemical Oxidation Reduction Decontamination (CORD) - This REDOX process is used to remove oxide films from stainless or high alloy steel surfaces without needing replacement of fluid contents of a system. It adds permanganic acid as a first step to oxidize the chromium to the hexavalent state. The decontamination solvent, dicarboxylic acid, is added directly, without the fluid contents of the system having to be replaced. Permanganic ions are reduced to manganous ions by an equivalent concentration of the decontamination solvent. Dissolved metals may be removed by ion exchange in real-time application or by subsequent evaporation of the solvent. This procedure is referred to as one cycle and can be applied several times, and may be applied to oxide films. An adequate DF is normally achieved after two cycles. (B.4)

Citric Acid ($C_6H_8O_6$) - Effective for decontaminating stainless steel when in mixture with oxalic acid. (B.2, B.4)

Compressed Air Cryogenic CO_2 Pellet Blasting - A variation on Grit Blasting in which CO_2 pellets are used as the cleaning medium. Small dry ice pellets are accelerated through the use of compressed air, which is less efficient than Centrifuge Cryogenic CO_2 Pellet Blasting. (B.1)

Drill and Spall - Technique involves drilling 1-½ inch diameter holes approximately three inches deep into which a hydraulically operated spalling tool is inserted. The spalling tool bit is an expandable tube through which a tapered mandrel is hydraulically forced in to spall off the concrete. (B.1)

TABLES B.1 - B.5: Decontamination

Dry Vacuum Cleaning - The vacuum cleaning method is effective for removal of loose debris and is used for dust/debris collection resulting from decontamination and/or demolition processes. (B.1)

Electropolishing - Item to be decontaminated is placed in a bath containing a decontamination solution (generally phosphoric acid or phosphoric acid/sulfuric acid) to act as the anode of an electrolyte cell. Electric current is passed through the bath, which causes oxidation, and consequent removal, of the contaminated surface. (B.2, B.5)

Expansive Grout - Material similar to Portland cement is poured into pre-drilled holes and allowed to cure. The material expands during curing, causing material to crack along planes connecting pre-drilled holes. (B.1)

Explosives - The top three to four inches of concrete are removed by detonating carefully placed and timed explosive charges. (B.1)

Fixative Stabilizer Coatings - Various agents can be used as coatings on contaminated residues to fix or stabilize the contaminant in place and decrease or eliminate exposure hazards. (B.1)

Foam/Sponge Blasting - Cleans surface with various grades of foam-cleaning media (i.e., sponges made of water-based urethane). (B.2)

Gas Phase Fluorination (ClF_3) - A process proposed for removing uranium fluoride deposit from piping and component internals of gaseous diffusion plants. (B.4)

Grinding - See Automated Grinding or Hand Grinding/Honing. (B.1)

Grit Blasting - This technique uses abrasive materials (e.g., sand, alumina, metal shot, etc.) suspended in a medium that is projected onto the surface being treated, and results in uniform removal of surface contamination. Compressed air, water or some combination can be used to carry the abrasive. (B.1-B.5)

Hand Grinding/Honing - Power-driven grinding equipment is used to remove the surface from an contaminated object. (B.3)

High Pressure Freon Cleaning - High pressure commercial Freon (an organic solvent) is utilized to remove contamination associated with grease, oil, etc. (B.1)

Hot Water Flushing - This technique involves flooding a surface with hot water, which dissolves contaminants. The resulting wastewater is collected and treated. (B.1)

Hydroblasting - This technique uses a high pressure water jet ($\leq$10,000 psi) to remove surface contamination. (B.1-B.3, B.5)

TABLES B.1 - B.5: Decontamination

Hydroblasting - Flexible Lance - This is a modification of the Hydroblasting technique, where small diameter piping/tubing is inserted inside piping to direct the high pressure water jet to internal surfaces. (B.4)

Hydrochloric Acid (HCl) - Removal of tightly adherent contamination using hydrochloric acid solutions in spray booth, dipping or flushing decontamination processes. It is also a strong mineral acid that is one of the first chemical cleaning agents used for utility boilers. Laboratory data indicated decontamination of stainless steel gave repeatable Decontamination Factors of approximately 10. (B.4)

Ice Blasting - This is similar to the Grit Blasting technique; the system employs low-pressure air and wet ice for surface cleaning.(B.1-B.3)

Industrial Floor Scrubbers - Commercially available floor polishers are used to clean smearable contamination from floors. (B.1)

In-Situ Electropolishing - Techniques developed for the in-situ electropolishing of objects that are too large for immersion. See Electropolishing. (B.2, B.4)

Kerosene - Used in decontamination for removing organic materials, grease, wax, oil and paint from surfaces and for cleaning clothes. (B.4)

Laser Etching/Ablation - Process uses absorption of laser energy and its conversion to heat (photopyrolysis) to selectively remove surface coatings or contamination. Emerging thermal technology for concrete decontamination. (B.1-B.3)

Low Oxidation State Metal Ion (LOMI) - This REDOX process is applied in a manner similar to that used for the CAN-DECON process. The reactor coolant is first adjusted to neutral pH and a low dissolved-oxygen level is then brought to a temperature of 80-90°C. The chemical decontamination solution is then injected, and a side stream of circulation coolant is passed through filter and cation exchange resin columns to regenerate the solution on line. Decontamination times are very short (i.e., 1-3 hours). It utilizes the vanadium (+2) ion (as vanadium picolinate) to reduce steel corrosion layers (Fe+3) to a soluble state; formic acid is then added to scavenge solubilized metal ions. (B.4)

Manual Brushing/Wiping/Scrubbing - Simple manual techniques for cleaning contaminated surfaces. It typically includes detergents or solvents, as appropriate. (B.1)

Nitric Acid (HNO_3) - A strong mineral acid used for dissolving uranium and its oxides in stainless steel and Inconel systems. It cannot be used on carbon steel because of the high corrosion rate. This strong oxidizing agent can be used alone, or in combination with other chemicals (e.g., sodium hydroxide (NaOH), ammonium permanganate, etc.) and is very effective in removing uranium. (B.4)

TABLES B.1 - B.5: Decontamination

Organic Acids - Acids used for contamination include oxalic acid ($C_2H_2O_4$), citric acid ($C_6H_8O_6$) and sulfamic acid (HSO_3NH_2), particularly as used in oxalate peroxide. It is generally used on metal surfaces and acts by dissolving the metal oxide film and sequestering or solubilizing the metal ion. Advantages: less corrosive (than strong mineral acids), superior safety and handling characteristics, and double role in dissolving oxide films and sequestering the metal contaminant. Disadvantages: more expensive than some of the strong mineral acids; slower reaction time; although less corrosive, still have some material compatibility and personnel considerations; can break down at high temperatures; and require neutralization before treating in a radioactive waste system. (B.2, B.3)

Oxalate Peroxide (OPP) - An oxidizing agent consisting of a mixture of oxalic acid and hydrogen peroxide. It is used for the simultaneous dissolution of UO_2 and the defilming and decontamination of metals. The oxalic acid decontaminates the surface, and the hydrogen peroxide enhances the decontamination and passivates the steel by its oxidative action. However, the peroxide destroys the oxalic acid, preventing reuse of the solvent. (B.4)

Oxalic Acid ($C_2H_2O_4$) - Used for removal of rust from iron. Excellent complexor for niobium (when present) and fission products in decontamination of reactor systems. (B.4, B.5)

Paint Remover - Solvents used with hand scraping, water washing and detergent scrubbing to remove metal-based paints. (B.1)


Piston Scabbler

Paving Breaker/Chipping Hammer - Although paving breakers (e.g., jackhammers, pneumatic drills, etc.) and chipping hammers are typically used for demolition, they can be used to remove surface contamination up to six inches thick. Concrete is removed by mechanically fracturing localized sections of the surface. (B.1)

Phosphoric Acid - Rapidly defilms and decontaminates carbon steel surfaces through formation of a ferrous phosphate film. The use of phosphates is not recommended when the waste end product will be glass. (B.4)

Piston Scabbler - High-speed, reciprocating, tungsten carbide-tipped pistons are used to pulverize protective coatings and concrete substrate in a single-step process. (B.1)

Planing - Layers of soft material, such as wood or lead, are shaved off. (B.5)

TABLES B.1 - B.5: Decontamination

REDOX Treatments - An oxidizing agent increases the oxidation state of another chemical species (e.g., potassium permanganate [$KmnO_4$], potassium dichromate [$K_2Cr_2O_7$], hydrogen peroxide [H_2O_2], etc.) and are used to condition metal oxide films, dissolve fission product debris/various chemical species, and oxidize the metal surface either for protection or corrosion. It could also be used to protect a metal surface or reduce higher oxidation states for sequestering agents. A reducing agent lowers the oxidation state. A change in oxidation state may be beneficial because some oxidation states are more soluble than others. Frequently, these two classes of chemicals are used jointly to maintain a specified oxidation level; some of these agents include alkaline permanganate (AP), low oxidation-state metal ion (LOMI), electrochemical low oxidation-state metal ion exchange (ELOMIX), and chemical oxidation reduction decontamination. Oxidizing agents find extensive application in decontamination by conditioning metal oxide films, dissolving fission product debris, dissolving various chemical species, and oxidizing the metal surface either for protection or corrosion. Most metal surfaces can be treated with oxidizing agents, but conditions must be adjusted to avoid excessive corrosion. (B.2)

Shot Blaster

Rotating Brushes/Honing - A device that utilizes cylindrical, mechanically rotated brushes, which are nylon strands attached to abrasive honing stones that are rotated at high speed. The device is inserted into piping to remove fixed contamination/oxide layers from internal surfaces. (B.4)

Rotating Cavitation Water Jet - A device that is inserted into piping that uses rotating water jets to clean fixed contamination from internal surfaces. The MOLE nozzle uses water pressures at 10,000 psig; the CaviJet uses 7,000 psig water with a specially designed nozzle to produce bubbles for cleaning action. (B.4)

Shot Blasting - An airless method that strips, cleans and etches a surface simultaneously. Portable units move along the surface that is being treated as the abrasive is fed into the center of a completely enclosed centrifugal blast wheel. As the wheel spins, abrasives are hurled from the blades, blasting the surface. The abrasives and surface debris are bounced back to a separation system for abrasive recycling and dust collection. (B.1, B.3)

Shrouded, Needle Scalar

Shrouded, Needle Scalar - Scarifier for removing concrete from outside edges, inside corners and wall surfaces. (B.1)

Soda Blasting - This technique uses sodium bicarbonate suspended in a medium that is projected onto the surface being treated, and results in uniform removal of surface contamination. Compressed air, water or some combination can be used to carry the sodium bicarbonate.

TABLES B.1 - B.5: Decontamination

Sodium Hydroxide (NaOH) - An alkaline salt that is also a strong base. It is frequently mixed in solutions with oxidizing agents and a reducing agent, which are not stable in acid solutions. It is used first as a conditioning step for stainless steel and other metal surfaces. When used in combination with potassium permanganate ($KmnO_4$), it aggressively attacks paints, coatings and films. This softens the paint so that it can be removed by mechanical means, which is often preferable to completely dissolving the paint because that may contaminate the surface under it. (B.4)

Smelt Purification - Purifies metals by introducing suitable additives to scrap metals that will react with impurities in the metal when melted. Impurities are then removed in the slag that separates from the molten metal. (B.2, B.3)

Steam Cleaning - Combination of solvent action of water with the kinetic energy effect of blasting. At relatively high temperatures, the solvent action is increased and required water volume is reduced. (B.1, B.2)

Steam Vacuum - Modification of Steam Cleaning technique that combines the steam cleaning action with a HEPA vacuum system to minimize spread of contamination and "spray-back."

Strippable (and Self-Strippable) Coatings - Application of a polymer mixture to a contaminated surface. As the polymer reacts, contaminants are stabilized, becoming entrained in the polymer. Generally, the contaminated layer is pulled off or, in the case of self-strippable coatings, coating cracks, flakes and falls off, taking loose contamination with it. This contamination can then be vacuumed up. (B.1)

Strong Mineral Acids - The main purpose is to attack and dissolve metal oxide films and lower the pH of solutions to increase solubility or ion-exchange of metal ions, and can be used on almost all metal surfaces except reactive metals such as zinc. They can be used alone, as dilute solutions, or in formulation mixtures with acid salts, such as sodium bisulfate ($NaHSO_4$), sodium sulfate (Na_2SO_4), ferric sulfate [$Fe_2(SO_4)_3$], ammonium oxalate ($NH_4C_2O_4$), ammonium citrate [$(NH_4)_2HC_6H_5O_7$], sodium fluoride (NaF) and other compounds with each other (e.g., HNO_3-HCl); includes hydrochloric acid (HCl), nitric acid (HNO_3), sulfuric acid (H_2SO_4) and phosphoric acid (H_3PO_4). (B.2-B.4)

Sulfamic Acid (HSO_3NH_2) - An organic acid used to remove contaminants from carbon steel surfaces. (B.4)

Superheated Water - Uses a high velocity stream of superheated water directed onto a surface to remove contamination. (B.1)

Turbulator - Large tank with propellers that direct the flow of cleaning solution across a component to remove surface contamination. (B.2)

TABLES B.1 - B.5: Decontamination

Ultra-High Pressure Water - Similar to Hydroblasting, except that the water pressures exceed 10,000 psi (as high as 55,000 psi). The water jet is forced through a small-diameter nozzle that generates a high-velocity water jet with speeds up to 3,000 feet per second. Deeper surface penetration is possible with the addition of abrasives. (B.1-B.3, B.5)

Ultrasonic Vibration - Contaminated component is placed into a bath, containing a cleaning solution. Vigorous scrubbing action is produced by means of ultrasonic vibrations to clean component surface. (B.2)

Vibratory Finishing - Objects are placed in a basket filled with abrasive media. The basket is then vibrated at a high frequency in a cleaning solution. The vibrating media produce scouring action that removes contamination. (B.1)

TABLE B.1 Decontamination - Concrete Surfaces - Unspecified Contaminants

	Floors				Walls/Ceilings			
	Large Area		Tight Area		Large Area		Tight Area	
	≥1/8"	<1/8"	≥1/8"	<1/8"	≥1/8"	<1/8"	≥1/8"	<1/8"
CHEMICAL EXTRACTION								
Acid Etching[a,b]	⊗	◑	⊗	◑	⊗	◑	⊗	◑
Alkaline Salts[a,c]	⊗	◔	⊗	◔	⊗	◑	⊗	◑
Chelation	⊗	◕	⊗	◔	⊗	○	⊗	○
Chemical Extraction[d]	⊗	◑	⊗	◑	⊗	◑	⊗	◑
Chemical Foam[e]	⊗	◑	⊗	◑	⊗	◑	⊗	◑
Industrial Floor Scrubbers	⊗	◕	⊗	◑	⊗	⊗	⊗	⊗
Manual Brushing/Wiping/Scrubbing	⊗	○	⊗	◑	⊗	◑	⊗	◑
Paint Remover[a,f]	⊗	◕	⊗	◕	⊗	◑	⊗	◑
COATINGS								
Fixative/stabilizer coatings	⊗	◕	⊗	◑	⊗	◑	⊗	◑
Strippable (and self-strippable) Coatings[g]	⊗	◑	⊗	◑	⊗	◑	⊗	◑

TABLE B.1 Decontamination - Concrete Surfaces - Unspecified Contaminants

	Floors				Walls/Ceilings			
	Large Area		Tight Area		Large Area		Tight Area	
	≥1/8"	<1/8"	≥1/8"	<1/8"	≥1/8"	<1/8"	≥1/8"	<1/8"
LASERS								
Laser Etching/Ablation	◔	◑	◔	◔	○	○	○	○
PHYSICAL METHODS								
Drill and Spall	○	○	◔	◔	◔	◔	◑	◑
Expansive Grout	◑	◑	◑	◑	◔	◔	◔	◔
Explosives	○	○	○	○	◔	◔	◔	◔
Grinding[a]	⊗	◑	⊗	◔	⊗	◔	⊗	◔
Paving Breaker/Chipping Hammer[h]	◑	◑	◕	◕	◔	◔	◔	◔
Piston Scabbler[a]	◕	◕	◑	◑	◔	◔	○	○
Shrouded, Needle Scalar	⊗	○	⊗	◑	⊗	◑	⊗	◕

TABLE B.1 Decontamination - Concrete Surfaces - Unspecified Contaminants

	Floors				Walls/Ceilings			
	Large Area		Tight Area		Large Area		Tight Area	
	≥1/8"	<1/8"	≥1/8"	<1/8"	≥1/8"	<1/8"	≥1/8"	<1/8"
VACUUMING/ BLASTING								
Centrifuge Cryogenic CO_2 Pellet Blasting[a]	⊗	◑	⊗	◑	⊗	◔	⊗	◔
Compressed Air Cryogenic CO_2 Pellet Blasting	⊗	◔	⊗	◔	⊗	◔	⊗	◔
Dry Vacuum Cleaning	⊗	◑	⊗	◑	⊗	◑	⊗	◑
Grit Blasting[a]	⊗	◕	⊗	◑	⊗	◑	⊗	◑
High Pressure Freon Cleaning	⊗	◑	⊗	◕	⊗	◕	⊗	◕
Hydroblasting[a,i]	⊗	◕	⊗	◕	⊗	◕	⊗	◕
Ice Blasting[a]	⊗	◑	⊗	◑	⊗	◑	⊗	◑
Shot Blasting[a,j]	⊗	◕	⊗	◔	⊗	◔	⊗	◔
Soda Blasting	⊗	⊗	⊗	◑	⊗	◑	⊗	◑
Steam Vacuum	⊗	◑	⊗	◑	⊗	◑	⊗	◑
Ultra-high Pressure Water[k]	◑	◔	◑	◔	◑	◔	◑	◔
WASHING								
Hot Water Flushing	⊗	◔	⊗	◔	⊗	◔	⊗	◑

TABLE B.1 Decontamination - Concrete Surfaces - Unspecified Contaminants

	Floors				Walls/Ceilings			
	Large Area		Tight Area		Large Area		Tight Area	
	≥1/8"	<1/8"	≥1/8"	<1/8"	≥1/8"	<1/8"	≥1/8"	<1/8"
WASHING (cont.)								
Steam Cleaning	⊗	◑	⊗	◑	⊗	◑	⊗	◑
Superheated Water	⊗	◑	⊗	◑	⊗	◑	⊗	◑

a typically used for coating or thin layer removal
b e.g., muriatic acid, fluoroboric acid, etc.
c e.g., KOH, NaOH, etc.
d e.g., TechXtract
e foam used as carrier for appropriate detergents and/or acids
f e.g., methylene chloride
g effective for stabilizing loose contamination; requires removal by other methods
h e.g., jackhammer, pneumatic hammer, etc.
i operation at < 10,000 psi
j e.g., Blastrac
k operation at > 10,000 psi

TABLE B.2: Decontamination - Equipment/Gloveboxes/Dismantled Piping - Unspecified Contaminants

	Large Components (In Situ Techniques)	Small Components, Equipment, Hand Tools[a]
CHEMICAL EXTRACTION		
Caustic Treatment (Detergents)[b]	◕	⊗[c]
Chelation[d]	◑	⊗[c]
Chemical Foam[e]	◕	⊗[c]
Chemical Gel[f]	◕	⊗[c]
Electropolishing[g]	⊗[c]	◑
In-Situ Electropolishing[h]	◑	⊗[c]
Organic Acids[i]	◑	⊗[c]
REDOX Treatments[j]	◔	⊗[c]
Strong Mineral Acids[k]	◑	⊗[c]
PHYSICAL METHODS		
Turbulator[l]	⊗[c]	◑
Ultrasonic Vibration[m]	⊗[c]	◑
Vibratory Finishing[n]	⊗[c]	◑

TABLE B.2: Decontamination - Equipment/Gloveboxes/Dismantled Piping - Unspecified Contaminants

	Large Components (In Situ Techniques)	Small Components, Equipment, Hand Tools[a]
THERMAL METHODS		
Smelt Purification[o]	◑	◑
VACUUMING/BLASTING		
Centrifuge Cryogenic CO_2 Pellet Blasting[p]	◑	◕
Foam/Sponge Blasting[q]	◑	⊗[c]
Grit Blasting[r]	◕	◕
Hydroblasting[s]	◑	⊗[c]
Ice Blasting	◑	⊗[c]
WASHING		
Steam Cleaning[t]	◑	⊗[c]
Ultra-high Pressure Water[u]	◑	⊗[c]

a small enough for tank immersion
b effective for loose contamination

TABLE B.2: Decontamination - Equipment/Gloveboxes/Dismantled Piping - Unspecified Contaminants

c	⊗ used to denote Technique or Method not appearing on pertinent table & therefore deemed not appropriate for a given application
d	examples include CORPEX process & a recyclable chelating solvent (EDTA/Carbonate/Peroxide) for uranium
e	foam used as carrier for appropriate detergents and/or acids; useful for complex shapes and loose contamination
f	sprayed-on gel used as carrier for appropriate detergents and/or acids
g	phosphoric acid; nitric acid & organic acids have also been investigated
h	electroswabbing
i	oxalic, citric sulfamic acids
j	e.g., LOMI, APAC, APACE, AP/CITROX, etc.
k	e.g, HCl, HNO_3, H_3PO_4; HNO_3 is traditionally used to remove uranium; addition of HF greatly increases DF
l	very effective for components with loose contamination
m	also used in conjunction with aggressive chemicals (HNO_3/HF) to improve DF
n	effective for removal of loose contamination
o	economically best to do as part of recycled product production than just for pure cleanup
p	centrifuge modification achieves higher pellet velocities for removal of fixed contamination; traditional CO_2 blasting not effective on fixed contamination
q	not effective for fixed contamination; requires impregnation of abrasives on which little data exists
r	water injection (air slurry blasting) and vacuum shrouds used to reduce airborne generation of conventional grit blasting; variety of different media is available (sand, alumina, glass beads, soda, etc.)
s	<10,000 psi
t	Steam Vacuum System (Kelly Vacu-Mac(™)) is excellent modification of this technique that combines the steam cleaning action with a HEPA vacuum system to minimize spread of contamination and "spray-back"
u	>10,000 psi

TABLE B.3: Decontamination -Sheet Metal/Structural Steel Surfaces/Stainless Steel Liners - Unspecified Contaminants

	Floors				Walls/Ceilings			
	Large Area		Tight Area		Large Area		Tight Area	
	≥1/32"	<1/32"	≥1/32"	<1/32"	≥1/32"	<1/32"	≥1/32"	<1/32"
CHEMICAL EXTRACTION								
Caustic Treatment[a,b]	⊗	◕	⊗	◕	⊗	◕	⊗	◕
Chemical Extraction[c]	⊗	◕	⊗	○	⊗	○	⊗	○
Organic Acids[d]	⊗	◑	⊗	○	⊗	○	⊗	○
Strong Mineral Acids[e]	⊗	◑	⊗	◔	⊗	◔	⊗	◔
PHYSICAL METHODS								
Automated Grinding	⊗	◕	⊗	●	⊗	●	⊗	●
Hand Grinding/Honing[f]	⊗	◑	⊗	◑	⊗	◑	⊗	◑
THERMAL								
Smelt Purification[g]	⊗	○	⊗	○	⊗	○	⊗	○

TABLE B.3: Decontamination -Sheet Metal/Structural Steel Surfaces/Stainless Steel Liners - Unspecified Contaminants

	Floors				Walls/Ceilings			
	Large Area		Tight Area		Large Area		Tight Area	
	≥1/32"	<1/32"	≥1/32"	<1/32"	≥1/32"	<1/32"	≥1/32"	<1/32"
VACUUMING/ BLASTING								
Centrifuge Cryogenic CO_2 Pellet Blasting[h]	⊗	◕	⊗	◑	⊗	◕	⊗	◑
Grit Blasting[i]	⊗	◕	⊗	◑	⊗	◑	⊗	◑
Hydroblasting[j]	⊗	◕	⊗	◑	⊗	◑	⊗	◑
Ice Blasting	⊗	◑	⊗	◑	⊗	◑	⊗	◑
Shot Blasting[k,l]	⊗	◕	⊗	◔	⊗	◔	⊗	◔
Ultra-high Pressure Water[m]	⊗	◕	⊗	◑	⊗	◑	⊗	◑

a detergents
b requires neutralization
c e.g., TechXtract
d well established for decontamination of stainless steel
e e.g., HCL, HNO_3, H_3PO_4; HNO_3 is traditionally used to remove uranium
f labor intensive
g economically best to do as part of recycled product production rather than just for pure cleanup
h centrifuge modification achieves higher pellet velocities for removal of fixed contamination
I water injection (air slurry blasting) & vacuum shrouds used to reduce airborne generation of conventional grit blasting; variety of different media available (e.g., sand, alumina, glass beads, soda, etc.)
J operation at < 10,000 psi
k metal shot recovered magnetically in a vacuum shroud
l e.g., Blastrac
m operation at > 10,000 psi

TABLE B.4: Decontamination - System[a] Piping/Tank Internals - Various Specified Contamination

	Hard Crud/Oxide Films (Reactor Systems)		Organic Deposits containing U/TRU/FP (Fuel Reprocessing)- Stainless Steel	Uranium Contamination (Uranium Enrichment)
	Stainless Steel & High Alloy Steels (Reactor System)	Carbon/Low Alloy (Mild) Steel		
CHEMICAL EXTRACTIONS				
Alkaline Permanganate Ammonium Citrate with Ethylenediaminetetraacetic Acid (APACE)[b]	◑	⊗[c]	⊗[c]	⊗[c]
CAN-DECON Process[d]	◑	◑	⊗[c]	⊗[c]
Chemical Oxidation Reduction (CORD) Process	◔	⊗[c]	⊗[c]	⊗[c]
Gas Phase Fluorination (ClF_3)[e]	⊗[c]	⊗[c]	⊗[c]	◔
Hydrazine Nitrate	⊗[c]	⊗[c]	◑	⊗[c]
Hydrochloric Acid[b]	◑	◑	⊗[c]	◑
In-situ Electropolishing	◑	○	⊗[c]	⊗[c]
Kerosene[f]	⊗[c]	⊗[c]	◔	⊗[c]
Low Oxidation State Metal Ion (LOMI) Process[g,h]	◑	◑	⊗[c]	⊗[c]
Sodium Hydroxide (NaOH)[I]	⊗[c]	⊗[c]	◑	⊗[c]

TABLE B.4: Decontamination - System[a] Piping/Tank Internals - Various Specified Contamination

	Hard Crud/Oxide Films (Reactor Systems)		Organic Deposits containing U/TRU/FP (Fuel Reprocessing)- Stainless Steel	Uranium Contamination (Uranium Enrichment)
	Stainless Steel & High Alloy Steels (Reactor System)	Carbon/Low Alloy (Mild) Steel		
CHEMICAL EXTRACTIONS (CONT.)				
Nitric Acid[j,k]	⊗[c]	⊗[c]	⊗	◑
Oxalate Peroxide (OPP)[l]	⊗[c]	⊗[c]	⊗[c]	◔
Oxalic Acid/Citric Acid/CITROX Process[g,m]	◑	⊗[c]	⊗[c]	⊗[c]
Phosphoric Acid[n]	⊗[c]	◑	⊗[c]	⊗[c]
Strong Mineral Acids[o,p]	⊗[c]	⊗[c]	◑	⊗[c]
Sulfamic Acid	⊗[c]	◑	⊗[c]	⊗[c]
PHYSICAL METHODS				
Rotating Brushes/Honing[q]	◕	◑	◕	◕
VACUUMING/BLASTING				
Grit Blasting[r]	◕	◑	◕	◕
Hydroblasting - flexible lance[s]	◑	◕	◑	◕
WASHING				
Rotating Cavitation Water Jet[t,u]	◕	◕	◕	◕

a system decontamination is primarily intended for dose reduction for follow-up dismantlement
b hard (high concentration) process
c ⊗ used to denote Technique or Method not appearing on pertinent table & therefore deemed not appropriate for a given application
d dilute process

TABLE B.4: Decontamination - System[a] Piping/Tank Internals - Various Specified Contamination

e considered specifically for removal of UO_2F_2 and UF_4 deposits in gaseous diffusion plants
f not effective as a chemical decon agent; marginal utility for rinsing of deposits
g process is typically preceded by an oxidizing treatment (e.g., alkaline permanganate) to oxidize chromites, if necessary
h both hard and dilute processes available; ELOMIX process is modification whereby ion exchange resins are electrochemically treated rather than grouted
I more effective on fission product removal than Pu/U
j in the organic contaminants column, may also include use of EDTA and/or other chemicals, such as AP (use of AP with nitric acid has shown very positive results)
k in uranium enrichment column, traditionally used for removal of uranium (typically includes use of other chemicals to improve effectiveness, such as alkaline salts $NACO_3$, $(NH_4)_2CO_3$, and others
l effective for dissolution of UO_2
m CITROX is highly corrosive to 400 series stainless steels, use restricted to Inconel and 300 series stainless steels
n established process at the N-Reactor
o sulphuric and phosphoric acid
p More effective than nitric acid on adherent contamination
q joints & elbows can be difficult to clean
r limited by accessibility to internal surface area (via manholes, etc.); tank internals only; piping is not cost effective
s ratings indicate loose material only; and reflect tank internals; piping is not cost effective
t e.g., Cavijet
u specifically designed for piping

TABLE B.5: Decontamination - Unspecified Contaminants - Lead Bricks

	Lead
CHEMICAL EXTRACTION	
Acid/Hydrogen Peroxide Dissolution[a]	◑
Electropolishing	◑
Oxalic Acid[b]	○
PHYSICAL METHODS	
Planing[c]	◕
VACUUMING/BLASTING	
Centrifuge Cryogenic CO_2 Pellet Blasting	◕
Grit Blasting[d,e]	◕
Hydroblasting	◕
WASHING	
Ultra-high Pressure Water	◕

a surface contamination only
b no data available
c i.e., sanding and wiping
d grit particles will pick up enough lead during blasting to become a mixed waste when recovered
e air slurry grit blasting uses water injection to reduce airborne generation

TABLES B.6 & B.7: Cutting and Sizing

Cutting and Sizing is divided into the broad categories of Structures and Steel Components. The Cutting and Sizing of Structures (Table B.6) is structured to score the following options separately: Heavily Reinforced, Thick Structures; Unreinforced, Thick Structures; and Walls and Floors (≤2 feet). Table B.7 (Cutting and Sizing Steel Components) groups the subject as either Instrument Tubing, Small Diameter Pipe, Large Diameter Pipe and Tanks, Flat Stock and Pressure Vessels, or Structural Steel. The cutting and sizing methods/technologies in both tables are broadly classified under the individual headings of Mechanical Cutting Equipment, Non-mechanical Cutting Equipment, and Non-cutting Methods. The following readily available technology options are included in the Preferred Alternatives Matrix:

Abrasive Cutter - Cutting tool consisting of a rotating wheel composed of resin bonded particles of aluminum oxide or silicon carbide. (B.6)


Backhoe Ram

Abrasive Water/Water Jet - Cutting tool utilizing abrasive particles entrained in a water jet. Used for cutting concrete and metal. (B.6, B.7)

Arc Saw - Metal cutting tool utilizing a high electric current between a rotating metal disk and a piece of metal to be cut. (B.6)

Backhoe Ram - Track-mounted equipment which can have reaches up to 23 feet for the demolition of concrete, brick, cinder block, steel and wood structures. Mist is required to control dust. Must section rebar in advance. (B.7)

Chipping Hammer - Powered chisel driven in a reciprocating motion. Used for breaking up concrete at the surface (e.g., jackhammer, pneumatic hammer, etc.). (B.7)

Circular Saw - Rotating abrasive wheel used to cut through concrete and occasionally metal. (B.6)

Controlled Blasting/Explosive Cutting - Specialized charges used to cut or sever specific points of a structure. (B.7)

Core/Stitch Drilling - Forming a continuous cutting line with side-by-side cuts from a drill. (B.7)

Diamond Wire - Cutting technology using a metal wire impregnated with diamonds. Tension and direction are maintained by pulleys. (B.6-B.8)

Expansive Grout/Demolition Compounds - Material similar to Portland cement is poured into pre-drilled holes and allowed to cure. The material expands during curing, causing material to crack along planes connecting pre-drilled holes. (B.7)

Explosive Charges/Explosive Cutting - See Controlled Blasting/Explosive Cutting. (B.6, B.7)

TABLES B.6 & B.7: Cutting and Sizing

Mobile Shear

Flame Cutting - Concrete cutting method using powered iron and aluminum in a directed stream of oxygen. (B.7)

Mechanical Saw - Metal cutting tool using a reciprocating hardened steel blade. (B.6)

Mobile Shears - Uses opposed cutting surfaces that work on the same principle as a conventional pair of shears. (B.6)

Nibbler/Shear - Smaller version of Shears most commonly used for metal cutting. (B.6)

Oxyacetylene Torch - Metal cutting tool using acetylene and pure oxygen. (B.6)


Oxyacetylene Torch

Plasma Arc/Arc Torch - Metal cutting technique based on establishing an electric current between an electrode and the metal. The current is facilitated by a stream of gas or water. (B.6)

Rock Splitter - Slow, quiet, non-cutting method for cutting and sizing concrete, brick or cinder block structures. Must first clear and section rebar. It is appropriate for confined space usage. (B.7)

Thermite Lance - High temperature cutting technique utilizing the combustion of iron, aluminum, and magnesium wires. Can be used on concrete and metal. (B.6, B.7)

Universal Processor - See Mobile Shears. (B.7)

Wall and Floor Saw - Mechanical equipment for removing large section of concrete en masse during cutting, demolition and sizing operations on brick, concrete, cinder block and wood structures. It tends to bind if used for long periods. (B.7)

Wrecking Ball/Slab - Heavy equipment for cutting, demolition and sizing concrete, brick, cinder block, steel and wood structures. It is not recommended for radiological work or reinforced concrete (rebar requires sectioning). This technique is limited to structures <100 feet in height. (B.7)

TABLE B.6: Cutting and Sizing - Structures

	Heavily Reinforced, Thick Structures	Unreinforced, Thick Structures	Walls & Floors (≤2 ft)
MECHANICAL CUTTING EQUIPMENT			
Diamond Wire	◕	◕	◕
Wall and Floor Saw	◑	◑	◕
NON-CUTTING METHODS			
Backhoe Ram	◕	●	◕
Chipping Hammer[a]	◔	◔	◑
Controlled Blasting	◔	◑	◔
Core/Stitch Drilling[b]	⊗	⊗	◔
Expansive Grout[c]	◔	◑	◑
Rock Splitter[d]	◔	◔	◔
Universal Processor	◔	◑	◑
Wrecking Ball/Slab	◑	◑	◕
NON-MECHANICAL CUTTING EQUIPMENT			
Abrasive Water Jet	◔	◔	◔
Explosive Cutting[e]	◔	◑	◔

TABLE B.6: Cutting and Sizing - Structures

	Heavily Reinforced, Thick Structures	Unreinforced, Thick Structures	Walls & Floors (≤2 ft)
NON-MECHANICAL CUTTING EQUIPMENT (CONT.)			
Flame Cutting	◔	◔	◔
Thermite Lance[f]	◔	◔	◔

a not suitable for large areas
b for special applications where access is limited & disturbance is a problem
c slow
d slow, must cut rebar
e suitable for beams
f will cut rebar

TABLE B.7: Cutting and Sizing - Steel Components

	Instrument Tubing	Small Diameter Pipe	Large Diameter Pipe & Tanks	Flat Stock & Pressure Vessels[c]	Structural Steel
MECHANICAL CUTTING EQUIPMENT					
Abrasive Cutter	◑	◑	●	◔	◔
Circular Saw	◔	◕	◑	◑	◑
Diamond Wire	○	○	◔	◔	⊗
Mechanical Saw	◔	◕	◑	◑	◑
Mobile Shears[a]	◕	◕	◑	◑	◕
Nibbler/Shear	◕	◕	◕	◑	◕
NON-MECHANICAL CUTTING EQUIPMENT					
Abrasive Water	⊗	⊗	◕	◔	○
Arc Saw	◔	◕	◑	◕	○
Explosive Cutting	○	○	◔	◔	◕
Oxyacetylene Cutting[b]	◕	◕	◕	◕	◕
Plasma Arc[b]	◑	◑	◕	◕	◑
Thermite Lance	⊗	⊗	◑	◕	○

a especially useful for bundles of tubing
b airborne contamination
c very limited data exists on site reduction of reactor pressure vessels and associated components

TABLES B.8 - B.10: Demolition

Demolition is arranged on the basis of the composition of the target structures, whether Concrete/Brick/Cinder Block, Steel, or Wood. For the Demolition of Concrete/Brick/Cinder Block (Table B.8), concrete is scored separately according to whether it is Reinforced (>2 feet thick), Lightly Reinforced (<2 feet thick), Non-reinforced (<2 feet thick), or in a Stack. Brick and Cinder Blocks are considered together with the distinction made as to whether they are part of a Structure or in a Stack. Both Steel (Table B.9) and Wood (Table B.10) Structures are scored separately based on whether or not Sheathing is intact. Demolition methods/technologies in each table are broadly classified under the individual headings of Heavy Equipment, Tools, and Miscellaneous Equipment/Methods. The following readily available technology options are included in the Preferred Alternatives Matrix:


Backhoe Mounted Ram

Backhoe Mounted Pulverizer - Track-mounted equipment for the demolition of concrete, brick and cinder block. It is capable of separating rebar and steel beams from concrete. Mist is required to control dust. (B.8)

Backhoe Mounted Ram - Track-mounted equipment with an approximate reach of 23 feet for the demolition of concrete, brick, cinder block, steel and wood structures. Mist is required to control dust. Must section rebar in advance. (B.8-B.10)

Backhoe Mounted Shears - Track-mounted equipment for the demolition of concrete, brick, cinder block, steel and wood structures. Mist required to control dust. It is capable of cutting separated metal and concrete. (B.8-B.10)


Grapple

Bulldozer - Heavy equipment for the push/pull demolition of wood structures. (B.9, B.10)

Controlled Blasting/Explosive Cutting - Specialized charges used to cut or sever specific points of a structure. (B.8)

Diamond Wire - Cutting technology using a metal wire impregnated with diamonds. Tension and direction are maintained by pulleys. (B.8-B.10)

Expansive Grout/Demolition Compounds - Material similar to Portland cement is poured into pre-drilled holes and allowed to cure. The material expands during curing, causing material to crack along planes connecting pre-drilled holes. (B.8)

Explosive Charges/Explosive Cutting - See Controlled Blasting/Explosive Cutting. (B.9, B.10)

Grapple - Track mounted “grips” used to hold or remove portions of a structure. (B.8-B.10)

Jackhammer - Type of impact hammer for the demolition of concrete, brick and cinder block structures. Rebar must be sectioned in advance. Its utility is limited to small areas of floors, hard to reach areas and stack foundations. (B.8)

TABLES B.8 - B.10: Demolition

Rock Splitter - Slow, quiet, non-cutting method for cutting and sizing concrete, brick or cinder block structures. Must first clear and section rebar. It is appropriate for confined space usage. (B.8)

Wall and Floor Saw - Mechanical equipment for removing large section of concrete en masse during cutting, demolition and sizing operations on brick, concrete, cinder block and wood structures. It tends to bind if used for long periods. (B.8, B.10)

Wrecking Ball/Slab - Heavy equipment for cutting, demolition and sizing concrete, brick, cinder block, steel and wood structures. It is not recommended for radiological work or reinforced concrete (rebar requires sectioning). This technique is limited to structures <100 feet in height. (B.8-B.10)

TABLE B.8: Demolition - Concrete/Brick/Cinder Block

	Concrete				Brick/Cinder Block	
	Reinforced Structure (>2' thick)	Lightly Reinforced Structure (<2' thick)	Non-reinforced Structure (<2' thick)	Stack	Structure	Stack
HEAVY EQUIPMENT						
Backhoe Mounted Pulverizer[a,b]	◑	◑	◑	◑	◕	◑
Backhoe Mounted Ram[b,c,d]	◕	◕	●	◑	◕	◕
Backhoe Mounted Shears[b,e]	◑	◕	◑	⊗	◑	⊗
Wrecking Ball/Slab[f,g]	◔	◕	◕	◑	●	●
TOOLS						
Jackhammer[b,h,i,j]	◑	◑	◑	⊗	◕	⊗
Rock Splitter[b,k,l]	◑	◕	◕	◑	⊗	⊗
Wall and Floor Saws[m,n]	◔	◑	◑	⊗	⊗	⊗
MISCELLANEOUS EQUIPMENT/METHODS						
Controlled Blasting/Explosive Cutting[b,o]	◑	◑	◑	◑	◑	◑
Diamond Wire[p]	◑	◕	◕	⊗	⊗	⊗
Expansive Grout/Demolition Compounds[e,q,r]	◔	◕	◕	◕	◕	◕
Grapple[a,e,s]	◑	◕	◕	⊗	●	⊗

a capable of separating rebar & steel beams from concrete
b use mist to control dust
c need to section rebar
d approximate 23' reach
e can cut separated metal & concrete

TABLE B.8: Demolition - Concrete/Brick/Cinder Block

f	not recommended for rad. work or reinforced concrete
g	limited to structures <100' in height
h	use on floors & hard to reach areas
I	small areas only
j	in stack situation, possible use on foundation is only identified application
k	use in confined space
l	quiet
m	use to remove large sections of concrete en mass
n	tends to bind if used for long periods
o	use delayed firing to control vibration
p	use for cutting large blocks of concrete to remove en mass
q	very little noise or vibration
r	cracks concrete
s	can use to load truck

TABLE B.9: Demolition - Steel Structures

	Sheathing Intact	Sheathing Removed
HEAVY EQUIPMENT		
Backhoe Mounted Ram[a,b,c]	◑	◑
Backhoe Mounted Shears[a,d]	◕	◕
Bulldozer[e,f]	◕	◕
Wrecking Ball/Slab[a,g,h]	◑	◔
MISCELLANEOUS EQUIPMENT/METHODS		
Diamond Wire[i,j]	◑	◑
Explosive Charges/Explosive Cutting[a,b,k]	◑	◑
Grapple[a,d,n]	●	●

a need to section rebar
b use mist to control dust
c approximate 23' reach
d can cut separated metal and concrete
e may be used to push-pull structure
f segregation of material is required
g not recommended for rad. work
h limited to structures <100' in height
I not very practical on steel
j secondary waste is water
k use delayed firing to control vibration

TABLE B.10: Demolition - Wood Structures

	Sheathing Intact	Sheathing Removed
HEAVY EQUIPMENT		
Backhoe Mounted Ram[a,b]	◕	◕
Backhoe Mounted Shears[a,c]	◑	◕
Bulldozer[d]	◕	◕
Wrecking Ball/Slab[e,f]	◕	◕
MISCELLANEOUS EQUIPMENT/METHODS		
Diamond Wire	⊗	⊗
Explosive Charges/Explosive Cutting	⊗	⊗
Grapple[b,h,i]	●	●
Wall and Floor Saws	⊗	◕

a use mist to control dust
b approximate 23' reach
c can cut separated metal and concrete
d may be used to push-pull structure
e not recommended for rad. work
f limited to structures <100' in height
g need to section rebar
h can use to load trucks

TABLE B.11: Waste Preparation - Various Materials - Unspecified Contamination

Waste Preparation scoring is based on the nature of the waste in question, resulting in the following five categories: Scrap Metal; Brick, Block and Concrete Rubble; Wood, Clothing, and Non-hazardous Items; Asbestos Containing Material; and PCB Items. Waste Preparation methods/technologies in this table are broadly classified under the individual headings of Destructive Treatment, Disposition, and Handling. The following readily available method/technology options are included in the Preferred Alternatives Matrix:

Chemical Conditioning - Asbestos containing material (ACM) may be converted into non-friable material through the application of chemical additives currently under development. In-situ and ex-situ processes convert the ACM into a non-regulated material by chemically breaking down asbestos. In instances where the ACM is contaminated with radionuclides, the resulting waste would be considered low level waste; volume reduction is not significant. (B.11)

Commercial Recycle - This includes all administrative controls, packaging and transportation required for commercial, licensed vendors to take title to contaminated scrap metal and other salvageable building debris and process material. Vendors may employ mechanical or chemical decontamination techniques, smelting or other processes necessary to release material through appropriate channels or produce products from the recycled material. Recycled products and/or waste streams, resulting from the vendor's activity may be returned to DOE depending on prior agreement and/or DOE policy; commercial recycle activities should be consistent with The Office of Environmental Restoration's Recycle 2000 and/or other policy initiatives. (B.11)

Compaction - Normally, hydraulically-driven systems are designed to compact dry, low density waste. Conventional compactors cannot handle metal and concrete in appreciable quantities; waste is usually pressed in a standard 55 gallon drum. Disc pressures of up to 150 psi can be achieved. The piston may require decontamination, if used on contaminated waste. (B.11)

Incineration - May be performed on combustible solids and/or PCB electrical components to reduce the volume of the waste and/or destroy hazardous constituents. The process employs ample oxygen, high temperatures and sometimes chemical additives to destroy organic or toxic agents and/or reduce combustible solids to ash. Airborne particulates are trapped by filters, which require eventual disposal. Ash must be disposed of as waste. (B.11)

In Place Burial - Solid waste is used to fill basement or excavated areas or exposed subsurface structures, resulting from decommissioning activities. Typically, the waste is not processed except, perhaps, for some in-place compacting with machinery. There may be a potential for authorization to include a specific minor amount of nuclear or chemical material, but the fill will be considered a sanitary landfill. (B.11)

TABLE B.11: Waste Preparation - Various Materials - Unspecified Contamination

Local Disposition - Includes all administrative controls and storage/disposal packages required to disposition solid waste at a facility prepared locally, rather than at a large central radioactive waste disposal site. The waste remains on DOE property; is not processed except, perhaps, for some degree of in-place compaction with machinery; and will generally be stored or disposed of in an on-site, engineered disposal cell. The waste may be either sanitary, LLW, mixed waste or TRU. (B.11)

Melting - Can be used to reduce the volume of packaging required for a given amount of scrap metal. The metal is simply melted and cast into ingots, which may result in volumetrically contaminated waste. Decontamination of the crucible and mold may be required following melting and casting of contaminated metal. (B.11)

Package As-Is for Storage and/or Shipment - Includes all administrative controls, transportation and/or disposal packages, and packaging equipment required to remove solid waste from the site to appropriate storage and/or disposal cells. The waste is not processed in any way. Packages must meet all DOT and/or disposal cell waste acceptance criteria (WAC). Waste may be either sanitary, LLW, mixed waste or TRU. (B.11)

Rubblizing - A technique analogous to Shredding applied to brick, block and concrete. Rock Crushers and Universal Processors can be used to reduce the volume of brick, block and concrete through extreme pressure and/or repeated blows. Pressure applying and striking surfaces may require decontamination if used to process contaminated material. Processed material is typically not decontaminated. (B.11)

Rubblizer

Shredding - Achieve volume reduction by tearing metal objects into small strips with counter rotating cutting wheels. It can be either electrically or hydraulically driven. Can be either stationary or mobile units. Cutting surfaces and shredding chamber may require decontamination, if used to shred contaminated metal. Processed metal is typically not decontaminated. (B.11)

Supercompaction - Hydraulically driven systems, similar to Compactors, but can achieve disc pressures up to 22,000 psi and, therefore, can handle metal and concrete. The piston may require decontamination, if used on contaminated waste. (B.11)

Survey and Free Release - Includes all administrative controls, real-time surveys and sampling required to certify scrap metal and other salvageable building debris as radiologically clean and suitable for recycle and/or reuse. Material determined to be contaminated must be dispositioned by other means. (B.11)

TABLE B.11: Waste Preparation - Various Materials - Unspecified Contamination

	Scrap Metal	Brick, Block & Concrete Rubble	Wood, Clothing & Non-Hazardous Items	Asbestos Containing Materials	PCB Items
DISPOSITION					
Commercial Recycle[a,b]	◑	◑	⊗[c]	⊗[c]	⊗[c]
In Place Burial[d,e]	◑	◕	◕	◕	◑
Local Disposition[d]	◕	◕	◕	●	◕
Survey and Free Release[f,g]	◕	◕	⊗[c]	⊗[c]	⊗[c]
HANDLING					
Compaction	◕	◕	◕	◔	⊗[c]
Package As-Is for Storage and/or Shipment	◕	◑	◕	◑	◑
Supercompaction	◔	◕	◕	◔	⊗[c]
DESTRUCTIVE TREATMENT					
Chemical Conditioning[h]	⊗[c]	⊗[c]	⊗[c]	◕	⊗[c]
Incineration[i,j]	⊗[c]	⊗[c]	◕	⊗[c]	◕
Melting	◔	⊗[c]	⊗[c]	⊗[c]	⊗[c]
Rubblizing	⊗[c]	◕	⊗[c]	⊗[c]	⊗[c]
Shredding	◕	⊗[c]	⊗[c]	⊗[c]	⊗[c]

TABLE B.11: Waste Preparation - Various Materials - Unspecified Contamination

	Scrap Metal	Brick, Block & Concrete Rubble	Wood, Clothing & Non-Hazardous Items	Asbestos Containing Materials	PCB Items
DESTRUCTIVE TREATMENT (cont.)					
Thermal Conditioning	⊗[c]	⊗[c]	⊗[c]	◔	⊗[c]
Vitrification	⊗[c]	⊗[c]	⊗[c]	◑	⊗[c]

a not affected by "no-rad-added" rules for scrap metal
b release an issue for brick, block, and concrete rubble
c ⊗ used to denote Technique or Method not appearing on pertinent table & therefore deemed not appropriate for a given application
d site dependent for scrap metal
e rarely done with asbestos containing materials
f labor intensive for scrap metal
g best for simple geometry for scrap metal
h limited data for asbestos containing materials
I limited availability increases costs for wood, clothing, and non-hazardous disposable items
j fluids particularly for PCB Items