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Redevelopment of Nuclear Facilities after Decommissioning

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OF NUCLEAR FACILITIES
AFTER DECOMMISSIONING

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FOREWORD

Being aware of reuse options for decommissioned sites is an important aspect of the decommissioning process. Early planning for site reuse can facilitate the transition from operation to decommissioning, possibly reduce the financial burden associated with decommissioning, re-employ workers and specialist staff, and alleviate the overall impact of decommissioning on the local community. Conversely, the lack of early planning for site reuse after completion of the decommissioning process can become a hindrance to implementing decommissioning in a cost effective and optimized manner. This strategic inadequacy may be caused by insufficient knowledge of experience with redevelopment opportunities that were exploited successfully in industries elsewhere.

This report provides an overview of decommissioning projects implemented worldwide with reuse of the decommissioned sites for new purposes after delicensing. Lessons learned from these projects and practical guidance on factors creating reuse opportunities are highlighted. Operators of nuclear facilities, decision makers at government level, regulators/authorities and elected officials at all levels, environmental planners and the general public are all important stakeholders in the site redevelopment process.

The subject area addressed in this report has not previously been addressed in IAEA publications on decommissioning except in only a marginal fashion. This report is intended to contribute to the systematic coverage of the entire range of decommissioning aspects within the IAEA's decommissioning programme. Three consultants meetings on the present subject were held in Vienna in 2003, 2004 and 2005. The initial draft was prepared by D. Hicks of the University of Bath, United Kingdom, in cooperation with the IAEA Scientific Secretary, M. Laraia of the Division of Nuclear Fuel Cycle and Waste Technology. Other experts provided further contributions to the drafting and review of this report. Special thanks are due to L. Boing, United States of America, who chaired all three meetings and contributed many of the examples quoted in the report.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION 1

2. PURPOSE AND SCOPE 4

3. STRUCTURE 5

4. CONSIDERATION OF DECOMMISSIONING ALTERNATIVES 7

4.1. Decommissioning options 7
4.1.1. Immediate dismantling 7
4.1.2. Deferred dismantling 7
4.1.3. Entombment 8
4.2. Decommissioning objectives 8
4.3. Decommissioning and reuse 8
4.4. Integration of decommissioning and redevelopment 10
4.5. Redevelopment phases 18

5. REDEVELOPMENT ISSUES 19

5.1. Policy issues in planning for redevelopment 20
5.1.1. Evaluating sites 20
5.1.2. Relationships with outside stakeholders 23
5.1.3. Social factors 25
5.1.4. Nuclear reuse 26
5.1.5. Long term site use/mission 28
5.1.6. Facility ownership 30
5.2. Management issues 31
5.2.1. Staff reduction strategy 31
5.2.2. Management complexity 33
5.2.3. Stewardship 34
5.3. Technical issues 35
5.3.1. Continuity of site services 36
5.3.2. Construction sequence 36
5.3.3. Redevelopment of buffer areas 37
5.3.4. Interim reuse 37
5.4. Property value issues 38
5.4.1. Radiological release criteria 38

5.4.2. Waste volumes 40
5.4.3. Site characterization data 41
5.4.4. Age and condition of structures 42
5.4.5. Trees and other natural features 42
5.4.6. Underground features 43
5.5. Key development assets 44
5.5.1. Standard of living 44
5.5.2. Electricity grid connection 45
5.5.3. Site accessibility 45
5.5.4. Infrastructure network 45
5.5.5. Skilled workforce 46
5.5.6. Accommodations for administration 46
5.5.7. Support services 46
5.5.8. Machine shops 47
5.5.9. Suitable terrain 47
5.5.10. Leisure facilities 47

6. REDEVELOPMENT: ORGANIZATION, ROLES AND RESPONSIBILITIES 48

6.1. Need for early planning for redevelopment 48
6.2. Key players in planning for redevelopment 48
6.3. Roles and responsibilities 50
6.3.1. Current owner 50
6.3.2. Authorities 53
6.3.3. Developers and investors 54
6.3.4. Other stakeholders 55

7. OPERATING EXPERIENCE IN REUSE OF DECOMMISSIONED SITES 56

7.1. Experience in the USA 57
7.1.1. United Nuclear Corporation Naval Products 57
7.1.2. Luminous Processes site 57
7.1.3. South Carolina Advanced Technology Park 57
7.1.4. Bergstrom Air Force Base 58
7.1.5. Pinellas plant 59
7.1.6. Santa Susana Field Laboratory facilities 59
7.1.7. Idaho National Laboratory facilities 60
7.1.8. Argonne National Laboratory facilities 60
7.1.9. Oak Ridge Reservation 61

7.1.10. Other USDOE sites 62
7.1.11. Superfund sites 62
7.1.12. Nuclear power plant sites 64
7.2. Experience in the United Kingdom 67
7.2.1. Winfrith site 67
7.2.2. Harwell site 71
7.2.3. Dounreay site 72
7.2.4. Other United Kingdom sites 72
7.3. Experience in other countries 73
7.3.1. Russian Federation 73
7.3.2. Germany 75
7.3.3. France 75
7.3.4. Italy 76
7.4. Reuse of cancelled nuclear projects 76
7.4.1. Zimmer power plant, Ohio, USA 77
7.4.2. Midland power plant, Michigan, USA 77
7.4.3. Satsop power plant, Washington, USA 78
7.4.4. Kalkar nuclear power plant, Germany 80
7.4.5. Zwentendorf nuclear power plant, Austria 80
7.4.6. Clinch River Breeder Reactor site, Tennessee, USA . . 81

8. SUMMARY AND CONCLUSION 81

APPENDIX: METHOD FOR EXPLORATION OF CLOSURE AND REDEVELOPMENT SCENARIOS 83

REFERENCES 87

ANNEX I: EXAMPLES OF NATIONAL EXPERIENCE 99

ANNEX I.A: REUSE OF THE ASTRA RESEARCH REACTOR, AUSTRIA 100

I.A–1. Introduction 100
I.A–2. Concept of reuse of the reactor building after decommissioning 101
I.A–3. Alterations for reuse of the buildings 102
I.A–4. Estimated costs 104
I.A–5. Conclusion 104
Reference to Annex I.A 105

ANNEX I.B: SITE REUSE EXPERIENCE IN BELGIUM 106

I.B–1. Introduction 106
I.B–2. Factors influencing the choice of the VITO location and the decommissioning and reuse strategy 106
I.B–2.1. Limitation of costs 108
I.B–2.2. Re-employment opportunities 108
I.B–3. Arrangements prior to the actual decommissioning activities 109
I.B–3.1. Preliminary reflections 109
I.B–3.2. Drawing up of the safety report 109
I.B–3.3. Definition of the unrestricted release and/or reuse limits 110
I.B–3.4. Gathering physical and radiological characteristics of the buildings 110
I.B–4. Decommissioning activities 111
I.B–4.1. Dismantling methodology 112
I.B–4.2. Decommissioning tools and equipment 113
I.B–4.3. Radiation protection 113
I.B–4.4. Material flow management 113
I.B–5. Results obtained and lessons learned from the decommissioning 113
I.B–6. Costs 114
I.B–7. Overall advantages and lessons learned from this reuse project 115
I.B–8. Current similar projects 116
I.B–9. Conclusion 116
Bibliography to Annex I.B 119

ANNEX I.C: DECOMMISSIONING AND SITE REUSE IN DENMARK 120

I.C–1. Introduction 120
I.C–2. Planning for decommissioning 121
I.C–3. Description of the nuclear facilities 122
I.C–3.1. Research reactor DR-1 123
I.C–3.2. Research reactor DR-2 123
I.C–3.3. Research reactor DR-3 124
I.C–3.4. Hot cell facility 126
I.C–3.5. Waste management plant with storage facilities 127
I.C–4. Considerations concerning reuse 128

I.C–4.1. DR-2 building reuse 128
I.C–4.2. Hot cell building reuse 129
References to Annex I.C 129

ANNEX I.D: SOCIAL ASPECTS OF THE DECOMMISSIONING AND REUSE OF THE GREIFSWALD NUCLEAR POWER PLANT, GERMANY 130

I.D–1. Introduction 130
I.D–2. Social strategy 131
I.D–3. Personnel strategy 131
1.D–3.1. Practical realization 134
I.D–4. Future site reuse 134
I.D–5. Conclusion 136

ANNEX I.E: FINAL FOOTPRINT PROJECT: BEST PRACTICE IN CLOSURE AND REDEVELOPMENT PLANNING IN THE SOUTH AFRICAN MINING INDUSTRY..... 137

ANNEX I.F: REUSE OF NUCLEAR SITES IN SWITZERLAND ... 142

I.F–1. Introduction 142
I.F–2. Reuse of the Lucens site 142
I.F–3. Reuse of the DIORIT and SAPHIR research reactor sites 142
I.F–4. Future reuse of Swiss power reactor sites 143
I.F–5. Collection of proposals for reuse of Swiss sites other than nuclear sites 148

ANNEX I.G: REDEVELOPMENT OF UNITED KINGDOM SITES 151

I.G–1. Introduction 151
I.G–2. Disposal of sites 152
I.G–3. Retained sites: reuse and renewal 152
I.G–4. Commercial development 154
I.G–5. Marketing 156
I.G–6. Stakeholder management 157
I.G–7. Site ecology 158
I.G–8. Conclusion 159

ANNEX I.H: REINDUSTRIALIZATION OF THE UNITED STATES DEPARTMENT OF ENERGY'S MOUND SITE 160

I.H–1. Introduction 160
I.H–2. Past operations 160
I.H–3. Present operations 161
I.H–4. Types of contaminant 162
I.H–5. Types of facility 163
I.H–6. Reindustrialization concept 163
I.H–6.1. Overview 163
I.H–6.2. Improvements/grant funding sources 164
I.H–6.3. Location/other assets 165
I.H–6.4. Business development 165
I.H–7. Cleanup progress 166
I.H–8. Reindustrialization progress and problems 167
I.H–9. Conclusion 169
Bibliography to Annex I.H 171

ANNEX I.I: REINDUSTRIALIZATION OF THE FORMER K-25 COMPLEX, OAK RIDGE, TENNESSEE, USA 172

I.I–1. Introduction 172
I.I–1.1. History of the K-25 complex 172
I.I–1.2. Types of facility remaining 173
I.I–1.3. Types of contamination 174
I.I–2. Reindustrialization concept 174
I.I–3. Community Reuse Organization of East Tennessee 175
I.I–4. Role of state and federal regulators 176
I.I–5. Cleanup actions 178
I.I–6. Reindustrialization progress and problems 178
I.I–6.1. CROET 178
I.I–6.2. British Nuclear Fuels 180
I.I–6.3. Decon Recovery Services 180
I.I–6.4. Pall Industrial Membranes 181
I.I–7. Problems encountered 181
I.I–7.1. Reuse of decommissioned facilities 181
I.I–7.2. Changing political priorities 184
I.I–8. Conclusion 187
References to Annex I.I 187

ANNEX II: PROBLEMS ENCOUNTERED AND LESSONS LEARNED FROM THE PROCESS OF REUSING DECOMMISSIONED NUCLEAR SITES 189

II–1. Argonne National Laboratory Site — CP-5 189
II–2. Argonne National Laboratory Site — EBWR 189
II–3. East Tennessee Technology Park — utility systems 190
II–4. East Tennessee Technology Park — access issues 190
II–5. Hanford site 191
II–6. USDOE (generic) — on-site versus off-site planners 192
II–7. USDOE (generic) — integrated approach to infrastructure 193
II–8. USDOE (generic) — environmental versus occupational risks 193
II–9. East Tennessee Technology Park — contractorization issues 194
II–10. East Tennessee Technology Park — impacts of policy changes 195
II–11. FRF-1/FRF-2, Germany 196
References to Annex II 196

GLOSSARY 199
CONTRIBUTORS TO DRAFTING AND REVIEW 203

1. INTRODUCTION

The International Atomic Energy Agency has served as a vehicle for the sharing of knowledge and experience on the peaceful uses of nuclear energy since it was established by the United Nations General Assembly in 1956. Initially that sharing concentrated on the development of nuclear technologies and their implementation in nuclear power reactors and the production of nuclear fuel. It was soon realized that the processing, storage and disposal of radioactive waste would be an integral part of that development, and the IAEA held its first Scientific Conference on Disposal of Radioactive Wastes in Monaco in 1959. Decommissioning of nuclear facilities, including radioactive waste management, is an important component of a country's nuclear energy policy.

The first IAEA publication in the field of decommissioning of nuclear facilities was issued in 1976 [1]. In the last 30 years, over 40 technical documents, conference proceedings, Technical Reports, Safety Series and Safety Standards Series publications have been issued covering specific aspects of decommissioning, such as technologies, safety and environmental protection, national policies and regulations, monitoring programmes, characterization of shut down facilities, and design and construction features to facilitate future facility decommissioning. The majority of early publications addressed decommissioning technologies, specifically decontamination and disassembly techniques and the management of resulting waste. These publications were prepared in the early 1990s and mainly reflected decommissioning experience gained on a relatively limited number of smaller research reactors or prototype facilities [2, 3]. At that time, only feasibility studies or preliminary plans to decommission larger nuclear facilities were generally available.

Experience in the decommissioning of a wider range of nuclear facilities has become available over the last 15 years, and this has altered the decommissioning picture somewhat. In many countries, the dismantling of major prototype and power reactors and of research and development facilities has been viewed by the operators and governmental decision makers as an opportunity to demonstrate to the public that decommissioning can be conducted in a safe and cost effective manner. These decommissioning efforts have also allowed the further testing and optimization of decontamination and disassembly techniques, the evolution of new technologies, the improvement of management aspects, and the creation of a 'decommissioning service market' including specialized contractors and suppliers. These developments have been reflected in a number of recently updated IAEA publications, e.g. Refs [4–6].

It is currently recognized that, to a large extent, the liabilities associated with decommissioning should be identified at the design stage and regularly re-examined during the operational period. This topic has been the subject of an IAEA report that reviewed best practices worldwide in the area [7]. Many older facilities, however, were commissioned before the benefits of this guidance were realized. In the coming decade the rate at which large commercial power units are retired is expected to rise steadily as about 150 reactors commissioned in the 1970s begin to reach the end of their operational lives and are permanently shut down. Additionally, the closure of redundant support facilities, such as research laboratories, pilot plants, and fuel manufacturing and reprocessing plants, is expected to continue. It is inevitable that the rate of facility closures will increase in the future and add to the inventory of shut down facilities requiring eventual dismantling. The IAEA has recently published a study summarizing the status of the decommissioning of nuclear facilities around the world [8]. Figure 1 is from that study and shows the anticipated costs of the decommissioning liability by five-year periods.

As these facilities lose their capacity to generate power or support other nuclear energy activities, they are often seen only in terms of their decommissioning liability. This is the liability associated with the owner's responsibility to

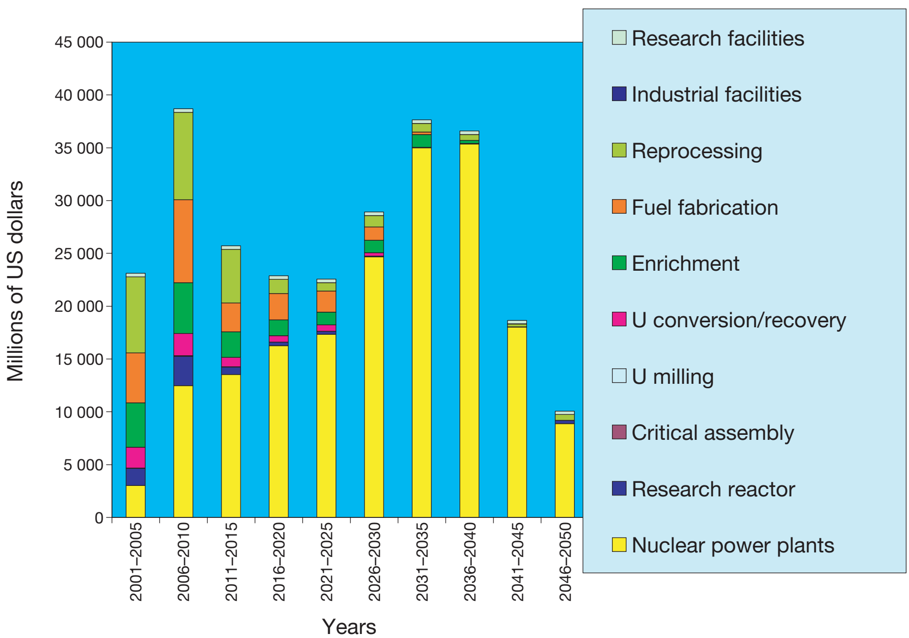

FIG. 1. Decommissioning liability by five-year periods [8].

keep the facilities in a safe condition and to eventually safely demolish them and dispose of the waste. In practice many such facilities and associated sites have significant potential for redevelopment.

Examination of the role of nuclear facility decommissioning in the move towards sustainable development suggests that this potential for redevelopment should not be ignored. Sustainable development implies the need to combine economic development with conservation of natural resources such as land. In the case of decommissioning, the recycling of land implied by redevelopment of a site offers a valuable means of avoiding the need to obtain further greenfield sites[1]. Sustainable development also implies economic development with maintenance of social and community integrity. Both of these benefits can be attained by the sensitive and organized redevelopment of sites to provide continuity of employment and new production opportunities. Finally, the principles of sustainable development suggest a more transparent and participative decision making process than has been the practice to date in many aspects of nuclear development. This presents a challenge to the nuclear industry to learn new ways to consult with and engage a wider range of interested parties and be able to accept their inputs as legitimate. Experience to date with redevelopment both inside and outside the nuclear field suggests that successful engagement with interested parties can be a key factor in promoting outcomes that are both profitable for the operator and recognized as responsible and worth while by the wider community.

Some aspects of the potential for reuse and recycling of materials, equipment, buildings and sites when they reach the end of their useful life have already been considered in earlier Technical Reports [9, 10] and other IAEA publications [11, 12], notably the control of risks arising from potential residual radioactive contamination. This report will extend that work to consider a wider range of redevelopment and reuse issues. It will address specifically the way in which opportunities for redevelopment can influence decommissioning planning and promote rapid, effective and economic decommissioning. Actions that can be taken throughout the life of the facilities concerned to increase their redevelopment potential will also be discussed. Specific instances of reuse of sites as an integral part of the decommissioning process will be also presented.

[1] For the purposes of this report, a greenfield site is a site that has been granted unrestricted release from regulatory control and where buildings have been demolished and no further productive use is planned.

2. PURPOSE AND SCOPE

The purpose of this report is to provide information and practical guidance on the reuse of nuclear facilities and their sites. Redevelopment should be considered as a logical next step after completion of decommissioning. Therefore opportunities for this aspect of the life cycle of a facility should be considered at the design and planning stages. This report will describe the experiences to date of nuclear organizations/licensees who have sought to reutilize the physical site assets by reusing either the facilities or the site, perhaps after modifications or development, for a new productive mission or use. This report is intended to be of use to owners and operators of nuclear facilities who might be considering reuse or redevelopment opportunities for their sites or installations as a means of reducing the decommissioning liability or to recover some of the costs of decommissioning.

The report is relevant to most types of nuclear facility. However, it is not specifically intended for application to uranium mining and ore processing sites, or to sites where only small quantities of radioactivity were used (in sealed sources, medical therapy or radioactive tracer experiments). Furthermore, it is not intended to address reuse of contaminated land after its cleanup, or problems that arise from a large release of radioactivity, such as in a nuclear accident or incident. While there is some possible overlapping with these areas, the emphasis in this report is on redevelopment of facilities and the sites on which single facilities or some larger complex of facilities might be situated for which redevelopment options are to be considered.

The report may be relevant to owners and operators of nuclear facilities for which future closure has not yet been considered in detail. Although the expected date of closure may be in the distant future, there can be opportunities to improve the closure strategy by an early recognition of the potential redevelopment value of the site and the need to protect its assets. By illustrating the range of uses for redeveloped nuclear sites, and by compiling the experience related to the main factors affecting successful redevelopment, it is hoped that this report will encourage those concerned with nuclear plant operation and decommissioning to consider reuse aspects in their planning process.

The report will also be of interest to nuclear regulators to document the fact that decommissioning of redundant nuclear facilities can be completed safely, speedily and typically in the best interests of all those affected, including local communities. However, the report will not elaborate on radiological cleanup criteria or on evaluation of the impacts of residual radiological levels on the public or the environment, while recognizing that these are important factors in orienting site reuse options. Other IAEA programmes deal with radiological criteria for site release.

The report is expected to facilitate a better understanding of site redevelopment by the key stakeholders involved in the decommissioning process, including authorities responsible for the land planning and redevelopment of territories at all levels (national, regional and local). In many cases the most valuable follow-on use for a redundant site or asset will be in an application that provides continuity of employment for the local workforce and contributes to the viability of the local economy and its tax base.

The diversity of nuclear installations and the variety of their settings in terms of geography, culture and politics mean that it is impossible in a report such as this to provide specific technical solutions to problems that will be applicable at all or even most sites. Instead the report will concentrate on describing some examples and seeking some general guiding principles that can be applied across a range of circumstances. Specifically it will aim to describe the course of enquiry needed to identify potential development opportunities and any special aspects of the planning and organization activities needed to facilitate their implementation.

3. STRUCTURE

This report spans the range from examining the conceptual approaches to decommissioning and redevelopment to operating experience in the field. Section 4 considers two alternative approaches: (1) decommissioning and demolition, and (2) decommissioning and redevelopment. Details of the pertinent factors to consider in planning and undertaking redevelopment of decommissioned sites are given in Section 5. Actions that the various parties can take to facilitate redevelopment of the site are described in Section 6. Section 7 presents examples of actual operating experience in the reuse of decommissioned sites. A summary and conclusions are included in Section 8. An appendix and Annex I present approaches and experiences of various Member States in the technical area. Annex II provides case studies of problems encountered, solutions and lessons learned in facility redevelopment. A glossary is included after the annexes.

Figure 2 provides an overview of the decommissioning and redevelopment process for a nuclear facility and the relevant issues in evaluating opportunities for site redevelopment. The dashed lines highlight the scope of this report.

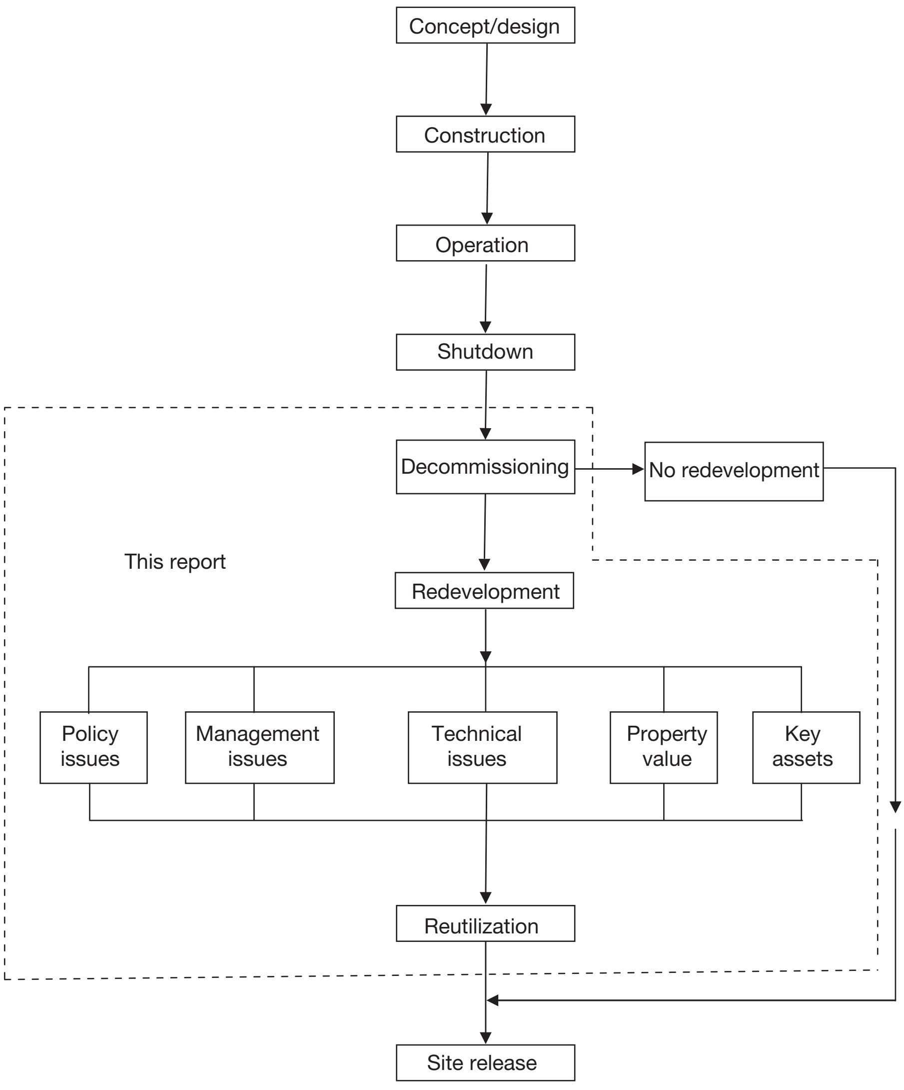

FIG. 2. Overview of decommissioning and redevelopment process of a nuclear facility.

4. CONSIDERATION OF DECOMMISSIONING ALTERNATIVES

4.1. DECOMMISSIONING OPTIONS

The generally accepted purpose of decommissioning projects is to allow the removal of all or some of the regulatory controls that apply to a nuclear site, while securing the long term safety of the public and the environment, and continuing to protect the health and safety of the workers involved in the decommissioning process. Underlying this are other practical objectives, including the release of valuable assets such as buildings and sites for alternative use, the recycling and reuse of materials, and the restoration of environmental amenities. In all cases, the basic objective is to achieve an end point that is sensible in technical, social and financial terms, and that properly protects workers, the public and the environment. This aim is consistent with the principles of sustainable development [13].

IAEA publications [14–16] refer to three primary options that are to be considered in implementing a decommissioning strategy for a particular site or facility. These primary options are immediate dismantling, deferred dismantling and entombment. Other options may be considered and are generally combinations or variations of these three primary ones.

4.1.1. Immediate dismantling

Immediate dismantling is the strategy in which the equipment, structures and parts of a nuclear facility containing radioactive contaminants are removed or decontaminated to a level that permits the facility to be released for unrestricted use, or possibly with restrictions imposed by the regulatory body. Activities typically begin shortly after permanent termination of operations and involve the removal and processing of all radioactive material from the facility and its transfer to another new or already existing nuclear facility for either long term storage or disposal.

4.1.2. Deferred dismantling

Deferred dismantling (sometimes called safe storage or safe enclosure) is the strategy in which parts of a nuclear facility containing radioactive contaminants are either processed or brought into a condition such that they can be safely stored and maintained until they can subsequently be decontaminated and/or dismantled to activity levels that permit the facility to be released for other use [17, 18].

4.1.3. Entombment

Entombment is the strategy in which radioactive contaminants are encased in a structurally long lived material until the radioactivity decays to a level permitting unrestricted release, or release with restrictions imposed by the regulatory body. Because radioactive material remains on the site, the site will be designated as a near surface waste disposal facility.

4.2. DECOMMISSIONING OBJECTIVES

In the past it was often envisaged that the final goal for decommissioning was the unrestricted release of the site and demolition of the remaining structures (a greenfield state). It should be noted that the safety driven definition of decommissioning given in the Glossary does not include non-safety-related activities, such as the demolition of clean structures or landscaping. It should also be noted that this definition does not exclude the option of reusing the site under restricted release conditions.[2]

It is becoming apparent that achieving ‘greenfield’ is an extremely demanding option from a technical as well as an economic perspective. For example, the costs of the demolition of clean structures and landscaping activities can be significant and should be taken into account within the scope of a decommissioning project [19, 20]. As a consequence, a better outcome might be attained by reusing the site (or parts of it) for another technical purpose [21]. The following sections describe the key aspects of an approach that builds on the concept of site reuse.

4.3. DECOMMISSIONING AND REUSE

Today it is generally recognized that decommissioning must be viewed as an integral part of a facility’s life cycle together with the design, construction and operational phases, and that it must be considered at an early phase of a facility’s life [7, 14–16]. Site redevelopment can be viewed as an extension of

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[2] IAEA Safety Glossary, Working Material, 2000, explanatory clauses to the definition of decommissioning.

decommissioning that closes the life cycle loop, and it should be considered early in the decommissioning planning stage. For example, it would be unnecessarily costly and time consuming to dismantle a building that could be conveniently reused, provided it could meet the site release criteria [22]. Similarly, surface decontamination and land remediation activities should be carried out only to a point compatible with the future use of a site. For example, industrial reuse might be consistent with site release levels higher than those for a residential reuse planning scenario. This is the concept of restricted release or restricted use (see definition in the Glossary) mentioned in Section 4.2. It should be noted, however, that while some national regulations, for example those in the United States of America [23], encompass this concept, there is currently no consensus on a preferred set of site release criteria, or indeed on the form of such criteria [22]. Other advantages of site reuse and the rationale for early planning for site redevelopment are given throughout this report.

Various strategies for decommissioning nuclear facilities can be envisaged in terms of how the planning and scheduling of activities and the motivational and morale aspects affect the efficient progress of the work. While the conventional ‘total dismantling’ approach is useful in assisting in the planning of decommissioning work at many facilities, it often results in decommissioning programmes that are more extended in scope and more prolonged than some might prefer. The desire simply to have the facility gone can fail to recognize the important role that its reuse might play in contributing to a positive end result of the decommissioning project and with respect to the site’s image and value to the stakeholders.

A hierarchy of objectives can be established to address these issues and provide a basis for decommissioning planning that protects worker safety and the environment in both the short and the long term, and that at the same time encourages the most constructive approach towards reuse and redevelopment of the facility and the land associated with it. In this case the sequence of decommissioning objectives can be formulated as follows:

(1) Continuous maintenance of operational safety;
(2) Reduction of hazard;
(3) Release of resources that can be used constructively for other purposes;
(4) Disposal of materials and restoration of any parts of the site not suitable for other uses.

Objective 1 is crucial. The fact that the continuous assurance of high levels of safety is accorded the highest importance requires a substantial commitment of resources. The aim of objective 2 is to reduce the reliance on operational maintenance of safety systems that are costly and cannot be assured indefinitely. Both objectives 1 and 2 involve networking with regulators and other stakeholders, and respecting this arrangement in the planning, communication, recruitment and training, research and development, design and maintenance activities needed to meet the continuing requirements to maintain safety and operability. Objectives 3 and 4 arise from the need to conserve resources and protect the environment in a manner consistent with progress towards sustainable development.

Table 1 shows the four objectives and the actions to be taken in order to achieve the goals of decommissioning and reuse.

As a sample of worldwide trends, the status of a number of shut down nuclear installations in the United Kingdom, the USA, France and Italy is summarized in Table 2, where it is apparent that immediate reuse is a common outcome of decommissioning and delicensing. To quote one significant example from other countries, the Japan Research Reactor 3 (JRR-3) at Japan Atomic Energy Research Institute (JAERI), Tokai, was partially decommissioned and removed to a storage building, and the building originally used for it is being reused for a new reactor, JRR-3M [24–27]. More examples are given in the rest of this report.

4.4. INTEGRATION OF DECOMMISSIONING AND REDEVELOPMENT

As a consequence of the value of the land released by decommissioning, the termination of one activity at the site will often lead to the land's reuse for a new activity. Most nuclear facilities benefit from favourable key assets, such as a flat topography and good access to utilities (see Section 5 for a more detailed listing), that enhance the potential for rapid redevelopment. In some cases non-nuclear spin-off activities are already established on the site before the end of nuclear operations and can provide the basis for regeneration of the site in a new role.

Given that this is the case, and that decommissioning of nuclear installations can usually be followed by site redevelopment, it is reasonable to consider the implications of deliberately planning for decommissioning as a

TABLE 1. HIERARCHY OF OBJECTIVES IN DECOMMISSIONING

1. Maintenance of operational safety

Site functions that need to be maintained during decommissioning:
- Security, to prevent unauthorized access both for public safety and to prevent vandalism and dumping.
- Monitoring and surveillance, to detect and respond to unexpected developments.
- Maintenance of site services needed for decommissioning, such as power and communications, and possibly for operational facilities, for example for waste treatment.
- Support for new equipment brought on to the site for specific operations.
- Construction of new temporary facilities as needed to support decommissioning activities.

New site functions that have to be established for the redevelopment approach, such as:
- Appropriate liaison with regulators, local community representatives and other stakeholders.
- Continuation of investigations, analyses, planning and decision making.

2. Hazard reduction

Actions necessary to eliminate the health, safety and environmental hazards associated with the facility:
- De-energize systems, remove dangerous materials, and eliminate dangerous structures and fall hazards.
- Undertake a site investigation to identify and post warnings for contaminated areas.
- Decontaminate redundant facilities.
- Reduce reliance on institutional controls that require continuous commitment of resources and are unreliable for long term protection.
- Remove radioactive material.

3. Release of resources

In parallel with hazard reduction, the release of resources for reuse in a new productive activity. The following activities have to be redirected in the case of the redevelopment approach:
- Inventory resources and identify facilities, material or equipment suitable for reuse.
- Assess the markets and opportunities for reuse or recycling.
- Recover and segregate scrap material for recycling.
- Remove or reallocate equipment or whole systems (such as a building) to a new use.
- Restore the landscape, amenity or functional value of an area of land so that it can be redeveloped.
- If feasible, reconfigure portions or all of the facility for reuse in a different role.

4. Site clearance

Once objectives 1 to 3 have included the redevelopment approach, site clearance results in the same activities as in the conventional approach, and the removal of residual materials and unusable structures along with restoration of the site must lead to a satisfactory condition:
- Confirm that the plant has no further potential for use, is free from hazards and is safe to take down.
- Remove and dispose of clean equipment.
- Demolish structures and remove or ‘rubbleize’ debris.
- Remediate contaminated soil and groundwater.
- Complete end point surveys and land quality statements, etc.
- Collect, analyse, segregate, sort, package and dispose of waste.

TABLE 2. STATUS OF SELECTED RETIRED NUCLEAR INSTALLATIONS

Country	Operator	Installation, location	Status
United Kingdom	UKAEA	Culcheth, Cheshire (RC/S)	Decommissioning complete; site sold for redevelopment as housing estate
		Winfrith, Dorset (RC/NPP/S)	Partially decommissioned; site partially redeveloped as business park
		Harwell, Oxfordshire (RC/S)	Partially decommissioned; site partially redeveloped as business park
		Dounreay (F/NPP/RC/S/W)	Partially decommissioned; site clearance plan will leave only buried waste; no plans for reuse of the site
		Universities Research Reactor, Risley, Cheshire (RR)	Decommissioning complete; building sold and converted to new business premises
	Ministry of Defence	JASON Training Reactor, Greenwich (RR)	Decommissioning complete; building space retained and reoccupied as part of naval college
	BNFL	B100-103 U Recovery (F)	Converted to a radioactive waste store
USA	Kerr–McGee	West Chicago, IL (I)	Fully decommissioned; site available for redevelopment as an unrestricted site
	Allied General Nuclear Services	Fuel reprocessing plant, Barnwell, SC (F)	Fully decommissioned; facility and site redeveloped as industrial park
	University of Virginia	Research reactor, Charlottesville, VA (RR)	Fully decommissioned; building space retained and available to be reoccupied

TABLE 2. STATUS OF SELECTED RETIRED NUCLEAR INSTALLATIONS (cont.)

Country	Operator	Installation, location	Status
USA (cont.)	Nuclear Materials Development Facility	Canoga Park, CA (F/RC)	Fully decommissioned; building space reoccupied by other research programmes
	Cintichem, Inc.	Cintichem Research Reactor, Tuxedo, NY (RR)	Fully decommissioned; property for sale; all buildings demolished
	Apollo Fuel Fabrication	Apollo fuel plant, Apollo, PA (F)	Decommissioning and redevelopment under way
	UNC Naval Products	Montville, CT (F)	Fully decommissioned; reused as a casino
	Luminous Processes	Athens, GA (I)	Fully decommissioned; property now site of a restaurant
	Westinghouse Electric Corporation	Saxton, PA (NPP)	In decommissioning; property planned to be maintained for use by power generating utility
	USDOE/Nebraska Public Power District	Hallam, NE (NPP)	Entombed; site reused for fossil fired generation
	USDOE	Elk River, MN (NPP)	Fully decommissioned; site reused for fossil fired generation
		Piqua, OH (NPP)	Entombed; site reused by local municipality
		Shippingport, PA (NPP)	Fully decommissioned; collocated on a site with an operating NPP

TABLE 2. STATUS OF SELECTED RETIRED NUCLEAR INSTALLATIONS (cont.)

Country	Operator	Installation, location	Status
USA (cont.)	USDOE (cont.)	Pinellas site, Largo, FL (RC/I)	Fully decommissioned; facility is a part of Pinellas County Industry Council high-tech industrial park
		Mound site, Miamisburg, OH (RC/I)	In decommissioning; site to be redeveloped as an industrial/office park after completion of decommissioning and restoration
		Janus Research Reactor, Argonne, IL (RR)	Fully decommissioned; building space reoccupied by research programmes
	Long Island Power Authority	Shoreham, NY (NPP)	Fully decommissioned; site available for reuse
	Consumers Energy	Big Rock Point, Charlevoix, MI (NPP)	In decommissioning; site to be released for unrestricted use
	Sacramento Municipal District	Rancho Seco, Heraldburg, CA (NPP)	In decommissioning; site considering repowering
	Bergstrom Air Force Base	Austin, TX (I)	Fully decommissioned; facility serves as city airport
	Northern States Power Company	Pathfinder, Sioux Falls, SD (NPP)	Fully decommissioned; repowered with natural gas
	Public Service Co. of Colorado	Fort St. Vrain, Platteville, CO (NPP/S)	Buildings partially decommissioned; fully nuclear decommissioned; repowered with natural gas

TABLE 2. STATUS OF SELECTED RETIRED NUCLEAR INSTALLATIONS (cont.)

Country	Operator	Installation, location	Status
USA (cont.)	Radiopharmaceutical manufacturers	Various (I)	Fully decommissioned; property reused for operations or sold after delicensing
France		Chinon-1 (NPP)	Converted to museum
		Pegase, Cadarache (RR)	Converted to spent fuel facility
		Zoe (RR)	Converted to museum
Italy		Avogadro (RR)	Converted to spent fuel facility
		RB-2 (RR)	Converted to mechanical test workshop

Note: Former purpose: F: fuel manufacture/reprocessing; I: industrial; NPP: nuclear power plant; RC: research centre; RR: research reactor; S: storage of fuels/waste; W: burial of radioactive waste. UKAEA: United Kingdom Atomic Energy Authority; BNFL: British Nuclear Fuels; USDOE: United States Department of Energy.

TABLE 3. DIFFERENCES IN APPROACH BETWEEN DEMOLITION AND REDEVELOPMENT

Perspective	Demolition	Redevelopment
Functional	Structures and assets with no useful function are removed.	Structures and assets with functional value for the next use of the site are retained and may be reconfigured for a new use.
Physical	The site is returned to a state similar to its predevelopment state.	The site is transformed into new industrial, commercial, recreational or residential property, possibly with some portions of the facility retained.
Ownership	The existing operator or owner may remain responsible for the facility for a long time after release from regulatory control, until a new owner takes over.	Ownership of the site is transferred during or soon after the elimination of radiological hazards. (Note: This process is based on national legislation.)
Risk based cleanup	Most conservative risk assumptions are used to determine remediation goals.	The proposed new site use determines the remediation goals, consistent with protection of human health and the environment.
Community	Economic activity associated with the site is lost.	New economic activity replaces economic activity lost by closure of the nuclear facility.
Decommissioning planner	The decommissioning end point is defined by what is known about the original state of the site and current legislative and regulatory requirements.	Identification of the decommissioning end point depends also on the planned end use and any redevelopment agreement.
Liability management	The owner remains liable for harm caused by any failure to completely restore the site until it is released from regulatory control. (Note: Liability after release from nuclear control is subject to national legislation.)	The owner transfers the site and possibly the residual liabilities to the new owner. (Note: This process is based on national legislation.)

TABLE 3. DIFFERENCES IN APPROACH BETWEEN DEMOLITION AND REDEVELOPMENT (cont.)

Perspective	Demolition	Redevelopment
Resource use	The land occupied by the nuclear facility is unavailable for use during decommissioning, demolition and restoration. The subsequent lead time needed for any new use will further delay access to the resource.	The land is returned to use earlier, allowing development on a brownfield site rather than on more sensitive or valuable land. (However, restrictions might be placed on use of a brownfield site.)
Financial	Cash flows are negative until the completely restored site is leased or sold.	Costs of decommissioning and restoration are reduced, can be offset by the development value of the land and are recovered more quickly.
Decommissioner	The decommissioner is free to plan and execute the work within financial and regulatory constraints.	Planning and execution of decommissioning are carried out in consultation with the developer to maximize the redevelopment value of the site.
Long term stewardship	The owner remains responsible for monitoring residual contamination and continues to maintain any institutional controls.	Management of all site activities becomes the responsibility of the new owner.

redevelopment tool. As discussed above, safety and environmental protection objectives must be fulfilled at all times and are essential factors in determining the end state of the decommissioning process. Table 3 is intended to offer additional input to the decision making process.

Integration of decommissioning and redevelopment activities offers the prospect of earlier reuse of the site, bringing forward in time the realization of the site value for the operator/licensee. From a planning perspective, however, integration of redevelopment has the potential to cause uncertainty if the redevelopment proposals are brought to the attention of those responsible for the decommissioning work at a late stage in the decommissioning project. Decisions regarding the redevelopment of an existing site or facility need therefore to focus on the desired end state. Site ‘master plans’ have been used in both the USA and the United Kingdom to aid in the redevelopment process. These plans are used to help ensure that the decommissioning and redevelopment activities are consistent with the planned end state and that any renewal of the site infrastructure is cost effective and furthers the desired outcome. Further information is provided in Annexes I.G and I.H. This process may require difficult renegotiations with the site redeveloper. In general, early planning for site redevelopment may alleviate these difficulties.

The general phases of the redevelopment process are detailed in Section 4.5. Experience from early nuclear site redevelopment has identified many issues that can have an important bearing on the redevelopment potential of sites and the work to be done. These aspects are discussed further in Section 5.

4.5. REDEVELOPMENT PHASES

This section is intended to provide a simple overview of the key phases of a redevelopment project on a nuclear site. This report is not intended to describe the activities and actions required to successfully realize the project. Detailed guidance on project management practices and techniques is widely available elsewhere (e.g. Ref. [6]). The key phases are:

(1) Initiation phase

The main goal of the initiation phase is to acquire information relating to the site assets and liabilities, the provisional boundary of the project area and its location with respect to the surrounding areas, and the important preconditions and limitations. The identification of those parties involved in the project will also take place, and in addition the views of the ‘key players’ should be sought during this phase.

The initiation phase should result in the preparation of a document that provides an overview of the juridical, policy, management and technical issues, and the potential problems and opportunities.

(2) Concept identification

The concept identification phase builds on the output from phase 1 and aims to identify potential redevelopment options for the facility/site. The achievable options are then developed to provide more detailed variants to be evaluated in relation to each other. Details of how to identify the ‘preferred redevelopment strategy’ are given in Ref. [28].

An important aspect of this phase is the need to build a consensus between the players involved with regard to the chosen concept. It is also essential that a detailed financial assessment take place at this stage to verify financing possibilities and acquire redevelopment grants.

(3) Redevelopment planning

During the redevelopment planning phase the concept identified in phase 2 is further refined. The goal is to ensure that the final outcome is consistent with the aims and objectives set out in the decommissioning plan for the facility/site and to take into account the activities in relation to redevelopment, construction and renovation.

The formal consultancies and licensing procedures should be completed as part of this phase.

(4) Project realization

The actual work to complete the redevelopment, renovation and construction work as identified in the preceding phases is performed during the project realization phase. A conceptual planning process for assisting certain United States Department of Energy (USDOE) sites to transfer surplus property is given in Ref. [29]. The process presents a number of different options for the transfer of property, including site needs, environmental site conditions and criteria for legal release of surplus property.

5. REDEVELOPMENT ISSUES

There is an increasing challenge to avoid further exploitation of greenfield sites and to restrict new development to sites with a previous industrial history (often referred to as brownfield sites). The redevelopment plans for these sites will need to consider whether site remediation can achieve end points that are compatible with their intended reuse. This is true for nuclear facilities and sites where controlled reuse may generate revenue to help offset some of the decommissioning costs.

Although redevelopment is a dynamic process often requiring an individual approach, a number of similar phases can be used to describe the project (see Section 4.5). It is also an iterative process in which several activities can take place simultaneously. Some of these may have to be repeated or restarted. Redevelopment also requires a continuous and interactive cooperation between the various players involved in the different phases. When based on a constructive and open dialogue, this cooperation is often the key to a successful and sustainable redevelopment [28]. As an example of the points of view found among members of the public, a formal survey of several hundred persons in the USA in early 2004 [30] identified the following as the most important reasons why brownfield sites require redevelopment:

— To remove an unsightly structure or site;
— To increase tax revenues;
— To reduce environmental risk;
— To reduce public health risk;
— To make more efficient use of infrastructure.

Just as with the reasons for redevelopment described above, reuse of nuclear facilities and sites may come in a number of forms, for example housing, new industry, recreational areas, museums or even authorized disposal facilities. An important step in exploring the possible redevelopment potential of a site is to identify key assets and to protect them from deterioration during the transition and decommissioning phases.

Careful planning and evaluation are therefore important, and the following section considers the redevelopment issues from the following points of view:

— Policy issues in planning;
— Management issues;
— Technical issues;
— Property value issues;
— Key development assets.

5.1. POLICY ISSUES IN PLANNING FOR REDEVELOPMENT

A number of the policy issues commonly encountered in the redevelopment of decommissioned nuclear sites are described in this section.

5.1.1. Evaluating sites

The location of a site and the quality of its communication links have an important bearing on its redevelopment potential and resale value. Many nuclear sites benefit from the good communication links needed for their construction and their day to day operation. Some sites (e.g. the Hanford site and Los Alamos National Laboratory (LANL) in the USA) are also located far from centres of population in remote areas, which may or may not be a disadvantage. Some nuclear sites already have visitors' centres (e.g. British Nuclear Fuels (BNFL) at Sellafield in the United Kingdom). Others have historical museums and science museums for visitors (e.g. Oak Ridge National Laboratory (ORNL), the Hanford site and LANL in the USA; see also Section 5.1.4). Figure 3 shows visitors watching decommissioning activities at Vandellós nuclear power plant in Spain.

Sites which have poor communication links and are not close to other economic activity are disadvantaged with respect to exploiting such aspects as a redevelopment asset. This can be overcome by attracting the establishment of other industrial or commercial activities close to the site, for example by making unused land available at low rent and by lobbying regional

FIG. 3. Vandellós reactor building visiting point.

development agencies to consider improving communication links to the site or region. Such initiatives may take considerable time to be realized, so the appropriate parties must normally be engaged well before the site closure process is begun in order for the initiative to be effective.

A significant number of nuclear facilities (e.g. research reactors) were initially built on the outskirts of large cities. With the population growth in these areas, these facilities have now been fully encompassed within the city borders, where the property values have often escalated dramatically. In these cases the sale of property can definitely be a major asset for offsetting some of the decommissioning costs and facilitating the redevelopment of the site. One such case was the Risley reactor (see Table 2). In the course of decommissioning, the site was marketed and eventually sold in 1996. The proceeds from the sale reduced the overall cost of decommissioning by about 60% [31].

In cases where the site is to be redeveloped in a phased fashion, developers may be attracted by there being independent access to the site via separate routes. Multiple routes can also be helpful in facilitating decommissioning and demolition work by allowing for the timely flow and control of materials entering and leaving the site and by allowing for the segregation of personnel and motor vehicles. Opportunities during the life of the site to secure multiple accesses should be considered in terms of both the benefits at the time and their potential future usefulness in site closure and redevelopment.

Decommissioned facilities that are in close proximity to the site boundary may be a special problem for reuse if surrounding areas have become more populated during the construction and early operation stages. On the one hand, difficulty may arise with respect to such a location as a result of more conservative land use and real estate management policies having to be incorporated into the decision making process than may have been the case during the facility's construction and operational stages. The idea of the facility or site being in close proximity to homes and to the general public may cause greater concern than in the past. On the other hand, stakeholders may support the use of some of these facilities to the greatest extent possible, in order to minimize construction of 'very short term use' new facilities to support the cleanup of an area or site [32]. In general, such a location may lead to shorter times for dismantling of facilities and site redevelopment.

Developers generally have a preference for level sites of simple shapes when viewed in plan (generally circular or rectangular overall shapes). Operators with sites of an awkward shape, or sites that are made up of distributed land areas or are separated from main routes of communication, might consider taking opportunities to purchase additional land where this would make the overall site more valuable for redevelopment.

When considering the potential redevelopment value of assets on the site, it is important to distinguish between the different valuations that may have been placed on assets. The accounting or 'book' value of the assets is often determined from an initial purchase price and an allowed annual depreciation sometimes determined by tax laws. This accounting depreciation does not take into consideration factors which affect the market value of assets, such as physical degradation or wear, the availability of spare parts and the availability of alternative assets with lower operating costs. Often a group of assets with low individual values can be configured into a system with a much higher value. For example, a turbine and generator set with only scrap value might provide the basis for local power generation if configured with an appropriate boiler. Potential assets should therefore be viewed in terms of their potential to contribute to a particular redevelopment plan rather than in terms of their intrinsic or individual values.

Companies or organizations evaluating the feasibility of reusing a decommissioned nuclear site usually will perform a cost–benefit analysis. From a strictly internal perspective, this may prove that sale or redevelopment of the site will not provide sufficient return on the investment necessary to make it attractive to a new owner or tenants. From a broader perspective, the benefits of reuse may be very large but accrue instead to the community, which would profit from the retention of jobs and stable or increased tax revenues. In these circumstances, facility owners may be able to negotiate grants or payments in kind from local governments in exchange for a commitment to prepare a decommissioned site for reuse.

5.1.2. Relationships with outside stakeholders

Regardless of the operator's commercial interest in progressive decommissioning and site redevelopment, there are regulatory drivers that influence the progress of decommissioning. While regulatory regimes vary in different jurisdictions, many are based on similar principles. In some countries, there are specified obligations on the operator to reduce hazard and to make the site available for another productive use as soon as reasonably practicable after final shutdown.

The operation of any nuclear facility normally involves interactions with different external agencies and organizations, including customers, suppliers, regulators, and regional and local officials. In the case of site redevelopment, new parties will take an interest in the project, and the range of outside stakeholders may well increase. New stakeholders may include the potential new owners or tenants of the site as a minimum. Good practice from other industries and the limited experience of redevelopment in the nuclear industry suggest that involvement at an early stage of a wider range of stakeholders from the local and regional communities is both to be expected and beneficial. For example, legislative body representatives may be involved in matters such as property taxes and financial incentives to developers. Regional economic development councils are often established as the result of the decommissioning of a nuclear facility and new redevelopment opportunities. One such example, for the Apollo area in the USA, is given in Ref. [33].

The dynamic evolution of new relationships has the potential both to help and to hinder the redevelopment process, and all parties should seek to develop mutual understanding and trust. By working to encourage productive reuse of the site, the operator is contributing to the economic and social development prospects of the local and regional communities. This can be a positive factor in relationships with local stakeholders and may engage their support in matters such as planning consents and making adjustments to the local infrastructure to enhance the market value and potential of the site. Equally, the past operation of the site may have been characterized by secrecy or viewed with suspicion by local communities, and this could be a barrier to developing cooperation and trust. Charismatic personalities, strongly held traditions and past history can greatly influence levels of trust and cooperation.

Demonstrating that nuclear decommissioning and site redevelopment can be accomplished safely, efficiently, economically and sensitively can affect the future viability of nuclear applications by maximizing the economic value of a site. This will increase public confidence in the operator's management ability and may improve the operator's prospects for undertaking future development. In some countries, this demonstration of a positive outcome from the decommissioning of nuclear sites may be an important factor in the future growth of nuclear applications. In the wider context of sustainable development, it may be appropriate for facilities to be dealt with in the framework of repeatable 'cycles' of development and redevelopment, making the best use of land as a productive resource and avoiding periods of dereliction or incomplete restoration of the site. Under these circumstances the site is effectively and efficiently utilized for all parties.

Local communities are often most concerned with the employment prospects offered by site redevelopment and with any legacies of residual contamination or hazard. Their interpretation of issues will often be based on a range of factors wider than only the technical aspects. This can be a strong argument for unrestricted release. Although the responsibility for the remediation work remains with the nuclear licensee, the involvement of an independent, knowledgeable developer with an interest in ensuring that the closure activities are carried out effectively can provide additional public reassurance that remediation work on the site is being properly done. At a number of sites undergoing remediation, community advisory organizations (commonly called site specific advisory boards) have been established to advise the performing organization and regulators on concerns regarding the environmental remediation and decommissioning activities [34].

5.1.3. Social factors

Any of a variety of social factors or combinations of these factors can be of concern to local and regional residents with respect to decommissioning and site remediation projects. Examples of social factors include: public desires for space/real estate reuse options, property values, employment issues, perception of remaining radioactive contamination and loss of tax revenues.

Workers' employment concerns have been addressed in various sections of this report (e.g. in Section 5.2.1). If a sense of 'working yourself out of a job' or employment termination prevails, the timely, cost effective and safe progress of decommissioning may be impaired. In turn, this will impact site redevelopment opportunities as well. However, a judicious selection of site redevelopment opportunities that takes into account workers' concerns will help to mitigate these issues. For example, during decommissioning, workers will develop a new set of skills, which can be useful to other licensees or site owners with similar needs. Early retirement and transition to new jobs elsewhere within or outside the same organization are possible strategies to be pursued (for example through retraining) and implemented. In some cases state funding can be provided to facilitate the retraining and personnel development aspects of this approach. A summary of the different strategies being utilized to address this issue is presented in Ref. [35]. A detailed report of the economic conversion carried out at the Hanford site is given in Ref. [36]. (See also Section 7.1.5 and Annex I.H.)

Public concern over social issues can eliminate certain redevelopment options from further consideration. This was the case of the planning for reuse of the Barsebäck site in Sweden. The local community preferred to use the space where the yet to be decommissioned plant is situated for redevelopment and use as a housing development, while local government authorities planned to take advantage of the available infrastructure and use it for electricity production with a different heat source [13, 37, 38].

If employment at the nuclear site declines significantly during decommissioning, the local economy must adapt and become more diverse and less dependent on the nuclear site operations. This may alter the willingness of the community to allow for higher residual contamination levels at the site after licence termination. For example, the local community may demand more stringent restoration and environmental cleanup standards. This may adversely impact the opportunity to perform the decommissioning in a timely and cost effective manner and may slow the redevelopment process significantly [39].

Many communities see that their interests will be carried forward by their elected officials joining groups that will play a key role in protecting their interests. In Europe, a network of nuclear municipalities has been cooperating over the years in advocating the interests of the various local communities in nuclear power matters [40]. In the USA, the Energy Communities Alliance (ECA) is an organization of local governments near the USDOE sites and strongly impacted economically by the funding and activities of the USDOE programmes. The mission of the ECA is to share information, establish policy positions and advocate community interests in order to effectively address the communities' environmental, regulatory and economic development needs [41]. In the Russian Federation, a somewhat similar organization was established in 2000 under the name Association of Closed Cities of Russia. This group was formed by the Ministry of Atomic Energy, Ministry of Economics and Ministry of the Treasury as a means for local administrators of closed cities under redevelopment to determine what projects merited funding to assist in the transition from a closed city to an open city economic status [42].

5.1.4. Nuclear reuse

In many cases, continuing use of a site for nuclear operations may be a logical and natural outcome for a site after decommissioning, owing to numerous advantages, such as the availability of well qualified technical staff, existing public acceptance of nuclear activities, availability of characterization data from the site (both physical and radiological), and local availability of customized nuclear and conventional services. The reuse strategy is accepted in legislation in countries like Japan where land is at a premium and the current decommissioning strategy is to install nuclear power plant units at the same site as decommissioned nuclear power plants [43]. In other countries, difficulties in identifying new sites for nuclear installations may lead to the same strategy.

In some situations a new nuclear facility with different characteristics may be envisaged for a site following completion of decommissioning. For example:

(a) An option might be to collect radioactive waste from a number of national applications at one decommissioned site, which then after modifications becomes a centralized national waste storage facility. Local concern is a critical issue with this strategy. If a longer term disposal option does not materialize, this might become the proposed strategy for the Paldiski reactor building in Estonia. The building houses two former naval prototype reactors encased in concrete and other relatively large amounts of radioactive waste from other on-site facilities [44].

(b) Preliminary studies on the decommissioned EWA reactor facility in Poland have shown that it could be reused as follows: (i) In the reactor concrete shaft a dry storage facility for spent nuclear fuel elements could be constructed to house all the spent fuel from EWA, as well as the spent fuel from the MARIA reactor. (ii) The hot cells could be used to encapsulate nuclear fuel elements that have accumulated during EWA operation, or for material testing or other work with radioactive materials. (iii) The administrative/laboratory building of the reactor could be used for technological support of the above mentioned programmes [45].

(c) A nuclear R&D centre could be established (e.g. the proposed International Thermonuclear Experimental Reactor (ITER) facility) [46]. For example, the Mestral Technological Centre at Vandellós 1 nuclear power plant in Spain [47, 48] has three main objectives: care and maintenance of Vandellós 1 nuclear power plant during its dormancy period; R&D in decommissioning; and training for other decommissioning projects. Also, a decommissioning centre of excellence has been proposed for Chapelcross nuclear power plant in the United Kingdom [49, 50].

(d) A research facility could be established in lieu of a nuclear research reactor. For example, in the USA the old National Aeronautics and Space Administration (NASA) Space Radiation Effects Laboratory synchrocyclotron was vacant for a short period after decommissioning but was then converted, new equipment was installed and the facility was transformed into the present USDOE Thomas Jefferson National Accelerator Facility [51]. In Latvia, it is planned to install an accelerator at the site of the Salaspils research reactor, which is currently undergoing decommissioning.[3]

(e) An irradiator facility could be established in place of a shut down research reactor, as in the case of the RV-1 reactor in Venezuela [52].

In the case of the EBWR facility at the Argonne National Laboratory (ANL) site in the USA, the decommissioned reactor containment structure was reused as a temporary transuranic waste storage facility pending off-site shipment of this packaged waste. This made effective use of the facility in its post-decommissioning state and avoided a costly new construction project that

[3] IAEA Technical Cooperation Project on Establishment of a Multipurpose National Cyclotron Facility (LAT/4/007).

would have been required to meet the stringent new construction requirements for such a structure. It is reported that reuse of EBWR saved several million dollars of new construction costs [53].

Similarly, spent fuel could be stored at the facility site. In fact, this seems the most likely use of a number of decommissioned US nuclear power plants, pending availability of a centralized national high level waste (HLW) disposal facility [54]. Dedicated independent spent fuel storage installations are constructed at the nuclear power plant during the decommissioning to support the dry spent fuel storage activity. It should be noted that this option prevents at least partly the effective and full redevelopment of the site. As reported in Ref. [55], several reactors in the European Union were converted to spent fuel facilities. One of these facilities was the Avogadro facility, where spent fuel has been stored from other Italian nuclear power plants for many years.

A number of nuclear museums have been established on the site of (partly) decommissioned facilities or are planned. For example:

— Chinon-1 nuclear power plant, France [56];
— FR-2 research reactor, Germany [57] (Fig. 4);
— Mutsu nuclear ship, Japan [58];
— HIFAR reactor, Australia [59];
— ORNL graphite reactor, USA [60];
— B reactor, USA [61];
— EBR-1 and HTRE reactors, USA [62, 63];
— AM reactor, Russian Federation [64].

Some nuclear facilities are more suitable than others to be converted to nuclear museums or nuclear exhibition centres. This may depend on factors such as the interest shown by local communities and tourists, and corporate promotion policies. Location and access would be other important factors. Conversion to a nuclear museum can also be a convenient way to release part of the site for unrestricted public access while allowing radioactive decay of the remaining structures. One caveat is that environmental cleanup and historic preservation might be incompatible in times of tight budgets. Much of the cost would most likely be related to decontaminating radioactive areas [65].

5.1.5. Long term site use/mission

Recognition that the long term mission of a site has been completed or changed may come suddenly with a decision to close a facility, or this recognition may be come to only reluctantly after a period of any number of

FIG. 4. Permanent exhibition in the reactor hall of the FR-2 reactor.

years of progressive reduction in demand for the site's services. In both cases this recognition can signal that a new direction is needed. The future for such sites can take many different forms. Some may be decommissioned and cleared for unrestricted release for use by others. A specific reuse may be planned for the long term or perhaps only for the short term, possibly for equipment storage, temporary offices, waste storage, etc. In some cases, sites may not be able to be released for unrestricted use within the available budget and resources, but may be compatible with some form of restricted use. Where it is deemed essential to complete decommissioning, institutional controls and monitoring are maintained until sometime in the future.

Some site owners have found beneficial reuses for parts of sites and decommissioned facilities in their continuing R&D missions. Certain commercial nuclear power plant operators have elected to replace the nuclear heat source with a conventional fossil fuelled heat source and reuse the site for continued electricity generation. Examples are the Hallam, Piqua, Pathfinder and Fort St. Vrain nuclear power plants in the USA [66–68]. Uncontaminated parts such as turbines at the recently closed Chapelcross nuclear power plant in the United Kingdom could be salvaged for construction of a new wood and coal burning plant at the site. The owner (BNFL) believes that the Chapelcross site has a number of key assets — a skilled workforce, a sizeable amount of land, an available electrical grid connection and good transport links —that make it ideal for various reuse options. The construction of a conventional power plant at the site could help mitigate job losses for the 430 workers employed at the Chapelcross station [50, 69].

Where the reuse is to be under a new owner, the original owner may transfer the responsibility for post-shutdown management of any remaining parts of the site and residual risks arising from previous operations to the new owner. In some regulatory regimes this is the only way of relieving the owner from a potentially indefinite responsibility or at least of providing indemnity against those risks. Strategically this can be an important issue for any operator that wishes to free its balance sheet from these indefinite liabilities. However, it is important to recognize that the new owner accepts the liabilities. This has historically been the strategy in countries where utilities were being privatized and nuclear liabilities were transferred to the State to further the privatization process.

5.1.6. Facility ownership

A major factor in deciding on redevelopment is the issue of ownership of the property or facility — whether it is a government owned asset or a commercially owned asset. Depending on the size of the governmental organization seeking to release a property for redevelopment following decommissioning, the path forward may often be based on past experience. In all cases the regulator will need to terminate the nuclear licence for a site before its redevelopment either as a newly licensed nuclear site or as a non-nuclear site.

Large, government owned and operated assets can sometimes pose a challenge as to their redevelopment. Often governmental entities might be reluctant to give back ownership/control of properties to the public owing to the loss of possession of the space/land, or for liability reasons. The site may be well positioned geographically or have other strategic features that make its redevelopment undesirable. Also, government owned facilities do not have the same profit motive as the typical commercial firm. There can be various requirements placed on different agencies in the government as to how the property is to be released per se. This might involve consideration by other government agencies as to whether or not they might wish to claim it for their needs.

On the other hand, it is possible that under certain conditions, specific legislation in some Member States might be passed by the legislative body to authorize redevelopment of different sites. This is the case with some of the USDOE facilities that are now no longer needed for their original mission.

Many of these are being remediated, transferred to the private sector, renovated and redeveloped as commercial enterprises, as authorized by the US Congress.

Commercial firms with a responsibility to shareholders are often much more interested in redeveloping a site after decommissioning and licence termination. Commercial firms need to generate revenue from their investment in this property or risk losing money on the property, since they are liable for real estate taxes on it.

5.2. MANAGEMENT ISSUES

A number of the management issues commonly encountered in the redevelopment of decommissioned nuclear sites are described in this section.

5.2.1. Staff reduction strategy

It is almost inevitable that any decommissioning project ultimately results in a loss of jobs. A large scale example of this fact is obvious when one looks at the reduction of the USDOE workforce over a period of years, as shown in Table 4 [70]. The total employment figures dropped by about 31% owing to the end of the Cold War, reduced R&D budgets for both commercial and defence programmes, and a transition to increased funding for decommissioning and environmental remediation. A judicious management of staff resources, however, may alleviate workers' concerns through job transfer and/or retraining mechanisms. To be fully effective, these may require the intervention and assistance of regional or national authorities, as described in several examples below.

In any decommissioning activity the selection and retention of the appropriate staff and the maintenance of good workforce morale are important management challenges. The positive outlook encouraged by a decision to redevelop rather than permanently close a site can make an important contribution to maintaining the morale and commitment of the workforce. When combined with good community relations, it also puts staff in the position of working for the benefit of the local community and with its support. These motivating factors are even stronger where there is a clear reuse plan and where the site will transfer quickly from one activity to the next so that continuity of employment and indirect economic benefits are certain. Poor redevelopment prospects, or a failure to convince the workforce and the community of the sincerity of the management commitment to successful

TABLE 4. STAFFING LEVELS AT VARIOUS USDOE SITES IN 1992, 1998 AND 2002

	1992	1998	2002
Fernald	1 489	1 977	1 554
Hanford	15 107	10 984	12 213
Idaho National Laboratory	7 901	5 743	5 273
KC Plant	4 489	3 256	3 106
Lawrence Livermore National Laboratory	7 981	6 608	7 081
Los Alamos National Laboratory	7 203	7 009	7 679
Mound	1 741	708	565
Nevada Test Site	6 670	2 515	2 806
Oak Ridge National Laboratory	17 257	13 573	11 172
Pantex	2 673	2 856	3 210
Pinellas	1 569	0	0
Rocky Flats	7 302	3 166	2 490
Sandia National Laboratories	8 473	7 501	8 042
Savannah River Site	20 979	13 082	11 755

redevelopment, can lead to feelings of insecurity, thereby undermining staff morale and cooperation. This is especially relevant in the case of remote sites where alternative employment is not available locally and the site is responsible through payroll payments, tax contributions and supply contracts for an important part of the whole economic activity of the area. In Section 7 and Annex I there are several examples of decommissioning projects where re-employment concerns were the driving force for site redevelopment (ORNL and Mound, USA, and Greifswald, Germany).

A common problem encountered in the site closure process is the loss of the best and most marketable staff members to other employers with a more secure future outlook. The loss of these key staff can seriously undermine the effectiveness of the closure work and redevelopment programme, leading to rising closure costs, extended closure programmes, and in the worst cases, failures in management and implementation of safety standards. At US nuclear power plants, there are several cases where staff incentives (bonuses) were used to retain key staff through completion of site decommissioning. By providing new employment opportunities associated with the site redevelopment activity, this problem can be further moderated. This was a key factor in triggering the Nuclear Cities Initiative discussed further in Section 7.3.1.

During the formulation and planning of site/facility redevelopment, one must not overlook the opportunity to redevelop the skills of the site staff either for new jobs in the community or even for jobs with one of the redeveloped site employers. The following are some examples of how the USDOE has exploited this aspect of further developing the skills and expertise of its own staff and its contractor staff:

(a) At the Portsmouth gaseous diffusion plant site, the community reuse organization worked with Ohio State University to implement a process for certification of workers in workforce skills levels. The purpose was to assist with building worker skills and encourage career advancement [71].
(b) At the LANL site, the local community colleges provided additional classroom style training for displaced workers. This included distance learning facilities and programmes on the campuses of the local community colleges and universities [72].
(c) At the Fernald site, the operating site contractor encouraged employees to explore professional development opportunities, and set up a career development centre and tuition reimbursement programme. Additionally, it supported the workforce in pursuing other jobs after the decommissioning and environmental remediation were completed by exploiting those skills acquired in actually performing that work [73].

5.2.2. Management complexity

In adopting a redevelopment strategy, the operator of a site takes on new responsibilities for preparing and marketing the site and for integrating the new user's needs into the work to decommission and release the site. This can add to the scope and complexity of the work and the variety of expertise needed. Strategies for reducing the overall complexity of the management problem can play an important role in maintaining management control. These strategies can include:

(a) Eliminating or reducing specific kinds of hazard so that the need to ensure the maintenance of the facilities, expertise, procedures and regulatory controls related to them is eliminated or reduced. Examples include the removal of fissile materials to reduce the need for criticality control and safeguards arrangements, and the removal of specific materials such as sodium and beryllium to reduce the occupational hazards these pose in the workplace.

(b) Reducing the physical ‘footprint’ and reducing the volume of work related to the site area or perimeter. In this way the scale of activities such as monitoring and the maintenance of security forces can be reduced.

(c) Transferring to the developer responsibility for some of the assets on the site before decommissioning starts. An example would be the turbines and the high voltage systems connecting to the electricity distribution grid in the case of redevelopment involving repowering of a former nuclear generating plant.

5.2.3. Stewardship

The objective of stewardship planning is to ensure that an entity is identified that is responsible for the long term care of the contaminated or uncontaminated areas, to preserve information on the location and longevity of residual contamination, and to ensure that future generations are aware of the contaminated areas. Stewardship planning does not determine the future use of contaminated land, but only the care that must be provided when contamination remains on the site [74]. At some USDOE sites, on-site waste disposal facilities have been used for disposal of decommissioning and remediation waste from site closure. These disposal facilities are an example of an area requiring long term stewardship.

Funding for future stewardship needs may be provided for in a variety of ways. A company may pay as it (or a third party) undertakes the necessary surveillance and maintenance activities. Often the responsibility for long term stewardship is transferred to the local or regional government, since they are likely to continue to function ‘in perpetuity’. In such a case, funding for stewardship may take the form of annual payments into a trust fund that can only be accessed after site closure. In either case, the company faces an indefinite liability for costs associated with ensuring that the site remains secure and no contamination can migrate to or affect off-site areas.

If reuse is to occur, then the degree of contamination remaining must be compatible with the chosen new use, and the new user will become responsible for most, if not all, of the stewardship conditions, activities and costs. A key action prior to transferring the site for reuse is the establishment of an information management system that will preserve the data on the location of residual contamination and the reasons for any associated institutional or physical controls. This is in addition to the facility drawings and other relevant records. Table 5 lists the types of information that are essential to long term stewardship.

Long term stewardship requirements will vary greatly depending on how the completed/decommissioned site is configured and on any plans for site reuse. Planning for the stewardship of a site is part of the decommissioning planning process, as the costs and liabilities associated with stewardship may influence the final decision on decommissioning implementation, degree of remediation and reuse of a site.

5.3. TECHNICAL ISSUES

A number of the technical issues commonly encountered in the redevelopment of decommissioned nuclear sites are described in this section.

If the greatest benefit is to be derived from redevelopment of a retired nuclear installation, it is imperative that:

— Sufficient detailed planning is performed;
— Preparations for redevelopment are both timely and thorough.

TABLE 5. CATEGORIES OF INFORMATION ESSENTIAL TO LONG TERM STEWARDSHIP
(adapted from Ref. [74])

Regulatory	Site management	Land use controls	Public education
Permit and licence applications and associated reports	Residuals and hazards remaining on-site	Deeds, affidavits, notices specifying land condition	Public information pertaining to environmental conditions and land uses
Siting permit	Elements of site infrastructure (residual and active)	Land use restrictions due to contamination	Educational information
Operating licence	Operating systems for contamination control	Plat maps of contaminated land	
Administrative record	Environmental information and monitoring data		
Post-decision documents	Operations records and personnel records		

Factors determining the most efficient sequencing of activities can have a strong influence on the overall cost and likelihood of success in this work.

5.3.1. Continuity of site services

By engaging in a partnership with the developer who will take over the site, the operator can make provision for the developer to support the final stages of decommissioning by providing continuity of site services. This is then a fully burdened cost that is avoided by the decommissioning project. However, it is important to note that the operator remains responsible for those areas until the turnover. For many closure projects the last stages are problematic because the communication, management and support structures on the site have been dismantled. This makes any work difficult. In the redevelopment case, the developer will be responsible for preserving or putting in place for the redevelopment activities the capacity necessary to support these last operations. This also applies to security, where in the final stages of decommissioning, maintaining the security of the site becomes increasingly difficult as the physical structures are removed and other infrastructure is dismantled. In the redevelopment case, the responsibility for security can pass progressively to the new developer, ensuring continuity of protection against illegal waste disposal, malicious damage and theft. The concerns of the security guards at the former ORNL K-25 gaseous diffusion plant in view of the forthcoming completion of the facility's decommissioning are described in Ref. [75]. In fact, there might be only a limited need for a security service once the facility is converted to a new use, owing to the less sensitive activities being committed.

5.3.2. Construction sequence

Many older industrial sites have developed from an initial core of facilities, sometimes centrally located on the site. These core regions of the site tend to contain facilities and installations (administration and design buildings, canteen facilities, and communication, security and stores functions) that are less specific to the productive purposes of the site. If in good condition, they represent a group of facilities suitable for reuse and provide the starting point for redevelopment of the site in a new productive use. In these circumstances the configuration of the site often lends itself to ready decommissioning of the installations outside the main area without significantly interfering with the viability of the central infrastructure. This is in contrast to sites, for example chemical sites, that are built as closely integrated systems and where decommissioning of any part of the site interferes with operation of the rest of the site.

5.3.3. Redevelopment of buffer areas

Many nuclear sites have areas, particularly around the outside of the plant or sometimes outside the plant perimeter, which are owned by the operator but which provide a 'buffer' area separating the operating plant from the nearest commercial activity or publicly accessible area. In some cases, these buffer areas can be safely developed early on after the nuclear facility has ceased production or once removal of the main radioactive inventories has been completed and the hazard level has been substantially reduced. Early redevelopment of these buffer areas can help to get the development process started and provide income to fund the decommissioning of the remaining site structures.

A secondary benefit arises from the progressive release of parts of the site for redevelopment, because the costs of many decommissioning activities and the associated care and surveillance activities are related to the area of the site considered to be the licensed site. Examples are: security, grounds maintenance and service, communication lines maintenance and surveys. By progressively releasing parts of the site for redevelopment as they become available, the size of the remaining site is reduced and these operating costs are also progressively reduced. By confining the decommissioning activity inside a smaller boundary, the potential for recontamination of clean areas sometimes used, for example, as temporary storage is reduced. Maintaining a small footprint area also encourages good housekeeping, for example early decisions on the disposition of accumulating waste packages.

It should be noted that some legislations, e.g. those in the USA, allow for early partial release of a portion of a site prior to completion of decommissioning for the entire site, on the basis of the risks associated with the early partial site release [76].

5.3.4. Interim reuse

Some sites may elect to select parts of certain facilities for an interim reuse. This is especially the case if modifications to an existing facility or area within a facility located in a very remote or confined area are required to finalize the decommissioning of the facility. Some limited decommissioning may be done to retrofit the decommissioned area to provide support for the final decommissioning of the entire facility or plant. This is true of an area that may be modified to allow for the processing of certain waste types remaining on the site that require treatment prior to disposal, e.g. high level liquid waste or possibly scrap metals generated in decommissioning, which may be melted for reuse in waste containers [32].

5.4. PROPERTY VALUE ISSUES

The redevelopment potential of any site will depend heavily on the characteristics of the particular site and the local circumstances. Often it is a combination of factors that create the most valuable redevelopment prospect for any particular site. There are no general rules that can be applied widely across sites to direct the investigation of redevelopment opportunities. Each site must be assessed individually on the basis of its assets and location. However, there are important aspects which apply to many sites and which site operators should consider in their site planning process. The factors that are often found to have an important impact on the redevelopment value of sites are of particular interest. These are considered below, with suggested actions that operators might take to enhance their site's potential value.

If the work required to return a nuclear site to its natural or baseline state is compared with that likely to be required in preparation for redevelopment, it is likely that in many cases the redevelopment option would require less work. For example, it would not be necessary to demolish any structures that were to be retained for reuse and it might not be necessary to fully restore soils to free release criteria in those areas where they will be covered by the new development. Section 7 gives several examples of structures that were reused for new purposes (some with adaptations, e.g. the CP-5 Vaporsphere at ANL, USA, Fig. 5). Another example is an old reactor building at the Hanford site that had been prepared for a new prototype test reactor. The facility was decommissioned and was then refitted for the new SP-100 space reactor programme [77].

5.4.1. Radiological release criteria

For some nuclear sites and in some regulatory regimes it may be economically impossible in the short term to meet the radiological criteria for delicensing. This situation may arise when a residual hazard, such as that from low levels of surface deposited radioactive contaminants, is sufficiently dispersed that remediation techniques cannot economically achieve those criteria. In these cases the actions available to operators who want to free themselves from the liabilities associated with the site are to transfer the ownership and operating licence for the site to some new user or to opt for restricted release of the site. Typically this is a less than desirable scenario for the regulators, who have difficulty in being able to verify the commitment of the licensee or the licensee's agent to effectively and diligently undertake the required actions until full site release can be granted. It should be noted that unrestricted release levels have generally been lowered in a number of countries over the last few years. In parallel, technological and statistical approaches to verify compliance with release criteria have been progressively refined. This evolution has resulted in cases where an already delicensed site has been reconsidered for further cleanup work [78], or release criteria have become more stringent in the course of decommissioning [79], causing significant extra costs and delays. The recent international harmonization of clearance levels [80] is expected to favour the establishment of clearance criteria and relevant compliance procedures in a number of decommissioning projects.

Cleanup criteria can help in identifying opportunities for a property or a part of it to be reused. For example, reuse of portions of the Fort St. Vrain nuclear power plant was possible because its radioactive side was decommissioned to unrestricted release and then the non-radioactive component was reused for a fossil fuelled power plant. This also resulted in a cost saving to the utility of about US $60 million through the use of existing facilities rather than building new facilities for the refired plant [81]. In the case of the K-25 site at the East Tennessee Technology Park (ETTP), cleanup of some areas was carried out, but some of these same areas are now being used for other radiological operations. (See Annex I.I.)

FIG. 5. Vaporsphere, formerly used as an auxiliary facility to the CP-5 reactor, was free released and reused by ANL Operational Services as a storage facility.

Safety and health are strong considerations in plans for any reuse. For example, whether a site is to be reused for a radiological or a non-radiological application, such as a child care centre (unrestricted reuse), has a strong bearing on the allowable criteria for residual contaminants and hence on the planning process for decommissioning. In the Superfund programme of the US Environmental Protection Agency (EPA) [82], there has been a focus on relieving the site owners of properties of some liabilities if future redevelopment would allow the sites to be released in a less than pristine condition. These sites are called 'brownfields' and are typically to be reused for an industrial (non-residential) operation. At a local community level, this same approach has been used in the USA in the city of Chicago. The city worked in cooperation with the local electric utility (Exelon) to convert old industrial sites into productive use by industrial firms, thereby increasing tax revenues for the city, while Exelon benefited through the sale of electricity to the new businesses [83, 84].

Another example from the USA is that of the Rocky Flats plant, formerly a USDOE nuclear facility. The majority of the site was managed as a security buffer around the plant and is an undisturbed setting for a variety of wildlife species. Following completion of the cleanup and closure efforts, scheduled to occur in 2006, the site will be transferred to the US Fish and Wildlife Service for management as a wildlife refuge and public recreation area. The USDOE will retain access rights to the site for the monitoring and management of certain remediated facilities [85, 86].

A proposed plan, called the Risk Based End State Vision, would allow the USDOE to explore the possibility of cleaning contaminated soil to meet industrial rather than residential standards. Applications of this strategy and the ongoing debate concerning it are given in Refs [87–89].

Setting broad environmental goals rather than fixed standards for cleanup may imply that cleanup decisions are made in practice on a case by case basis. Inconsistencies in decision making inevitably arise. In contrast, setting an unambiguous set of cleanup standards has the advantage that it provides a clear end point for site decommissioning and encourages redevelopment strategies [39].

5.4.2. Waste volumes

Operators have a responsibility and a financial incentive to minimize the amounts of radioactive waste and other waste arising from the decommissioning process. By leaving intact and handing over to the developer structures on the site that are useful to the future planned site activities, the work of demolishing them and processing the resulting demolition waste is avoided. In practice much material is handled as radioactive waste even though it probably falls below clearance criteria. This is done owing to the cost and difficulty of demonstrating that the material is below the clearance criteria and to alleviate societal concerns. This issue may be avoided where structures are left in place. In some cases it may be possible to benefit from additional decay of any radioactivity in structures that present no significant contamination hazard. In the same way, other secondary emissions and environmental impacts associated with demolition and waste treatment are reduced in the redevelopment case. One good example in this regard, although on a small scale, is the RB-1 decommissioning project described in Section 7.3.4.

5.4.3. Site characterization data

Reusing a site is often a convenient strategy in terms of the information and legal authorizations that would usually already be available to the redeveloper. For example, copious information on demography, geology, hydrogeology, seismology, floods, etc., is usually available as part of the licensing process for a nuclear site. This information would not need to be produced again from the start, as is the case for a new industrial site. Associated with this issue, site permits and records (with regard to electrical lines, non-radioactive and radioactive discharge limits, etc.) that are based on the above mentioned site characteristics would already be in place for a new plant at the site and would not need to be requested from the authorities. This is particularly relevant where new nuclear uses are being considered and licences for nuclear operations are already in place. One typical case is that of the JRR-3 site (Section 4.3), where the site was re-equipped with a new reactor using the existing infrastructure, licences and technical basis for the safety case. (See also Section 6.3.1.3.)

The work previously performed to characterize a nuclear site in terms of structural conditions, groundwater monitoring, quantification of seismic hazard and the condition of installed facilities and services (non-nuclear infrastructure) can be attractive in reducing the initial level of investment of any developer considering the site and in reducing the risk associated with new industrial uses. Details of site surveys, analyses and assessments should have been retained and be available. Conversely, uncertainty about contamination levels on the site might discourage investment. Therefore it is important that records be retained that support claims that contamination of the site is below regulatory release values and well understood. On large operating sites, it may be appropriate to segregate areas and allocate them to nature conservation or some other productive use (farming is possible in outlying parts of some sites or buffer areas; see Section 5.3.3), which, in later years, would support arguments that these areas are clearly not radiologically contaminated.

Certain facilities may have areas that are inaccessible during operation and have residual contamination or activation present in structural materials. In the course of decommissioning, these areas may become accessible. They may or may not pose a hazard to the new user, depending on the final planned use of the facility, and may be able to be isolated to allow for reuse of other parts of the site. For example, clean areas are freely open and accessible to visitors. This is the typical condition where nuclear museums are installed (Section 5.1.4). Depending on the residual contamination or activation levels, certain restrictions may be placed on the options for reuse of the decommissioned facility [32].

5.4.4. Age and condition of structures

It is typically easier to find a beneficial reuse for a newer structure than for an older one. Although short term use of the structures may be possible, long term use may not be cost effective or even possible, owing to structural degradation. In addition, decontamination and dismantling can weaken the structural integrity of buildings, especially if they involve (a) removing large areas of concrete, or (b) 'chasing leaks' of radioactivity into underlying foundations. An assessment will need to be performed of the financial resources available and/or needed in order to beneficially reuse those areas that have structural degradation from the decommissioning.

Older facilities may need to be evaluated to determine whether they can be modified in a cost effective manner to comply with any relevant 'beneficial occupancy' structural building codes. Since many of these structures are likely to be more than 20 years old, they may not be able to comply with many of the current structural requirements (or are able to comply only at the cost of expensive, time consuming reassessment, thus precluding some reuse opportunities) [32]. Reuse may still be possible if the local building codes (or the relevant regulatory body) will allow some exceptions. Reference [90] gives an interesting example of how deteriorated structures may hinder facility redevelopment.

5.4.5. Trees and other natural features

Where land is to be used for non-commercial (residential or leisure) development, its value can be significantly increased by the presence of mature trees. Mature trees can also have other environmental benefits for operating sites and sites in decommissioning:

— They can be used to improve security by impeding unauthorized vehicle access.
— They can be useful in restoring the site to a ‘natural state’, including, inter alia, preservation of wildlife and biodiversity.
— They can recontour the site to facilitate drainage.
— They can provide a screen that reduces the visual impact, noise and dust from site demolition and construction work.
— They offer shade, which is especially valuable in warmer climates.

Operators might consider tree planting as a measure to improve the long term redevelopment value of the site, especially where the site is located close enough to centres of population that it might be suitable for residential or light commercial development.

A similar rationale would be applicable to lakes, meadows and other natural features. For example, lakes and ponds may favour the restoration of wildlife and ecosystems that will be of advantage in the restoration of adjoining land, or may allow the establishment of marinas and boat clubs. In turn, the return of wildlife to the site may favour ecological and biological studies, taking advantage of environmental assessment skills that may have existed during a facility’s operation. Large areas of meadows may, for example, allow the establishment of golf courses [91]. Large fields may be returned to agricultural uses and remaining buildings reused for the associated food industry.

5.4.6. Underground features

The presence or absence of any of a number of various underground features may impact the ability of a site to be redeveloped after completion of the decommissioning process. The underground features considered in this connection might include: vaults, tanks, pits, water supply systems, fire protection systems, sewerage systems and other waste retention systems. Often as a part of the decommissioning, some of these structures or systems may, if contaminated, require removal or remediation. Depending on the planned future use or redevelopment plans for the site, full removal of the remaining clean systems may not be beneficial. Even some radiological systems may be left in place if another follow-on application as a nuclear facility is envisaged. A comprehensive discussion of the decommissioning issues raised by underground structures, systems and components is given in Ref. [92]. Factors are discussed that may favour the retention of such elements in place or determine a dismantling strategy.

In the case of one former nuclear facility [93] that was successfully decommissioned, the fact that the site had an existing underground infrastructure enhanced the potential for site redevelopment over that of another site in the same general area.

5.5. KEY DEVELOPMENT ASSETS

Experience suggests that the development potential of a redundant site is often dependent on one or two key assets left over from the site's operating life. These assets can provide an important catalyst for a particular redevelopment plan or serve to improve the attractiveness of the site as an investment proposition for developers.

An important step in exploring the redevelopment potential of a site is to identify these potential key assets and assess their relevance to future development scenarios. Once identified, these assets should be protected from deterioration during the remaining life of the site. In the case of nuclear facilities, these might include:

- A desirable area with a high standard of living;
- High quality electricity grid supply connections;
- Airstrips and road, rail or sea access with offloading facilities;
- Sewerage and other piping networks;
- A partly 'captive' local workforce with a high level of technical skill;
- Office space, in particular prestigious old buildings, perhaps with historical significance;
- Support services (catering, public transport, etc.);
- Non-radioactive machine shops, workshops and general production facilities, especially those with large machinery, stocks of spare parts or consumables;
- A large, flat site suitable for a substantial manufacturing investment or for a smaller investment while still retaining the future potential for contiguous expansion;
- Sports and leisure facilities.

5.5.1. Standard of living

A facility located in close proximity to or in an area with a comfortable standard of living will be more desirable for redevelopment. Advantageous conditions would include: good quality education systems, a reasonable tax base, a low crime rate and a user friendly living environment. These attributes were cited for the marketing and redevelopment of the USDOE Mound and Pinellas sites. In the specific case of the Pinellas site, its close proximity to a high technology corridor while also being only ten minutes by car from a beach was seen as a very attractive feature [93, 94]. (See also Annex I.H.)

5.5.2. Electricity grid connection

A high capacity connection to an electricity distribution grid is present at most nuclear power plant sites. This makes them especially suitable for redevelopment as an alternative electricity generation plant, or for an industrial development dependent upon heavy electrical power usage (see Section 5.1.5 on conversion of nuclear power plant sites for new kinds of electricity production). Furthermore, most nuclear sites are equipped with backup electricity systems, typically diesel backup generators, which can frequently be converted to non-nuclear applications.

5.5.3. Site accessibility

Site accessibility can be a key asset either for industrial applications or for recreational activities in some cases. The operation of a nuclear facility requires frequent access for staff and equipment for facility maintenance and repair, as well as visitor access. In the USA the former AGNS nuclear site, which following decommissioning was transformed into the South Carolina Advanced Technology Park, is so located that there is easy access to air, rail and waterway transport facilities, all within a 200 km radius or less of the site [95]. In contrast, some nuclear facilities are situated in remote, almost inaccessible places owing to security and/or radiological concerns. This could be a complication for industrial redevelopment purposes, but depending on the redevelopment envisaged, isolation could actually be a significant asset, for example for the siting of hazardous industries. An interesting case is the use of a small area of the USDOE Nevada Test Site where isolation of the area is very advantageous. Large and small scale testing of hazardous materials for personnel emergency response training purposes, field test detection, plume dispersion, exposure testing, and equipment and materials testing can all be performed by different organizations through a fee based system [96].

5.5.4. Infrastructure network

The availability of a sewerage network is another good asset for site redevelopment. However, the underground piping in some parts of a nuclear facility may have collected radioactive leaks during plant operation, and assurance of an absence of residual contamination should be provided before reuse is allowed. One recent case is described in Ref. [97]. The water authorities in the interested counties have determined that there are no insurmountable obstacles that would prevent the construction of a desalination facility near the San Onofre nuclear power plant in the USA. The pipes used to draw in sea water to cool the reactor could be used in the desalination process, dramatically lowering the cost of constructing the desalination plant.

5.5.5. Skilled workforce

The local workforce employed at the site is an important issue at the time of decommissioning and subsequently of site redevelopment. In fact, it may happen that some skilled labour may leave the site before decommissioning is fully implemented, owing to long term employment concerns. Early planning for redevelopment may attract some personnel to remain and possibly be involved in supporting the redevelopment activities. In contrast, some skilled labour may have personal reasons not to leave the area and yet cannot find adequate alternative jobs locally. The availability of local skilled labour is a potential advantage for site redevelopment if industrial contractors can recruit from the local workforce. (See Annexes I.H and I.I.)

5.5.6. Accommodations for administration

Office space is a valuable asset from the viewpoint of any redevelopment. Practically any reuse will require space for offices for administration, visitor access, etc. Depending on building size, reuses such as theatres and conference halls may be considered. In parallel, most nuclear facilities offer laboratories, buildings, warehouses, etc., that can easily be refurbished to support such purposes. This is an area where the challenge is basically to match the supply with the demand. Prestigious buildings may lend a distinctive character and may accommodate or support facilities such as museums and exhibition spaces. (See the Jason reactor case described in Section 7.2.4.)

5.5.7. Support services

Support services, such as catering, motor pools and public transport, may have been available to support the workforce during operation and decommissioning of the nuclear facility. Such services should be an asset for the establishment of new companies when the site is being redeveloped and utilized. It would be important for the site planners to prevent any long periods of discontinued services that could lead to their permanent cessation. In the case of the redevelopment of the USDOE Pinellas site, the availability of a children's daycare service, and on-site dining and meeting facilities were identified as key assets [94].

5.5.8. Machine shops

Machine shops could be converted to non-nuclear applications, also by taking advantage of skilled labour. This process may require preliminary decontamination of nuclear workshops, an operation that can usually be accomplished without much difficulty. Stocks of spare parts or consumables (heating fuel, liquid nitrogen, etc.) may be reused for machine shops or other new facilities. (See Annex I.H.)

5.5.9. Suitable terrain

A large, flat site would be desirable to allow open space for new industries while maintaining adequate space for on-site roads, parking lots, etc. As mentioned earlier, it is also important that infrastructure facilities, such as electric power, a sewerage network, and an industrial and potable water network, be available. Normally all these facilities are present as a result of the operation of a nuclear facility, but refurbishment activities may be needed in order to accommodate the redevelopment needs. In the case of the former AGNS site mentioned in Section 5.5.3, a suitable terrain was a key asset for the redevelopment of the site and its utilization as an industrial park [95].

5.5.10. Leisure facilities

In the case of one site (see Annex I.E), the key asset was a high quality sports and social club built in traditional style and with excellent facilities. It was originally provided for the employees and their families on the edge of the production site but served as the base for redeveloping the site as a leisure park, also making use of the mine water lake as the focal point of a new golf course.

6. REDEVELOPMENT: ORGANIZATION, ROLES AND RESPONSIBILITIES

6.1. NEED FOR EARLY PLANNING FOR REDEVELOPMENT

Once redevelopment opportunities are identified, they can be incorporated into planning for the future of the site. For example, if the opportunities rely on key assets, these can be identified for protection and conservation. In many cases, areas free from surface contamination may be suitable for residential or recreational development. These should be identified in the site plans to avoid their becoming contaminated or otherwise unavailable.

Early planning for closure provides opportunities that may not be available in conventional development planning. In particular, by discussing the long term prospects for redevelopment of a site with local planners and potential development partners, the upgrading of local infrastructure can be influenced to favour the development of industrial activity and communication links. By using the site to attract other commercial activities, the disruption in employment caused by closure may possibly be reduced. In some cases, advance planning for decommissioning may identify problems that require either new technology (such as cleanup techniques) or the development of new infrastructure (such as waste disposal facilities). By identifying these needs early, the opportunity is created for orderly development of solutions, and the potential for costly delays in decommissioning and redevelopment is reduced.

Delays are commonly encountered in decommissioning projects because of inadequate provision of funding. Such delays can lead to missed redevelopment opportunities and can undermine partnerships with co-developers. Advanced planning provides an opportunity to estimate the future costs of redevelopment and the potential income from the sale of the site and its assets. It is important that the operator take account of these anticipated cash flows so that financing is available at the appropriate time to pursue the most economically attractive option overall.

6.2. KEY PLAYERS IN PLANNING FOR REDEVELOPMENT

Decisions regarding site decommissioning and reuse are ideally made with some input from outside stakeholders. This ensures that as planning, decommissioning and reuse proceed, regulatory and stakeholder needs and concerns will be properly addressed. Regulatory authorities will monitor the decommissioning process and results to ensure that their requirements are met. The local community, including elected officials, interested citizens, workers, business interests and environmentalists, will have a range of opinions regarding the closure of the nuclear facility and its redevelopment.

Good relationships, including open communications, with regulators, government officials and other stakeholders can lead to faster approvals and increase the supportive participation of these persons in site rezoning planning and other regulatory issues. In addition, they can motivate the community to be successful in obtaining new investments in the decommissioned site [98]. Inviting input from stakeholders early in the process will increase public confidence that any residual risks will be appropriately managed. This facilitates the redevelopment process and reduces pressure for possibly stricter redevelopment standards.

The following sections discuss the roles and responsibilities of various organizations in enhancing the redevelopment potential of their sites. The suggested actions are grouped in terms of the area of responsibility of those who would need to initiate them within the respective groups. Four groups are considered:

(a) *The current owner* has the overall responsibility for safety and decommissioning, and is usually represented by senior management, property management and technical support. It should be noted that in some instances the owner and licensee might be different organizations. In these cases the licensee is responsible for safety and for regulatory interfaces.
(b) *The authorities,* i.e. nuclear regulators and environmental authorities, will ensure that regulatory requirements are met and that reuse of the site can take place without undue risk to future tenants, the public or the environment. Early involvement of the authorities in the planning of reuse will be beneficial to the process.
(c) *The redeveloper,* as represented by the redeveloper organizations and potential investors, will procure funding and be focused on profitable development of the site to ensure business success.
(d) *Other external stakeholders* include elected officials, neighbouring communities and non-governmental organizations (NGOs). Some stakeholders can be the source of innovative solutions to site problems, while some can have conflicting agendas. Past relationships with stakeholder groups during the operational period can also influence public trust in the ongoing dialogue. It is therefore important to solicit input from a variety of stakeholder organizations. This includes low income groups, ethnic minorities, indigenous peoples and other groups that are traditionally less

well represented. Local residents will also need to be informed of the project as it develops [99].

In general, many (if not all) of the key players identified above will be involved in the four phases (Section 4.5) normally encountered in a redevelopment project.

6.3. ROLES AND RESPONSIBILITIES

6.3.1. Current owner

Several representatives of the current owner are key players in the redevelopment of the site. These include senior management, the property manager, and facility operators and designers.

6.3.1.1. Senior management

Senior managers can facilitate redevelopment by:

(a) Defining the policy for the management of the closure of the liabilities and site.

There is a tendency for matters relating to the eventual closure of an operating facility to be considered of low priority. This is often because there is no perceived urgency for action and because there are few management indicators that focus attention on closure. Therefore it is especially important that management policy include closure and that managers be accountable for the way in which their actions affect the long term liabilities faced by the organization.

(b) Ensuring that approved decommissioning and closure plans are prepared for all installations and liabilities, and that these are used to identify the need for short term actions.

These plans provide, among other things, assessments of the expected costs and schedule, and potential benefits likely to arise when the installation reaches the end of its useful life. More importantly, these plans also offer the opportunity to consider immediate actions that could increase the future benefits and reduce actual or potential costs.

(c) Making managers accountable for the effect of their actions on the closure liabilities faced by the organization.

One way to help identify these immediate actions is to consider a range of anticipated scenarios for the end of life of the installation, including decommissioning and site redevelopment, and to identify and evaluate those scenarios that are most favourable.

(d) Appointing staff to monitor and promote the future redevelopment potential of the site.

In adopting a redevelopment strategy, the operator takes on new responsibilities for preparing and marketing the site and integrating the needs of new users into the scope of work to decommission the site. This adds to the scope and complexity of the task and to the variety of the expertise needed. These factors point to the potential benefits of having a designated person to be responsible for monitoring and promoting the redevelopment potential of the site in response to changing circumstances (both on the site and in the local economic area). Senior managers should therefore consider delegating this responsibility to an appropriate person.

6.3.1.2. Property manager

A specialist property manager can help ensure that site redevelopment is cost effective by:

(a) Determining what work should be completed prior to disposal of the site by identifying those existing buildings and facilities that have an economic future and those that do not and should be demolished.

Despite the common features shared by many nuclear sites, redevelopment opportunities are rarely the same for any two sites. This is because of local and random factors impacting development opportunities and because of the different regulatory, political, climatic and geographical conditions in different regions. It follows, therefore, that the redevelopment plan takes into account the specific circumstances of the site and the local factors affecting its redevelopment potential. This planning requires the specific expertise of property managers rather than that of the corporate managers discussed in Section 6.3.1.1.

(b) Seeking the advice or interest of development groups who have experience in the area, bearing in mind that they are potential future partners in any redevelopment activity. This will also involve discussing the possibilities with local (including state, municipal and regional) planners to determine the long term economic development plans for the local area and the surrounding region.

6.3.1.3. Facility designers

A facility designer can assist future redevelopment by:

(a) Considering the implications of decisions taken at the design and construction phases for future potential reuse of the facility or site.

Many aspects of the design of nuclear facilities have a direct bearing on their future redevelopment for reuse. A comprehensive discussion on how design features may facilitate — or complicate — decommissioning and possible reuse is given in Ref. [7].

(b) Establishing a comprehensive set of data that characterize the site and provide a basis for future redevelopment.

It should be noted that some record keeping activities at the design and construction phase will often be beneficial for future site redevelopment. For example, a baseline radiological, environmental and geotechnical characterization of the site for the proposed facility will normally be required for the purpose of licensing. A quantification of the natural activity in backfill soil and the building material used in construction is an essential component in demonstrating compliance with future clearance and target cleanup levels [100].

6.3.1.4. Facility operators

Facility operators can assist future site redevelopment by:

(a) Maintaining sets of complete as-built drawings for each facility (including all modifications made during the operating life of the facility) and keeping accurate records of both routine operations and incidents, etc.

These records are very important in planning for and implementing the closure and decommissioning of a facility. Records of the locations of areas of past spills and routine flow paths of different materials into and out of the facility indicate areas that are likely to require consideration for restoration actions. Records of any major facility modification may also identify other areas requiring attention but which may not be readily obvious to the current facility manager or technical staff [100].

(b) Protecting the non-operational areas of the facility or site.

Measures such as protective coatings will protect non-operating areas of the facility from contamination, especially if these areas are used for the temporary storage of wastes. It is also good practice to ensure that activities are managed in a way that minimizes environmental contamination (or ensuring that surveys are conducted if any doubt exists). For example, having preselected transport routes out of the working areas would ensure that any spread of contamination would be localized along those routes [7]. In addition, maintaining good standards of maintenance and housekeeping will help to minimize the spread of contamination from operational to non-operational areas.

6.3.2. Authorities

Regulatory authorities can assist redevelopment by:

(a) Involving themselves as appropriate from an early stage in the site planning process.

Regulators that may be involved with the closure and decommissioning of a site include radiological health and safety, non-radiological health and safety, and environmental authorities. It should be noted that in several countries the successful completion of nuclear decommissioning including unrestricted release of the site marks a transfer of regulatory functions from the nuclear regulators to the authorities responsible for the regulation of industrial or other site uses. The remaining presence of chemical contaminants may impose site release conditions, impact on approval times for certain activities and prevent certain uses, e.g. as childcare centres or parks. Such institutional control conditions are passed on from the nuclear regulators to the environmental authorities for implementation or may be independently established by the latter, depending on national legislation. In order to ensure a timely and cost effective transition, the development and implementation of release criteria are therefore a key consideration for regulators.

(b) Maintaining an ongoing dialogue with the licensee/owner throughout the decommissioning and redevelopment process.

In some cases, a critical issue is the conflict between the need to commit to a fixed plan and taking the opportunity to adjust decommissioning in light of the actual contamination levels and reuse options identified. Maintaining an ongoing dialogue with the regulators will help provide such flexibility. It should be noted, however, that while this may be economically beneficial, it may complicate and lead to delays in the site release and the redevelopment process.

6.3.3. Developers and investors

Developers and investors can assist in future redevelopment as described below.

6.3.3.1. Developer organization

The developer organization facilitates site redevelopment by:

(a) Striving to find market driven, economic development opportunities, and maintaining good relationships and open communications between all parties involved.

The objective of the redeveloper organization is to focus the interests of the various groups of stakeholders on achieving an effective and successful realization of the redevelopment plan. This ensures that as decommissioning and reuse proceed, stakeholder needs and concerns will be properly addressed, a key means of ensuring successful redevelopment and a market driven, economic development opportunity.

Good relationships and open communications with government officials and other stakeholders can speed approvals for rezoning, site plans and regulatory agency permits. In addition, it can motivate the community to be successful in capturing new investment at the decommissioned site [98]. Inviting early input from stakeholders will increase public confidence that the residual risks will be appropriately managed. This increases the acceptability of redevelopment and reduces pressure for stricter redevelopment standards.

(b) Initiating financial incentives for seller-to-buyer transactions. A list of selected actions and incentives is provided in Ref. [98].

The tasks and responsibilities of the redeveloper end with the successful transfer of the redeveloped site to the future tenants and investors.

6.3.3.2. Potential investors

Potential investors need to be assured that the risks resulting from former activities on the site are below the regulatory values set for site clearance. It is unlikely that an investor will accept any potential liability arising from the past use of the site. Land quality statements and indemnities are therefore important in securing the confidence of investors. All other business risks should remain with the investor.

6.3.4. Other stakeholders

Redevelopment can be facilitated by involving relevant stakeholders, such as elected officials, the public and NGOs, at an early stage of the planning process.

6.3.4.1. Elected officials (local, regional, national)

Elected officials can facilitate site redevelopment by:

(a) Promoting the redevelopment plans in the community and providing advice and notice of funding opportunities for redevelopment/site enhancement.

The role of elected officials at all levels is very important, since they are charged with making decisions in the best interest of their jurisdiction. Generally these officials are supportive of beneficial and productive reuse of facilities being decommissioned, especially when attracting new industries can offset declines in employment. In conjunction with local government staff, such as planning and zoning authorities, these officials are charged with decision making regarding land use within their jurisdictions. They control what types of infrastructure may be available to support redevelopment of a site, and can often provide resources from the jurisdiction's budget or by virtue of its access to regional or national grants for economic development.

For large facilities facing decommissioning, elected officials at regional or even national level may have an interest in the development and have to be consulted. This is particularly the case for publicly owned facilities such as national research laboratories. In such cases the cost of decommissioning will be met from public funds, and parliaments and other elected bodies will have to be involved or advised of decisions on possible redevelopment of the site.

6.3.4.2. Surrounding public

The public near the facility can facilitate site redevelopment by communicating to officials their desire for continued employment and development at the site and for the site's redevelopment. Section 5.1.3 gives examples of how this has been achieved in the USA and the Russian Federation.

6.3.4.3. Non-governmental organizations

Non-governmental organizations can facilitate site redevelopment by taking an interest in future development and participating constructively in the planning process.

The various groups involved may wish for different outcomes from the redevelopment of a nuclear site. For example, environmental groups may view the closure of the site as an opportunity to return the area to its former use, or as an opportunity to decongest an industrial region. Examples of where these types of issue have been addressed are given in Section 7 and in Refs [101, 102].

7. OPERATING EXPERIENCE IN REUSE OF DECOMMISSIONED SITES

This section provides selected examples of decommissioning projects resulting in the redevelopment of either entire nuclear facilities/sites or of parts thereof. Along with simple descriptions of reuse histories, the rationale for the options selected is given as far as possible. Moreover, information is provided on how reuse objectives affected the planning and management of decommissioning.

7.1. EXPERIENCE IN THE USA

7.1.1. United Nuclear Corporation Naval Products

United Nuclear Corporation (UNC) Naval Products formerly operated a facility situated in Montville, Connecticut, on 240 acres (971 000 m^2) of land used for the manufacture of naval nuclear fuels. The entire facility consisted of about 430 000 ft^2 (40 000 m^2). The facility was decommissioned in the period 1991–1993. The land was then purchased by the Mohegan Tribe of Native Americans, and it is now a gambling casino referred to as the Mohegan Sun Casino. The tribe converted the facility into a gaming casino since it was structurally and environmentally sound, was located with close access to railway, highway and river transport, and had all utilities in place. The tribe was able to use all but four of the original buildings for their operation [32, 103].

7.1.2. Luminous Processes site

The Luminous Processes site was a commercial venture located in the state of Georgia. The building was situated on a 1 acre (4000 m^2) site, was operational from 1952 to 1978 and carried out the application of radioluminescent substances on to watch and clock dials. The owners abandoned the site in 1980, leaving behind significant radioactive contamination (^{226}Ra and ^{3}H (tritium)). The regulatory authorities of the state of Georgia (a regional regulator) took the lead for the cleanup under a cooperative agreement with the EPA, and the cleanup was completed in five months, ending in December 1982. Approximately 18 000 ft^3 (500 m^3) of contaminated soil was excavated and disposed of as radioactive waste. A restaurant now occupies the site [104].

7.1.3. South Carolina Advanced Technology Park

The former Allied General Nuclear Service plant was constructed in the 1970s for nuclear fuel reprocessing. However, it never opened, owing to a shift in US Government policy on spent fuel reprocessing in the mid-1970s. The site lay dormant for more than 20 years, with only some occasional minor work being carried out with radioactive materials for various small R&D efforts in support of USDOE programmes. The idea for a bold transformation took shape in 1991, at a time when rural Barnwell County, South Carolina, where the site is located, was looking for solutions to combat high chronic unemployment problems. After much discussion, in 1995 the Three County Alliance was formed and the entire region began to strategically work together to recruit industry to locate in the area. Eventually the 1600 acre (6 475 000 m^2)

decommissioned site was available for reuse. The new South Carolina Advanced Technology (SCAT) Park officially opened in September 2000 and has already attracted a diverse group of tenants. The SCAT Park has capitalized on its rural location, with the benefits of having no overcrowding or traffic problems, and its location adjacent to the Savannah River Site (SRS), a major USDOE nuclear facility. The latter offers opportunities for consulting with experts in the environment and technology fields, and for profiting from a significant high-tech workforce that has recently been downsized as a result of funding reductions at the SRS. In addition to an available workforce, the park offers infrastructure features already in place to support redevelopment. For instance, the site boasts on-site rail service, a stand-alone waste treatment plant and on-site water treatment, and because it was originally constructed as a nuclear plant, the SCAT Park also offers a unique fire prevention system: a 56 million gallon (210 000 m^3) on-site lake. Additionally, the presence of this water store means that companies locating in the park could realize significant savings on insurance coverage [93, 95, 105].

7.1.4. Bergstrom Air Force Base

There has been a significant downsizing in the number of US military sites over the last ten years. An example of redevelopment of one of these sites is the case of Bergstrom Air Force Base. The US Department of Defense remediated and restored this site for beneficial reuse by the city of Austin, Texas. From 1941 to 1993, Bergstrom was used for the maintenance and repair of aircraft. This involved the use of solvents, paints, adhesives, diesel fuel, etc., and to some extent radioactive materials. During more than 50 years of operations at the base, industrial activities (which met standards in effect at the time) allowed cleaning fluids, solvents and fuels to be disposed of in a manner that eventually resulted in seepage into the soil and into groundwater. The closing of Bergstrom helped to meet a major challenge for the city of Austin: the need for a new airport. Before the property could be made available for reuse, 481 spill areas required investigation and potential cleanup at the site. The Air Force and interested citizens in the form of a Citizens Advisory Board worked together on the establishment of cleanup levels appropriate for the site’s reuse as an airport, the use of soil from cleanup operations to cap a landfill and the recycling of construction concrete to avoid costly disposal fees for this material [106].

7.1.5. Pinellas plant

The Pinellas plant located in Largo, Florida, was the first former USDOE nuclear facility to be transferred to a local government for redevelopment and commercialization. The USDOE transferred the 96 acre Pinellas site to the Pinellas County Industrial Council in 1995 after having closed out its mission several years earlier. At the Pinellas plant, tritium was the main radionuclide of concern; however, tritium operations were confined to small areas, and the contamination was very localized. The entire Pinellas plant site was turned over to the Pinellas County Industrial Council for use as a high technology industrial park. All Pinellas buildings were cleaned to unrestricted release levels, with an independent contractor funded by the USDOE performing a verification survey to ensure that cleanup levels had been met. There are now 20 firms located at the site, including firms performing analytical and environmental testing services, as well as custom microelectronic design and manufacturing, and there are even two local universities. It is worth noting that the site now employs more staff than when it was operated by the USDOE [42, 93, 94, 107, 108].

7.1.6. Santa Susana Field Laboratory facilities

During the last 40 years, numerous nuclear research facilities have been operated at the Santa Susana Field Laboratory, also known as the Energy Technology Engineering Center. This site is situated on the outskirts of Los Angeles, California, near the community of Canoga Park. Many of these facilities have been decommissioned and have been released by the state of California nuclear licensing authority, and now many are being beneficially reused. For example [32]:

— The former Sodium Reactor Experiment Building is being used for storage of scientific research equipment.
— The former Nuclear Materials Development Facility is being used for a laser R&D programme after being successfully decommissioned from its earlier function as a plutonium fuel fabrication facility.
— The former DeSoto Avenue Fuel Fabrication Facility is now being reused for the manufacturing of NASA space shuttle engine components.

7.1.7. Idaho National Laboratory facilities

At the Idaho National Laboratory (INL), formerly called the INEEL facility, parts of several early reactor development facilities have been decommissioned and reused for new missions. For example:

- The SPERT-I reactor building was deactivated in 1964, all equipment was removed in 1969, and in 1980 [109] the building began to be reused to house the Power Burst Facility plant protective system equipment.
- Similarly, the SPERT-III reactor building was decommissioned and reused to house the Waste Experimental Reduction Facility.

7.1.8. Argonne National Laboratory facilities

The following paragraphs describe several cases of facility reuse after decommissioning at the Argonne National Laboratory (ANL) site [32]:

(a) The EBWR decommissioning was completed in 1996, and the facility was converted and modified into a waste storage facility. The end result was a waste storage facility for packaged transuranic waste on the four levels of the facility and in the former reactor cavity and fuel pool, pending off-site shipment for disposal.

(b) The CP-5 reactor facility decommissioning project was completed in 2000. The former CP-5 Vaporsphere was an ancillary structure used as part of the emergency ventilation system. With only a minimal amount of fence moving and cleanup, this structure was free-released and reused as a road salt storage facility. A drive-through opening was made into the dome and the facility was operational (Fig. 5). It was estimated that this resulted in cost savings of about US $200 000 as compared with the cost of constructing a new facility. Moreover, the Vaporsphere was centrally located for easy access.

(c) Over 60 gloveboxes in nine laboratories were decommissioned in the period 1993–1996 and the 7500 ft^2 (700 m^2) of laboratory space was released for USDOE reuse. This resulted in cost savings for the USDOE of about $1.4 million as compared with the cost of constructing a new research facility.

(d) A former plutonium fuel research laboratory facility was decommissioned and the space reused for a new nuclear mission, the New Brunswick Laboratory [110].

7.1.9. Oak Ridge Reservation

At the USDOE Oak Ridge Reservation (ORR), land use policy has been extensively developed through an intensive community input initiative to determine a realistic future use for ORR properties at the completion of cleanup activities. Through this process, future land use scenarios for the Heritage Center (formerly the East Tennessee Technology Park, ETTP), the Y-12 plant and ORNL have been determined to be industrial rather than recreational or residential. This determination is the foundation of the Reindustrialization Program, which reflects the desire of the community to retain skilled employment opportunities at each of these sites while USDOE missions are modified. In this context, reindustrialization involves the development of relationships with private industry on the basis of a business's need for manufacturing assets (e.g. space, equipment, facilities and transportation) and the need for the USDOE to organize disposition of these facilities and equipment in the best interests of the US Government. Further planning, management and organizational details are given in Refs [111–115]. The approach taken at ETTP to derive cleanup criteria for facilities to be leased for industrial use is given in Ref. [116].

Some examples of companies that occupy facilities and premises formerly operating on the K-25 site are:

(a) A recycling centre specializing in reconditioning, refurbishing and remarketing computers, electronic systems and peripherals;
(b) A laboratory providing materials characterization, forensic testing, treatability studies, metals speciation, risk assessment, and chemical systems development and optimization (a history of this company presenting a lessee's view of the industrialization process along with lessons learned is given in Ref. [117]);
(c) A tool and die shop that makes sheet metal stamping dies for use in the automotive industry, a medical isotope production facility, a company providing specialized trucking services and a company manufacturing infrared heating systems [118].

A comprehensive description of the K-25 reindustrialization process is given in Annex I.I.

The Tower Shielding Facility (TSF) is a small research reactor, including support equipment, that was used for various experiments at ORNL. BioNeutrics Inc. planned to convert the TSF to an outpatient cancer treatment centre utilizing a new cancer therapy called boron neutron cancer therapy. This therapy uses neutrons rather than gamma rays, and attacks cancer cells that have absorbed a compound of boron that has been given intravenously. Details of the reactor conversion and the licensing process are given in Ref. [119]. This conversion did not materialize, owing to funding issues. The refurbishment and conversion of another ORNL facility for new productive uses is described in Ref. [120].

7.1.10. Other USDOE sites

Similar approaches for reuse have been implemented at the USDOE's Mound and SRS facilities and are described in Refs [121, 122]. The Mound plant was one of several production sites in the USDOE nuclear weapons complex. As a result of the downsizing of the weapons programme due to the end of the Cold War, certain operations at Mound are being terminated or transferred to other USDOE sites. Therefore many former production buildings at Mound are being dismantled and operations terminated. The objectives of these programmes are to reduce the hazardous and financial liabilities to the USDOE by fostering and advocating the reuse of facilities for economic development. Since Mound has a variety of buildings in excellent physical condition, private industry is being marketed to lease these buildings and the site will gradually be developed into an industrial park. This would minimize USDOE expenses, but more importantly, it would help restore employment levels and the community tax base [123]. A comprehensive description of USDOE contractual policy for reutilization of the Mound site as part of the decommissioning process is given in Ref. [124]. (See also Annex I.H.) A detailed list of SRS facilities available for reuse, including their main radiological characteristics, construction type and features, is given in Ref. [125]. A specific reuse project at SRS is assessed from an environmental assessment viewpoint in Ref. [126]. A number of other USDOE redevelopment activities are described in Ref. [127].

7.1.11. Superfund sites

Thousands of US properties were used for various industrial practices over the past 50 years. These practices included then unregulated disposal of certain hazardous waste at these sites. As a result of legislation passed by the US Congress in 1980, these sites must now be remediated to a safe condition. Some of these sites are contaminated from the previously unregulated use of radioactive substances. Citizen concerns and environmentalist group activism regarding the extent of this problem led Congress to establish the nationwide Superfund programme in 1980 to locate, investigate and remediate the worst sites. The EPA administers the Superfund programme in cooperation with individual states and tribal governments. Table 6 presents a breakdown of 'recycled' Superfund sites, including 133 sites in actual or planned reuse, 30 sites in continued use and 7 sites that are in restored use [128]. A site is in actual or planned use if a new commercial, residential, ecological, recreational, agricultural, governmental or other new use is occurring at the site, or if a detailed plan for a new use is in place. A site is in continued use if the EPA has undertaken or overseen cleanup at the site that allowed the site to be used productively during and after the cleanup. Restored use has occurred at a site when a pre-existing use was halted during cleanup and was resumed after completion of the site cleanup.

Among redeveloped Superfund sites formerly containing radioactive materials, one can mention the following representative examples:

(a) Treasure Island Naval Station (Hunter's Point), San Francisco, California. Formerly a military base, the site is now used by the San Francisco Police Department as a crime lab. In addition, artists and caterers lease several properties, and at the dry dock, a metals recycler dismantles Navy ships.
(b) Denver Radium, Denver, Colorado. Formerly a radium processing facility, this site is now a retail store. The company entered into a partnership with the EPA to participate in the cleanup of the contaminated soil in exchange for limitations on the company's liability for any future contamination remediation. The store is responsible for maintaining the protective cap as well as for ensuring that the property is never used for residential purposes and that the groundwater is never used for drinking water.

TABLE 6. SUPERFUND SITES IN PRODUCTIVE REUSE

	Primary use[a]						
	Commercial	Residential	Ecological	Recreational	Agricultural	Governmental	Total
Actual use	64	3	16	15	3	10	111
Planned use	15	None	1	4	None	2	22
Continued use	25	2	None	None	1	2	30
Restored use	5	1	None	None	None	1	7
Total	109	6	17	19	4	15	170

[a] Only the primary productive use of a site is counted, although some sites may have more than one type of productive use (for example, both ecological and recreational use may be occurring at the same site).

(c) Cecil Field Naval Air Station, Jacksonville, Florida. Formerly a military base, this site now includes a computer training software and technical manuals shop and a jet component repair shop.
(d) US Army Materials Technological Laboratory, Watertown, Massachusetts. Formerly a military base housing a research reactor, its post-cleanup use includes a planned yacht club, a business centre, a public park and weapons research.

One particular option for Superfund redevelopment is to convert a site to golf facilities; this is discussed in detail in Ref. [91].

7.1.12. Nuclear power plant sites

A number of nuclear power plant sites, after having completed the decommissioning process, were converted for other power generation or reuse applications. This section provides details on these projects.

The Piqua Nuclear Power Facility (PNPF) was a prototype nuclear power plant constructed and operated in the town of Piqua, Ohio, in the 1960s. After only a few years of operation, PNPF was decommissioned and the reactor vessel complex entombed. At last report, the local municipality had accepted the caretaker role and was actively reusing the facility as a motor pool/ maintenance storage area [32] (Fig. 6).

A full history of the Fort St. Vrain plant through its nuclear and conventional generation phases is given in Refs [129, 130]. Another approach to convert a nuclear power plant into a fossil fired station is given in Ref. [131].

FIG. 6. Piqua reactor.

In connection with another reuse application, discussions took place between Portland General Electric Co. (PGE) and the State of Oregon Parks Department concerning the donation of 500 acres (2 000 000 m^2) of the decommissioned Trojan nuclear power plant site for a new state park, leaving about 130 acres (526 000 m^2) for other uses, including some 100 acres (400 000 m^2) for producing non-nuclear-origin electricity and 30 acres (120 000 m^2) for other uses, possibly for dry storage of Trojan spent fuel and for a buffer zone around the casks. The area available to produce electricity contains the transmission infrastructure and several small training and office buildings [132]. Similar conversion efforts are under way at the Maine Yankee nuclear power plant, which was fully decommissioned in 2005, where it is planned to develop the property as a technology park. A recent study contains a clear definition of what assets need to be removed and which will continue to have a useful life on the property when it is turned into a viable commercial/industrial site [133–135].

At the Rancho Seco nuclear power plant decommissioning project, the owner has received final state approval for a 500 MW natural gas fired combined cycle power plant to be constructed on the original nuclear site just south of the current security fence. Construction started recently on the first of two planned 500 MW units to be constructed at the site. The plant will make use of the existing switchyard, transmission lines and site water supply [136, 137]. The application for the new power plant is given in Ref. [138].

The former Shoreham nuclear power plant, located on Long Island in New York state, was decommissioned and its operating licence terminated. The reactor containment building remains on the site. In early 2005, the Long Island Power Authority installed two wind turbines on the site as a part of its Clean Energy Initiative. Plans are to establish a large scale wind generating project off-shore in an adjacent area [139]. Photos of the wind turbines installed at Shoreham are shown in Figs 7 and 8.

An interesting case is the ongoing debate between the operator of the shut down Connecticut Yankee (CY) nuclear power plant and the local authorities. The licensee wanted to sell a 30 acre (120 000 m^2) portion of the site to a local institution for development of a natural gas fired power station, but this was linked to the construction of a spent fuel dry storage facility at the site. Town planning officials asserted that zoning regulations require the storage facility to be built in the industrially zoned footprint of the shut down nuclear power plant, while CY officials objected that the storage facility would be too close to the planned gas fired plant. More details are given in Refs [140–143].

FIG. 7. Shoreham nuclear power plant after decommissioning.

FIG. 8. Shoreham nuclear power plant. Wind turbines.

7.2. EXPERIENCE IN THE UNITED KINGDOM

7.2.1. Winfrith site

The nuclear facilities at the Winfrith site, owned by the United Kingdom Atomic Energy Authority (UKAEA), are now all shut down. A strategy has been developed to remediate the site and establish a new science based business park creating high quality jobs within the local community. The essential elements of this strategy are [144]:

- Decontamination and conversion of buildings suitable for reuse;
- Removal of the redundant facilities and remediation of the land for further development;
- Removal of remediated areas of the site from regulatory control (delicensing);
- Sale of land in a condition that is consistent with its future environmental management needs;
- Retention in a safe condition of those facilities that cannot be decommissioned in the near term.

The following issues are seen as the most important drivers behind the development of a restoration strategy for the site:

(a) When operational, the site employed up to 2000 people and was a major employer and economic influence in the local community. Many of the staff were highly qualified and had a scientific and technical background. With the closure of these facilities there will inevitably be a decrease in employment requirements on the site, with limited local re-employment opportunities. Thus an objective exists to develop new businesses on the site and to restore all or some of the original 2000 jobs.

(b) The development and adaptation of old facilities for occupancy by new tenants is an important part of both the mission to create a science park and the economics of the site. Conversion of redundant facilities to a new use has been successful in attracting new organizations to the site as paying tenants. In particular, the engineering workshops were converted to office space for the United Kingdom Defence Evaluation and Research Agency, and the plutonium laboratories have been decommissioned and converted to offices and laboratories for the National Environmental Research Council. Another large tenant is RWE Nukem, a decommissioning services provider. Qinetiq, another tenant, has been described as Europe's largest science and technology organization.

Currently there are over 40 organizations located on the Winfrith site, including a number of small and very diverse businesses [101, 145]. Of the 1600 people employed permanently on the site, about two thirds are employed by tenants. The next step is the separation of the Winfrith Technology Centre from the longer term decommissioning work. This is being actively pursued and will be achieved by 2006 [145]. A recent update is given in Ref. [102]. Figures 9 and 10 show the Steam Generating Heavy Water Reactor (SGHWR) fuel pond during reactor operation, and visitors viewing the pond after it was successfully drained and decontaminated [146]. Figures 11 and 12 show the Nestor Reactor before and after decommissioning.

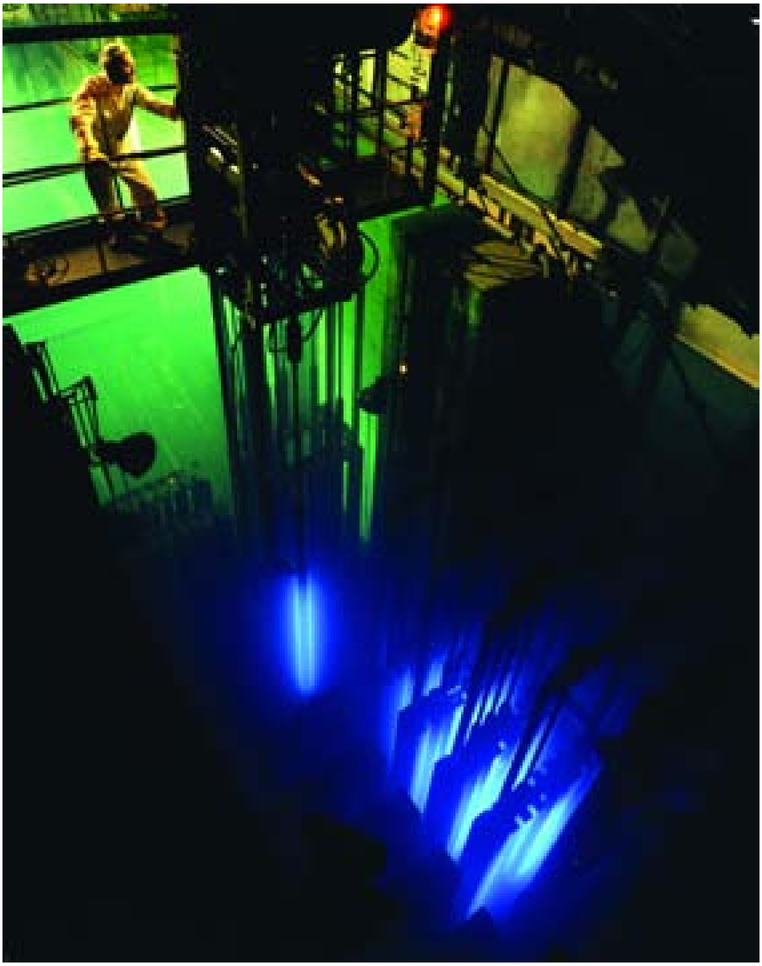

FIG. 9. Fuel pond at SGHWR at Winfrith when the reactor was operational.

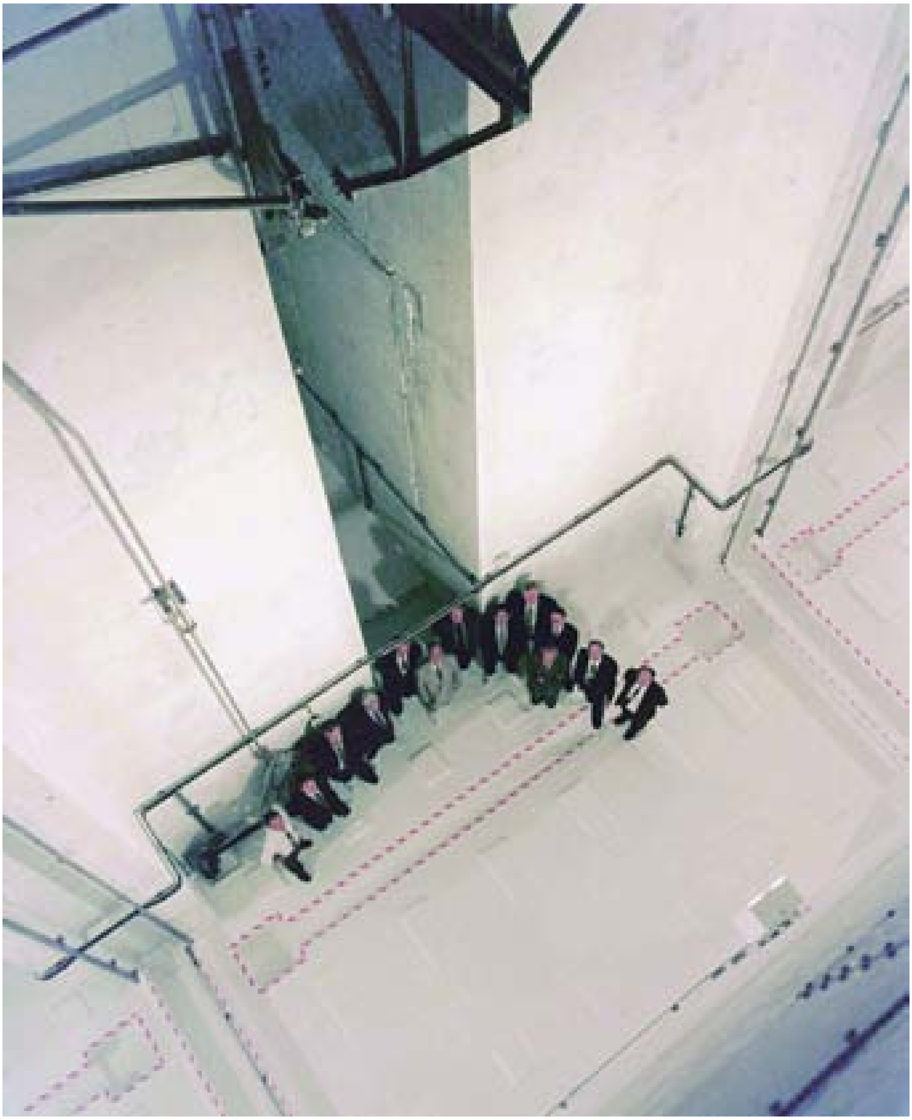

FIG. 10. Visitors viewing the fuel pond at Winfrith, which was successfully drained and decontaminated.

(c) Winfrith was originally built on heathland and was therefore a true greenfield site, having had no previous history of economic development. The site is still ecologically sensitive, and significant areas are designated as among the Sites of Special Scientific Interest for their importance as a habitat for flora and fauna.

FIG. 11. Nestor reactor (Winfrith) before decommissioning.

FIG. 12. Nestor reactor (Winfrith) after decommissioning.

7.2.2. Harwell site

Another UKAEA redevelopment project is under way at the Harwell International Business Centre, which was originally a nuclear research centre that included a large number of research buildings and several research reactors. There are no plans to use any of these facilities for nuclear purposes and the site is to be redeveloped as a business centre.

One important legal problem to note is that United Kingdom legislation allows a licensee to end their ‘period of responsibility’ and to vary the boundary of the nuclear licensed site by demonstrating to the regulators that “there has ceased to be a danger from ionizing radiation from anything on the site or parts thereof”. Recognizing that absolute safety is unobtainable, UKAEA presented a proposal to the regulator to interpret ‘no danger’ as ‘tolerable risk’. It is currently planned to subdivide the Harwell site into a series of zones and then to delicense and release land value on a phased basis. The advantages of this approach are:

- Delicensing cases will be smaller and easier to prepare, review and approve.
- The delicensing programme is responsive to the decommissioning programme.
- The release of the land can be timed to maximize value according to the local property market.
- Phased realization of land value can potentially enable the later stages of the project to be self-funding.

The current decommissioning programme projects complete delicensing of the northeastern area (25 hectares) of the site by the year 2008 [147]. The rest of the Harwell site will be made available for new development [148] as decommissioning proceeds. A recent example of this is the refurbishment by a private sector developer of the old library building that supported the nuclear research. Investment by the developer enabled the disused and dilapidated library to be extensively refurbished and converted into modern specification office accommodation. Further new premises are planned adjacent to the library to provide up to 7500 m^2 of flexible business space [149]. More information on the Harwell redevelopment strategy and achievements is given in Ref. [150].

7.2.3. Dounreay site

The remote location of the UKAEA site at Dounreay creates different redevelopment challenges. A recent study by the Highlands and Islands Enterprise (HIE) Network [151] evaluated how it might secure economic benefits from the decommissioning of Dounreay. The report recognized the importance of diversifying the local economy in order to reduce the reliance on the current employment base and the need to develop the local business infrastructure. It also highlighted the opportunities for inward investment and prioritized how the HIE Network would support the growth of new and existing businesses, develop the local skills base and strengthen the community.

Two recent examples of these redevelopment activities are the following. The Learning, Education and Development (LEAD) Centre was opened early in 2004. It provides high quality training and skills development opportunities for employees of UKAEA and contractors at Dounreay and other nuclear sites in the United Kingdom [152]. The Dounreay Visitor Centre attracted more than 8000 cosmopolitan visitors within a few months of its opening in April 2004 [153].

7.2.4. Other United Kingdom sites

Several research reactors in the United Kingdom have been dismantled and their sites released for non-nuclear use. JASON was a low energy training reactor located at the Royal Naval College (RNC), Greenwich. It was housed within the King William Building, which is a listed building and is part of an ancient monument. It was important to ensure that dismantling was performed with minimal impact on the historically significant structures surrounding the reactor. After decommissioning, the RNC was transferred to non-defence use and the reactor hall is now a lecture theatre (Fig. 13). More details on the JASON decommissioning can be found in Refs [154, 155]. Similar success has been achieved in decommissioning the Universities Research Reactor near Manchester, which has been fully dismantled and the site reused for an office building [156].

The Atomic Weapons Establishment at Cardiff produced many of the non-fissile components for all UK warheads. It was in operation between 1961 and 1997. Most of the buildings were cleared between 1999 and 2001. During 2002–2003 the concrete base and topsoil were removed for disposal. It is currently planned to use the site for retail development [157].

FIG. 13. Decommissioning of the JASON reactor. Top left: during dismantling operations; top right: removal of spent fuel; bottom left: reactor's pit after dismantling; bottom right: current state, a lecture theatre.

In addition, the B100-103 uranium recovery facility at Sellafield was converted to a radioactive waste store [55].

7.3. EXPERIENCE IN OTHER COUNTRIES

7.3.1. Russian Federation

The Nuclear Cities Initiative (NCI) is a joint US–Russian programme designed to reduce the size of the Russian nuclear weapons complex. Begun in 1999, NCI provides an environment hospitable to developing a civilian employment sector and eases the transition from military to commercial activities in the 'secret cities' of the former Soviet Union [158]. (See also Section 5.1.3.)

Throughout the Cold War, the Soviet Union designed and constructed its nuclear weapons at several closed cities in various locations within Russia. Operated by the Ministry of Atomic Energy (Minatom) and its predecessors (organizations similar to the USDOE and its forerunners), these cities were closed to the outside world. After the end of the Cold War, Russia's nuclear weapons establishment was no longer appropriate to the international circumstances. Through NCI, the USA is assisting Minatom in reindustrializing its atomic cities through:

— Reducing the physical footprint of the weapons manufacturing facilities;
— Removing equipment or destroying its function;
— Creating sustainable employment consistent with the education and skills of employees;
— Creating market opportunities for new products.

NCI has established a presence in three cities — Sarov, Snezhinsk and Zheleznogorsk — where notable progress has been made. In Sarov, the Avangard weapons assembly plant has been closed ahead of schedule. Forty per cent of its usable building space was converted into a civilian technology park for non-weapons-related commercial work, such as metal fabrication, rubber and plastics moulding, and microelectronics circuit board assembly. A similar technology park is planned for reusable space at the weapons assembly facility in Zarechnyy. At research institutes in Sarov and Snezhinsk, NCI has created open computing centres that serve as incubators for the civilian information technology market. In Zheleznogorsk, NCI has removed isotope extraction equipment from one of two plants operating plutonium production reactors. This equipment is now used in the production of plant growth stimulants and health care preparations. A new commercial zone has also been created within the defence security area for production of rare earth metals as a civilian business. In all three cities, NCI upgraded telecommunications infrastructure to support high speed Internet connections [159, 160]. About 15 000 former Russian weapons workers are now involved in NCI funded activities [161].

A conversion project similar to NCI is also under way in the Russian Federation concerning the reuse of Cold War shipyards for civilian purposes. Russian shipyards such as Zvezdochka, Sevmash and Nerpa — formerly used to construct nuclear submarines equipped with submarine launched ballistic missiles — are now being used to dismantle the same Soviet era nuclear submarines to comply with various arms treaties. The funding for some of this work has been provided through the US Government's Cooperative Threat Reduction assistance programme (sometimes referred to as the Nunn–Lugar Program), while other funding has been provided internally by the Russian Government [162].

Some of these same shipyards are being used to construct passenger carrying tourist submarines, for the fabrication of oil and gas industry equipment and installations, and to convert some nuclear submarines for non-nuclear applications, for example for the transport of nickel in raw form [163].

7.3.2. Germany

Eight units of the Russian designed WWER-440 are located at the Greifswald site on the territory of the former German Democratic Republic. Shortly after the reunification of Germany, a decision was taken to decommission all units. As an initial step, measures had to be taken to reduce the large number of employees. To solve this problem, the following measures were employed:

— Early retirement of older employees;
— Privatization of services and infrastructure, and of technical areas where possible;
— Training for decommissioning and also for privatization;
— Dismissal of employees with initial economic support.

In this way it was possible to reduce the personnel from around 6000 to only 1400, which is still high but is justifiable. During this personnel reduction phase, it was possible to establish a number of small to medium size enterprises, and a total of just under 1000 jobs were created. Moreover, two contracts were placed for the construction of gas fired power plants, and another 400 jobs were ensured. Thus, despite the rather isolated location of the site, the Greifswald management succeeded in keeping the site as an industrial and energy production site [164].

7.3.3. France

In France, three of the oldest facilities have been partially dismantled and converted to a nuclear museum or to a different nuclear reuse.

The Chinon-A1 gas cooled reactor operated from 1963 to 1973, and the Zoe heavy water moderated small power reactor at Fontenay operated from 1948 to 1975. Both of these reactor facilities were converted into nuclear museums. The Pegase reactor in Cadarache, which operated from 1963 to 1974, was converted into a spent fuel facility [55].

7.3.4. Italy

Two small research reactors, RB-1 and RB-2, were dismantled in the late 1980s at Italy's research centre of Montecuccolino, near Bologna, and their premises reused for other purposes. The RB-1 reactor (10 W(th)), a cylinder of 286 cm diameter and 300 cm height, rested on a steel base plate. The cylinder and base plate were contained in a steel vessel with inner dimensions of 340 cm diameter and 495 cm height. The decision was made to dispose of the reactor vessel in situ by filling it with radiological debris from the demolition of the other components. Concrete was then poured in to fill the voids, forming a smooth, level floor surface suitable to use of the area for non-nuclear applications. This is a case (albeit a small scale one) where consideration of site reuse affected the decommissioning strategy [165, 166].

In the case of the RB-2 reactor, a similar disposition strategy was implemented. RB-2 was an Argonaut type reactor that was also dismantled in the late 1980s. Following removal of the reactor tank and major components, a small volume of the floor (0.55 m^3) where the reactor was embedded showed some activation slightly higher than the unrestricted release criteria (Fig. 14). However, because of the heavy reinforcement of the floor, demolition would have required considerable effort and would have perhaps jeopardized the floor's structural stability for possible future reuse. Eventually a mechanical test laboratory was established on the site [167] (Figs 15 and 16).

The pool type reactor Avogadro at Saluggia, which ran from 1959 to 1971, was partially decommissioned and converted into a spent fuel facility [55].

7.4. REUSE OF CANCELLED NUCLEAR PROJECTS

There are instances of nuclear plants and facilities that have been constructed but were never operated as intended (often owing to changes in government policy towards nuclear power). It can be tempting to view these structures as having little or no commercial value and to simply mothball them in an attempt to minimize further expenditure. The following examples illustrate some of the more innovative approaches to the reuse of such facilities and to the recycling of some components, materials and equipment.

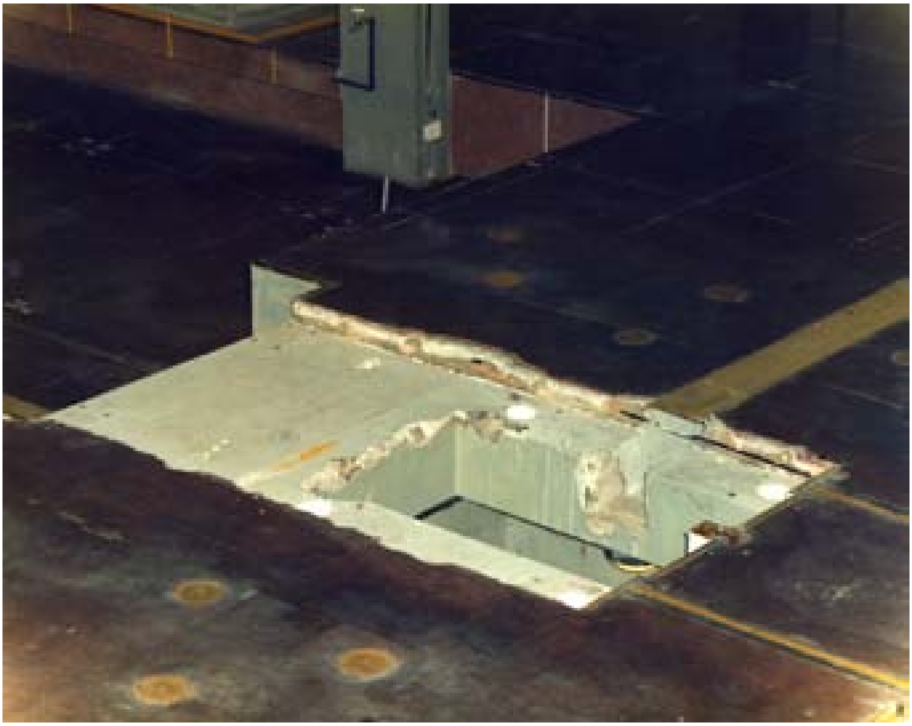

FIG. 14. RB-2 reactor, Montecuccolino, Italy. Reactor hall floor after removal of the reactor (1986).

7.4.1. Zimmer power plant, Ohio, USA

The William H. Zimmer power plant, located in southern Ohio, was 95% complete in 1984 when, owing to cost concerns, the decision was made by the utilities constructing the unit to convert it from a nuclear powered unit to a coal fired unit. The coal fired plant went on-line in 1991 [168].

7.4.2. Midland power plant, Michigan, USA

The 1500 MW Midland power plant constructed near Midland, Michigan, was initially envisaged to be a nuclear fired unit. Even after being 85% complete, it too was converted to a fossil fuelled plant, in this case to a natural gas fired cogeneration plant producing both electricity and steam. The steam was sent to the adjacent Dow Chemical site and the electricity distributed to the electricity grid [168].

FIG. 15. RB-2 reactor. Reactor hall floor during dismantling.

7.4.3. Satsop power plant, Washington, USA

The unfinished Satsop nuclear power plants, located in the western part of the state of Washington, are currently undergoing a transformation from

FIG. 16. Former hall of the RB-2 reactor, now converted to an experimental test laboratory for structures and components at ambient and high temperature.

mothballed nuclear units into a business park. These units have been kept in a mothballed condition since the mid-1980s. The Grays Harbor Public Development Authority has been designated as the managing authority for the transformation of these units into the Satsop Development Park. This park is envisioned to be a business park for further economic development of the area. The marketing approach for the site points out the extraordinary infrastructure as a key development feature. For example, the turbine building's two overhead cranes can work together to lift 500 t between the loading bay and the upper floors. There are doors at each end of the loading bay enabling trucks to drive straight through. Other features include:

— A fully functional wastewater treatment plant;
— A state of the art communication system;
— A water system with rights to nearly 15 000 gal/d (about 57 000 L/d);
— A site electrical infrastructure, another unusually strong feature;
— Its position at a major intersection of two West Coast power grids.

A curious detail is the proposed use of the huge cooling towers as the highest climbing wall in the world [169]. The developer is gradually selling off certain reusable components from the one unit on-site (unit 5) as a source of revenue. It hopes to sell all of the systems and components from the adjacent unit 3 in their entirety to another utility, since construction on that unit was very nearly completed. A description of redevelopment opportunities is given in Refs [170, 171].

Two similar nuclear power plant units, WNP-1 and WNP-4, were located in the eastern part of the state of Washington and, like the Satsop facilities, were partially built — to 63% and 17% completion, respectively — when the project was halted in 1982. It eventually became clear that it was unlikely that the plants would ever be completed as a nuclear generating facility. Outside interest was not expressed either in reusing a portion of the facilities or in developing the site for business use [172].

7.4.4. Kalkar nuclear power plant, Germany

The Kalkar nuclear power plant was nearly ready to start commercial operations in the early 1990s. However, public opposition eventually led to the cancellation of the project. Kalkar's sturdy structure presented a serious demolition problem, and eventually a proposal was made to reuse the nuclear power plant. The turbine building was to become a family hotel, the reactor was to be transformed into a diving tank, and two vast steel lined hangars were to be turned into a swimming pool, ballroom and casino complex. A discotheque was to be housed in the emergency diesel power supply plant. Work was completed recently [173]. The accommodation, recreational and other facilities offered by the former nuclear power plant are described in Ref. [174].

7.4.5. Zwentendorf nuclear power plant, Austria

The Zwentendorf nuclear power plant of the Gemeinschaftskern-kraftwerk Tullnerfeld AG, a 700 MW(e) BWR, was built in the early 1970s and was in the process of going into operation when a public referendum held in November 1978 resulted in the plant never becoming operational. Thereafter some components of the plant were dismantled for reuse in other similar installations and the building was maintained in a safe configuration. The licences for the plant site, some infrastructure and other main grid installations were reused for two newly erected blocks of coal fired power plants nearby at Durnrohr [175].

7.4.6. Clinch River Breeder Reactor site, Tennessee, USA

A different case is that of the former Clinch River Breeder Reactor site located in the eastern part of the state of Tennessee. The site has steep terrain and a 35 ft (10 m) deep hole dating from the time when the USDOE was considering developing a breeder reactor in the early 1980s. Some early site preparation activities were performed at the site, but the project was eventually cancelled in 1983. The land contains no roads, water or sewer lines, or electrical capability. Following unsuccessful attempts to sell the land to big industry, the owner is considering reclassifying some of the land for uses such as conservation, recreation, wildlife management, forestry and residential development. Some of the land could remain slated for industrial use, but by multiple tenants rather than one large user [176].

8. SUMMARY AND CONCLUSION

In the coming decades a large number of nuclear facilities will reach the end of their useful lives and require decommissioning. Many of these facilities will be decommissioned with the aim of either replacing them with new facilities that serve the same purpose or reusing the site for another, completely different purpose. By recognizing and promoting the redevelopment potential of facilities and their sites at the design stage or earlier in their operating life, it is possible to enhance the prospects for worthwhile redevelopment offsetting the costs of decommissioning and ensuring that best use is made of the material, land and human resources associated with each facility. A range of factors to consider have been identified and illustrated using case studies drawn from Member States, and practical guidance has been provided for parties involved in these activities to help promote successful and effective redevelopment of retired and decommissioned nuclear installations in the future.

Appendix

METHOD FOR EXPLORATION OF CLOSURE AND REDEVELOPMENT SCENARIOS

The method[4] described is intended to provide an appreciation of the range of circumstances in which a specific plant might be closed in the future so that changes to the design or operation of a plant that may prolong plant life or reduce decommissioning costs and impacts may be considered.

The method is based on the proposition that closure of a plant or site is associated with a management decision to close it and that the primary factors in that decision are:

— Management's knowledge of the plant state and the surrounding physical environment;
— The actions and views of outside stakeholders (suppliers, regulators, customers, local residents, etc.).

On the basis of this proposition, a list of the main stakeholders can be used as prompts to help identify possible reasons for a decision to close the plant. Each of the possible reasons identified is explored by trying to create a plausible scenario in which that reason for closure might intervene. The scenarios can then be analysed for implications that relate to the design or mode of operation of the plant.

The procedure is given below and is illustrated in the example that follows:

Stage 1. Make list of key features of the project and key stakeholders.

Stage 2. For each item on the list, consider how it might be relevant to a future decision to close the facility.

Stage 3. For each idea, try to construct a plausible scenario and describe this in two or three sentences.

Stage 4. Consider the likely effects on decommissioning costs and impacts, and on redevelopment prospects if the scenario were to be

[4] This methodology is described as an example and is not officially endorsed by the IAEA.

TABLE 7. EXAMPLE OF CLOSURE SCENARIOS ASSESSMENT

(Fictitious example case: ABC Sources Inc. operates a small shielded glovebox suite preparing sealed caesium radiation sources. The suite is located in a large building with mostly redundant isotope handling production facilities.)

Stakeholder	Decision to close associated with:	Possible future scenario	Current implications for protecting development prospects
Customers for the sources	Fall in demand for sources	A new design of source which makes handling and accounting easier has been launched by ABC Sources and is displacing the original product.	Consider whether the plant can be reconfigured to reprocess returned sources of the old design.
Radioisotope supplier	Change in quality of isotopes provided	The supplier of the caesium isotope has converted to recovery of caesium from wastes and can supply the caesium only in liquid form. The plant is too old to upgrade to provide the extra conversion stage and will be replaced.	Maintain good communications with the supplier so that changes in its supply capability can be anticipated.
Regulator	Introduction of new legal requirements	The law is to be changed to stop manufacture of small sources, which are too frequently lost by the operators of the radiography equipment in which they are used.	Consider accelerating decommissioning of the redundant facilities surrounding the suite to make space for the extra facilities that would be needed if the manufacturing requirement were to change.

Workforce	Rising labour costs	Higher labour rates make manufacturer uncompetitive compared with alternative locations in newly industrialized economies. ABC Sources is forced to relocate manufacture of the sources to the Republic of Korea to remain competitive in the world market.	Closure of the facility may not be too far in the future and development of new products, more challenging to manufacture, will be needed to maintain a lead on competitors. Consider partnership with a life sciences specialist to develop isotope products for the medical market.
User	Merger of ABC Sources with a larger manufacturer	ABC Sources has been taken over by a manufacturer of the computer aided tomography (CAT) scanners in which most of the sources are used. The new company is seeking to consolidate manufacture of the scanning head assemblies on one site.	The high investment in infrastructure makes the existing site an attractive location for the new consolidated manufacturing unit, provided the site and its services are suitable. The site management must maintain the quality of facilities on the site and good neighbour relations if it is to be able to attract new investment in development of new facilities.

realized, and whether changes to the design or operation of the facility might avoid or reduce undesirable effects or increase desirable effects.

Table 7 gives an illustration of the kind of results expected. The method might be used periodically, including at the design stage of a new plant, to identify any potential decommissioning scenarios that are unacceptable (and that have to be 'designed out' or made sufficiently unlikely) and redevelopment prospects to be cultivated.

The scenarios identified and any actions to be addressed should be recorded.

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Annex I

EXAMPLES OF NATIONAL EXPERIENCE

The examples provided in this annex cover a variety of topics, from national policies and legislation to detailed technical and organizational aspects. It is believed that all these aspects are useful for providing practical guidance and information on how decommissioning projects are planned and managed in various Member States with a view to ensuring successful redevelopment of decommissioned sites. The examples given are not necessarily best practices, nor has their consistency with the IAEA's guidance been tested in detail. Rather they reflect a wide variety of national policies, social and economic conditions, nuclear programmes and traditions. Although the information presented is not considered to be exhaustive, the reader is encouraged to evaluate the applicability of these cases to a specific decommissioning project.[5]

The following table summarizes the examples presented.

Country	Annex	Name of facility	Highlights
Austria	I.A	ASTRA research reactor, Seibersdorf	Modifications of buildings, costs
Belgium	I.B	VITO Laboratory	Delicensing of a hot laboratory to a refurbished material and process laboratory
Denmark	I.C	Risø Laboratory	Reuse of DR-2 building
Germany	I.D	Greifswald nuclear power plant	Social aspects of employees
South Africa	I.E	AngloGold Ltd, Welkom	Redevelopment of mining sites into a leisure park
Switzerland	I.F	Lucens, DIORIT, SAPHIR, nuclear power plants	Future plans for nuclear power plants and research reactors
United Kingdom	I.G	Harwell and Winfrith	Site redevelopment and reuse
USA	I.H	USDOE Mound site	Site redevelopment
USA	I.I	USDOE ETTP site	Brownfields reuse

[5] Data and statements were provided by national contributors and are not necessarily endorsed by the IAEA.

Annex I.A

REUSE OF THE ASTRA RESEARCH REACTOR, AUSTRIA

I.A–1. INTRODUCTION

After 39 years of successful operation, the 10 MW ASTRA research reactor, located at the Austrian Research Centers GmbH (ARC) near Seibersdorf, underwent final shutdown on 31 July 1999 to prepare for decommissioning.

Of the possible options evaluated for implementation, the selected option was immediate dismantling after a preliminary stage of deactivation and safe storage. This allows for final shipment of spent fuel, complete removal of higher levels of radioactive waste from the site and surveillance measures. This will be followed by a total facility dismantling activity with reuse of the site. As of July 2004 the removal of low level radioactive waste (LLW) was under way at the site.

Prior to the final shutdown, there was careful consideration of the possible options and the required stages for decommissioning and removal of the radioactive components. An evaluation of these options was performed and appropriate financial provisions were arranged for the implementation of the selected strategy. This process was performed in compliance with the provisions stipulated in Ref. [I.A–1].

From the very start of the planning for the decommissioning process, it was the intention of the Austrian Government to create an independent organization, to be operated and financed separately from the other activities at ARC, to cope with all the decommissioning activities, thereby releasing the other research units of ARC from these responsibilities. In November 2003 the entity Nuclear Engineering Seibersdorf GmbH (NES) was established to accomplish this objective.

One of the objectives of NES is the operation of a Radioactive Waste Management Department (RWMD) acting as the central facility for the collection, conditioning and intermediate storage of radioactive waste arising in Austria. Additionally, NES is also tasked with the safe handling of radioactive material of medical and industrial origin, as well as with responding to emergencies in this field. Lastly, NES is assigned to decommission the nuclear laboratories and areas within the premises of ARC which were used for work in the earlier days of the research centre and are now undergoing decommissioning for release to be put to new use.

Apart from the decommissioning of ASTRA, which is scheduled for completion in 2006, NES continues to operate the Hot Cell Laboratories (HZL), now used in the conditioning of intermediate level waste, arising mainly from the dismantling of the reactor. HZL is due to be decommissioned after the ASTRA decommissioning is completed.

I.A–2. CONCEPT OF REUSE OF THE REACTOR BUILDING AFTER DECOMMISSIONING

In planning the decommissioning of ASTRA, attention was directed to the reuse of the available infrastructure for future site work. Several suggestions were presented, including a proposal to use the buildings as an international training centre for first responders to emergency situations. Finally, and for the reasons stated below, it was decided to use the structures for purposes directly connected with the objective to act as the central national facility for the collection, conditioning and intermediate storage of radioactive waste (Fig. I.A–1).

The RMWD design capacity is 15 000 drums (200 L size) of conditioned radioactive waste. This was calculated to be sufficient until 2015. On its premises there is adequate room for only about 9500 drums stored in transfer configuration (access for inspection of every single drum possible).

Since the erection of new storage facilities would be subject to an environmental impact statement, with public acceptance much in question, it

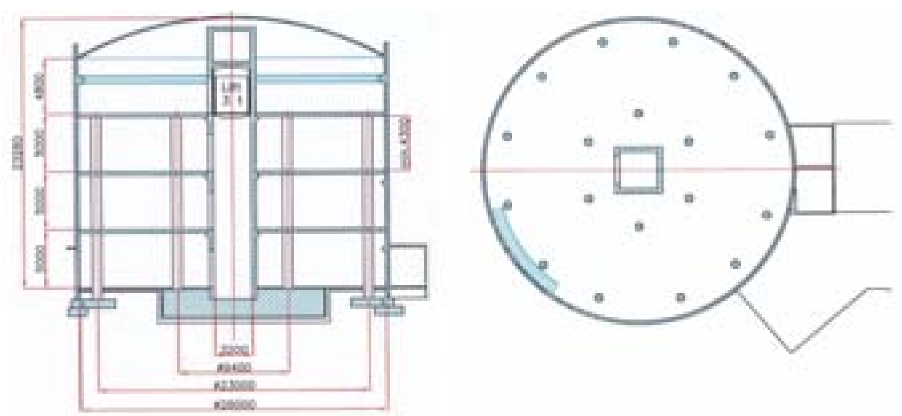

FIG. I.A–1. ASTRA building after the planned modifications. The three upper levels and the central lift are shown.

would be advantageous to adapt the cleared ASTRA reactor building to provide additional storage space for another 5500 drums on the three upper levels of the facility. A new building to be erected and attached to the rear entrance of the reactor, needed for the extensive clearance measurements performed during the decommissioning process, could give a safe and covered entrance to the storage facility, using only a small portion of the ground floor of the former reactor building to give the necessary access.

The remainder of the ground floor could then be developed into an active working area, replacing the then decommissioned HZL. Auxiliary buildings directly attached to the reactor could, with minor modifications, house the necessary ventilation and filtering systems to support these operations. In addition, the younger personnel remaining — having a reactor operator's background, experienced in engineering and handling of radioactive materials, and with a knowledge of hot cell work — as well as an already established group managing the industrial radioactive source service, would be well equipped to operate the new facility. Last but not least, the area of the former reactor is directly connected to the area of the RMWD.

I.A–3. ALTERATIONS FOR REUSE OF THE BUILDINGS

The ground floor will be divided into two areas by radial walls (Fig. I.A–2). The smaller portion at the side of the former rear entrance and accessible via the newly erected hall is for manipulations connected to the operation of the LLW storage facilities. The remaining, larger area will be equipped for radioactive operations since it is accessible via the original airlock and will be adapted for low pressure operations. A new ventilation system can be housed in the attached auxiliary buildings. Heating and electrical installations complete the interiors. A portion of the working area will be enclosed with a wall and will function as a safe storage for sensitive materials, with all the security necessary. The former, heavily shielded valve pit and the former storage areas can be adapted for storage of higher activity sealed sources.

The three upper levels of the building (Fig. I.A–3), with access through the newly erected entrance building, the former rear entrance of the reactor, and via the 3 t elevator within the centre of the building, will be used as an intermediate waste storage area (see Section I.A–2). The 200 L drums of conditioned LLW are to be stored in crates each holding two drums and to be stacked to a total height of six drums. The arrangement of the stacks takes into account the need for easy accessibility for inspection.

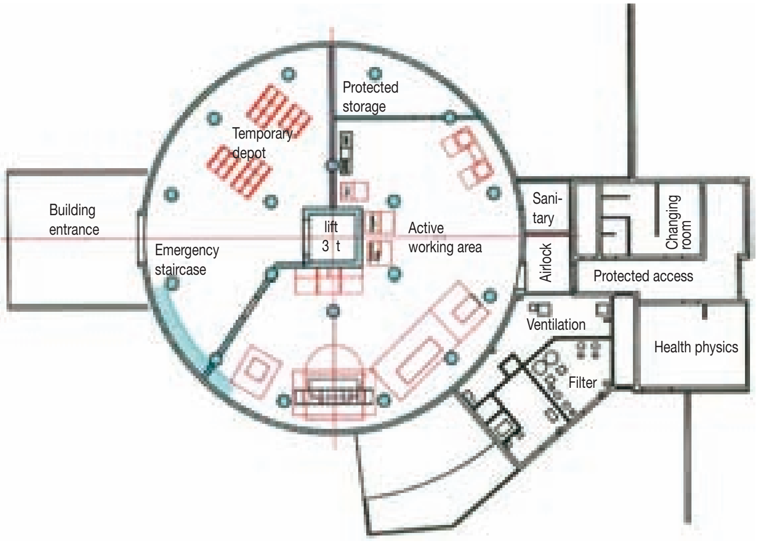

FIG. I.A–2. Layout of the ground floor.

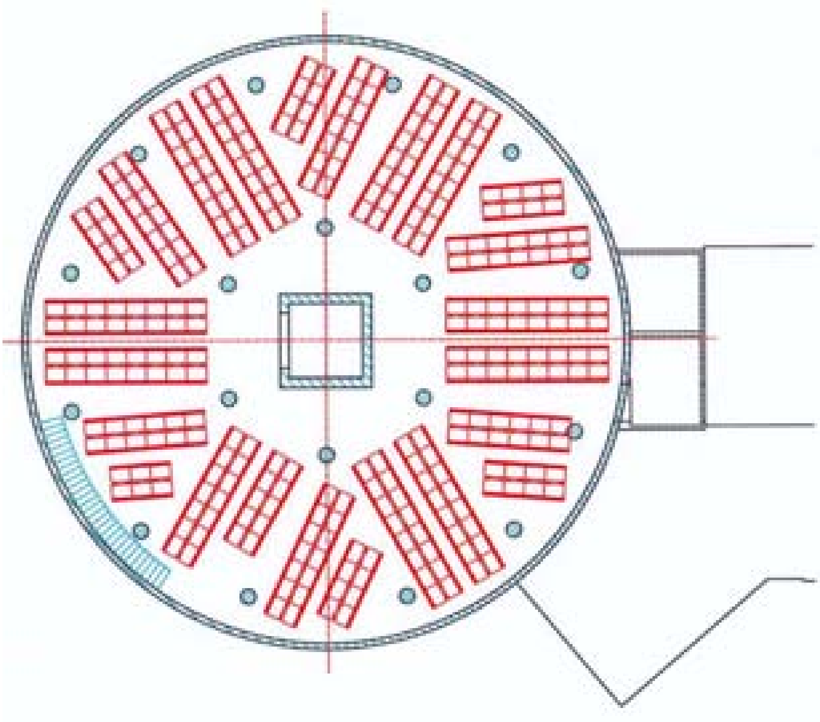

FIG. I.A–3. Layout of the upper levels.

I.A–4. ESTIMATED COSTS

The estimated costs (in euros) covering the necessary investment for reusing the reactor building are divided into three major categories:

(a) Modifications to building

Planning, including stress analysis of the building	116 000
Building construction (foundations and floors)	815 000
Electrical installations	145 000
Ventilation system, elevator, fork-lift crane	155 000
Subtotal	1 231 000

(b) Furnishing the transfer storage (three upper floors)

Storage crates for drums	642 000

(c) Furnishing the active working room (ground floor)

Planning	20 000
Interior building works	80 000
Ventilation, heating, plumbing, lighting	220 000
Erecting of hot cell	255 000
Transfer of equipment, including installation	75 000
Subtotal	650 000
Estimated total cost of the entire project	2 523 000

I.A–5. CONCLUSION

The decommissioning of ASTRA was initiated in 1999 after the conditions of transition from operation to decommissioning had been cleared. The project final decommissioning objective is the release of all buildings for unrestricted reuse. In addition, a concept for the reuse of the buildings was conceived taking into account the future needs of NES, and adequate funding was ensured. The completion of the project is expected in 2008.

REFERENCE TO ANNEX I.A

[I.A–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Transition from Operation to Decommissioning of Nuclear Installations, Technical Reports Series No. 420, IAEA, Vienna (2004).

Annex I.B

SITE REUSE EXPERIENCE IN BELGIUM

I.B–1. INTRODUCTION

In the past, SCK•CEN (Belgian Nuclear Research Centre) was involved in both nuclear and non-nuclear research programmes. In the early 1990s, the Belgian Federal Government decided to restrict the objective of SCK•CEN to the strictly nuclear programmes. A new research centre, VITO (Flemish Institute for Technological Research) was founded by the regional government and took over all non-nuclear activities. Furthermore, the federal and the regional governments agreed to house VITO partly in former SCK•CEN buildings and partly in new buildings to be erected on the site, having in mind a number of additional benefits, such as re-employment and reduction of costs compared with the acquisition of a new location. However, in addition to highly equipped non-nuclear laboratories and offices, some of these buildings contain laboratories and installations with a radiological history.

In general, decommissioning aims at reaching the greenfield state by dismantling the equipment, removing contaminated parts of walls and floors using appropriate techniques, and finally demolishing the remaining structures using conventional techniques. Since important parts of some of the buildings in question contain valuable non-nuclear infrastructure and equipment, SCK•CEN decided to deviate from the common strategy by limiting the decommissioning work to the radioactive parts of the nuclear installation and to obtain permission for unrestricted reuse of the building after removing all radioactive material. After refurbishment, the building can be used for new industrial purposes outside the nuclear field.

The choice of the reuse strategy proved to be economically, socially and ecologically advantageous. Experience from this project has shown that it will be advantageous to consider future redevelopment and reuse of a nuclear site at an early stage, while it is still being used for its original purpose.

I.B–2. FACTORS INFLUENCING THE CHOICE OF THE VITO LOCATION AND THE DECOMMISSIONING AND REUSE STRATEGY

The deterioration and even disappearance of an industrial activity, with the inevitable loss of jobs, has resulted in abandoned and dilapidated sites, also called brownfields. Such sites may give rise to a feeling of insecurity, they degrade the quality of the landscape, they are used as illegal dumping grounds and they become prey to all kinds of destruction, vandalism and crime.

In the past such sites were deliberately neglected by investors and property developers, who opted for pristine grounds for new development (greenfields). Reasons for their reluctance towards brownfields may be found in the fact that they have little or no control over:

- Location of the site;
- Condition of the buildings;
- Former industrial activities;
- Possible contamination;
- Responsibility for decontamination.

During the 1990s increasing attention was paid to the existence of these brownfields in Belgium and to a means for redevelopment and reuse. Indeed, once redeveloped, these sites could become the catalyst for the revival of the whole surrounding area, and they could initiate a process of sustainable development, among other things through:

- Reuse of existing infrastructure;
- Re-employment opportunities;
- Improvement of living conditions;
- Attraction of new investments.

The ideas behind the redevelopment and reuse of the brownfields are also to a great extent applicable in the nuclear field. However, the SCK•CEN reuse project is somewhat special owing to a number of reasons:

- The site is still in use.
- SCK•CEN is a public organization and its assets belong to the federal government.
- Non-nuclear activities already existed on the site.
- There were no costs for the transfer of assets from the federal to the regional government.

Nevertheless, at the time the most important motivations to partly reuse the SCK•CEN nuclear site for the establishment of an institute for non-nuclear activities were:

— Limitation of costs;
— Re-employment.

I.B–2.1. Limitation of costs

Two different scenarios were considered, namely greenfield and reuse.

As a first step towards cost assessment, a replacement value was allocated to the buildings (including the 'nuclear' ones) and land intended to be transferred to VITO. Together with these data, an outline of the costs (decommissioning and demolition) was calculated for the nuclear buildings to go to greenfield. Considering the very high cost of the greenfield option (including the erection of new buildings), and in spite of the uncertainty about the decommissioning cost, the strategy was chosen to decommission only the radioactive parts of the nuclear buildings so that they could be reused without restrictions.

Table I.B–1 gives an overview of the different costs taken into account to select the strategy.

I.B–2.2. Re-employment opportunities

Another reason in favour of the establishment of VITO at the SCK•CEN site was the presence of highly skilled personnel previously engaged in the non-nuclear activities of SCK•CEN. This group of 320 people could without difficulty be transferred to VITO, stabilizing the employment situation.

TABLE I.B–1. COST ASSESSMENT OF NUCLEAR BUILDINGS (10^3 € 1991)

Building	Chemistry, block 3	Metallurgy	Physics	Radiobiology	
				Bio 1	Bio L
Land value	5	16	14	14	20
Building value	833	1921	1690	1161	1608
Conventional demolition	5	16	14	9	12
Conventional waste	20	60	53	33	46
Decommissioning[a]					
Radioactive waste[a]					

[a] To have a complete picture of the cost for the greenfield strategy, the cost for decommissioning and radioactive waste should be added in this table. However, since these costs (Table I.B–3) are to be taken into account for both scenarios, they have been omitted here.

I.B–3. ARRANGEMENTS PRIOR TO THE ACTUAL DECOMMISSIONING ACTIVITIES

I.B–3.1. Preliminary reflections

(a) Compared with highly active nuclear installations where dose and activity are actual risks, the above mentioned buildings in general represent only potential activity. This means that one can only refer to problems in terms of suspicions.

(b) Nevertheless, every suspected item, whether infrastructure or equipment, has to be investigated and remains under suspicion until proven harmless. Dismantling and/or treatment of the individual objects will be carried out according to the necessary nuclear safety precautions until a direct $\alpha\beta\gamma$ measurement can possibly lead to their release.

(c) The decommissioning often has to be carried out in a non-nuclear environment. People not familiar with radioactivity have to be convinced that they will receive a perfectly clean building.

(d) To avoid unnecessary nuclear waste production, an accepted measurement methodology (including limits) and an organized waste treatment scheme are necessary. Separation, size reduction, decontamination and restricted reuse can positively influence the quantity and type of nuclear waste.

(e) Once the reuse strategy has been chosen, attention must be given to optimizing the dismantling in order to prevent unnecessary building damage.

I.B–3.2. Drawing up of the safety report

Before starting the actual decommissioning activities, a safety report must be produced and approved by the SCK•CEN Safety Service. This safety report describes:

- Installation to be decommissioned;
- Nuclear inventory and pollution based on historical data and measurements;
- Dismantling methodology and techniques used;
- Different measurement techniques applied in order to release the building afterwards;
- Safety precautions taken for personnel and environment;
- Material flow management scheme.

If an external company will carry out the decommissioning activities, the safety report also serves as the terms of reference for the call for tenders.

I.B–3.3. Definition of the unrestricted release and/or reuse limits

In the absence of a well defined Belgian regulation for unrestricted release of materials from regulatory control, the SCK•CEN Safety Service, in association with the Authorized Control Organization for Radiation Protection (AVN), specified the following release limits:

— 0.4 Bq/cm^2 surface contamination for βγ emitters;
— 0.04 Bq/cm^2 surface contamination for α emitters;
— The residual radioactivity of the radionuclides present in representative samples of the construction materials of the building must be similar to that of corresponding construction materials originating from a non-nuclear zone.

SCK•CEN and AVN based the drafting of these limits on already existing Belgian rules and on regulations in preparation by the IAEA and other international organizations.

They also specified the methods that must be used to analyse and monitor the radioactivity from the start of the decommissioning until the final release, namely:

— Monitoring the entire wall and floor surfaces;
— Radiological analyses of the wash water of walls and floors;
— Measurement of selected core samples.

When the results of these measurements and analyses are below the above mentioned limits, the Safety Service confirms unrestricted reuse and submits this for approval to the independent Control Body.

I.B–3.4. Gathering physical and radiological characteristics of the buildings

The buildings that needed to be decommissioned were the physics building, the metallurgy building, block 3 of the chemistry building and two radiobiology buildings.

The physics building consists mainly of laboratories, offices and a waste storage room. Only a few laboratories were used for experiments and measurements with radioactive materials such as ^{14}C, ^{137}Cs, ^{60}Co, ^{133}Ba and ^{90}Sr. The total wall and floor surface of these laboratories covers approximately 700 m^2.

Average contamination levels were below 2.5 Bq/cm^2, with hot spots having up to 30 Bq/cm^2 for βγ emitters and 0.1 Bq/cm^2 for α emitters.

The decommissioning of the metallurgy building is, compared with that of the physics building, somewhat more complicated. Besides a number of conventional laboratories, a large hall for materials testing, some cellars, a storage room and a wastewater collection tank were contaminated. In these laboratories, characterization programmes for different kinds of fuel, fissile material and waste were carried out, resulting in contamination with thorium and uranium isotopes. The total wall and floor surface of the potentially contaminated areas is approximately 4800 m^2. Average contamination levels were below 2 Bq/cm^2, with hot spots having up to 60 Bq/cm^2 for βγ emitters and 0.5 Bq/cm^2 for α emitters.

Block 3 of the chemistry building consists mainly of laboratories and offices. The laboratories were used for experiments and measurements with radioactive material, fuel and fissile material. The total wall and floor surface of these laboratories covers approximately 4300 m^2. Average contamination levels were below 5 Bq/cm^2 for βγ emitters and 0.12 Bq/cm^2 for α emitters. Hot spots of 50 Bq/cm^2 for βγ emitters and 1.5 Bq/cm^2 for α emitters were found.

Two radiobiology buildings needed to be decommissioned, namely the Bio-lab and the Bio-animals-1 building. Both buildings contain laboratories, offices and storage rooms. In addition, the Bio-animals-1 building contained several animal cages. Extensive experiments and measurements of the impact of radiation and contamination on plants and animals were carried out in these laboratories. A whole range of isotopes, including ^{3}H, ^{14}C, ^{32}P, ^{238}U, ^{239}Pu and ^{241}Am, were used. The total wall and floor surface of these laboratories and cages covers approximately 3500 m^2. Average contamination levels for the surfaces were below the limits for unrestricted release/reuse. Hot spots of 1.5 Bq/cm^2 for βγ emitters and 0.15 Bq/cm^2 for α emitters were found.

Table I.B–2 gives an overview of the suspected or contaminated surfaces and the average and upper contamination levels of the buildings.

I.B–4. DECOMMISSIONING ACTIVITIES

In contrast to decommissioning with the aim of reaching a greenfield state, the actual activities were limited to the removal of the radioactive parts of the nuclear installation/infrastructure.

TABLE I.B–2. PHYSICAL AND RADIOLOGICAL DATA OF THE BUILDINGS

Building	Surface (m^2)	Average contamination levels (Bq/cm^2)		Upper contamination levels (Bq/cm^2)	
		βγ	α	βγ	α
Physics	700	2.5		30	0.1
Metallurgy	4800	2		60	0.5
Chemistry, block 3	4300	5	0.12	50	1.5
Radiobiology	3500			1.5	0.15

I.B–4.1. Dismantling methodology

The shortened operational methodology used for decommissioning the described facilities consists of the following:

(a) Preparation of the zone to be decommissioned, including:
- Isolation from the rest of the building;
- Installation of hand/foot monitors and an air monitoring device;
- Establishment of areas for decontamination, materials reduction, sorting and packaging.

(b) Treatment of loose materials and equipment.

(c) Treatment of utilities anchored in the walls and floors (ventilation pipes, fume hoods, waste piping, etc.).

(d) Vacuum cleaning and washing of floors and walls.

(e) Mapping and sampling of all wall and floor surfaces.

(f) Removal of contaminated parts by cutting and drilling.

The sequence of washing, mapping and cutting is repeated until all contamination has disappeared.

(g) Final sample collection (wash water, core samples) and elimination of demarcation zone. Treatment may include:

- Dismantling to smaller parts;
- αβγ measurement;
- Decontamination;
- Sorting of the waste (e.g. free release, restricted reuse, radioactive);
- Disposal.

Supervision by Safety Service personnel is required during the decommissioning.

I.B–4.2. Decommissioning tools and equipment

The choice of decommissioning tools was based on their ease of use and the ability to minimize cross-contamination.

Standard saws were used for dismantling and size reduction of contaminated pieces. Ventilation pipes were cut by means of electrical nibblers and scissors. Contaminated wall plaster, concrete, stone and tiles were removed using electric and pneumatic needle scabblers and drills. Water and common decontamination agents were used for washing walls, scrubbing floors, cleaning equipment, etc.

I.B–4.3. Radiation protection

During all the dismantling and decontamination operations, the crew wore protective clothing and, if needed, full face masks. When leaving the demarcated zone, they removed their protective clothing and were checked for contamination by means of a hand/foot monitor. At the end of the decommissioning of the building, every crew member had a whole body count to check for possible internal contamination.

I.B–4.4. Material flow management

All solid radioactive waste was packed and disposed of according to the specifications of the National Institute for Radioactive Waste and Enriched Fissile Material (NIRAS). Wash water collected during decontamination was sampled, measured by α and γ spectroscopy, and disposed of as liquid waste.

I.B–5. RESULTS OBTAINED AND LESSONS LEARNED FROM THE DECOMMISSIONING

The decommissioning of the physics building, executed by the intervention crew of SCK•CEN, was used as a test case. During the decommissioning work, the daily activities in the non-contaminated parts of the building went on as usual. This caused some stress for members of the staff not familiar with radioactivity. Therefore it was very important to hold an information meeting for the employees before each decommissioning phase.

No major problems were encountered during the decommissioning of the building itself. Nevertheless, the contamination level of some parts of the infrastructure, such as window sills and doors, was higher than expected.

The metallurgy building, block 3 of the chemistry building and the two radiobiology buildings were decommissioned by an external company selected on the basis of a call for tender. The SCK•CEN Technical Liabilities Team and the Safety Service supervised all the activities. Before each decommissioning phase, a meeting was held to inform the employees of VITO about the decommissioning activities and the safety conditions.

After complete decommissioning of the buildings, the $\alpha\beta\gamma$ contamination was below 0.001 Bq/cm^2. The core samples had a radionuclide spectrum similar to that of corresponding material coming from a non-nuclear zone. The total $\alpha\beta\gamma$ activity measured on those samples was below 1 Bq/g.

The decommissioning certifications were obtained in 1993 for the physics building, in 1994 for the metallurgy building, in 1995 for block 3 of the chemistry building and in 1997 for the radiobiology buildings. For each case VITO has confirmed its agreement to the transfer of the decommissioned buildings.

I.B–6. COSTS

The dismantling and waste costs for the different buildings are given in Table I.B–3. The dismantling costs include the expenditures for SCK•CEN personnel and external personnel. Waste costs are calculated according to the NIRAS waste tariff for the different types of waste and include conditioning, storage and disposal.

TABLE I.B–3. DISMANTLING AND WASTE COSTS (10^3 € 1996)

Building	Physics	Metallurgy	Chemistry	Radiobiology
Dismantling	35	210	65	117
Waste	55	362	100	141
Total	90	572	165	258

I.B–7. OVERALL ADVANTAGES AND LESSONS LEARNED FROM THIS REUSE PROJECT

Comparing the cost for the greenfield strategy (Tables I.B–1 and I.B–3) with that for the reuse strategy (Table I.B–1), even without taking inflation into account, the latter strategy yielded substantial financial profit owing to the fact that no costs had to be incurred for:

— Conventional demolition;
— Acquisition of new land;
— Erection of new buildings.

In addition, the shortage of industrial sites in Belgium is all the more reason to opt for reuse in this specific case and for redevelopment and reuse of brownfields in general. Furthermore, every redevelopment of a brownfield saves a greenfield from bulldozers.

Although not all benefits were recognized right from the beginning of the reuse project, the project proved to be advantageous with regard to the choice of the VITO location. By selecting the SCK•CEN technical domain to house VITO, immediate use could be made of existing:

— Utilities (e.g. electrical power, water supply, industrial sewer system, communication system);
— Transport infrastructure (e.g. roads, canal);
— Security arrangements (e.g. fence, guards, fire brigade);
— Sport and leisure facilities;
— Hotel, restaurant and cafeteria;
— Accommodation.

As mentioned earlier, VITO not only took over the SCK•CEN personnel already working on non-nuclear projects but extended its employment up to 450 at this time.

In general, it is advisable to start as early as possible, even during operation, with an orientation towards redevelopment and reuse of a (nuclear) site. In Belgium, owners of a nuclear installation are obliged to prepare and periodically update a decommissioning plan. One of the chapters in this plan deals with the choice of a decommissioning strategy and also addresses future use of the installation or site. As future use is becoming increasingly important in influencing the strategy, an elaboration of the following items is advisable:

— Possible scenarios (e.g. industrial park, residential area, sports park, nature reserve);
— Economic impact (e.g. on decommissioning cost);
— Social impact (e.g. on employment, affected region, public acceptance);
— Ecological impact (environmental impact assessment);
— Legal responsibilities (liabilities);
— Financial mechanisms (e.g. tax reduction, low rate for loans).

I.B–8. CURRENT SIMILAR PROJECTS

At present SCK•CEN is involved in two similar projects, namely:

— Redevelopment of a greenhouse and adjacent laboratories formerly used for radioactive experiments on soil and plants;
— Partial dismantling and reconstruction of a waste pipeline passing through a residential area.

In the case of the BR3 reactor it has been decided to reassess the final goal of the decommissioning, taking into account the evolution of social, economic and ecological aspects observed during the last ten years.

I.B–9. CONCLUSION

SCK•CEN has demonstrated that decommissioning and measurement techniques are available to clear, in accordance with legal rules, old laboratories to the level of unrestricted reuse so that they can be accepted by the non-nuclear community. In addition, the choice to locate VITO at the former SCK•CEN premises as well as the choice of the reuse strategy proved to be economically, socially and ecologically advantageous.

Experience from this project has shown that it will be advantageous to consider future redevelopment and reuse of a nuclear site at an early stage, while the site is still being used for its original purpose. In Figs I.B–1 to I.B–6, each set of photos compares a location before/during decommissioning with the same location after refurbishment by VITO.

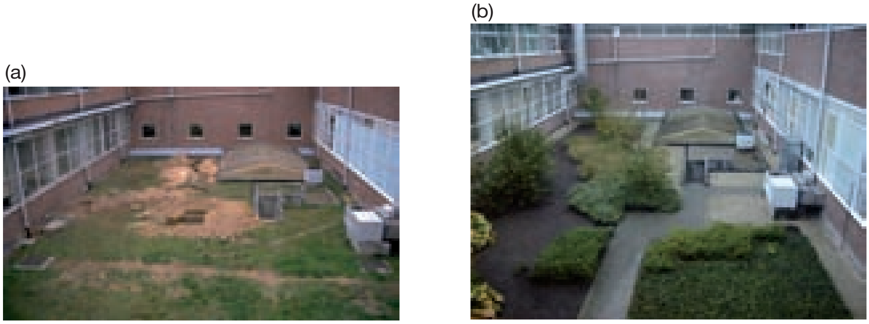

FIG. I.B–1. (a) SCK•CEN metallurgy building, courtyard. Decommissioning of radioactive waste piping and collector tank. (b) VITO materials and process technology building, courtyard.

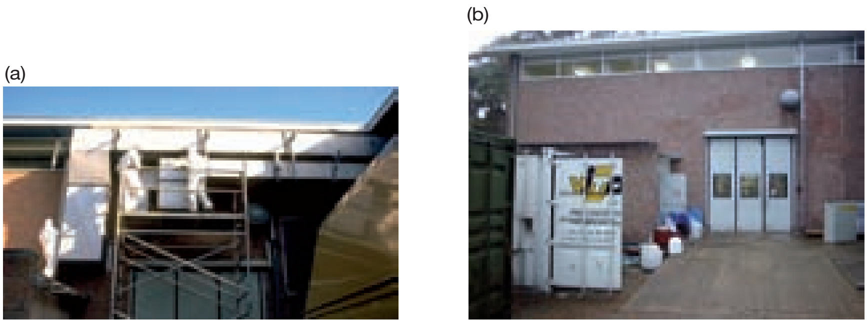

FIG. I.B–2. (a) SCK•CEN metallurgy building, hall-1-bis outside. Removal of contaminated ventilation ducts. (b) VITO materials and process technology building, process hall outside.

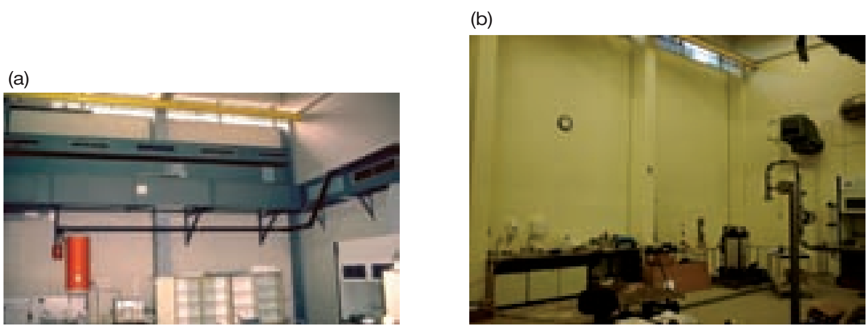

FIG. I.B–3. (a) SCK•CEN metallurgy building, hall-1-bis inside. Contaminated ventilation ducts. (b) VITO materials and process technology building, membrane technology hall inside.

(a)

(b)

FIG. I.B–4. (a) SCK•CEN metallurgy building, controlled area. Contaminated laboratory and equipment. (b) VITO materials and process technology building, refurbished laboratory.

(a)

(b)

FIG. I.B–5. (a) SCK•CEN metallurgy building, controlled area. Contaminated laboratory and equipment. (b) VITO materials and process technology building, refurbished laboratory.

(a)

(b)

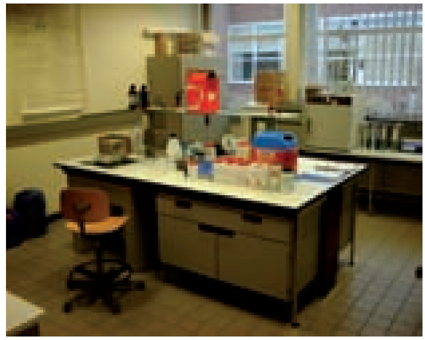

FIG. I.B–6. (a) SCK•CEN metallurgy building, controlled area. Removal of contaminated parts from walls and floor. (b) VITO materials and process technology building, refurbished laboratory.

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Annex I.C

DECOMMISSIONING AND SITE REUSE IN DENMARK

I.C–1. INTRODUCTION

Risø National Laboratory (RNL) was established in the late 1950s as a Danish research centre for the introduction of the concept of nuclear fuelled electricity generation in Denmark. The laboratory is located about 6 km north of the city of Roskilde (about 40 km west of Copenhagen) at the shore of Roskilde Fjord, as shown in Fig. I.C–1.

A total of three research reactors and a number of supporting laboratories were constructed. However, Denmark never did build any nuclear power plants, and in 1985 the Danish Parliament decided that nuclear power should no longer be an option in the framework of the national energy planning. Therefore the facilities at RNL are the only nuclear facilities in Denmark.

FIG. I.C–1. Aerial photograph of Risø National Laboratory. Reactor DR-2 can be seen in the foreground. DR-3 is situated at the left hand side of the peninsula. DR-1 is hidden to the far right in the picture.

Subsequent to the parliament's decision, the research at RNL related to nuclear power was significantly reduced and the utilization of the facilities concentrated on other applications. Some work had already been accomplished, envisioning the need for decommissioning at some point in the future. In 1975, one of the research reactors was taken out of service for economic reasons and the activities moved to the 10 MW DR-3 materials test reactor. Further, in 1989 the hot cell facility was closed, and over the next four years it was partly decommissioned.

I.C–2. PLANNING FOR DECOMMISSIONING

In 2000, as a part of RNL's strategic planning, it was realized that the largest of the research reactors, DR-3, was quickly approaching the end of its useful life. Since most of the other nuclear activities at RNL depended on DR-3 being operational, it was decided to decommission all nuclear facilities at RNL once that reactor was finally closed. Therefore a project was initiated with the goal of producing a report on the technical and economic aspects of the decommissioning of the RNL nuclear facilities. The scope of this study included the entire process, from the termination of operation to the establishment of a greenfield, assessing the required human and economic resources, estimating the amounts of radioactive waste that would be generated and other such details for this work. The planning and cost assessment for a final repository for radioactive waste were specifically not included as a part of the project scope. Such a repository is considered a national question, because it will have to accommodate waste from other applications of radioactive isotopes, e.g. medical or industrial uses.

In September 2000, RNL's Board of Governors decided that DR-3 should not be restarted after an extended outage. The outage was caused by the suspicion of a leak in the primary system of the reactor. Extensive inspection of the reactor tank and primary system during the outage showed that there was not any leak, but at the same time, some corrosion was noted in the aluminium tank. According to the inspection consultant, the corrosion called for more frequent inspection of the tank. Therefore management judged that the costs of bringing the reactor back into operation and of its continued operation outweighed the benefits from continued operation in the remaining few years of its expected lifetime.

The closure of DR-3 of course accentuated the need for decommissioning planning and for the results of the above mentioned project. By the end of February 2001 the project report [I.C–1] was completed and published. The study was followed by other studies, in order to prepare a proposal for legislative action by the Danish Parliament to provide funding for the decommissioning process. Among other aspects, the possible decommissioning strategies were evaluated and two overall strategies were considered: (1) an irreversible entombment, where the nuclear facility is covered by concrete and thereby transformed into a final repository for low and medium level waste; and (2) decommissioning to greenfield, where all buildings, equipment and materials that cannot be decontaminated to below established clearance levels are removed. The entombment option was rejected rather quickly as being unacceptable, among other things for ethical reasons (the principle that each generation should take care of its own waste). Instead, three different decommissioning scenarios were considered with greenfield as the end point, but with different durations — 20, 35 and 50 years.

After thorough preparations, including an environmental impact assessment, the Danish Parliament in March 2003 gave its approval to funding the decommissioning of all nuclear facilities at RNL to a greenfield condition within the next 20 years. The decommissioning is to be carried out by a new organization, Danish Decommissioning [I.C–2], which is independent of RNL, thus avoiding any competition for funding between the decommissioning and the continued non-nuclear research activities at RNL.

I.C–3. DESCRIPTION OF THE NUCLEAR FACILITIES

The nuclear facilities include three research reactors (DR-1, DR-2 and DR-3), a hot cell facility and a waste management plant with storage facilities. The activity content in each of the nuclear facilities has been estimated from both measurements and calculations, and the results are shown in Table I.C–1 with reference to the year 2000.

Tritium in the heavy water from reactor DR-3 constitutes the largest single radioactivity source at the nuclear facilities, as can be seen in Table I.C–1, but it is a very low toxicity radionuclide. The major potential for a radiological risk would arise during the decommissioning of reactor DR-3 and the hot cells, although the potentially largest doses could arise from exposure to waste in the storage facility for high level waste. However, this waste is safely contained in steel drums and the probability for personnel exposure is rather low.

The major characteristics of each of the nuclear facilities at RNL are briefly presented in the following paragraphs. A more detailed description of these facilities can be found in Ref. [I.C–1].

TABLE I.C–1. ESTIMATED ACTIVITY (GBq) IN THE NUCLEAR FACILITIES AT RNL IN 2000 [I.C–1]

	β/γ activity	α activity
Storage facility for high level waste	700 000	30 000
Storage hall for waste drums	4 800	—
Waste management plant	8 500	10
Research reactor DR-3 (excluding fuel)	200 000	—
Hot cell facility	3 000	100
Research reactor DR-1 (including fuel)	100	5
Research reactor DR-2	60	—
Cellar DR-2 (tritium in heavy water from DR-3)	3 000 000	—

I.C–3.1. Research reactor DR-1

DR-1, shown in Fig. I.C–2, was a 2 kW thermal, homogeneous solution type reactor, which used 20% enriched uranium fuel and light water as moderator. The first criticality was obtained in August 1957. During the first ten years of operation the reactor was used for neutron experiments and thereafter mainly for educational purposes. In the autumn of 2000, it was decided to close down the operation of the reactor, subsequent to the closure of DR-3.

The reactor core consists of a spherical steel vessel containing about 15 L of uranyl sulphate dissolved in light water, which has now been drained. Around the core there is a graphite reflector contained in a steel tank and a biological shield made of heavy concrete. The reactor has various irradiation facilities. Two stainless steel control rods containing boron carbide controlled the reactor. In addition to these major reactor components there are the typical connecting pipes, recombiner, lead shield, cooling coil and other equipment items.

I.C–3.2. Research reactor DR-2

DR-2 was a pool type, light water moderated and cooled reactor with a thermal power level of 5 MW. The reactor went critical for the first time in December 1958. It was used mainly for isotope production and neutron scattering experiments. It was closed in October 1975 and partially decommissioned. After the final shutdown, the spent fuel elements were shipped back to

FIG. I.C–2. Entry level view of the DR-1 reactor block.

the USA since they were of US origin. The reactor block and the cooling system were sealed and the reactor hall was used for other purposes until 1997, when a pre-decommissioning study was commenced. During its 5905 days of operation the integrated thermal power of DR-2 was 7938 MW·d. Figure I.C–3 shows a cutaway drawing of DR-2.

The reactor block is made of ordinary and heavy concrete and contains the reactor tank, made of aluminium, and a lead shield surrounding the core position. A graphite thermal column is situated next to the core position. The reactor tank is 8 m in height and 2 m in diameter. The primary cooling system, including the heat exchangers, is made of aluminium.

I.C–3.3. Research reactor DR-3

DR-3 was a 10 MW tank type reactor with heavy water as moderator and coolant and a graphite reflector. It is of the DIDO/PLUTO family of reactors designed in the United Kingdom. The reactor went critical for the first time in January 1960 and then was operated in a four week cycle with 23 days of

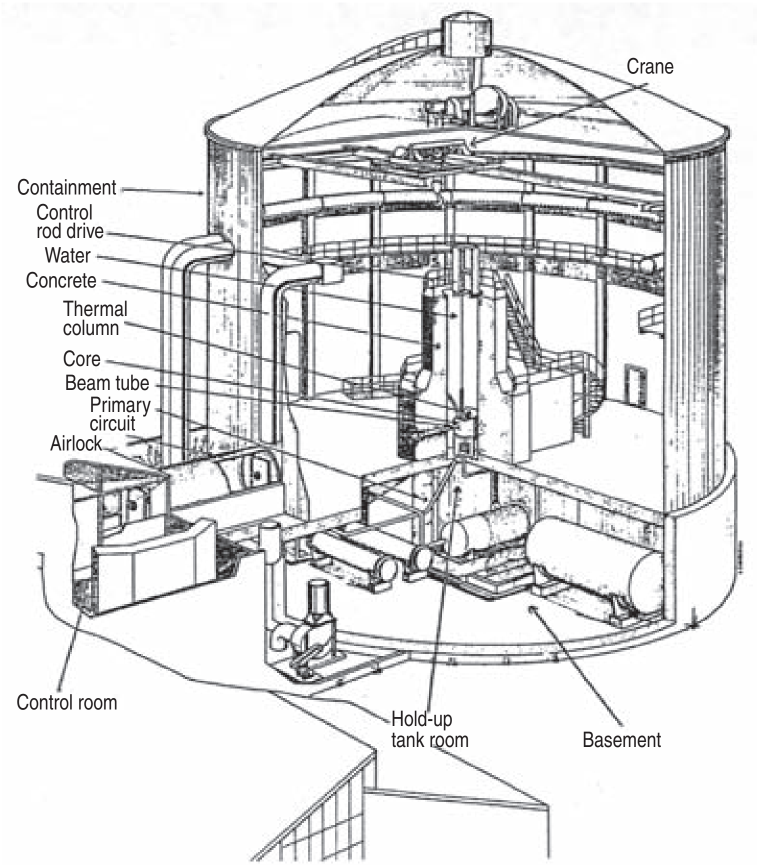

FIG. I.C–3. Cutaway drawing of DR-2.

continuous operation and 5 days of shutdown. It was shut down for the final time in September 2000. After the final shutdown the fuel elements were removed and shipped to the USA and the heavy water was transferred into stainless steel drums (about 15 000 L). Figure I.C–4 shows a cutaway drawing of DR-3.

The reactor was used for materials testing, beam experiments, isotope production and other functions. The main reactor components are: aluminium reactor tank, primary cooling system (steel), graphite reflector, steel reflector tank, lead shield and biological shield (heavy concrete). The coarse control arms (cadmium contained in stainless steel) are stored outside the reactor in a storage facility for high level waste. The auxiliary systems are still in place, but are presently undergoing modification or are being removed.

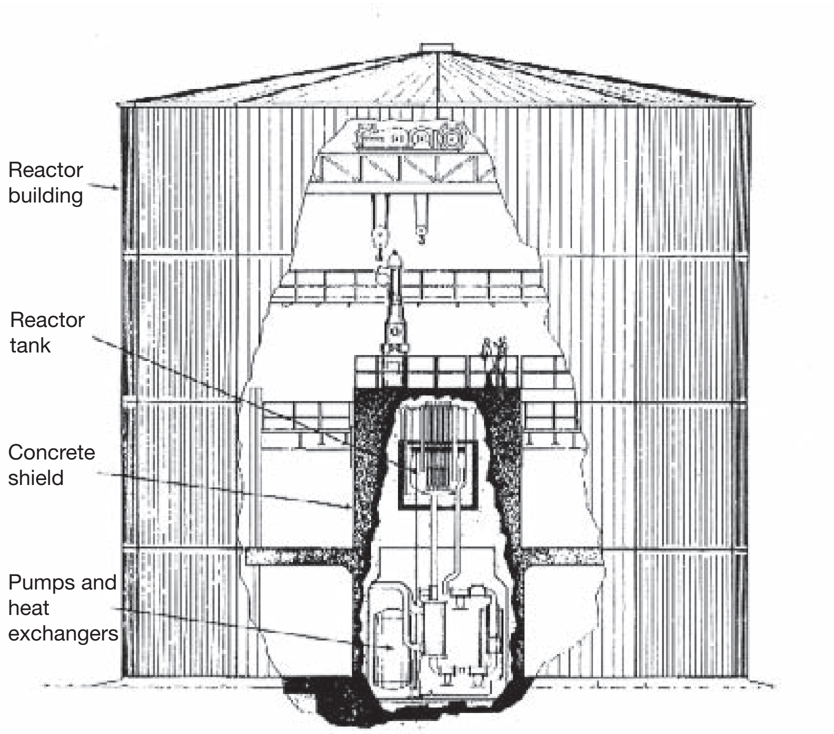

FIG. I.C–4. Cutaway drawing of DR-3.

I.C–3.4. Hot cell facility

The hot cell facility was commissioned in 1964 and operated until 1989. The six concrete cells have been used for post-irradiation examination of irradiated fuel of various kinds, including plutonium enriched fuel pins. A variety of non-destructive and destructive physical and chemical examinations have been performed. In addition, various sources for radiotherapy, mainly ^{60}Co, have been produced from pellets irradiated in DR-3. Following a partial decommissioning of the hot cell facility from 1990 to 1994, only a row of six concrete cells remains as a sarcophagus inside the building. The remaining part of the building has been released and is now being used for other purposes.

The dimensions of the interior of the six cells are: 39 m length, 4 m width and 5 m height. The cells are shielded by approximately 2 m of concrete wall with lead glass windows. The cells are lined inside with steel plates and a conveyor belt, and parts of the ventilation systems still remain. Only long lived fission products and actinides remain in the cells, together with some small activated cobalt pellets. Figure I.C–5 is a sketch of the partly decommissioned hot cell facility.

I.C–3.5. Waste management plant with storage facilities

The waste management plant is responsible for the collection, conditioning and storage of radioactive waste from the laboratories and the nuclear facilities at RNL, as well as from other Danish users of radioactive materials. No final disposal of radioactive waste has taken place in Denmark, and all waste units produced since 1960 are presently stored in three interim storage facilities at the Risø site.

The decommissioning of the waste management plant will not take place until the decommissioning of all the other nuclear facilities has been completed and a suitable substitute for the plant has been provided. After decommissioning of the nuclear facilities there will still be a need for a system for treatment of radioactive waste in Denmark, because radioactive isotopes will still be used in medicine, industry and research.

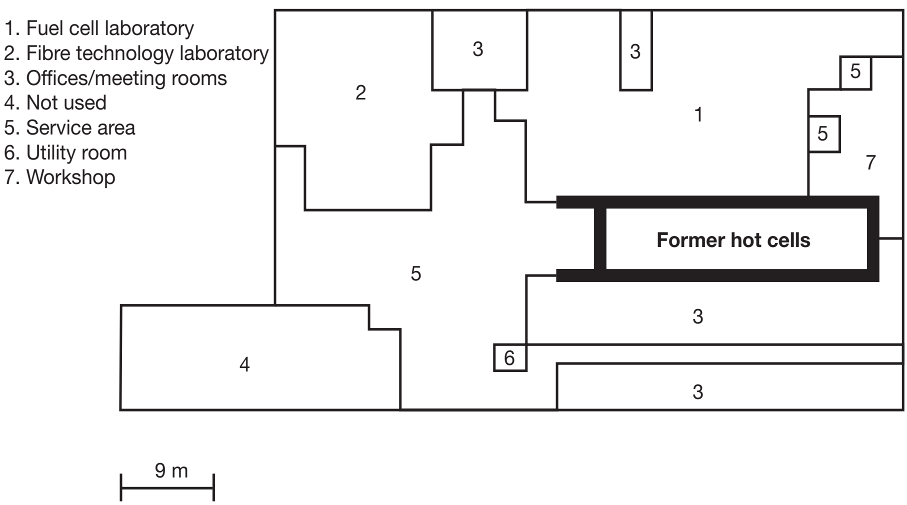

FIG. I.C–5. Schematic of the partly decommissioned hot cell facility.

I.C–4. CONSIDERATIONS CONCERNING REUSE

Although the nuclear facilities are being decommissioned, RNL will continue to exist and carry out research within other areas of natural science [I.C–3]. It has therefore from the outset been the plan that those buildings and facilities that remain after decommissioning will be reused in some capacity by RNL. No firm planning about the future use has been performed to date. Also, it is not known whether it is worth while to keep the buildings and facilities or whether they might be demolished. For the DR-1 building, however, it is known that RNL wishes to keep it, because it offers good facilities for a 'semi-large' laboratory, e.g. a gantry crane. Another incentive to maintain the building is that it is situated in a location where it would be very difficult to get permission to build a new building.

Some reuse has already taken place for the DR-2 building and the hot cell building, as described in more detail below. For the largest reactor, DR-3, it can be foreseen that the office building and two or three auxiliary buildings will be retained for further use by RNL, or by other institutions, while the reactor building and an active handling hall may have to be demolished. The waste treatment plant will have to be replaced by another, probably smaller, facility to handle radioactive waste arising from industry and hospitals in the future. Thereafter it will be decommissioned, and it is not anticipated that there will be any reuse of the buildings.

I.C–4.1. DR-2 building reuse

After the closure and partial decommissioning of DR-2, the reactor building was clean enough to be used for other purposes. Thus in the period 1979–1995 it served for large scale chemical engineering experiments, with a goal of developing methods to extract uranium from Greenlandic ore, and later for developing other processes for non-radioactive materials. These experiments left the building in a less than clean condition; but in order to prepare for a characterization project that started in 1997, the building was cleaned once again and surfaces were painted so that they would be easier to decontaminate.

The control room, workshops and office building belonging to DR-2 have been regularly used for other purposes since the closure of the reactor in 1975. Whether the reactor building itself will be reused is doubtful, although the frame and foundation seem to be in fair condition. However, ideas have been aired about converting the 20 m tall cylindrical building to offices in several storeys. From a radioactivity point of view it is anticipated that the building will be easily cleaned to below the free release limits.

I.C–4.2. Hot cell building reuse

After the hot cell facility had been partly decommissioned in 1994, the radioactive parts remained as ‘a block of concrete’ in the middle of the building. The remaining part of the building was refurbished and now serves as offices and laboratories for research programme staff.

The decision not to fully decommission the hot cells in 1990–1994 was based partly on the philosophy of delaying the production of large amounts of decommissioning waste from this facility until the other facilities at RNL were to be decommissioned — and possibly in the hope that a final repository for radioactive waste would have been established by then. The latter has not yet been realized, but the process for establishing a repository has been started. However, the fact that the hot cells are going to be decommissioned within a few years from now inevitably will create inconvenience for the activities that have been established in the building. Possibly the laboratories and offices will have to be evacuated during decommissioning, unless — as is the aim — the cells can be decontaminated completely without requiring total demolition of the concrete walls.

If Danish Decommissioning is successful in cleaning the cells without having to tear down the concrete, the cells will offer very safe storage facilities, for example for valuable documents or equipment.

REFERENCES TO ANNEX I.C

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[I.C–2] DANISH DECOMMISSIONING, http://www.dekom.dk

[I.C–3] RISØ NATIONAL LABORATORY, http://www.risoe.dk

Annex I.D

SOCIAL ASPECTS OF THE DECOMMISSIONING AND REUSE OF THE GREIFSWALD NUCLEAR POWER PLANT, GERMANY

I.D–1. INTRODUCTION

The German reunification caused enormous economic and social impacts in the regions previously part of the German Democratic Republic. The Greifswald nuclear power plant (Fig. I.D–1) complex and the surrounding region were not exceptions in this respect.

The entity Energiewerke Nord GmbH (EWN) is the legal successor of the former operator of the Greifswald complex, the Kombinat Bruno Leuschner, and accepted responsibility for the nuclear power plant sites at Greifswald and Rheinsberg after Germany's reunification in 1989. Shortly after the reunification, the operation of the units already completed, as well as all construction work, were completely stopped. Serious efforts were undertaken to restart the more modern units in Greifswald or to use the site for new

FIG. I.D–1. Map of Greifswald.

nuclear and/or conventional power plants. However, the decision was firm to decommission all of the operation and construction activities, mainly because of a lack of political acceptance of the safety margin for the operation of these types of reactor design and the lack of a secured financial basis.

Therefore EWN was faced with a formidable task: to safely and efficiently shut down and decommission both nuclear sites with all six nuclear power plants under the above mentioned boundary conditions. Initially difficulties were encountered with the massive personnel reductions that were required, from a total of over 13 600 persons (5600 operational staff and 8000 construction staff) to only about 1400 employees — a staffing reduction of about 90%. In addition, this occurred in combination with the introduction of a market based economy and the imposition of the laws and procedures of the Federal Republic of Germany on the reunified country. This had almost shocking social impacts for this region of Germany. EWN has now achieved successful restructuring of the company and has reached the optimal staffing for its execution of the decommissioning task.

I.D–2. SOCIAL STRATEGY

The first action to be undertaken was to reduce the number of employees, since under the new circumstances the number of staff was too large. To solve this problem, the following measures and principles were introduced:

(a) No major contractors were to be hired.
(b) A retirement package was prepared.
(c) Privatization and outsourcing of some special functions were undertaken.
(d) Enhanced education or re-education of redundant staff was performed with respect to:
   — The decommissioning task to be implemented;
   — Attaining a better position in the labour market for seeking other employment.
(e) Severance package support was obtained.
(f) Redevelopment opportunities for the site were evaluated.

I.D–3. PERSONNEL STRATEGY

At the time of the reunification of Germany, employment had reached about 4900 people at the Greifswald site and about 675 people at the

Rheinsberg site. In addition to these staff there were staff deployed to other sites and institutes:

— Morsleben final storage facility	280
— Stendal nuclear power plant construction site	980
— Research Institute in Berlin	199
— Research Institute in Leipzig	805

All of these employees, in total more than 7800, were staff members of the Kombinat Bruno Leuschner. The sites in Stendal and the Research Institute in Leipzig were privatized in 1992, and the staff at the Morsleben site were completely taken over by a federal institute in 1991.

During the period 1990–1994, the personnel management actions at the Greifswald site resulted in the following:

(a) Privatization and departure with economic support: about 1900 people, including:
  — Retirement: about 275 people;
  — Retraining/education about 400 people.

(b) Dismissal: about 1600 people.

(c) Remaining personnel at the site: about 1400 people.

The privatization efforts concentrated on activities outside the nuclear operation, including functions such as:

— Building maintenance and simulator operation;
— Catering, hotel and cleaning services;
— Site security;
— Educational centre and research institutes.

There are no detailed statistics as to where the displaced employees were re-employed after their employment was terminated. It is estimated that about 25% managed to find a new job, about 25% went into retirement and about 50% remained in the ranks of the unemployed. The overall development of the EWN personnel is summarized in the figures following Table I.D–1.

TABLE I.D–1. PERSONNEL DEVELOPMENT OF EWN IN THE YEARS 1990–2000

	Greifswald	Rheinsberg	Morsleben	Stendal	Leipzig	Berlin	Total
1990	4889	675	280	943	805	199	7791
1991	4645	586	[a]	844	659	170	6904
1992	3216	424		[b]	[c]	83	3723
1993	1759	321				[d]	2080
1994	1489	303					1792
1995	1398	295					1693
1996	1299	268					1567
1997	1265	261					1526
1998	1245	267					1512
1999	1219	249					1468
2000	1178	227					1405

[a] Privatization of Morsleben repository	Dec. 1990	263
[b] Privatization of the Stendal nuclear power plant	Aug. 1991	655
[c] Privatization of the Research Institute in Leipzig	Aug. 1991	565
[d] Privatization the Research Institute in Berlin	Jun. 1992	55

In conclusion:

— About one third of the employees remained with the company.
— About one third of the employees obtained new jobs or retired.
— About one third of the employees were unemployed.

Once these major staffing decisions were taken, efforts were initiated to provide counselling to the staff. It was difficult for the personnel to change from an ‘operations mode’ to a ‘decommissioning mode’ mentality, especially when the reason for doing so was neither very clear nor acceptable to most of the staff. In addition, the entire social fabric had been transformed. Unfortunately, this adjustment takes time and patience and can only be resolved when living conditions finally start to improve.

1.D–3.1. Practical realization

1.D–3.1.1. Changing of the company structure

The reason for all of the changes was to create a new company structure for the new site mission. This transformed the old operational structure into a new structure based on Western market requirements and on the laws of the reunified Germany and procedures for the continued site functions. After the decision to shut down and to decommission all the nuclear power plant units, the operational structure was successfully changed into a new decommissioning project structure.

1.D–3.1.2. Reduction of personnel

The following outlines the basis on which the management reduced the number of staff and what was done for the staff in each case.

(a) Selection by social criteria for comparable employees:
- Comparable jobs;
- Interchangeability according to employment contract;
- Remuneration.

(b) Release by:
- Special regulations for early retirement;
- Work termination contract;
- Dismissal.

(c) Contributions according to social plan:
- Payments additional to legal contributions (unemployment benefit, temporary payments for partial retirement);
- Redundancy pay
  - Half-pay × years of service;
  - Fixed upper limit;
  - 100% dismissal;
  - 60% work termination contract;
  - Temporary partial retirement, similar to dismissal.

I.D–4. FUTURE SITE REUSE

The decommissioning and the dismantling of the Greifswald nuclear power plant, as well as the construction and commissioning of the Interim Storage North (the waste storage facility), have determined the development of the site. The Greifswald project (the world's largest nuclear dismantling project) is an essential factor for stabilizing the economy in the region of Ostvorpommern and the bordering regions.

In 1998 the EWN management was instructed by the shareholder to sell identified property areas which were no longer needed for decommissioning purposes to qualified investors to encourage new industries to locate on the site. The federal government and the government of Mecklenburg–Vorpommern, as well as the regional development planning, support the preservation of the energy production site at Lubmin and the creation of new jobs. Usable areas for the settlement of industrial and commercial enterprises and an intact infrastructure are available. Together with other institutions, EWN strives to win innovative enterprises with a promising future for the site.

The industrial area comprises about 120 ha. Up to now 34 ha have been sold for industrial purposes:

— 20 ha for gas and steam power plants;
— 12 ha for the industrial harbour;
— 2 ha for small enterprises.

The starting situation for future development opportunities is advantageous owing to the following:

— The existence of a new industrial harbour;
— The existing railway system for trains with a length of up to 360 m;
— The availability of highly qualified personnel at the site;
— The existence of 30 smaller companies with 655 employees that are already established at the site.

The following projects have already been conceived:

(a) Gas and steam power plant (3 × 400 MW(e))
— Planned construction start: beginning of 2005;
— Investment volume: about 600 million euros.

(b) Gas pipeline Berlin–Lubmin
— Planned construction start: 2005;
— Investment volume: about 150 million euros.

The following ideas were taken into account for future development:

(1) Delivery, consumption and distribution of natural gas
— Planned consumption of gas on the site: 200 000–400 000 m^3/h;

— Gas pipelines from the Russian Federation to Lubmin and from Lubmin to the European grid.

(2) Processing of renewable raw material for the production of synthetic fuel
— Capacity: 1 000 000 m^3/a.

(3) Production of large components for the shipbuilding industry.

I.D–5. CONCLUSION

After initial difficulties caused by massive personnel reductions combined with the introduction of a market economy and West German laws and procedures, EWN has succeeded in restructuring the company to maintain an appropriate number of staff for the task of implementing site decommissioning. A positive atmosphere has now been created to enable work to proceed effectively and to prepare the personnel and the site for the new redevelopment tasks envisioned by the new site occupants.

The decommissioning and dismantling of the Russian WWER type reactors do not pose any specific problem in comparison with their Western equivalents. However, the size of the project and the resulting mass flow is extraordinary, and mass balance and control is the issue more than anything else. In order to achieve a safe and cost effective project and a forward looking vision for the site, close cooperation between all stakeholders, i.e. EWN, the authorities and authorized experts, is necessary.

For the future, the two natural gas fired power stations will be well positioned to keep the site as an energy producing site and for it to remain a nucleus for additional industrial establishments.

Annex I.E

FINAL FOOTPRINT PROJECT: BEST PRACTICE IN CLOSURE AND REDEVELOPMENT PLANNING IN THE SOUTH AFRICAN MINING INDUSTRY[6]

A systematic approach to minimizing the future socioeconomic disruption caused by closure of mines already well into their period of operation is described in this annex. The mining company in question is AngloGold Ltd, a gold mining subsidiary of Anglo American plc (Anglo). The approach is described with examples from the town of Welkom, where it was initiated, a large but isolated town 230 km south-west of Johannesburg in a sparsely populated area. Welkom had grown up over decades next to a successful gold mining operation in a region ranked fifth in the world for gold production. Through a combination of diminishing gold resource and increasing efficiency, the contribution of gold production to employment and economic activity at Welkom had fallen to a small fraction of its historical level.

Knowledge of the mine reserves had allowed this decline of production to be forecast in advance and prompted recognition by AngloGold of the need to take action to avoid economic collapse and dereliction of the kind that had been seen at other former mining towns in the country. These actions would have the dual motive of protecting the local community from future economic dislocation and maximizing the redevelopment or sale value of Anglo's property assets associated with the mine. A number of initiatives were taken and the more successful ones have been adopted by Anglo for application to other Anglo-owned mines in South Africa. The approach can be described in terms of four main actions.

The first action was to survey the existing assets and land and to assess their suitability for use in various forms of development. For example, heavily contaminated land or land liable to future subsidence would be identified as suitable for only a limited range of development, excluding housing and public amenities such as schools. Clean land would be identified as suitable for a wider range of development. In addition, aspects or features of the site with special potential to attract specific kinds of development were highlighted as the 'family jewels'. Examples of these at Welkom were an attractive employee

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[6] Although the closure of mining facilities is not, strictly speaking, part of the scope of this Technical Report (see Section 2 of the main text), it is believed that this annex will contribute useful information and practical guidance.

sports club comprising a large colonial style clubhouse and extensive, attractive grounds and sports fields, as well as a freshwater lake, which was a significant landscape feature in an otherwise arid area. Using the results of this survey, a development planner would draw up one or more outline plans of how the redeveloped site might look (its 'final footprint'), making best use of the assets available.

The second step was to draw the tentative outline plans to the attention of the local planning authority to alert them to the redevelopment potential of the site and hence its capacity to contribute to sustaining the integrity of the community after the mine closed. This would serve to throw into relief aspects of the wider community infrastructure and development proposals that would contribute to or hinder the mine redevelopment prospects. With this information, development planners were more likely to take decisions on infrastructure development that were consistent with successful future redevelopment of the mine assets. Examples of such decisions might be the allocation of land for similar kinds of development in the area adjoining the mine, increasing the chances of achieving a 'critical mass' for the kind of development anticipated, or the routing of highways and other services close to the mine, leading to improved access and service provision.

The third action involved convincing the mine management of the importance and plausibility of the redevelopment proposals to gain their commitment to controlling future development so that the redevelopment plans were not obstructed by inappropriate mine planning. In particular it was important to avoid placing contaminative wastes, even temporarily, on land identified for residential development or sensitive amenity uses, and to protect those features of the landscape and facilities which made up the 'family jewels'.

The result of these first three actions was to build an informal but active coalition between representatives of the local community and the operational management of the mine, mediated by the company's property management function, with a shared awareness of, and investment in, the sensitive redevelopment of the mine assets.

The fourth action was to engage the support of outside development agencies in specific initiatives where their skills and finance were necessary for the overall redevelopment to be successful. This generally involved commercial developers able to complete the market research for a proposed new development, to secure the finance necessary and to manage the physical redevelopment.

A few projects where assets at Welkom were redeveloped or reused are given below as examples. In one case a crude concrete accommodation block for mine workers on the edge of the town had been turned into comfortable flats, and other buildings had been converted to accommodation for the elderly and for use as a children's refuge. In another case, a tailings impoundment had provided the location for the local landfill waste disposal site. In a third case, a large and comfortable mine office building had been taken over as the new headquarters for the local police. The projects were not all without their misfortunes. In the case of the landfill site, the new use led to the release of pollution from the tailings into a local waterbody, which required remediation work by Anglo. In one of the residential developments, a party had absconded without completing the work.

More ambitious plans were intended to redevelop much of the mine site as a nationally important leisure resort, with a major resort developer, using the mine golf course and sports facilities together with the freshwater lake as the starting point for the redevelopment.

The willingness to consider unusual ideas is illustrated by one case where serious consideration was given to a proposal to locate a cemetery on a tailings disposal site with high concentrations of uranium. The site was not suitable for other development because of the high radiation dose rates associated with the decay of uranium and its daughter nuclides.

A number of factors can be listed in turning what would have been property liabilities into community assets as the mine was run down. These factors can be characterized in terms of five maxims:

— "Have your dreams and then take a reality check." This implies a separation between the creative identification of possibilities and the rational examination of their worth.
— "Everything is possible." This encourages an openness to new ideas.
— "Keep your plan flexible..."
— "...but only change it by decision (and not default)." This relates to the need to balance a readiness to respond to opportunities with an imperative to encourage engagement and commitment in a clearly defined plan.
— "Expect some failures." This recognizes the high risk nature of some of the initiatives but encourages a risk-aware, as opposed to risk-averse, approach.

For the practical implementation of redevelopment, the importance of personal trust networks is to be emphasized because of the need to share risks between the individuals representing the organizations involved. It is also important that no one in the partnership should take any credit until the job is completed, to avoid alienating other collaborators.

On the basis of AngloGold's experience of end of life property management, a number of suggestions can be given for the design of new industrial developments. The first of these is to consider leasing rather than owning properties. Although this can constrain the choice of property available for a particular application, it offers flexibility for the industrial operator whose requirements may change over time (requiring a move to a new property) and separates the generally longer term property life cycle from the relatively shorter term industrial development life cycle. It also makes a strong case for locating buildings in towns rather than at the mine. This is especially relevant to those administrative, management and accommodation functions that do not have to be located close to the plant. For the industrial developer, a building in town would benefit from integration with local services and would represent an investment in property likely to appreciate in value. For the community, there would be benefits in efficient supply of services to the developer and the legacy of a building with wider potential for reuse at the end of the development. These advantages need to be balanced with the potential communication difficulties associated with the dispersion of staff to separate mine and town locations.

The need to protect existing landscape or property features in new industrial developments, especially those features, such as waterbodies, which might later form the basis for other forms of development on the site, is another important issue. The protection should extend beyond simply avoiding the removal or destruction of such features and should include protecting their setting, where inappropriate industrial development close by would destroy their development potential. It is features such as these which may, at the end of the development's life, become the 'family jewels' capable of providing a new redevelopment opportunity for the site.

Overall the facilities at Welkom provided the most convincing demonstration of the value of advance action to stimulate redevelopment in relation to the closure of an industrial facility. The actions that AngloGold had taken demanded very little in resources (a portion of the time of the properties manager and two of his planning staff in planning and liaison with other parties and the preparation of 'final footprint' plans). In the examples discussed, all of the physical redevelopment action needed was undertaken by the developer in partnership and paid for from the proceeds of the sale of the redeveloped asset. The success of this work was widely recognized in the company.

On the basis of historical evidence, a commitment was given by Anglo to ensuring that when the gold ran out, Welkom would not become a ghost town like others before it. This initial commitment does not detract from the value of the experience embodied in the approaches described above but suggests that, for them to be applied successfully, a high level of senior management commitment is also necessary, and that the objective of redevelopment needs to be identified from the beginning of the initial development cycle. The successes at Welkom appeared to be in part due to the careful nurturing of ideas and relationships over many years, particularly with respect to changes to strategic infrastructure development, and this raises the question of the extent to which the process could be speeded up in circumstances where that was necessary.

Annex I.F

REUSE OF NUCLEAR SITES IN SWITZERLAND

I.F–1. INTRODUCTION

Switzerland has experience in the reuse of formerly licensed nuclear sites for which the licence has been terminated after completion of decommissioning. In addition, it is currently decommissioning a research reactor at the Paul Scherrer Institute (PSI).

In the following sections, the Swiss experience is reported and the plans for future reuse of these sites are discussed. The collection of concepts in this annex is considered to be a contribution for upcoming discussions and for the formulation of decommissioning plans required for Swiss nuclear power plants in the future.

I.F–2. REUSE OF THE LUCENS SITE

Lucens was the site of the first Swiss pilot nuclear power reactor, which was constructed in an underground cavern and commenced operations in 1968. An incident occurred during facility operations in 1969 and the facility was dismantled within three years of that date. The main part of the underground cavities were refilled and sealed over a 30 year period, and finally the site was delicensed in 2003.

The remaining parts of the underground cavity now serve as a storage area for cultural and museum pieces for the canton Vaud (Figs I.F–1 to I.F–5).

I.F–3. REUSE OF THE DIORIT AND SAPHIR RESEARCH REACTOR SITES

The former DIORIT (heavy water moderated) research reactor is now in the final stages of dismantling, and the area will be reused for both nuclear and non-nuclear purposes.

The lowest part of the reactor building, which represented the former fuel transfer channel, will be used as an interim storage for dismantled waste already conditioned for final disposal in the Swiss national repository for low and medium level radioactive waste.

FIG. I.F–1. Lucens cultural centre, external view.

The remaining area of the building has been completely decontaminated and can be free released. This part of the building will be used in the near future by a working group of astrophysicists for theoretical research.

The building structure of the SAPHIR research reactor, which is the reactor the USA left in Switzerland after the 1956 Conference on Peaceful Uses of Atomic Energy in Geneva, will be completely dismantled. On the site of this building, PSI will construct new buildings for future research programmes.

I.F–4. FUTURE REUSE OF SWISS POWER REACTOR SITES

At present Switzerland has five reactors in operation, and the current planned decommissioning scheme for these plants will be carried out over a period of 26 years. The decommissioning schedule is part of the Swiss National Waste Management Strategy, which is periodically updated by SwissNuclear, a federation of the Swiss nuclear power plant operators. The current schedule foresees the decommissioning strategy being implemented in the years shown below for each of the identified nuclear power plants:

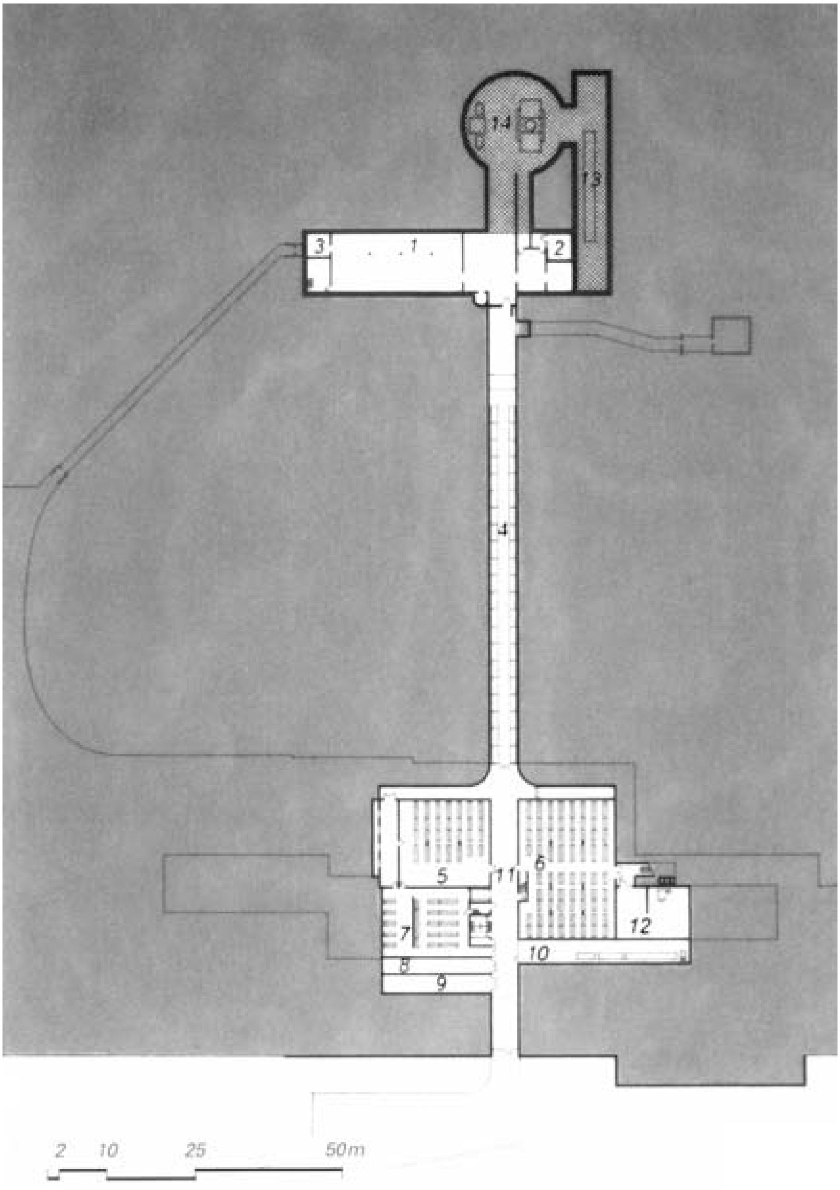

FIG. I.F–2. Lucens cultural centre, lower level. 1. Shelter; 2. Cold chamber; 3. Technical room; 4. Collection of minerals (MCAH, Cantonal Museum of Archaeology and History); 5. Ethnology store (MCAH); 6. Anthropology store (MCAH); 7. MCAH store; 8. Waiting hall; 9. Store; 10. Treatment of water soaked wood; 11. Loading/unloading; 12. Technical room (Depôt des biens culturels); 13. Nuclear fuel pond, grouted; 14. Reactor core, grouted.

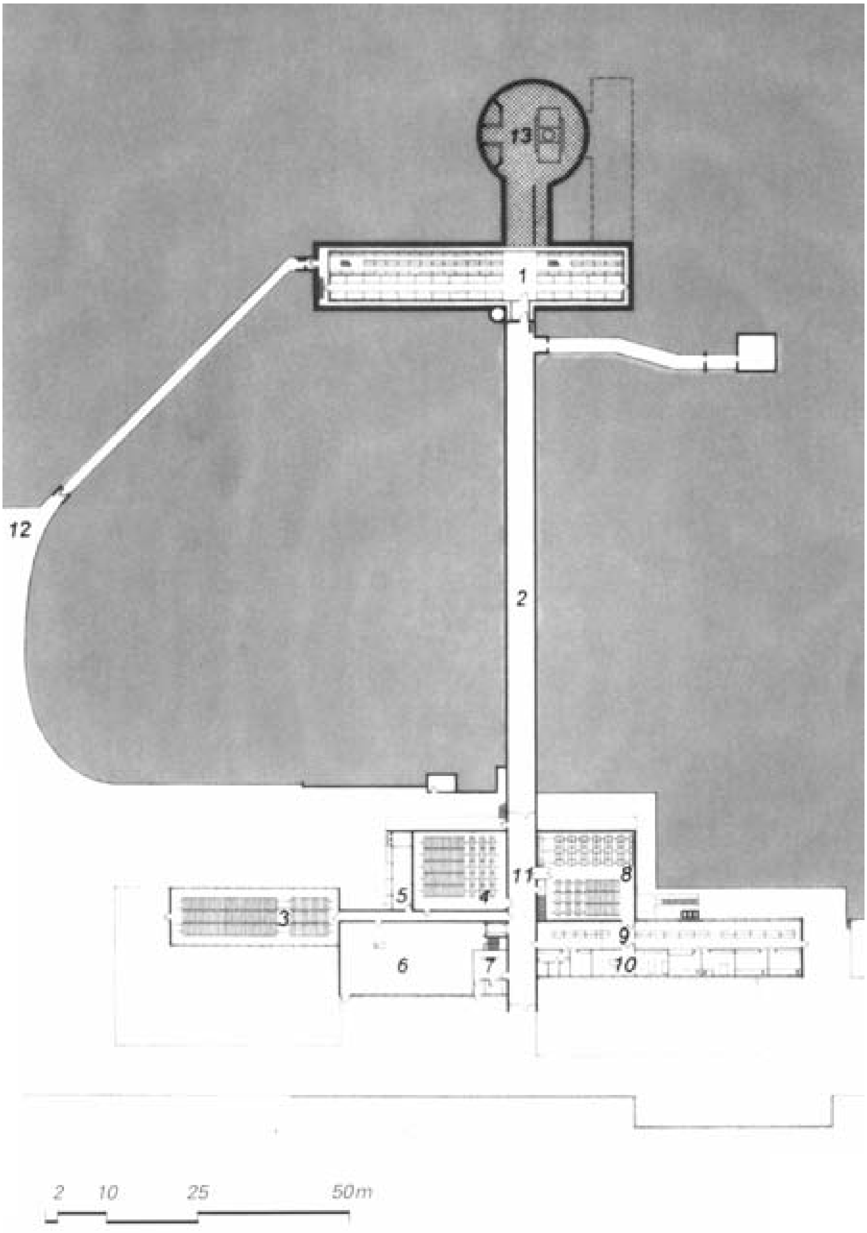

FIG. I.F–3. Shelter of cultural items. 1. Upper level; 2. Access tunnel; 3. Store (BCU, Cantonal University Library); 4. Botanical Museum/Musée de l'Elysée; 5. Cover; 6. MCAH shop; 7. Entry/bar; 8. Zoology store; 9. Intermediate zoology store; 10. Offices/shop/laboratories, Zoology Department; 11. Loading/unloading; 12. Emergency exit tunnel; 13. Reactor core, grouted.

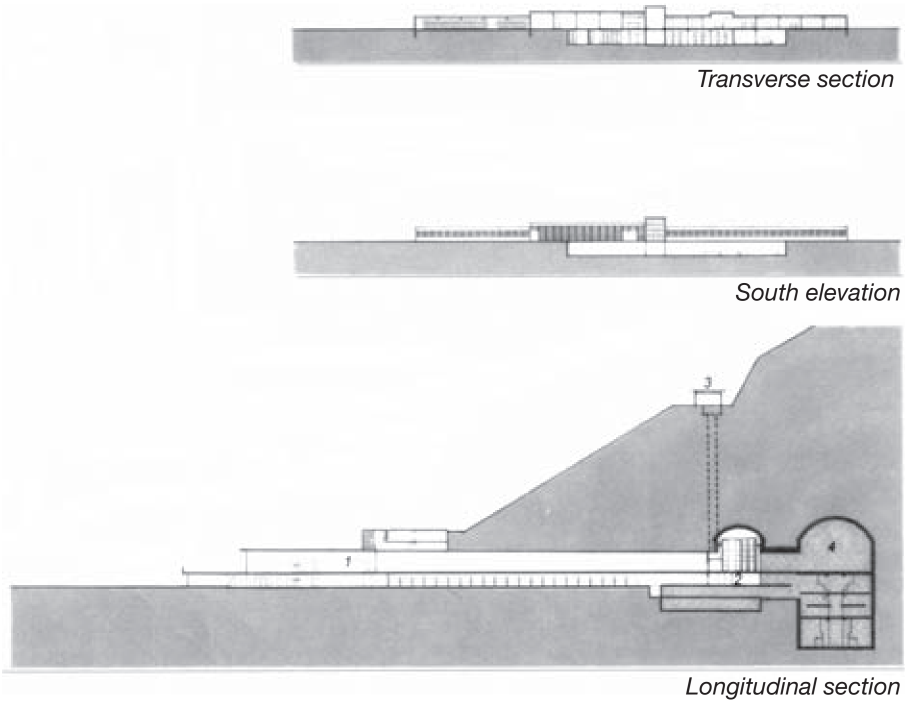

FIG. I.F–4. 1. Store of cultural items; 2. Shelter of cultural items; 3. Upper station; 4. Reactor core, grouted.

(a)

(b)

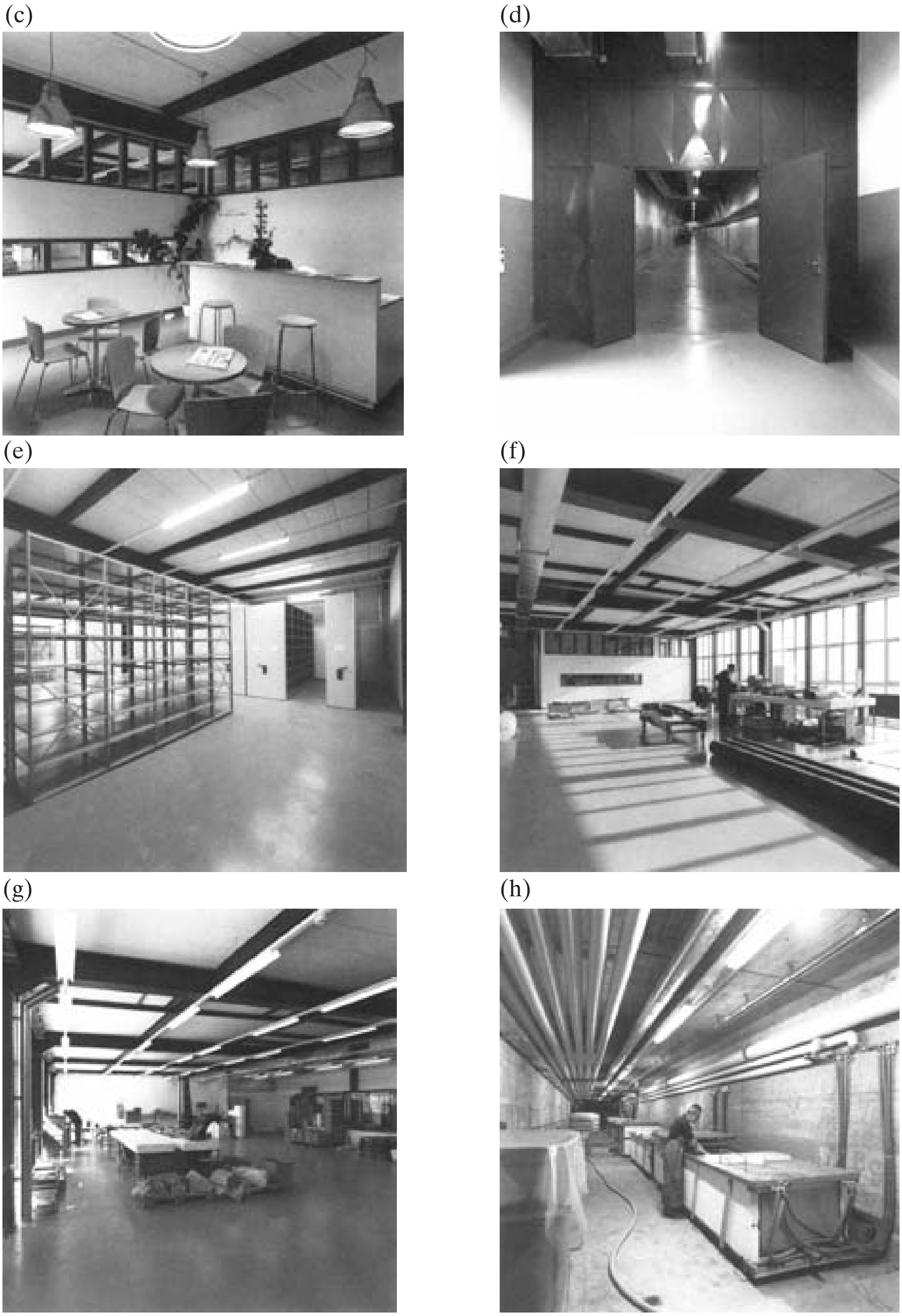

FIG. I.F–5. Lucens cultural centre. (a) View from the west; (b) view from the east; (c) entrance/cafeteria; (d) access tunnel; (e) zoology store; (f) MCAH shop; (g) MCAH shop; (h) treatment of water soaked wood.

Beznau I and II	2013 (after a 40 year operating period);
Mühleberg	2015 (after a 40 year operating period);
Gösgen	2021 (after a 40 year operating period);
Leibstadt	2027 (after a 60 year operating period).

The actual generating lifetime is the result of several measures which were undertaken in the past and enabled the extension of the design life for these plants. The extension of the design life for Leibstadt nuclear power plant (which has applied for a 60 year operating period) is the result of a series of refurbishing and upgrading measures. The first nuclear unit will be retired in 2013 and the last unit in 2027, with the last decommissioning project envisaged for completion in 2038. On average, a dismantling period of 12 years is assumed for these projects.

To date there are no official plans for what to do with the sites after decommissioning, but in view of the 40% contribution of Swiss nuclear power to the total power production, it can be concluded that the sites should be used further for future power production. Moreover, the substantial generation of nuclear power cannot adequately be replaced by renewable energy on the area of these four small sites.

If the recent public referendum on whether to continue to utilize the Swiss nuclear power plants and to not phase out their use immediately had not been so overwhelming (63% agreed to continue their use), the Swiss utilities would have had to initiate the first decommissioning activities within the next few years.

Gösgen nuclear power plant will definitely have an on-site spent fuel management activity through at least 2050, which would appear to limit subsequent consideration to some degree. Yet recently officials from the main shareholders of some of the larger nuclear power plants publicly remarked that the nuclear energy future of Switzerland will include a new, modern design pressurized water reactor beginning operation in the year 2020. It was not explained which of the existing nuclear sites will house this new reactor.

I.F–5. COLLECTION OF PROPOSALS FOR REUSE OF SWISS SITES OTHER THAN NUCLEAR SITES

Since Switzerland's four nuclear power plant sites have several common features, it is not necessary to consider the sites one by one. In Table I.F–1, typical site features and building structures of nuclear sites are given with respect to their capability for being reused, and the potential reuse is identified. It is assumed for planning purposes that the site, remaining buildings and infrastructure are definitively released from nuclear licence requirements and that funds have been earmarked to dismantle any of the remaining buildings to facilitate future site modifications for future activities at the site.

TABLE I.F–1. COMMON FEATURES OF SWISS NUCLEAR SITES FOR POST-DECOMMISSIONING REUSE

Features of sites	Features utilizable for reuse	Potential reuse
Not far from smaller or larger cities	Generally accepted in the surrounding area At least 400 to 800 households familiar with the former use of the site	Re-employment on-site of qualified personnel for new enterprises
Small and medium sized industry and trade established in the vicinity	Availability of people with certain kinds of skill	Settlement of small scale production companies
Good access interconnections with public rail and road networks	Established transportation for daily commuting personnel, bulky loads and express shipment	Installation of storehouses for any kind of goods
Established industry infrastructure, e.g. switchyards	Use of given industrial infrastructure possible Working in a green area	Any production industry, even with large machinery Service enterprises
Attractive administration and information centre buildings	Available for any kind of administrative use	Schools, administration or business offices
Robust industrial buildings, e.g. turbine halls	Assembly of industrial components	Mechanical workshops
Massive structures; contamination and activation completely removed at the end of decommissioning	Reactor building internal rooms completely isolated and protected from external influences	Archives for books, paintings, computer documents, etc. Clean room condition production Installation of H_2 electrolysis plants Production of highly toxic pharmaceuticals Construction of lofts Installation of vibration free research projects Installation of grid idle power compensating rotating masses Installation of flywheels as power stores

TABLE I.F–1. COMMON FEATURES OF SWISS NUCLEAR SITES FOR POST-DECOMMISSIONING REUSE (cont.)

Features of sites	Features utilizable for reuse	Potential reuse
Cooling towers	Huge outer surfaces	Observation towers
	Huge inner empty volume	Application of photovoltaic modules
		Leisure
		Aviaries, other zoological facilities
		Tropical gardens
		Free climbing walls
		Tower-top restaurants and skydiver blower
		Discotheques, open air concerts
		Wildwater channels for kayaking
		Bungee jumping

Annex I.G

REDEVELOPMENT OF UNITED KINGDOM SITES

I.G–1. INTRODUCTION

The United Kingdom Atomic Energy Authority (UKAEA) is an organization that was set up as part of the United Kingdom State funded research and development programme on nuclear power. Part of the UKAEA remit was to operate and manage the sites that were used in the delivery of its programme. As research into nuclear power declined, the UKAEA was faced with the need to develop a clear future strategy for these sites.

Since most of the UKAEA sites in England occupied attractive and valuable locations, selling them on a freehold basis or developing them as science and technology parks were potential courses of action. At the time, however, these sites were:

— Effectively ‘self-sufficient’ (i.e. the sites were UKAEA owned, controlled and managed with little by way of ‘publicly’ adopted or managed infrastructure and support systems);
— Largely used for nuclear research;
— Partially or wholly subject to formal nuclear licensing regimes;
— To be subject to decommissioning work for many years to come.

For some sites these issues were relatively straightforward, and freehold disposal was appropriate. For others sites, ‘sale’ would not be simple, and a managed approach was therefore required to:

— Increase the value of the sites;
— Prove land condition to enable its sale and/or development;
— Service and manage the sites and buildings in a more commercial manner;
— Reuse existing buildings and develop new premises in order to enhance the sustainable nature of the sites.

To allow clarity on the delivery of these aims and aspirations, an overall ‘property strategy’ was developed. Aspects of this are discussed below.

I.G–2. DISPOSAL OF SITES

Part of the UKAEA property strategy was to dispose of two sites (both in the north-west of England) on a freehold basis. The first of these, at Culcheth in Cheshire, is an example of how a site formerly used for nuclear research can be restored and reused. The primary use of the 15 hectare Culcheth site was as a post-irradiation examination (PIE) facility for reactor components. The nuclear facilities were decommissioned and removed, and the remediated site was sold in 1992 for residential development. Photographs of the Culcheth site in the mid-1980s and post-remediation are shown in Figs 1.G–1 and 1.G–2, respectively.

The second site sold by UKAEA, at Risley in Cheshire, is being developed as a major business park.

I.G–3. RETAINED SITES: REUSE AND RENEWAL

A strategy to rationalize the use of space has freed accommodation and buildings for reuse by external tenants or for demolition. Since 1990, over

FIG. I.G–1. Culcheth site in the mid-1980s.

FIG. I.G–2. Culcheth site post-remediation.

100 000 m^2 of redundant space has been demolished at Winfrith (a 300 hectare site) and Harwell (a 300 hectare site), which has both reduced site operating costs and opened up development opportunity.

A major contribution to cost reductions has resulted from infrastructure renewal programmes at Harwell, Winfrith and Culham. These have:

— Replaced life-expired and inefficient utility systems, which had become expensive to operate and maintain;
— Secured adoption of the utility systems by the public utility companies, thereby transferring commercial risk;
— Reduced environmental as well as financial costs, for example a reduction of about 75% in water consumption at Winfrith since 1998;
— Provided fit-for-purpose infrastructure to support present needs but which can be extended for future commercial development.

This work to improve and commercialize the provision of services is continuing. For example, some of the old catering facilities have been demolished, and planning permission has now been granted at Harwell for the development of a new business hotel and restaurant, which will be operated commercially. New commercial development is also providing enhanced childcare facilities and other amenities for workers.

I.G–4. COMMERCIAL DEVELOPMENT

Decision making regarding the redevelopment of an existing campus must focus clearly on the desired end state for the site. ‘Masterplans’ have been developed for the Culham Science Centre, the Harwell International Business Centre and the Winfrith Technology Centre that bear a number of similarities to the planning systems used by local authorities in the United Kingdom. In order to encourage their use as both reference and guidance documents, these plans rely on a mix of pictures, drawings and text. Moreover, they are ‘live documents’ that have continuously evolved to meet the key objectives of defining the:

— Overall strategy for the development of the site;
— Key development goals and principles;
— Key milestones.

The value of this approach is demonstrated by the infrastructure renewal work described above, which could not have been completed in a cost effective manner without clearly defined goals for the site.

UKAEA launched the Harwell International Business Centre at the end of 1996. As a new entrant in the business parks market, Harwell faced the conventional entry problems (e.g. no market presence) but also obstacles such as perceived nuclear blight and uncertainties regarding land quality. A programme of land quality surveys and investigations was initiated to provide the necessary technical confidence and reassurance. Providing evidence of a track record of successful site development was considered essential for attracting major institutional investors. UKAEA concluded that working with property developers (as well as new occupants) on individual projects had a key role in taking the development forward and in establishing the market credibility necessary to secure longer term investment interest.

In 2000, Harwell Innovation Centre opened (following an agreement between UKAEA and Oxford Innovation) with the capacity to support up to 250 new jobs. Further developments, including a second innovation centre, are in progress. A private sector developer has recently refurbished the old library building that supported the nuclear research. Investment by the developer has enabled the disused and dilapidated library to be extensively refurbished and converted into modern specification office accommodation (Fig. I.G–3). New premises being developed adjacent to the library will provide up to 7500 m^2 of flexible business space.

The location of major scientific developments and the related investment in infrastructure can increase the demand for commercial development and the

FIG. I.G–3. Refurbished library at Harwell.

returns that can be generated. At Harwell, UKAEA is facilitating the construction by neighbouring government research institutes of a new generation of science research facilities by providing land, infrastructure and planning support. These new major facilities include:

— Diamond, a new £300 million synchrotron, which is the United Kingdom's largest science project in 30 years;
— A £100 million extension to the ISIS neutron source to provide a second target source;
— Mary Lyon Centre, a new £15 million facility supporting genetics research.

At its peak, Winfrith employed about 2000 UKAEA staff, and at one time it had nine operational nuclear reactors. To date, considerable successes have been achieved in both decommissioning work and the establishment of tenants. At the end of 2002, the tenant base had grown to 40 different companies employing approximately 1000 staff. The range of work now established at Winfrith provides a focus for its further development as a scientific and technical centre of excellence. Facilities have been created in partnership with the district council for small and startup businesses, while strong links are being encouraged with universities that have an interest in areas such as environmental research. Together they will form a vital part of the local commercial community, stimulating growth through interaction and innovation.

A significant restored area of the Winfrith site was sold by UKAEA to English Partnerships in March 2004. English Partnerships, the United Kingdom Government's specialist regeneration agency, will take forward the sustainable development of the site and the surrounding area to deliver the Government's wider policy objectives. Some smaller additional land areas will transfer once their restoration and delicensing have been completed by UKAEA.

I.G–5. MARKETING

Harwell, Winfrith and UKAEA's fusion research site at Culham have established reputations as centres of science and technological enterprise. The marketing strategy builds on these existing strengths by promoting these sites to private and public sector organizations in the science and technology sector. The adopted 'brand names' – Harwell International Business Centre, Winfrith Technology Centre and Culham Science Centre – reflect this.

Some common factors underpin the selling points for the sites:

(a) Supportive planning frameworks. The planning authorities see the sites as appropriate locations for science, high technology and other knowledge based industry. In addition, the sites are all technically brownfield sites, and their continued use and redevelopment are consistent with government policy for sustainable development.
(b) Locations in attractive areas surrounded by environmentally designated rural landscape.
(c) Campus style layout that provides an attractive cross between conventional business park, science park and university campus.
(d) Good long term sustainable development credentials, being well located in relation to key transport corridors and existing or planned residential settlements.
(e) An established road and utility infrastructure to facilitate further growth and development.

(f) A wide range of staff amenities and business support services.
(g) Existing premises to let (although the available space is diminishing).
(h) Significant new development potential.

To an extent the market is self-selecting. Those companies interested in the prospects at UKAEA sites tend to be in the science and technology sector or a related business support area. Reasons for this include the potential synergies from clustering – with researchers, businesses and services in similar sectors — but they can be as simple as wishing to benefit from a 'recognized address'.

I.G–6. STAKEHOLDER MANAGEMENT

The stakeholder issues associated with the reuse of old nuclear sites are not straightforward. Liaisons with regulators are extensively dealt with in the main body of this Technical Report and are not discussed further in this annex.

The operator of a nuclear licensed site in the United Kingdom has a duty to liaise with and to provide information to local people. This has been developed as the nuclear operations have diminished and new developments have taken place. One example of this has been the local communication about site remediation work undertaken by UKAEA at Harwell. Regular and open communication, including newsletters, briefings, tours and noticeboards, has helped two major land remediation projects (involving chemicals, beryllium and uranium ore) receive positive feedback from the local community and resident organizations. Now that these remediation works have been completed, it is intended to further promote sustainability of the Harwell campus by pursuing residential development on an adjoining area of land. The stated intention to leave a thriving business community has often strengthened the support of the local communities for the site restoration work and their acceptance of some of the necessary environmental consequences, such as temporary increases in environmental discharges.

The vital importance of close working relationships with the various government agencies and other bodies involved with promoting economic development and seeking inward investment at regional and subregional levels was recognized at an early stage. UKAEA has also worked closely with the relevant district and county councils in relation to economic development issues as well as to their capacities as local planning and highway authorities.

UKAEA has pursued a focused, property related public relations programme (with the support of a major public relations and advertising consultant) and produces promotional material to support marketing. For example, a property specific web site has been established for the Harwell International Business Centre and Culham Science Centre.

Dealing with the nuclear history of sites can, however, be difficult. For example, tenants funding new building schemes often require assurances regarding land quality to secure the support of their bank or other financial institution. The UKAEA approach is to provide a land quality statement prepared by an independent expert. This covers all aspects of a site's historic use and the results of an extensive sampling and testing programme, and effectively provides the investor/developer with assurance from an independent expert that the risks of investing in the site are acceptable.

I.G–7. SITE ECOLOGY

A clear strategy now exists to develop a number of the UKAEA sites by decommissioning redundant facilities and constructing new buildings, site infrastructure and amenities. Within this strategy there is scope for the diverse wildlife present in various habitats ranging from grassland, wetland and wooded areas to more formal landscapes. A new approach to site management has been adopted. This approach is designed to preserve areas of particular diversity and to ensure that new landscaping complements the natural environment. This provides diverse sites that benefit those working on them by improving their working environment and providing them with ready access to open spaces for recreation and other purposes.

This new approach means that an ecology plan has been integrated into the overall site strategy. It marks a departure from the old style estate management. While there are still formal flower beds and close mown lawns, a better balance is being restored with more informal settings to encourage native flora and fauna. The plan includes the management of the following types of area:

- Grassland: Cutting is planned around the life cycle of the wildflowers.
- Trees: Mature trees are managed in both formal and woodland settings, and new trees are planted to assist in restoring the natural environment.
- Wetlands: Pond and wetland areas are being established to support their own rich diversity of wildlife.

Nest boxes have been set up to encourage the return of birds to the site.

I.G–8. CONCLUSION

In the coming decades a large number of nuclear installations will reach the end of their useful lives and will require decommissioning. Through the early recognition, planning and promotion of the potential reuse of its sites, UKAEA has enhanced the prospects for their worthwhile redevelopment. Ultimately these efforts will both help offset decommissioning costs and ensure that the best use is made of the material and land resources associated with the UKAEA sites.

Annex I.H

REINDUSTRIALIZATION OF THE UNITED STATES DEPARTMENT OF ENERGY'S MOUND SITE

I.H–1. INTRODUCTION

The Mound site was established in late 1946 on a plot that was initially about 170 acres (690 000 m^2) in size. The site was later expanded to 306 acres (1 240 000 m^2). The land had previously been used as farmland and was situated to the south of the city of Miamisburg, Ohio. The site was established to conduct research work on atomic energy and the possible future peacetime use of the atom. The site was constructed at this location owing to the following:

— The site offered a reasonably flat plateau of considerable size.
— Adjacent to the plateau was a hillside of considerable height which could be used to site some underground buildings.
— The soil conditions were favourable for construction activities.
— Drainage from the site, including effluents, could be passed into the Great Miami River.
— The location allowed for easy access to public roads.

I.H–2. PAST OPERATIONS

Several operators have managed and operated the Mound site for the United States Department of Energy (USDOE) both during its production period and now during its site closure period. The site property is federal property of the United States Government. The operators have all had a contract with the USDOE to operate and maintain the site as directed by the federal government through the USDOE, which serves as both the owner and the primary regulator. The Mound site also produced the plutonium heat sources used by the National Aeronautics and Space Administration (NASA) for decay heat power suppliers of electricity for long duration deep space missions. During its peak operations the site consisted of about 130 buildings. In 1993 the decision was made to permanently close the Mound plant, and the site mission changed from that of an industrial production facility to that of an environmental cleanup project.

The Mound site was placed on the National Priority Listing by the US Environmental Protection Agency (USEPA) in 1989 because of past waste disposal practices and the resultant releases to the environment. Cleanup efforts are required to comply with the Federal Facility Agreement dated July 1993 and its associated documents and milestones. This is a binding cleanup agreement between the regulators, the site management and its contracted operators. Cleanup of the site actually began in earnest in 1995, although some decommissioning and environmental restoration work had been completed prior to that date over the operating period of the site dating back to the late 1970s. At the peak of its operating period the site employed over 2000 persons. Currently operations under way at the site require only several hundred personnel.

The past operating contractors have been:

(a)	Site operators	
	— Monsanto Research Corporation	1948–1988
	— EG&G Mound Applied Technologies	1988–1997
(b)	Site restoration/closure	
	— Babcock & Wilcox	1998–2003
	— CH2M Hill	2003–2006 (estimated)

I.H–3. PRESENT OPERATIONS

The name of the site was changed in the late 1990s from the Mound site to the Miamisburg Environmental Management Project. The plant was to be closed, and in the course of the site closure, cleanup of the site would be performed to comply with all relevant USDOE and USEPA environmental regulations.

The current $314 million performance based operating contract for the site closure operations was awarded to CH2M Hill Inc., which is a consortium composed of CH2M Hill, Washington Group International and BWXT of Ohio. A clearly defined scope of work which allows maximum flexibility to achieve the site closure was included in the current contract. In cases where work scope uncertainty is an issue, the contractor is able to propose strategies for minimizing impacts on cost and schedule to achieve the closure by the targeted date. Likewise, the USDOE has a well defined process for its role in providing the government oversight of the closure operations. The current targeted completion date for the closure work is March 2006. The funding levels are of the order of $95 million per year. The identified scope of work is to:

(a) Demolish 66 facilities and transfer 9 other facilities to the Miamisburg Mound Community Improvement Corporation (MMCIC) for redevelopment;
(b) Remove all above ground utility structures and components;
(c) Investigate, clean up, close and document all known contaminant release sites;
(d) Store, characterize, process, package and ship waste and nuclear materials in accordance with all applicable regulations;
(e) Restore the site landscape to grade, with all debris and extraneous materials removed.

The end state condition envisioned for the site is the establishment of an industrial technology centre, with about 2500 employees to be working at the centre by the year 2020. The targeted date for the site closure process to be completed is currently 2006. As a part of this process, both the USEPA and the regulators of the state of Ohio would need to be engaged as primary stakeholders along with the public and the local USDOE. To facilitate this cleanup action, including the decommissioning of the facilities on-site, a Federal Facility Agreement was signed by the USDOE and the USEPA in 1990. The state of Ohio EPA also signed this agreement in July 1993. The USDOE is the lead agency for the site cleanup activities and ultimately the site closure activities, with oversight provided by both the USEPA and the Ohio EPA. There is a broad, active group of interested stakeholders involved in the decision making process.

I.H–4. TYPES OF CONTAMINANT

The main contaminants at the site are not only those in the radioactively contaminated facilities but also volatile organic contaminants (VOCs) that have migrated to the underlying site groundwater as a result of past operations. In order to support the site closure function, it is necessary to demolish many of the on-site structures. Some of the non-contaminated buildings will be reused. In order to facilitate site closure, the decommissioning and the groundwater cleanup must be carried out to allow the site to be released for other purposes.

Currently there is a treatment unit which is using an air stripper to remove the VOCs from the groundwater. This system is treating of the order of 140 000 gallons (530 m^3) of groundwater per day.

In addition to the contaminated structures and organically contaminated groundwater, there is an area at the site where discharges were made in the past during operations. This area is referred to as the Miami–Erie Canal, and the sediments in this area are contaminated with ^{238}Pu from the operational period of the facility owing to a waste line rupture in 1969 and a subsequent rainfall event that washed the contaminants down the hillside. This area was remediated through excavation of the soil for disposal at an off-site disposal facility.

I.H–5. TYPES OF FACILITY

The site facilities were formerly used to produce detonators for activating explosives in nuclear warheads, to recover and purify tritium from weapons components, and to construct plutonium heat generators for use in NASA satellites. Therefore some of the main processing buildings are very robust in construction and design, while others that support non-radiological or non-hazardous material processing are of standard conventional design and construction.

I.H–6. REINDUSTRIALIZATION CONCEPT

I.H–6.1. Overview

In 1993, the decision was made to end operations at the Mound site as a result of the end of the Cold War. In addition to the typical closeout activities (deactivation, decommissioning, waste management and environmental restoration) from operations at a nuclear site, the USDOE is working closely with the local stakeholders to transfer the remaining site facilities for redevelopment by the private sector. The city of Miamisburg hoped that this transfer and redevelopment would:

— Abate the loss of 2500 jobs;
— Preserve the Mound technology capabilities;
— Maximize past investment in Mound technology, equipment and facilities;
— Provide continued economic benefit to the Mound staff, the local community, the region, the state government and the federal government;
— Ensure the transfer of an environmentally clean site (as an asset) to the local community;
— Transform Mound to a private business enterprise.

As a result of the cooperation of all entities involved, the Mound Advanced Technology Center (MATC) was born. The city of Miamisburg then formed the MMCIC to lead the overall redevelopment effort. The MMCIC developed and is now in the process of implementing the Miamisburg Mound Comprehensive Site Reuse Master Plan, a long range development plan and implementation strategy for the Mound site redevelopment as an industrial and technology park. The work on the development of the reuse plan was performed by a property redevelopment specialist company. It is planned to invest over $48 million in the repair, renovation and upgrading of the Mound facilities and to make them a marketable asset to the surrounding area.

I.H–6.2. Improvements/grant funding sources

Improvements will be necessary and will be made to the site to facilitate the redevelopment. Improvements planned, or in some cases already made, are, among others, to:

— Improve poor site configuration by demolishing certain structures;
— Upgrade remaining buildings;
— Expand parking areas;
— Construct new roadways;
— Create green spaces;
— Address code and maintenance issues;
— Decentralize heating, ventilation and air-conditioning systems;
— Integrate Mound facilities into the local utility systems;
— Develop previously underutilized parcels on-site as additional business park space.

These extensive improvements have been possible owing to the broad base of support for the redevelopment of this site. The funding necessary for these improvements has been made available through grants and other funding arrangements from a variety of funding sources, including:

— USDOE;
— US Department of Commerce;
— State of Ohio;
— MMCIC;
— City of Miamisburg;
— Montgomery County.

I.H–6.3. Location/other assets

The technology and business park is located in Miamisburg, between the larger cities of Cincinnati and Dayton. The area is well connected with transportation links to interstate highways and major state routes. This area is served by the Dayton International Airport, with more than a dozen commercial airlines plus several area freight companies. In addition, 50 area trucking and motor freight companies operate locally, and in addition to these, the area has access to freight railroad service. Other assets of the site which should encourage companies to locate at the MATC include:

— Multiple feed electrical power and high speed communications infrastructure;
— Direct access to transportation corridors;
— Competitive rates for renting of space;
— Job creation tax credits and tax abatements;
— Low interest loans.

The area has a gentle, rolling topography and views of the Great Miami River. Major technical and academic centres are close at hand, for example Wright Patterson Air Force Base, the former Gentile Air Force Base (now the Kettering Business Park) and the University of Dayton.

I.H–6.4. Business development

Today, the MATC (formerly the Mound site) is home to 19 businesses with over 200 employees. Of the total of 24 companies that joined the original Mound redevelopment effort, 21 remain in business. While some have grown and introduced new high-tech products, others have been bought out and relocated. All of the firms have improved their financial position and secured a place in the market. Private companies lease or occupy over 80% of the available space, as of the time of this writing. Equipment formerly used in the operation of the site is excessed and made available to firms interested in its use for redevelopment purposes. The types of firm currently operating at the MATC include:

— Research and development concerns;
— Flexible circuit manufacturer;
— Precision machine shops;
— Engineering offices;
— Communication companies;
— Environmental consultants.

I.H–7. CLEANUP PROGRESS

In the past, the USDOE has funded numerous decommissioning projects and other environmental projects at the site. Several of these have resulted in significant restoration of on-site areas to a reusable condition. Likewise, under the current contractor much work has been accomplished on transforming this site into the industrial use future envisioned for it by the local community. Figure I.H–1 shows an aerial photo of the main portion of the Mound site.

As of April 2004:

(a) The last classified areas on-site have been closed out and high contamination area removals completed. Over 200 gloveboxes and associated process equipment were removed from the site.
(b) Of 66 buildings, 28 have been demolished.
(c) Seven buildings are ready for demolition to proceed.
(d) Seven buildings are being prepared for demolition.
(e) The site participated in a USDOE Large Scale Demonstration Project for Tritium Facilities to identify, demonstrate and evaluate improved technologies applicable to the decommissioning of surplus tritium facilities. This work was performed in the T Building and R/SW Building on-site.
(f) A total of over 2 million cubic feet (56 000 m^3) of contaminated soil has been excavated and transferred off-site for disposal, in addition to the demolition rubble from building removal activities.
(g) Nearly 60% of the waste shipments off-site to the USDOE Nevada Test Site, located near Mercury, Nevada, for disposal are complete, amounting to over 106 000 ft^3 (3000 m^3) of low level waste shipped to date in 74 trucks.

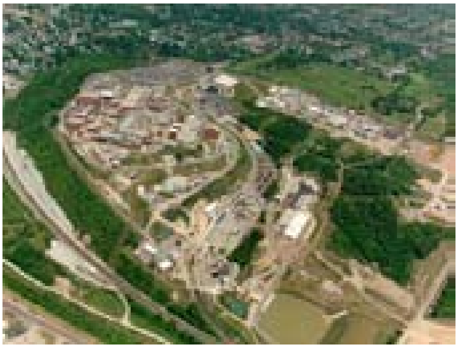

FIG. I.H–1. USDOE Mound site.

(h) Nearly 52% of the waste shipments to the Envirocare disposal site, located near Clive, Utah, for disposal are complete, amounting to over 424 railcars or 1.05 million cubic feet (30 000 m^3) of low level waste shipped to date by rail.
(i) A draft Long Term Stewardship Plan has been submitted to the USDOE.

The MMCIC has now taken responsibility for the site redevelopment; however, the USDOE maintains responsibility for the areas on-site undergoing environmental cleanup. The US Government has scheduled these cleanup activities to be completed by the year 2006. It is expected that the redevelopment efforts will continue up to two to four years after the USDOE vacates the property fully. Even after that, should any environmental liability remain, the USDOE will retain responsibility for remediating these areas.

As parcels are cleared for redevelopment, they are turned over to the MMCIC by the USDOE.

I.H–8. REINDUSTRIALIZATION PROGRESS AND PROBLEMS

The basics of the redevelopment process are summarized in this section.

In 1994, under the authority of Section 649 of the Department of Energy Organization Act (Public Law 95-91) and the National Defense Authorization Act of 1994 (Public Law 103-160) Section 3154 (also known as the Hall Amendment), the USDOE entered into a General Purpose Lease with the MMCIC, which is a non-profit organization that serves as the Community Reuse Organization for the city of Miamisburg. This release allows the MMCIC to lease, and then to sub-lease to tenants, site buildings as they are deemed releasable and reusable by the USDOE and other regulatory bodies.

The USDOE reviews and approves all sub-leases before they take effect to ensure that the sub-lessees' proposed activities are not harmful to human health or to the environment. Likewise, potential sub-lessees are made aware of the remediation activities being planned and performed at the site. Safety protocols are in place to ensure that all parties perform their work in a safe and conscientious manner. Additionally, there are opportunities, through routine stakeholder meetings, for all parties to openly discuss concerns.

At present the USDOE leases 19 buildings around the site to the MMCIC (Table I.H–1).

The lease itself consists of a set of General Terms and Conditions. Each building lease also contains an inventory of personal property, which may have been leased in place (or identified as low value and transferred to the MMCIC at the time of the lease), a Limits of Operation, a description of any preventive

TABLE I.H–1. BUILDINGS LEASED TO MMCIC

Building	Use
DS	Lab/office, metrology and calibration
COS	Office and lab
GH	Office
GP-1	Firing range
3	Powder processing and storage
27	Powder processing
28	Machine shop (old ceramics shop)
49	Office/machine shop
60	Machine shop (vacant)
63E	Production facility
63W	Surveillance facility
80–84	Magazines (storage bunkers)
87	Testing facility (pyrotechnics)
88	Storage/warehouses
104	Maintenance shop

maintenance requirements, a Real Property Condition Report and a Phase I Environmental Assessment Report. A separate lease exhibit contains all current utility charges, including electricity, gas, grounds maintenance and telephone. All utility charges are passed through the MMCIC as a service of the leaser.

The lease requires that all routine building and infrastructure maintenance be performed by the lessee with the exception of the exterior superstructure, which will be maintained by the USDOE and the site operating contractor. This latter activity consists primarily of patching or repairing roofs. Also, unless the tenant chooses to provide its own, the site contractor provides roads and grounds services, including snow removal and grass cutting for the areas adjacent to the leased space. The costs for these services are recovered from tenants by the MMCIC.

Access to some site areas is restricted and specific badging is required to enter those areas, but otherwise companies are able to freely access the work area within their leased space.

The actual site operating contractor has very little or no direct contact with the tenants. Most issues are resolved directly with the MMCIC. Occasionally, when building modifications are planned, the contractor will interface with the tenants to ensure that the proper safety precautions are in place for the work and that the work is planned so as to be performed in a safe manner.

I.H–9. CONCLUSION

On the basis of some early successes in getting this project fully under way and site closure on track, there were several noteworthy lessons to be learned from the process. These are summarized in this section.

(1) Use of the core team approach

All regulators need to concur on the readiness for transfer of a facility for follow-on development and reuse. This is critical for the regulators to ensure that impacts to worker and public health and safety and to the environment are negligible or insignificant. It is critical for early and continuous involvement of the regulators as a part of the core team for the project. This facilitates timely turnover to everyone's satisfaction and release of regulatory control over the areas in a timely manner. This interaction from an early part of the project planning phase all throughout the project should help to avoid the problem of late stage regulator disagreement for achieving site or facility exit.

This approach:

— Expedites decision making and actions;
— Reduces the risk of prolonging schedules and increasing costs;
— Assists in planning by the future owner for beneficial reuse of the facilities.

(2) Efficiency in operations

In order to achieve the desired completion date for the closure activities at the Mound site for turnover to the MMCIC, the contractor realized that it needed to address some past inefficiencies in the characterization stage of the project. The contractor was not making efficient use of the radiological characterization of existing facilities with a view to future facilities. In other cases it had collected more data than needed to support the facility demolition. In still other cases, when field characterization data were collected, they overlapped the other operational characterization data collected prior to field operation. This was clearly inefficient.

A preferable approach:

- — Reduces the characterization required by using existing, available information;
- — Focuses characterization on critical and specific information needs;
- — Minimizes the extent of the characterization efforts.

(3) Release of facilities with radiological process history

In order to maximize the reuse of some very slightly contaminated facilities, while also minimizing radioactive waste disposal costs, it was necessary both to obtain a regulatory agreement for the release of areas and to allow for the timely turnover of the areas in a known radiological condition to the new site owner.

This approach:

- — Reduces disposal costs for only slightly or even only suspected radiological waste from demolition;
- — Satisfies stakeholder groups of the potential reuse organization by leaving the facility intact where it is economically best to do so.

(4) Facility disposition re-engineering

It was a known fact that the site was undergoing final closure with a fixed budget. Therefore, rather than having the deactivation or safe shutdown process separate from the decommissioning process, the two were merged into one step.

This approach:

- — Reduced costs for the project by about 30%, saving nearly $142 million.

In conclusion, the transition of the facility from a former nuclear site to a business park site appears to be making significant strides towards that goal and is being favourably received by the stakeholders and others in the local community.

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Annex I.I

REINDUSTRIALIZATION OF THE FORMER K-25 COMPLEX, OAK RIDGE, TENNESSEE, USA

I.I–1. INTRODUCTION

I.I–1.1. History of the K-25 complex

The Oak Ridge Reservation (ORR) covers 33 750 acres (136 km^2) in the eastern portion of the state of Tennessee. The ORR is one of the largest of the United States Department of Energy's (USDOE) currently operating sites. The ORR has three major facilities — the Y-12 National Security Complex, East Tennessee Technology Park (ETTP) and Oak Ridge National Laboratory (ORNL) — which occupy about 30% of the ORR. In addition, an undeveloped portion of the ORR has been designated a National Environmental Research Park to provide protected land for environmental science research and education. The ORR lies almost completely within the city of Oak Ridge and two counties, Anderson County and Roane County. ORNL and ETTP are located in Roane County, and Y-12 is located in Anderson County [I.I–1].

The Manhattan Project was the US Government's crash programme to develop the atomic bomb during the Second World War. The first facilities sited under the Manhattan Project were in a rural area about 20 miles (32 km) west of Knoxville, Tennessee, on land acquired in late 1942. The government chose this portion of the Clinch River watershed for a number of reasons. The river provided adequate quantities of water, the Tennessee Valley Authority furnished sufficient electricity to meet the enormous demands for the uranium enrichment process and the region was relatively isolated. The industrial plants were hidden and sheltered between steep ridges. A residential community for workers was built in conjunction with the production of research facilities [I.I–1].

The K-25 site, also formerly known as the Oak Ridge Gaseous Diffusion Plant, is located 10 miles (16 km) west of downtown Oak Ridge and is situated on 1500 acres (6.07 km^2). Named after the initial gaseous diffusion building, the K-25 site produced enriched uranium using the gaseous diffusion process, which is based on the principle that molecules of a lighter isotope will pass through a porous barrier more readily than molecules of a heavier one [I.I–1]. The plant ceased producing enriched uranium in 1985; however, it continues to store about 6000 cylinders of uranium hexafluoride (primarily depleted uranium). This material is scheduled to be shipped off-site for treatment by

2008. There are also thousands of containers of legacy wastes and scrap stored on-site, some outdoors and others inside various buildings, including vaults of the deteriorating K-25 building [I.I–2, I.I–3].

In 1997, the K-25 site and the surrounding area were renamed ETTP and are now dedicated to accelerated cleanup and transition to a private sector industrial park. ETTP is home to the Toxic Substances Control Act (TSCA) Incinerator. This is the only incinerator in the country permitted to treat mixed wastes — wastes with both hazardous and radioactive contaminants — that also contain polychlorinated biphenyls (PCBs) [I.I–1].

I.I–1.2. Types of facility remaining

The buildings at the K-25 site were used primarily to support the gaseous diffusion production mission. The site went through a number of cycles of demolition of obsolete support facilities to make way for new projects, such as an experimental centrifuge complex, utilized from 1960 to 1985 [I.I–2], and the TSCA Incinerator, which started operation in 1992. Nearly 500 facilities covering about 15 million square feet (1.39 km^2) remain at ETTP. Most of these are due to be demolished under the terms of an accelerated cleanup plan [I.I–3]. They include five huge gaseous diffusion buildings (K-25, K-27, K-29, K-31 and K-33), a decontamination and recovery facility (K-1420), laboratories, garages, machine and maintenance shops, transportation depots, substations, warehouses, change houses, offices, holding ponds, cooling towers, utility support buildings, disposal areas, treatment plants and a cafeteria. Figure I.I–1 shows the configuration of ETTP in 2002 [I.I–3].

FIG. I.I–1. Aerial photograph of ETTP prior to implementation of the Accelerated Closure Plan. Photo courtesy of the USDOE.

I.I–1.3. Types of contamination

Operation of the K-25 complex involved extensive use of hazardous materials in addition to the radioactive isotopes of uranium and its daughter products, and minor amounts of transuranic and fission products from recycled nuclear fuel. The hazardous materials included solvents (e.g. tetrachloroethylene, carbon tetrachloride, methylene chloride and benzene), metals (e.g. arsenic, mercury, lithium, chromium, nickel and beryllium), gases (fluorine, hydrogen fluoride, welding fumes, hydrogen cyanide, chlorine, chlorine trifluoride and ammonia), acids (e.g. nitric and hydrochloric), epoxy resins, fungicides and PCBs [I.I–2]. Additional hazards are posed by construction materials, including asbestos insulation and tiles, lead based paint and other materials [I.I–3]. The primary contaminants of concern for the general public (including workers at private industries at ETTP) are uranium, ^{99}Tc and PCBs.

I.I–2. REINDUSTRIALIZATION CONCEPT

Reindustrialization was introduced in 1996 as a means to accelerate cleanup while encouraging private companies to lease usable facilities to replace jobs being lost because of cutbacks in USDOE related employment in the area. It was hoped that this would diversify the local economy by attracting companies that were not dependent on federal funding while also accelerating cleanup via a wide variety of innovative contracts. Many of the buildings and much of the equipment, as well as skilled workers, were recognized for their potential value to the private sector. The ultimate goal is to transition ETTP to a private industrial park, retaining buildings in good condition and demolishing those with structural problems or excessive contamination.

In some cases, companies could choose to decontaminate site facilities in return for discounts on leased space. Reindustrialization has saved the USDOE a significant amount of money by having the cleanup of some leased facilities accomplished by tenants and eliminating the need for surveillance and maintenance activities. The savings can then be applied to the remediation of other USDOE facilities at ETTP.

The leasing mechanism is accomplished through a non-profit community reuse organization to manage the property (see Section I.I–3). This organization leases the facilities from the USDOE for a nominal fee and then subleases the space to private companies.

I.I–3. COMMUNITY REUSE ORGANIZATION OF EAST TENNESSEE

The Community Reuse Organization of East Tennessee (CROET) was formed in 1995. The Board of Directors consists of about forty representatives from the 16 governmental jurisdictions in the CROET service area, regional economic development organizations, labour unions, environmental organizations and a variety of business specialties.

CROET structured itself as an economic development organization. The facilities and land at ETTP were its main focus. In addition to the buildings at the K-25 complex, CROET was able to negotiate a lease for an additional, new greenfield industrial park on USDOE land to the east of the K-25 site. These two sites were the newly named Heritage Center (K-25 site) and the Horizon Center (new site). The organization then launched a grant acquisition and partnering campaign to fund improvements at these sites to support reuse of the Heritage Center buildings and development of Horizon Center as a high-end industrial park.

At Heritage Center, lease rates initially were negotiated to take into account whether the company would undertake any cleanup, the quality of the facility and whether specialized equipment was included. CROET also provided incentives in the form of reduced lease rates for increasing employment, corporate growth and hiring of workers displaced from USDOE related employment. Additionally, the USDOE provided funding for an assets utilization office that supported the reuse activities. The USDOE Environmental Management programme continues to fund necessary surveillance and maintenance in the unleased facilities.

CROET's presence at the K-25 complex grew, with reindustrialization leases peaking in 2002. The utilities, including heavy duty electrical service, natural gas, sanitary sewer, potable water, cooling water, fire protection water, steam, gas (argon, nitrogen and oxygen) supply systems and compressed air, were leased from the USDOE to CROET, which then subcontracted to Operations Management International (OMI) for management and provision to the tenants. The railroad, including locomotives, trackage and 12 miles (19 km) of right of way, was leased by CROET to provide rail access to tenants and cleanup firms. Contracts and sub-leases of pieces of this system were then negotiated with private firms on-site. CROET also has leased the barge terminal on the Clinch River, although the facility is currently not in use.

As CROET's holdings grew, the executive committee grew increasingly concerned regarding the liability of the organization. In 2000, the CROET Board of Directors approved a strategic plan that called for the formation of subsidiary corporations that would be effectively independent from the

CROET Holding Company. This plan was implemented over the next three years, resulting in the ultimate formation of three subsidiary corporations: Heritage Center, LLC; Horizon Center, LLC; and Heritage Railroad, LLC. Each of these subsidiaries had its own five person Board of Directors, two of whom also served on the CROET Holding Company Board. However, the reorganization removed the ability of the holding company to impose policy or other control over the subsidiary corporations, and consequently the CROET Board of Directors no longer had input into the leasing process or industrial park development.

I.I–4. ROLE OF STATE AND FEDERAL REGULATORS

The entire ORR is listed by the US Environmental Protection Agency (EPA) on the National Priorities List as a contaminated site that is required to be cleaned up under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), more popularly known as the Superfund Act. The EPA and the state of Tennessee have a long term Federal Facility Agreement (FFA), with USDOE cleanup of contamination at the ORR on a given schedule. In addition, the USDOE provides funding for the state of Tennessee to maintain a USDOE Oversight Division Office for the Tennessee Department of Environment and Conservation (TDEC) in Oak Ridge. Table I.I–1 shows the interplay of various parties in the Oak Ridge redevelopment project.

Cleanup of ETTP was allowed to be delayed because the USDOE argued that there was no longer any industrial activity on the site. With the advent of the reindustrialization programme in the mid-1990s, this argument was no longer valid, as the non-USDOE workers were considered equivalent to the general public with respect to the assessment of risk from radioactive and hazardous contamination. Regulatory pressure reactivated ETTP as a priority under the FFA. Initially, cleanup was to proceed on large, lightly contaminated buildings via an innovative fixed price contract initiated by the reindustrialization programme. Less contaminated facilities could be leased if appropriate precautions were taken to protect workers or if the companies committed to decontaminating their workspace.

One of TDEC's major roles in the reindustrialization process was to undertake facility surveys and review information provided by the USDOE. These surveys document historical releases of contamination and investigate the potential for ongoing and future releases, especially from ventilation or piping [I.I–1]. The facilities with the highest likelihood of being leased were given priority for early survey.

TABLE I.I–1. PARTIES INVOLVED IN THE OAK RIDGE REDEVELOPMENT PROJECT

<table>
<tr><th>FFA parties</th><th>Divisions involved with reindustrialization</th><th colspan="3">Private industry and managing organizations involved with reindustrialization</th></tr>
<tr><td rowspan="4">USDOE, Oak Ridge Operations</td><td>Environmental Management</td><td>Bechtel Jacobs Company</td><td colspan="2">Subcontractors for remediation work</td></tr>
<tr><td rowspan="3">Assets Utilization</td><td rowspan="3">CROET</td><td>Heritage Center, LLC</td><td rowspan="2">Tenants and subcontractors at ETTP</td></tr>
<tr><td>Heritage Railroad, LLC</td></tr>
<tr><td>Horizon Center, LLC</td><td></td></tr>
<tr><td rowspan="2">State of Tennessee</td><td>TDEC, USDOE Oversight Division</td><td colspan="3" rowspan="3"></td></tr>
<tr><td>Emergency Management Agency</td></tr>
<tr><td>EPA, Region 4</td><td>Federal Facilities Branch</td></tr>
</table>

Despite the fact that these private companies would normally be subject to oversight by the state of Tennessee Occupational Safety and Health Administration, the state agency declined to inspect and oversee the facilities because they are on federal property. Consequently the USDOE assumed the responsibility for health and safety oversight. Workers on the site are required to undergo Park Worker Training, and the companies belong to the ETTP Health and Safety Council, which meets regularly to discuss safety issues. The council has a USDOE funded advocate, and the council monitors the tenants' health and safety plans.

In 2003 a conflict arose between the state of Tennessee Emergency Management Agency (TEMA) and the reindustrialization programme. TEMA requires the USDOE to report all on-site emergencies that have potential for affecting areas outside of the ORR. The USDOE has delegated this responsibility to its ETTP site management and cleanup contractor, Bechtel Jacobs Company (BJC). BJC is not allowed to classify types of operational emergency for the private companies located at ETTP, so that TEMA would not know if an emergency was confined to the site or might threaten off-site areas. The USDOE maintains that the responsibility for such classification lies with each individual company. The state disagrees, saying that anything that occurs on the ORR is the USDOE's ultimate responsibility.

I.I–5. CLEANUP ACTIONS

Prior to and in conjunction with the advent of reindustrialization, a number of cleanup actions took place at ETTP. Several remedial or removal actions at disposal areas and contaminated waterways were undertaken. Three sites were closed under the Resource Conservation and Recovery Act. In the process buildings, deposits of enriched uranium were removed from piping and other process equipment in order to eliminate the possibility of a criticality incident.

In support of the reindustrialization programme, buildings were evaluated as to lease potential. Those without such potential were slated for demolition, a process that began in earnest in the late 1990s. BJC gave priority for maintenance and decontamination actions to buildings with good lease potential.

In 2001, the focus of work changed under an initiative from USDOE Headquarters to accelerate cleanup of sites across the country by addressing the most contaminated and highest risk facilities first. As a result, the USDOE Environmental Management programme embarked on an accelerated cleanup programme at ETTP to help alleviate regulatory concerns. After completion of remediation activities, the envisioned end state would be a brownfield site suitable for a private sector industrial park.

I.I–6. REINDUSTRIALIZATION PROGRESS AND PROBLEMS

I.I–6.1. CROET

After its inception, CROET proceeded to actively market and lease facilities at ETTP, attracting a variety of companies. These were predominantly firms that had contracts — or that hoped to gain contracts — with the USDOE for environmental supplies or services: a manufacturer of B25 waste boxes, a painting firm, waste management companies, a construction company, a hazardous materials transport firm, laboratories, a safety equipment supplier and a temporary worker service. Other companies were attracted by specialized facilities or equipment. Some companies were high technology spin-offs from ORNL. Three of the firms were contracted by CROET to manage services at ETTP: OMI to manage the utilities, Railway Technologies & Consulting, Inc. to operate the railroad and Oliver's Catering to run the cafeteria. The quantity of leased space peaked at approximately 726 700 ft^2 (67 510 m^2) under roof with 39 companies in 2002. However, in 2003, with the advent of the accelerated cleanup programme, which will require demolition of most of the leased industrial facilities, this statistic dropped to 515 400 ft^2 (47 730 m^2) under roof with 34 companies.

Companies at ETTP terminated or declined to renew their leases for a variety of reasons. Many of these were due to routine business decisions. However, there were a number of problems related directly to the reindustrialization programme:

(a) Problems with utilities surfaced. In some cases, air-conditioning systems were not working or water was not available where needed. Additionally, since there was no metering on-site, billing for utilities was based on an estimated usage formula taking into account the area of leased space and type of activity. Consequently utility costs tended to be higher than what would otherwise be charged by a public utility board. The Electric Department of the city of Oak Ridge eventually installed over 50 electric utility meters to alleviate this problem. Utility problems played a role in the bankruptcy of one tenant company.

(b) Security on-site was a mixed blessing. All companies were 'behind the fence'. All employees needed to be badged and visitors cleared prior to entering the site. While this provided a benefit for manufacturing operations with proprietary techniques or expensive equipment, it created a problem for those companies that depended on customers and suppliers being able to easily access their facilities. Several such companies declined to renew their leases, citing the time and effort of escorting visitors through security, especially after the USDOE instituted more stringent restrictions in the wake of the terrorist attacks of 11 September 2001.

(c) Excessive bureaucracy related to operating on a USDOE site (safety training, security, limited access, radiation briefings for workers, etc.) proved to be intolerable to several company owners more accustomed to a private sector work environment.

Other issues that led to termination of leases included:

(1) Companies that were originally subcontracted to perform cleanup work did not have their contracts renewed.

(2) Companies that located at ETTP with the expectation of gaining subcontracts did not win the expected work.
(3) There were bankruptcies.

I.I–6.2. British Nuclear Fuels

British Nuclear Fuels (BNFL) was contracted by the USDOE in 1997 to decontaminate and make ready for reindustrialization three enormous buildings at ETTP. This Three Buildings Project was to address the buildings designated K-29, K-31 and K-33, all the newest of the gaseous diffusion buildings and the least contaminated of such process buildings at ETTP. The first building to be addressed was K-33, the world's largest industrial building, with 2.8 million square feet (0.26 km^2) of floor space. BNFL's fixed price contract specified that the company could recover, decontaminate and recycle valuable metals from the process equipment within the three buildings.

When Secretary of Energy Richardson declared a moratorium on recycling metals from the nuclear complex in 2000, the BNFL contract was renegotiated such that the USDOE was to pay market prices for the scrap and also dispose of it. This drove up project costs. In addition, BNFL lost money on a subsidiary it had acquired specifically to undertake the decontamination and metal management. When it became clear that these buildings had structural or widespread contamination problems, the focus of the mission changed to ready K-29, and possibly K-33, for demolition instead of reuse [I.I–4].

I.I–6.3. Decon Recovery Services

Decon Recovery Services (DRS) submitted an unsolicited proposal to the USDOE and was awarded a contract in 1997 to undertake decontamination of Building K-1420 in exchange for the equivalent of five years of surveillance and maintenance funding. K-1420 was the decontamination and recovery facility that supported the gaseous diffusion process and contained specialized equipment. DRS proposed either to turn the building back to the USDOE after decontaminating it to radiological industrial standards, or to lease K-1420 itself in the hope of supporting further cleanup work at ETTP. In 2001 it became clear that the funding was insufficient to complete the job, and DRS went bankrupt, leaving the USDOE with a building that was incompletely decontaminated. K-1420 is currently scheduled to be demolished.

I.I–6.4. Pall Industrial Membranes

Pall Industrial Membranes (PIM) manufactures filtration systems. PIM approached the USDOE about applying technology developed at ORNL and classified equipment housed at ETTP to produce non-classified filtration systems. This lease was accomplished in 1998 through the Assets Utilization office. In addition, PIM pays a royalty to the USDOE for use of the technology. Its building is now scheduled for demolition, and the corporation may relocate to a different building at ETTP that will be transferred to CROET or to a facility elsewhere on the ORR.

I.I–7. PROBLEMS ENCOUNTERED

The problems encountered at ETTP fall into two major categories. The first is that of dealing with the difficulties inherent in reusing decommissioned federal government facilities, including community relations. The second is the less predictable but more ‘impactful’ effect of changing political priorities.

I.I–7.1. Reuse of decommissioned facilities

I.I–7.1.1. Residual contamination

Contamination remaining in the buildings was a strong disincentive for some businesses. Ultimately the ones that located in these facilities were not concerned about this issue, in part because some firms routinely dealt with environmental hazards and in part because all employees were trained by the USDOE regarding the extent of site hazards. CROET and the USDOE developed a series of fact sheets explaining the risk of working in each of the facilities. For example, workers in Building K-1401, a former machine shop and maintenance facility, may receive an estimated annual dose of up to 1.4 mrem/a (14 μSv/a).

However, this issue proved to be a focus for community activists to attack the reindustrialization programme. In the Oak Ridge area, there are many current and former workers from the K-25 complex that claim to have been harmed by exposure to radioactive and hazardous substances. The residual contamination in soils and in some buildings became cause for protest. In particular, Building K-1401, which houses several manufacturing interests, has fixed radioactive (alpha) contamination in the rafters above the height of 8 ft (2.4 m) off the floor, an area that non-USDOE employees are restricted from entering. While this did not pose any health threat to the employees, its presence was used to promote concern about radioactive exposure throughout the community.

A more problematic issue was the residual contamination on equipment and personal property leased or transferred to private entities in conjunction with leases of the buildings. A 2002 USDOE Inspector General report cited lack of documented radiological control reviews as contributing to increased safety risks for both off-site contamination and for private workers at ETTP. USDOE Oak Ridge Operations had relied only on lease restrictions and other administrative and physical restraints to prevent unintentional off-site release [I.I–5].

I.I–7.1.2. Maintenance problems

Possibly the most significant source of problems for the reindustrialization programme was the age and physical condition of many of the buildings and facilities. The K-25 site was established during the Second World War, with additional facilities and buildings being added over the next few decades. The older buildings in many cases were poorly constructed, with only a limited lifetime intended for them. Also, owing to budget constraints and changes in usage, many facilities were not properly maintained. Roofs were allowed to deteriorate, which led to water damaged interiors. The railroad bed was in such poor condition that train speeds had to be kept low to prevent derailments. There were cases where utilities were not in a condition to support the industries moving into leased space, forcing upgrades and repairs on an ad hoc basis.

I.I–7.1.3. Federal bureaucracy

One of the most difficult obstacles to deal with has been the entrenched federal bureaucracy. The USDOE agreed to ensure tenant compliance with health and safety requirements because the state of Tennessee Occupational Health and Safety Administration would not assume regulatory responsibility for private businesses operating on federal property. Under the aegis of CROET, companies were required to belong to an internal safety organization, which met regularly to discuss safety and other tenant issues. At a minimum, workers were required to undergo Park Worker Training, which includes some basic information regarding radiation safety, as a condition for working at ETTP. Some businesses found these requirements onerous to deal with.

The reindustrialized portions of ETTP currently remain ‘behind the fence’. The USDOE had planned to move the security area back to allow free access by tenants. Unfortunately, the terrorist attacks of 11 September 2001 significantly changed the security situation. Instead of fewer restrictions, the USDOE imposed additional security requirements. Foreign nationals were barred from the site. This impacted several businesses with employees or corporate personnel who were not US citizens. Some businesses were frustrated by an inability of their suppliers, visitors and customers to easily gain access. The few ventures by retail businesses to locate at ETTP were unsatisfactory from this perspective.

I.I–7.1.4. Diversifying the local economy

Although one of the major factors driving reindustrialization was the need to attract strong companies not dependent on the USDOE for economic viability, this turned out to be more difficult than anticipated. Despite the lease of facilities to several manufacturing firms, the major interest has been from companies that have contracts — or that hope to obtain contracts — from the USDOE or its major environmental contractor, BJC. Effectively this programme drew companies from downtown Oak Ridge to the lower cost space at ETTP, but created few new jobs to replace those lost by declines in USDOE budgets.

I.I–7.1.5. Regulatory issues

Because ETTP remains federal property, the state of Tennessee expects the USDOE to ensure that appropriate reporting continues, although private industries are legally responsible for their own permits and activities. A problematic case in point has been hazard assessments for the purpose of emergency planning. The TEMA requires the USDOE, via its site contractor, BJC, to report any general emergencies where hazardous materials are released off-site. BJC maintains that it is each company’s responsibility to ensure that such an incident is reported, although BJC has collected data to support hazard assessments for each facility. The USDOE is formally on notice from the state of Tennessee that it (or its contractor) must abide by the terms of the reporting agreement, whether or not a private company is involved.

I.I–7.1.6. Local government issues

ETTP lies in Roane County and is mostly within the city limits of Oak Ridge, although it lies about 10 miles (16 km) from the city centre and 6 miles (10 km) from the west end of the residential area. The city collects modest personal property taxes from industries at ETTP, but not taxes on real property. The facilities are owned by the federal government and are leased by

CROET (a non-profit organization), despite the sub-leases to private businesses. Owing to ETTP's location on USDOE property, the city does not provide the same level of municipal services to those industries that it does within the non-reservation areas of Oak Ridge. Instead the USDOE or CROET addresses these issues. If facilities at ETTP are transferred to CROET, and the USDOE leaves the site as planned, the utilities and responsibility for fire protection, and probably the site fire station, will transfer to the city. Even if able to tax real property, Oak Ridge may find it must provide services and access to utilities for a relatively small number of businesses, a money-losing situation for the jurisdiction.

I.I–7.2. Changing political priorities

Reindustrialization was initially heralded as a means to accomplish cleanup more cheaply as well as to bring new industries into the Oak Ridge area. As the result of a top-to-bottom review of all agencies, including the USDOE, an analysis found that at ETTP the remediation activities were not necessarily addressing the highest risk buildings and that proper oversight of contractor personnel was not being provided at the site [I.I–6].

A new and updated Accelerated Closure Plan was developed for the site with the purpose of demolishing the highest risk and most maintenance intensive buildings at ETTP as quickly as possible. Under this new paradigm, reindustrialization via leasing of facilities is no longer supported, except when CROET agrees to assume ownership of buildings on the USDOE's timeline for demolition, with facilities coming up for final disposition decisions between 2003 and 2006 [I.I–4].

The USDOE has evaluated two scenarios: cleanup of ETTP with reindustrialization such that leased facilities remain (Fig. I.I–2), and cleanup of ETTP without reindustrialization, effectively removing all buildings [I.I–3]. Because neither the USDOE nor CROET wishes to be saddled with the liability of contaminated facilities or the contaminated soils underlying these facilities, almost all of the industrial properties are slated to be demolished. Even though 26 facilities, totalling approximately 6 million square feet (580 000 m^2), may still potentially be transferred to CROET, most of these are office buildings. The enormous K-31 and K-33 buildings, decontaminated by BNFL, will be demolished unless tenants are found before 2008. This change in the USDOE's priority has resulted in damage to the reindustrialization programme, for example the following:

FIG. I.I–2. Artist's rendition of ETTP after implementation of the Accelerated Closure Plan, with reindustrialization. Photo courtesy of the USDOE.

(a) The steam plant, which supplies heat to the complex, will be demolished, and much of the utility infrastructure will also be disrupted. This will impact several of the existing users until planned utility improvements can be made at the site with help from the city of Oak Ridge.

(b) Some of the businesses depend on specialized facilities, and in fact the USDOE will be disrupting businesses that it is currently using for cleanup support.

   (i) Materials and Chemistry Laboratory, Inc. (MCLinc) leases 25 000 ft^2 (2300 m^2) in the Building K-1006 Development Laboratory, an older contaminated building. The lease includes numerous pieces of advanced instrumentation; this equipment cannot be moved without damage, so this company will be put out of business when the move occurs. MCLinc completed decontamination and removal of hoods and asbestos remediation in general use areas of the building as part of its lease agreement. It currently has a contract to perform analytical work on hazardous, radioactive and classified materials in support of the accelerated cleanup.

   (ii) East Tennessee Materials & Energy Corporation (M&EC), a waste treatment facility, has been removing old centrifuge equipment, cleaning the centrifuge buildings and placing waste treatment facilities into the renovated space, an investment of tens of millions of dollars. The company has contracts with the USDOE for legacy waste treatment as well as long term contracts with industrial clients.

M&EC would like to purchase these lightly contaminated buildings from the USDOE, but whether that is possible or whether the company will be evicted and the buildings demolished at the end of the current lease period is still unknown.

(iii) PIM uses classified specialized equipment in its building to manufacture inorganic membranes used in industrial filtration and separation processes. PIM leases a 56 390 ft^2 (5240 m^2) facility in Building K-1037, portions of which it has decontaminated. This company may be able to move its operation to other facilities on the site or elsewhere on the ORR.

(iv) Dienamic Tooling Systems, a tool and die shop, relies on the existing heavy tonnage overhead cranes, a large open bay and built-in compressed air systems in K-1401, the former maintenance shop [I.I–7]. This heavy duty industrial facility would cost tens of millions of dollars to reproduce elsewhere.

(c) With over 30 businesses on-site, planned demolition of nearly all contaminated facilities will lead to relocations for most of these. Many cannot afford the expense and time to move office and manufacturing operations to new locations. CROET is attempting to acquire uncontaminated acreage at Heritage Center on which to construct new buildings into which a few of the current tenants can be relocated, but this will not resolve the problems for most of the businesses. It should be noted that all the leases signed state clearly that the site is on the EPA's National Priorities List and that the tenant may be asked to vacate the premises early owing to cleanup schedules.

(d) In October 2003, the USDOE Inspector General released an audit report, Reindustrialization of the East Tennessee Technology Park, that criticized the USDOE's spending of cleanup funds to prepare facilities for reuse. Reportedly, the USDOE has spent $231 million to date to clean up potentially reusable facilities. Most of this was on the BNFL project. The report recommended that such expenditures be allowed only in cases when CROET has formally agreed to accept ownership of a building [I.I–4].

The following buildings were scheduled to be transferred in fiscal year 2004 to CROET's ownership: K-1007, K-1336, K-1335, K-1330, K-1225, K-1580, K-1400 and Parcel ED-5 East. Most of these are uncontaminated administrative buildings. An additional 18 facilities and several parcels of land can be transferred by fiscal year 2008 [I.I–3], but this will only happen should tenants be found or if CROET can absorb the maintenance costs. Owing to liability issues, neither the USDOE nor CROET wishes to leave partially decontaminated facilities standing for industrial clients. This decision is also influenced by the desire to accomplish soil and secondary source remediation adjacent to or beneath the industrial facilities.

I.I–8. CONCLUSION

Reuse of facilities at ETTP can be successful, but only if there is continued programmatic support by the federal government for the process. It is possible to overcome the technical problems associated with decontamination, provision of utilities, and maintenance or upgrade of ageing buildings. Much more difficult to address are changing political priorities. In this case, the focus on decontamination and reuse has shifted to the perceived lower long term risk option of demolition and remediation. Although several uncontaminated administrative buildings will be preserved for reuse, the remaining heavy industrial buildings will be demolished, leaving a brownfield site for new industrial development.

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Annex II

PROBLEMS ENCOUNTERED AND LESSONS LEARNED FROM THE PROCESS OF REUSING DECOMMISSIONED NUCLEAR SITES

The following examples of lessons learned comprise an outline of the problems encountered at the nuclear facilities involved. The situations are typical of the difficulties that can arise when planning or implementing the reuse of a decommissioned site for a new mission. Although the information is not intended to be exhaustive, the reader is encouraged to evaluate the applicability of the lessons learned to a specific site redevelopment project.

II–1. ARGONNE NATIONAL LABORATORY SITE — CP-5

Problem. Surplus out-buildings at the CP-5 reactor were cleared of radioactivity but had no identified use. They in principle required conventional demolition as a means to clear the space they occupied. The buildings included the Vaporsphere and a Butler Building style storage facility.

Solution. Once the space was advertised as available to the first users who wished to rent it, the space was used by the Waste Management Organization for storage of packaged radioactive and chemical wastes pending shipment off-site and by the Plant Facilities and Services Division for storage of road salt for use in the winter months for snow removal and road clearing operations.

Lessons learned. Aggressive marketing of available, surplus space is necessary to ensure timely and optimal utilization of these facilities, which may otherwise be demolished without any reuse opportunity. These reuse opportunities allowed the use of funding that might otherwise have been used for infrastructure support to instead be used for new research facilities — a valuable commodity at a research institution.

II–2. ARGONNE NATIONAL LABORATORY SITE — EBWR

Problem. Additional on-site storage space was needed for the storage of packaged transuranic waste awaiting shipment off-site. The plan had been to construct a new facility for this purpose rather than using any other structures, since none were available to meet the shipping organization's needs.

Solution. The recently decommissioned EBWR Facility Containment Building was available for reuse after the full facility had been completely decommissioned and declared to be delicensed. With only minor modification and upgrades to the safety documentation and procedures, the facility was able to be reused immediately and over $2–4 million in costs could be avoided.

Lessons learned. Decommissioned facilities should always be evaluated as possible opportunities for redevelopment rather than constructing new facilities on greenfield sites.

II–3. EAST TENNESSEE TECHNOLOGY PARK — UTILITY SYSTEMS

Problem. Managing the ageing utilities at East Tennessee Technology Park (ETTP) was often a problem. The Community Reuse Organization of East Tennessee leased the systems from the USDOE and sub-leased them to a utility management contractor. Electrical and water metering was unavailable for individual tenants, some of whom leased space within larger buildings. In one case, an office facility within an area otherwise designated for manufacturing use was not provided with air-conditioning owing to ventilation system problems, resulting in excessively hot working conditions.

Solution. The utility systems, though of industrial capacity, required a great deal of maintenance and upgrading, resulting in increases in cost rather than savings as had been expected. The lack of upgraded metering resulted in billings for consumption based on the size of tenants' leased area and the type of work they were doing. The resulting costs were significantly greater than would have been charged by a local utility board. The air-conditioning problem took weeks to resolve and resulted in diminished productivity.

Lessons learned. Prior to even partial reuse of a site, the utilities need to be carefully evaluated as to their suitability, not just from a capacity standpoint, but also from the viewpoint of what utilities are specifically needed and where in the buildings they are needed. In this case, the lack of metering and the solution that was put in place ended up costing the companies more than they would have paid if they had relocated to a typical industrial park. The ventilation problems should have been foreseen and remedied before the space was leased. As it was, this situation contributed to major difficulties for the company involved.

II–4. EAST TENNESSEE TECHNOLOGY PARK — ACCESS ISSUES

Problem. The reindustrialization tenants at ETTP were in facilities which remained 'behind the fence', requiring employees to pass through a security gate going to and from their businesses. This resulted in access problems for tenants, especially those having to allocate personnel to escort unbadged employees, clients, suppliers and visitors. After the terrorist attacks of 11 September 2001, suppliers' trucks were searched, further delaying delivery schedules. In addition, foreign nationals were barred from entering ETTP, affecting several businesses. Retail operations did not renew their leases, owing to the difficulties customers had with visiting their stores.

Solution. The USDOE planned to reconfigure the security zone to allow easier access for reindustrialization tenants. However, the terrorist attacks of 11 September 2001 ended that initiative, and the resulting increased emphasis on security thwarted the effectiveness of the prior modest accommodations.

Lessons learned. Site security is a significant problem for some types of business. This needs to be recognized by the site owner, and all requirements must be disclosed during pre-lease discussions. For other businesses, especially those with proprietary techniques or valuable materials, the security provides an additional benefit, and thus can be used as a selling point to attract other, similar industries.

II–5. HANFORD SITE

Problem. During the turnover of property in the 3000 Area of the USDOE Hanford Site, some problems were encountered in the implementation of the transfer/redevelopment efforts of a particular piece of real property. There needed to be a better and clearer definition of information to facilitate the property transfer and the associated plans for future redevelopment.

Solution. The 71 acre (287 000 m^2) area, with about 15 buildings situated on it, was transferred to the local property transfer authority for turnover of the facilities to the local authority for redevelopment. Application of the lessons learned in this instance would have allowed for a more timely and efficient turnover than occurred in this case. In this instance, the government turned the site over to the redeveloper, who then became responsible for its development.

Lessons learned. At the time of property transfer to the developer, the following key actions should be taken:

(a) There should be some transition period when the current owners are still available to the new owners for consultation and to resolve any confusion over actual conditions at the site.

(b) There should be a strong effort made to transfer detailed, accurate records on utility locations, especially those underground. Otherwise it could be more expensive than planned to locate and repair pipes, wires, etc., which, owing to poor record keeping, could be damaged in further site development activities.

(c) There should be a detailed site assessment performed of any environmental conditions left at the site at the time of turnover.

(d) There should also be a turnover of information on the site telecommunication system and transfer of information on utility billing costs to assist with the redevelopment [II–1].

II–6. USDOE (GENERIC) — ON-SITE VERSUS OFF-SITE PLANNERS [II–2]

Problem. The Consortium for Risk Evaluation with Stakeholder Participation (CRESP) recently studied how on-site planners interact with off-site planners. The study found that, for on-site planners, land use planning is not performed in a consistent manner across sites. In addition, none of the Points of Contact were actually trained planners. Finally, interaction was done only on an 'as needed' basis. Off-site planners stated that there was little or no direct communication between USDOE sites and local planners. Additionally, off-site planners had little faith that the site would incorporate local input.

Solution. Each site has its own unique set of land use characteristics, levels of contamination, types of use, suitability for redevelopment, and flora and fauna. Additionally, there are different regional characteristics, including demographic and economic population profiles, regional culture and politics. All of these together make it difficult to generate a single model to improve communication between on-site and off-site planners.

Although a single model may not be applicable to all sites across the USDOE complex, the communication barriers between on-site and off-site planning may be narrowed by adopting a set of recommendations. First, land use planning should be done with stewardship in mind. In this case it is important to apply realistic scenarios within the planning. Second, a communication mechanism with off-site local planners at the sites should be defined. This is important to increase the communication between on-site and off-site planners. Third, sites should be forthright with communities about excess lands and contamination levels. If the USDOE is going to have excess lands, it is important to communicate this so that appropriate planning can take place. Related to this is the need to be open about contamination levels in order that the proper planning for the excess lands can take place. Finally, the USDOE should consider using multi-agency cooperative planning organizations to assist regions, since many other agencies are going through similar stewardship phases. Adopting these recommendations will generate better communications between on-site and off-site planners and assist in fostering a better relationship between the USDOE and local communities.

Lessons learned. Better communication needs to be established between on-site and off-site land use planners. Better communication will benefit both the USDOE and local communities in expediting facility properties transitioning for redevelopment.

II–7. USDOE (GENERIC) — INTEGRATED APPROACH TO INFRASTRUCTURE [II–3]

Problem. Mission, infrastructure and land use planning should be approached on an integrated cross-functional, site-wide basis, not as three separate activities. The need for roads in a town or an equivalently large USDOE site is a function of land use and the need to connect one area with another. The size, location and other characteristics of these roads are a function of their intended use and their role in supporting site missions and activities. The same is true of wastewater collection and treatment systems, water treatment and distribution systems, fire and safety facilities, and numerous other widely used infrastructure systems. Building new facilities, expanding existing facilities or abandoning old facilities — each impacts on different elements of the overall infrastructure system that the site relies on. Making long term planning decisions about land use (missions) without consideration of the infrastructure required to support such uses creates confusion and delays, and generally increases the cost of moving forward.

Lessons learned. The key point in this case is to highlight the importance of long term site planning considerations of infrastructure that are comprehensive and developed in an integrated fashion, with the objective of coordinating facility and site infrastructure development, maintaining environmental quality, and shaping the overall character of the site to align with mission requirements

II–8. USDOE (GENERIC) — ENVIRONMENTAL VERSUS OCCUPATIONAL RISKS [II–4]

Problem. Site remediation involves a trade-off between environmental risks to the public and environmental and other occupational risks to workers. Trade-offs also exist on the benefits side of the equation as decision makers and the public consider the value of cleanup jobs, long term employment, housing, open space and so forth. The remediation and reuse of contaminated lands is a multidimensional problem involving science, technology, an appropriate balancing of risks, political factors, and effective communication that allows the public to fully consider the amount and distribution of risk and benefits in an open and ethical manner. For example: the release of contaminated sites requires that workers be exposed to significant risks during site remediation; the environmental remediation process may actually elevate public and environmental risks above those that exist while contamination is 'contained' within site boundaries; and the transfer of once contaminated lands to the public for economic redevelopment may expose the public to unnecessary risks from residual contamination. Developing an optimal strategy requires balancing risks and benefits, ensuring that activities are ethically sound, and developing a sound understanding of potential alternatives for community land use so that communities can evaluate when it is in their best interests to pursue federal lands that may be transferable under applicable federal statutes.

Lessons learned. The remediation and reuse of contaminated lands is a multidimensional problem involving science, technology, an appropriate balancing of risks, political factors, and effective communication that allows the public to fully consider the amount and distribution of risk and benefits in an open and ethical manner.

II–9. EAST TENNESSEE TECHNOLOGY PARK — CONTRACTORIZATION ISSUES

Problem. Both British Nuclear Fuels (BNFL) and Decon Recovery Services (DRS) undertook D&D efforts under fixed price contracts. After the work was well under way, the number of unexpected problems drove costs far beyond what had been estimated. In the case of BNFL, these problems included unexpected levels and distribution of contamination, difficulty in screening decontaminated materials for release, a moratorium on the recycling of decontaminated metals from USDOE facilities and safety problems. BNFL sought redress from the USDOE for unanticipated costs, with mixed success. DRS was forced into bankruptcy, leaving the Decontamination and Recovery Facility (Building K-1420) unfinished.

Solution. In the case of BNFL's Three Buildings Project, only one of the decontaminated gaseous diffusion buildings, K-31, is suitable for a new tenant. Although the company has been releasing K-33 in sections back to the USDOE, its unsuitable layout and huge maintenance costs may make it unattractive to industrial users. It is therefore likely to be demolished. The K-29 structure has been determined to be too contaminated to decontaminate and decommission for reuse by industry, so BNFL has removed all equipment from it and prepared it for demolition, with only minor decontamination work. These changes in project scope, particularly at K-29, were a concession by the USDOE to help offset BNFL's losses. The DRS project proved to be uneconomic, and K-1420 will now be demolished rather than reused.

Lessons learned. Large, unique D&D projects carry a great deal of uncertainty. The need to control costs on the part of the USDOE must be balanced with the degree of risk that a company assumes when it submits a low bid on a large, fixed price contract. In lieu of extensive site characterization to develop a detailed scope of work, the project instead can be broken up into smaller segments such that a contractor does not have to assume excessive risk. In addition, the buildings need to be carefully evaluated from the perspective of how attractive they will be to industry once decontaminated and of whether there are other problems, such as ventilation, interior layout or structural problems that would be too costly to remedy for potential new industries. Whichever entity retains title to the facility post-D&D must also be willing and able to fund the owner's costs associated with keeping the facility available for a potential future tenant.

II–10. EAST TENNESSEE TECHNOLOGY PARK — IMPACTS OF POLICY CHANGES

Problem. The reindustrialization programme at Oak Ridge was affected by two major changes at the national level. The first was a moratorium on the recycling of scrap metal from USDOE facilities. This invalidated an agreement between the USDOE and BNFL, a contractor that wished to sell recovered metals as a portion of its remuneration for the Three Buildings Project at ETTP.

A top-to-bottom review documented that the liabilities for the USDOE were not being reduced in a timely manner and that significant resources were being directed at efforts less related to cleanup than to economic development. As a result, the focus of cleanup at ETTP shifted from support of reindustrialization to an accelerated closure project, with reindustrialization having a much reduced priority.

Solution. The USDOE ended up buying scrap metal from the Three Buildings Project at the daily market value. This solution preserved the revenues for BNFL, but resulted in costs to the US Government considerably greater than originally anticipated for the project.

After the change in government policy, uncontaminated buildings, for the most part office buildings, were designated for direct transfer to the Community Reuse Organization of East Tennessee (CROET). This helped preserve income for CROET; however, the tenants were contractors to the USDOE as opposed to the new industries that reindustrialization was designed to attract in order to replace jobs dependent on the federal government. CROET plans to build new facilities on uncontaminated sites in order to relocate some of its industrial tenants; however this action is on hold owing in part to a lack of capital for construction purposes.

Lessons learned. Abrupt changes due to changes in government policy can be disruptive of innovative programmes such as reindustrialization. This was especially true in this particular case. Both a major D&D contractor and the community were adversely affected by significant changes in policy and priorities. Local programmes need to be carefully evaluated by the communities they are designed to benefit as to their economic viability in the absence of federal funding and their ability to be self-sustaining in the long term.

II–11. FRF-1/FRF-2, GERMANY [II–5]

Problem. The FRF-1 reactor was shut down in 1968 and again from 1970 to 1977 while certain components were partially dismantled. The reactor building, the biological shield and certain components were earmarked for reuse in a new facility at the same site and building, the FRF-2 (TRIGA). Commissioning and construction of FRF-2 were completed, but the new reactor never went critical.

Solution. FRF-2 (including residual components of FRF-1) was put into a period of safe enclosure in 1983, and parts of the reactor building were used as a storage facility for radioactive waste from the University of Frankfurt.

Lessons learned. The amount of waste can be reduced when parts of components, or the building of a shut down facility, can be reused for a new facility. Also, if a facility is designated as a safe enclosure, parts of the building can be used for storage of radioactive waste from other sites.

REFERENCES TO ANNEX II

[II–1] UNITED STATES DEPARTMENT OF ENERGY, Reference DOE Lessons Learned Database, http://lts.apps.em.doe.gov/center/reports/doc1/1_c.html

[II–2] UNITED STATES DEPARTMENT OF ENERGY, Office of Environmental Management, Lessons Learned, http://web.em.doe.gov/lessons/dbform.html, keyword search: redevelopment, http://plweb.apps.em.doe.gov/plweb-cgi/fastweb.exe?getdoc+view1+lessons+381+1++%28Facility,%20Soil,%20Ground,%20Surface,%20Treatment,%20Disposal,%20Packaging,%20General,%20Stewardship,%20All%20%20%20%20%20%20%20%20%20%20%29%3APROJECT%20AND%20%28Lessons%20

[II–3] UNITED STATES DEPARTMENT OF ENERGY, Office of Environmental Management, Lessons Learned, http://web.em.doe.gov/lessons/dbform.html, keyword search: redevelopment, http://plweb.apps.em.doe.gov/plweb-cgi/fastweb.exe?getdoc+view1+lessons+381+1++%28Facility,%20Soil,%20Ground,%20Surface,%20Treatment,%20Disposal,%20Packaging,%20General,%20Stewardship,%20All%20%20%20%20%20%20%20%20%20%20%29%3APROJECT%20AND%20%28Lessons%20

[II–4] UNITED STATES DEPARTMENT OF ENERGY, Office of Environmental Management, Lessons Learned, http://web.em.doe.gov/lessons/dbform.html, keyword search: redevelopment, http://plweb.apps.em.doe.gov/plweb-cgi/fastweb.exe?getdoc+view1+lessons+381+1++%28Facility,%20Soil,%20Ground,%20Surface,%20Treatment,%20Disposal,%20Packaging,%20General,%20Stewardship,%20All%20%20%20%20%20%20%20%20%20%20%29%3APROJECT%20AND%20%28Lessons%2

[II–5] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Research Reactors: Evolution, State of the Art, Open Issues, Technical Reports Series No. 446, IAEA, Vienna (in press).

GLOSSARY

All definitions are taken from the IAEA's Radioactive Waste Management Glossary, 2003 Edition[1], except where marked with an asterisk.

activation. The process of inducing radioactivity. Most commonly used to refer to the induction of radioactivity in moderators, coolants, and structural and shielding materials, caused by irradiation with neutrons.

brownfield*. Real property, the expansion, redevelopment or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant or contaminant.[2]

clearance level. A value, established by a regulatory body and expressed in terms of activity concentration and/or total activity, at or below which a source of radiation may be released from regulatory control.

contamination. (1) Radioactive substances on surfaces, or within solids, liquids or gases (including the human body), where such presence is unintended or undesirable, (2) the presence of such substances in such places or (3) the process giving rise to their presence in such places.

decommissioning. Administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility.

decommissioning plan. Documentation containing information on the proposed decommissioning activities for a facility. This would allow the regulatory body to make a proper evaluation to ensure that decommissioning of the facility can be performed in a safe manner.

decontamination. The complete or partial removal of contamination by a deliberate physical, chemical or biological process.

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Radioactive Waste Management Glossary, 2003 Edition, IAEA, Vienna (2003).

[2] ENVIRONMENTAL PROTECTION AGENCY, Brownfields Definition, www.epa.gov/swerosps/bf/glossary.htm

demolition*. Clearance and removal of a structure in order to achieve greenfield or carry out the redevelopment plan.

greenfield*. For the purposes of this report, a condition when the nuclear site has been granted unrestricted release from regulatory control, buildings have been demolished and no further redevelopment is planned.

infrastructure*. Public improvements which support development, including street lighting, sewers, flood control facilities, water lines, gas lines, telephone lines, etc.[3]

institutional control. Control of a waste site by an authority or institution designated under the laws of a country. This control may be active (monitoring, surveillance and remedial work) or passive (land use control) and may be a factor in the design of a nuclear facility.

investor*. An individual or an organization that devotes time and money with the expectation of achieving a worthwhile end result.

licence. A legal document issued by the regulatory body granting authorization to perform specified activities related to a facility or activity. The holder of a current licence is termed a licensee. A licence is a product of the authorization process, although the term licensing process is sometimes used.

market value*. What a willing seller could reasonably expect to receive if he or she were to sell the property on the open market to a willing buyer.[3]

masterplan*. A document that defines the overall strategy for the site and sets out the key development goals and principles.

nuclear facility. A facility and its associated land, buildings and equipment in which radioactive materials are produced, processed, used, handled, stored or disposed of on such a scale that consideration of safety is required.

[3] SAN FRANCISCO REDEVELOPMENT AGENCY, Glossary of Terms, www.ci.sf.ca.us/site/sfra_index.asp?id=21370

operating organization (operator). The organization (and its contractors) which undertakes the siting, design, construction, commissioning and/or operation of a nuclear facility.

property manager*. The individual responsible for the ongoing management of the land and buildings to support the efficient operation and restoration of the site.

redevelopment*. Planning, development, replanning, redesign, clearance, reconstruction or rehabilitation of all or part of a project area.[4] A process specifically designed to help local governments in revitalizing their communities.[5]

redevelopment plan*. Plan for revitalization and redevelopment of land within the project area in order to eliminate blight and remedy the conditions that caused it.[4]

regulatory body. An authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby for regulating the siting, design, construction, commissioning, operation, closure, decommissioning and, if required, subsequent institutional control of the nuclear facilities (e.g. near surface repositories) or specific aspects thereof.

reindustrialization*. A programme to enable commercial companies to reuse buildings, equipment and land at former nuclear facilities, thereby saving investments, creating new jobs to compensate for jobs lost by the closure of the former facility, and saving previously undeveloped land from being used for industrial purposes.[6]

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[4] SAN FRANCISCO REDEVELOPMENT AGENCY, Glossary of Terms, www.ci.sf.ca.us/site/sfra_index.asp?id=21370

[5] SAN FRANCISCO REDEVELOPMENT AGENCY, Understanding Redevelopment, website www.ci.sf.ca.us/site/sfra_index.asp?id=21365

[6] MURRAY, M.N., et al., The Economic Benefits of the US Department of Energy for the State of Tennessee, Univ. of Tennessee, Knoxville (2004), http://cber.bus.utk.edu/pubs/mnm102.pdf

restricted use. The use of equipment, materials, buildings or the site, subject to restrictions imposed for reasons of radiation protection and safety.

site. The area containing a nuclear facility. It is defined by a boundary and is under effective control of the operating organization.

stakeholder*. A person or group that can affect or is affected by an action.[7]

stewardship*. The acceptance of the responsibility for and the implementation of activities necessary to maintain long term protection of human health and of the environment from hazards posed by residual radioactive and chemically hazardous materials.[8]

unrestricted use. The use of equipment, materials, buildings or the site without any radiologically based restrictions.

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[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Organization and Management for Decommissioning of Large Nuclear Facilities, Technical Reports Series No. 399, IAEA, Vienna (2000).

[8] UNITED STATES DEPARTMENT OF ENERGY, STEWARDSHIP WORKING GROUP, The Oak Ridge Reservation: Stakeholder Report on Stewardship, Vol. 2, Oak Ridge Operations, Oak Ridge, TN (1999).

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In the coming decades, a large number of nuclear facilities will reach the end of their useful lives and require decommissioning. Many of these facilities will be decommissioned with the aim of either replacing them with new facilities that serve the same purpose or reusing the site for another, completely different purpose. By recognizing and promoting the redevelopment potential of facilities and their sites earlier in their operating life, or even at the design stage, it will be possible to enhance the prospects for worthwhile redevelopment. This approach will at least partly offset the costs of decommissioning and ensure that best use is made of the material, land and human resources associated with each facility and nearby territories. A range of factors to consider are identified in this report and are illustrated using case histories. Practical guidance is provided for parties involved to help promote successful and effective redevelopment of decommissioned nuclear installations in the future.

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