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REDEVELOPMENT AND REUSE OF NUCLEAR FACILITIES AND SITES: CASE HISTORIES AND LESSONS LEARNED

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IAEA NUCLEAR ENERGY SERIES No. NW-T-2.2

REDEVELOPMENT AND REUSE OF NUCLEAR FACILITIES AND SITES: CASE HISTORIES AND LESSONS LEARNED

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2011

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email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
May 2011
STI/PUB/1432

IAEA Library Cataloguing in Publication Data

Redevelopment and reuse of nuclear facilities and sites : case histories and lessons learned. — Vienna : International Atomic Energy Agency, 2011.
p. ; 29 cm. — IAEA nuclear energy series, ISSN 1995–7807 ; no. NW-T-2.2)
STI/PUB/1432
ISBN 978–92–0–100210–5
Includes bibliographical references.

1. Nuclear facilities — Decommissioning — Management. 2. Nuclear power plants — Decommissioning — Management. I. International Atomic Energy Agency. II. Series.

IAEAL 11–00679

FOREWORD

Evaluating potential 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, reduce waste volumes and alleviate the overall impact of decommissioning on the local community. Conversely, the lack of early planning for site reuse can hinder implementation of a cost effective and optimized decommissioning. This strategic inadequacy may be caused by insufficient knowledge or experience with redevelopment opportunities that have been exploited successfully in industries elsewhere.

An earlier IAEA publication, Redevelopment of Nuclear Facilities after Decommissioning (Technical Reports Series No. 444), provided information and practical guidance on reuse opportunities. It discussed the advantages of planning for redevelopment as opposed to traditional decommissioning strategies aimed at site release with no consideration of further use. It also identified roles and responsibilities of all important stakeholders in the site redevelopment process including operators of nuclear facilities, decision makers with the government, regulators/authorities and elected officials at all levels, environmental planners and the general public. This report is a follow-up to Technical Reports Series No. 444. It provides an overview of decommissioning projects implemented worldwide with reuse of the decommissioned sites for new purposes, and highlights lessons learned from these projects. It draws heavily on the experience from the non-nuclear sector, where redevelopment and reuse of former industrial facilities and sites have become mandatory, profitable or at least fashionable in many countries.

This report is intended to contribute to the systematic coverage of the entire range of decommissioning aspects within the IAEA's decommissioning programme. The initial draft was prepared by E. Fourie and A. Visagie of the National Energy Corporation of South Africa. Other experts provided further contributions to the drafting and review of this report. Special thanks are due to S. Gawarecki (USA), who chaired both meetings. The IAEA technical officer responsible for this publication was M. Laraia of the Division of Nuclear Fuel Cycle and Waste Technology.

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SUMMARY

The initial concept of decommissioning management for nuclear facilities was generally that of a closed life cycle that entailed the removal of buildings, final disposal of waste and the restoration of a site to its original condition. This concept is no longer considered optimal. Decommissioning should not be an end point of a facility or site, but should enable opportunity for redevelopment and reuse of a facility or site.

The redevelopment and reuse of disused and decommissioned buildings, facilities and sites should be promoted as an opportunity rather than a constraint. In recent times, redevelopment and reuse as a decommissioning end point has moved to the forefront due to:

— The increase in requirements for scarce industrial development sites, including the demand by the nuclear industry due to the current nuclear renaissance.
— A preference for development of new nuclear facilities at locations previously used by the nuclear industry.
— A preference for redevelopment of ‘brownfield’ sites over ‘greenfield’ sites. The principal economic driving force for this approach is the reduced decommissioning cost due to less strict regulations with regard to decommissioning to brownfield rather than greenfield criteria.
— Specialized or robust infrastructure associated with nuclear facilities that may be valuable for other uses or reuse.
— Requirements to reduce waste volumes directed to waste sites.

The redevelopment and reuse of nuclear facilities after decommissioning is an option that is currently not optimized. With increased interest in nuclear power redevelopment and reuse of existing nuclear sites, it is necessary to preserve increasingly valuable industrial or public land. In the non-nuclear sector, there are successful cases of redevelopment and reuse of decommissioned facilities. Lessons learned during the redevelopment of these decommissioned facilities should be communicated to the stakeholders in a nuclear decommissioning project, as well as those planning a new nuclear facility.

With the revival of the nuclear programme, nuclear power plants (NPPs) may opt to have their licences extended, using decommissioning as a step towards new uses for facilities. A few years ago, local officials were faced with the end of local tax revenues and years of being host to a plant site with a negative value; today, they see years of continued operation, with an alternative future productive use of the site. Redevelopment and reuse options are now being promoted by several legislative and policy initiatives.

Decommissioning costs can be significantly lower if the redevelopment and reuse potential of facilities or sites is identified at an early stage, since the extent of decommissioning can be influenced by the redevelopment and reuse options when engineering new facilities. Designs that will aid decommissioning should be incorporated into the redevelopment and reuse plans. Early redevelopment and reuse plans will ensure that best use is made of the assets and land resources associated with the sites. This approach also minimizes decommissioning waste, both radioactive and non-radioactive.

Due to the need for quality industrial space, it is important that there be early consideration of redevelopment and reuse strategies for industrial development so that the use of vacant industrial facilities and the developed infrastructures (e.g. roads, railways, electrical substations, etc.) associated with them is optimized.

Many disused industrial sites have historical contamination problems from decades of poorly controlled industrial activities. Examples of industrial contamination may include asbestos, lead and other heavy metals, chlorinated hydrocarbons, polychlorinated biphenyls (PCBs) and other chemical contaminants. Nuclear sites have the additional complication of potential radiological contamination. Removal of these materials is necessary to protect human health and the environment, and must be completed by trained personnel. The presence of contamination is an additional barrier to the redevelopment of facilities, but should not be seen as impossible to overcome. Contaminated industrial facilities and sites must be assessed on a case by case basis with regard to redevelopment and reuse options and their associated decommissioning. An early evaluation of the site should be conducted to confirm conditions and minimize the impact of poor site planning.

Sustainable development implies the need to combine socioeconomic development with conservation of natural resources and maintaining community integrity. The identification of redevelopment and reuse options helps to ensure this requirement and should result in uninterrupted employment. The operators of nuclear and non-nuclear facilities have an ethical, if not legal responsibility towards the employees and the local communities. This responsibility should not be seen as a burden, but may actually be profitable for operators, ensuring sustainable development. Reusing facilities/sites contributes to the overall concept of sustainability.

This report covers experience and lessons learned from the nuclear as well as non-nuclear industry as illustrated by case studies involving reuse of the following:

— Power plants (turbine halls, electric stations and grids);
— Large industrial buildings and sites;
— Bunkers (buildings with thick walls and floors, subsurface facilities);
— Contaminated areas associated with other facilities (closed waste sites, broad areas of secondary contamination);
— Smaller buildings on multi-facility sites (small research reactors, laboratories, offices, etc.);
— Marine, floating or offshore facilities (nuclear ships/submarines, oil drilling platforms);
— Other facilities (stacks, cooling towers, water towers, sewage plants).

1. BACKGROUND

Over time, buildings, monuments, bridges, industrial factories, mines, and a wide range of civilian and industrial structures reach the end of their original functions. They may either assume new functions or become disused and ultimately abandoned or demolished. Reasons for these changes include: technical or economic obsolescence, the predominant elite dictating national priorities, prevailing religion(s), social interests or evolving traditions, and natural or human caused events (e.g. fires). The reuse of sites and facilities or parts thereof has generally received higher priority over demolition and starting new developments afresh.

Over the centuries, humanity has refurbished, adapted and eventually reused historical places for new purposes. Re-adapting and reusing rather than demolishing has been mandated by convenience (e.g. the usefulness of sturdy, usable structures), economics, and more recently, visual and aesthetic factors. In many cases, new constructions were built on top of older buildings to take advantage of the existing foundations. For example, today's St Paul's Cathedral in London, England is the fifth church built on the same site. At Troy, in modern Turkey, as many as 12 archaeological strata have been uncovered.

There are thousands of historical examples of reuse projects. The following list is intended to convey a variety of factors that prompted reuse and of the types of facilities reused:

- **Fethiye Cami (the Mosque of Victory), Athens, Greece.** The mosque was built in Athens after the arrival of Mehmed II Fatih around 1458. From October 1687, after Athens was occupied by Venetian troops, until April 1688, the mosque was converted into a Catholic church. When the Venetians left the city, the mosque returned to its previous use, which changed after the Greek War of Independence in 1821. In 1824, it was used as the School of the Society of the Muses' Friends, while the building was later managed by the Greek Army. As a result, the building was first used in 1843 as a guardhouse. It was later used as a military prison, garrison headquarters and a military bakery. Today, the mosque is the property of the Archaeological Society, and acts as a storehouse of archaeological material [1];
- **The Pantheon, Rome, Italy.** At first a Roman temple, it then became a Christian Church and ultimately a National Memorial (Fig. 1). But it is still used as a cathedral.
- **Brick Lane Chapel, London, England.** This chapel built by Huguenot weavers in the 18th century was converted into an orthodox synagogue in the 19th century when Jews fleeing from Russia arrived in the East End. When they grew richer and moved to the suburbs, the next wave of poor immigrants, from Bangladesh, converted it into a mosque known as the Jamne Masjid [2].

FIG. 1. The 2000 year old Pantheon in Rome, Italy.

— **The Chilworth Gunpowder Company, Chilworth, UK.** This company closed its works in 1920 because the end of World War I caused a massive overcapacity in the industry. On closure, many of the buildings were burned as the standard and most effective way of decontaminating former explosive buildings. There was such demand for housing after the Great War that many haphazard plotland settlements grew in the inter-war period. At Chilworth, a number of process buildings were retained and converted into dwellings. A variety of structures were adapted, including small brick-built magazines, corrugated-iron process buildings, and more recently, erected structures including the press house and the acetone recovery stove [3].

— **The Roman Ruins, Vienna, Austria.** There were Roman houses at Hoher Markt, Vienna for almost 2000 years; more recent buildings were erected on top of them [4] (Fig. 2).

— **The Royal Palace, Stockholm, Sweden.** It took centuries to build a tower that watched over the passage of ships from Saltsjön on their voyages between the Baltic Sea and Lake Mälaren. Later, a fortress was built and the tower was adorned with three gilded crowns. The castle was converted into a Renaissance palace in late 1500s. The construction of the palace was largely complete when it was destroyed by fire in 1607, with only the north wing surviving the blaze. Financial difficulties held up the reconstruction, but eventually the new Royal Palace was completed in 1754 [5] (Fig. 3).

Awareness has grown over a long period on the intrinsic value of old buildings and other structures. Reuse was no longer a matter of convenience or dictated by inevitable circumstances; preserving or incorporating the signs of the past became a symbol of national pride or added extra prestige to modern works. The antiquity of structures is considered a bonus by present day developers. The following is a selection of examples.

— **The Sofiensaal, Vienna, Austria.** The building was completed in 1826. It was originally used as a steam bath and known as the Sofienbad. Between 1845 and 1849, it was converted into a dance hall and renamed the Sofiensaal. Johann Strauss I performed there regularly and conducted at its opening ball in 1848. The building's large vaulted ceiling and the pool beneath the floor gave the hall excellent acoustic properties. For this reason, Decca Records adopted the building as its principal European recording venue from 1956 to the mid-1980s. In later years, the Sofiensaal fell into disuse as a recording studio and was used for parties and discotheques, and later on for concerts and theatre shows. In May 2001, the building's owners announced that it would be used as a conference centre, but it was destroyed by fire on 16 August 2001 due to careless routine maintenance work. The fire burned for more than eight hours and completely destroyed the main ballroom,

FIG. 2. Roman ruins at Hoher Markt, Vienna, Austria.

FIG. 3. The Royal Palace, Stockholm (http://www.trekearth.com/gallery/Europe/Sweden/photo536110.htm).

although the facade and walls of the building survived. It was announced that the Great Hall, the Foyer and the facade would be rebuilt, and the former functions of the building as a theatre and concert hall reinstated [6] (Fig. 4).

— **The Hub, Edinburgh, UK.** The historic, Grade A listed building forms an integral part of the architectural fabric of Edinburgh. Constructed between 1842 and 1845 and originally named Victoria Hall, it was built as the Assembly Hall and offices for the Church of Scotland. In 1956, the building was named the Highland Tolbooth St John's Church following the union of the Church of Scotland and the United Free Church. The Edinburgh International Festival acquired the building in 1995 and it underwent a huge transformation before opening to the public in July 1999. It is now used for banquets, weddings, and artistic and social activities [7] (Fig. 5).

— **Oxford Castle, Oxford, UK.** The development of this castle began in 1071. It was strategically located near the river on the western edge of the Saxon town defences. The Castle, while remaining a Royal Residence, soon became the Sheriff's centre for administration. The local assize held courts and trials at the Castle, and although the jail was not officially recorded before 1230, it is believed that it was used in part as a prison long before then. By the middle of the 15th century, the Castle had begun to fall into decay, but its use as a court and prison continued. In the 1770s, a prison report condemned the buildings, stating that years of neglect had made them unfit for human habitation. The site was reacquired by the Government and a major redevelopment programme ensued. The site became home to a new County Hall and a remodelled county jail and court. The prison eventually closed in 1996. The site was then acquired by the County Council and gained popularity with filmmakers. Eventually, site regeneration was explored. The site is now home to a hotel (with guest rooms located in the former jail), restaurants, and meeting halls [8].

— **Michaelhouse, Cambridge, United Kingdom.** St Michael's was built in 1328 as both a parish and a collegiate church. In the second half of the 20th century, the church was used as a parish hall for Great St Mary's, with which it remains closely linked. In the early 1990s, it was felt that the Church should serve the wider community as a valuable resource in the heart of Cambridge, and funds were raised for its thorough refurbishment. The broad strategy was simple: to restore a magnificent medieval church, provide well appointed, versatile rooms and facilities for meetings and activities, and offer the refurbished building to the community of Cambridge. The detailed planning took 12 years. The result is the Michaelhouse Centre. It is now run by a charitable trust and employs a full-time manager and a chaplain to develop its ministry to the City of Cambridge. The site is used for religious services, as a café, and for social events [9] (Fig. 6).

FIG. 4. The Sofiensaal after the fire.

FIG. 5. The façade of the Hub in Edinburgh, Scotland (http://www.flickr.com/photos/maxf/158593775/).

Museums often make use of pre-existing historical buildings, factories and other unique structures, as shown in the following examples:

— **The Imperial Stables, Vienna, Austria.** Built in 1723–1725, the Imperial Stables were altered and enlarged in the 19th century, and reused as the Vienna Exhibition Palace. In the later years of the 20th century, the buildings were eventually converted to a Museum Quartier ('Museum Island'), incorporating the Architecture Centrum and Library, Museums of Modern and Contemporary Arts, and related offices. Extensive public debate contributed to the decision on the reuse option [10], demonstrating that interaction with the public and other stakeholders is an important aspect of reuse (Fig. 7).

FIG. 6. The interior of St Michael's Church, Cambridge, UK, as redeveloped today for various functions.

FIG. 7. Inside the Museum Quartier, Vienna, Austria. The short buildings were once the Imperial Stables. The cube like building was erected in the late 1900s to house a museum.

— **Thoney's furniture factory, Vienna, Austria.** This furniture factory of the world known Thonet firm dating back to late 1800s was refurbished by the architect F. Hundertwasser and rebuilt in his style. This venue now houses art exhibitions and other public attractions.

— **The Prestongrange Industrial Heritage Museum, Prestonpans, Scotland.** This museum occupies the site of the former Prestongrange Colliery, which closed in the early 1960s. The museum charts the development of local industries from coat mining, which first took place on this site in the 12th century, to brick and pipe making, pottery, salt and soap manufacture and brewing, all of which depended on the local coal industry. The Prestongrange Colliery opened around 1852 [11].

— **Grand-Hornu Industrial Site, Hornu, Belgium.** This is an old industrial mining complex and a remarkable reminder of the Industrial Revolution. Built in 1810–1830, it is a true example of an urban project. At the start of the great era of industrialization, it is a functional town planning, unique on the European continent. Built in the neoclassical style, Grand Hornu consists of workshops, offices, a workers' estate and the administrators' residence, known as De Gorge Castle. With their arcades, pediments and half-moon windows, the colliery workshops and offices form a majestic whole. It is now the venue of the Museum of Contemporary Art [12].

— **The Pass, Frameries**, **Belgium,** site is a former colliery in the Borinage area of the Hainaut Region, in Wallonia. The original buildings are protected as part of the country's industrial heritage and include the Belvedere, the Pit-Head Frame and the Machine Room. These buildings have been converted to culture and science on the initiative of the Wallonia Region and the European Union, and are complemented by new architecture, which enhances the site's industrial character and history. The Pass is now a museum dedicated to science, technology and society [13].

— **Musée d'Orsay, Paris, France**. This museum was originally a railway station, Gare d'Orsay, which was constructed for the railway from Paris to Orléans and finished in time for the 1900 World's Fair. It was the terminus for the railways of south-western France until 1939. By 1939, the station's short platforms had become unsuitable for the longer trains that had come to be used for mainline services. After 1939, it was used for suburban services and part of it became a mailing centre during World War II. The station's hotel closed on 1 January 1973. In 1977, the French Government decided to convert the station to a museum and it was opened by President François Mitterrand on 1 December 1986. The Musée d'Orsay holds mainly French art dating from 1848 to 1914, including paintings, sculptures, furniture, and photography, and is probably best known for its extensive collection of impressionist masterpieces [14] (Figs 8(a) and 8(b)).

As noted above, the antiquity or the historical significance of a building or site is now worth consideration, leading to preservation (or conversion to new uses) rather than demolition. Buildings may often be considered landmarks. In the mid-20th century, the industrial monuments were regarded as relics of manual labour and abusive working conditions; consequently they were swept away in urban development or land clearance schemes. During the second half of the 20th century, the cultural meaning of industrial structures began to change. A transformation occurred that turned derelict industrial remains from once functional structures to icons of an innovative industrial past. In some cases, aesthetic values compete with the desire to preserve the historic value of the archaeological context and issues of public health and safety. This controversy can be exemplified by tidying up mine tailings, capping of mine shafts, and is fully applicable to the nuclear sector [15].

One interesting case from the nuclear industry is the Dounreay Demonstration Fast Reactor dome in Caithness, Scotland. The future of the 50 year old steel sphere remains unresolved as the site is decommissioned. On the one hand, the potential of the dome as a landmark and national monument should not go unexplored; on the other hand, the sphere could be corroded and radioactively contaminated and any future owner would be faced with

FIG. 8. Gare d'Orsay Museum, Paris (a) as a railway station, (b) as an art museum today.

large expenses just to paint it [16–18]. It is curious that the debate divided environmentalists: some said preserving the building would serve as a reminder of the nuclear legacy; others disagreed, arguing that “the legacy should be that we learn not to do it again” [19]. Several possible reuses have been proposed for the dome, including an exhibition and conference centre, a leisure centre, a hotel and nightclub, a space observatory and a nuclear museum [20] (Fig. 9). Figure 10 shows another likely candidate for preservation as a national monument, the egg shaped dome of the Philippines Research Reactor, in Quezon City, Philippines.

In conclusion, one should also note that:

— Consideration for site/facility reuse may increase the interest for prompt decommissioning of obsolete structures and foster early planning for decommissioning (a recommendation constantly reiterated by the IAEA for a number of years) [21, 22].

FIG. 9. The Dounreay Dome, also known as the ‘golf ball’.

FIG. 10. The egg shaped dome of the Philippines Research Reactor.

— The redevelopment and reuse of historical or otherwise remarkable buildings and other structures attracts publicity. This in turn is likely to increase the value of land/premises and encourage investors.

2. INTRODUCTION

The initial concept of decommissioning management was that of a closed life cycle for nuclear facilities, which entailed the final disposal of waste and the restoration of a site to its original condition. This concept is no longer the only option. Decommissioning should not be an endpoint of a facility or site, but should provide an opportunity for redevelopment and reuse.[1] Total demolition of a facility or site should be only one decommissioning option under consideration, and various redevelopment and reuse options should be explored in the decommissioning strategy.

The redevelopment and reuse of disused and decommissioned buildings, facilities and sites should be promoted as an opportunity rather than a constraint. In recent times redevelopment and reuse as a decommissioning end point has moved to the forefront, in view of industrial development, due to:

— The increase in demand for scarce industrial development sites, especially the nuclear industry due to the so called ‘nuclear renaissance’;
— A preference for redevelopment of brownfield sites over greenfield sites due to less strict regulation, and consequently lower cost, with regard to decommissioning to the respective criteria [23];
— A preference for development of new nuclear facilities at locations previously used by the nuclear industry; and
— Specialized or robust infrastructure associated with nuclear facilities that may be valuable for other uses or reuse.

The redevelopment and reuse of nuclear facilities after decommissioning is an option that is seldom explored. The so-called ‘nuclear renaissance’ is starting to apply pressure on the developers to redevelop and reuse existing nuclear sites. Over the past few years, several cases were documented as proof of successful redevelopment and reuse of decommissioned facilities. Lessons learned during the redevelopment of these decommissioned facilities should be communicated to the stakeholders in a decommissioning project, as well as those planning a new nuclear facility.

Prior to the ongoing ‘nuclear renaissance’, local officials were faced with an end to local tax revenues and years of being host to a former nuclear plant site with a negative value. Today they see years of continued operation, with an alternative future productive use of the site. redevelopment and reuse options are now promoted by several legislative and policy initiatives. One such case is the new decommissioning law passed in New Hampshire, USA. The law changed the greenfield cleanup requirement to a commercial/industrial site restoration standard. This change included a specific mandate to the local community of Seabrook to have a voice in the ultimate fate of the decommissioned site. Recognizing the importance of the economic development of the region was also made a requirement in site restoration [24].

Decommissioning costs can be significantly lower if the redevelopment and reuse potential of facilities or sites are identified at an early stage in the life cycle of a facility, since the extent of decommissioning can be influenced by the redevelopment and reuse options. When engineering new facilities, designs that will aid decommissioning should be incorporated into the plans. Early redevelopment and reuse plans will ensure that best use is made of the assets and land resources associated with the sites. This approach also minimizes decommissioning waste, thus saving money for the owner.

[1] Similar keywords found in the literature are ‘revitalization’, ‘regeneration’, ‘reindustrialization’ and ‘rehabilitation’, etc. These terms are often used interchangeably, although, strictly speaking, they do not have identical meanings.

The need for quality industrial space renders profitable the early consideration of redevelopment and reuse strategies. Industrial development is important so that the use of vacant industrial facilities and sites and the well developed infrastructures (e.g. roads, railways, electrical substations, etc.) associated with these industrial facilities can be optimized.

Decommissioned properties that remain disused can be associated with vandalism, unlawful occupation and criminal activities, resulting in the reduction of property values and less interest in any future redevelopment and reuse investments. Disused properties place a social and economic liability on local municipalities within which they are located. The effect of disused buildings can easily spill over to affect neighbouring areas and surrounding communities through an impact to property values. Building and industrial areas earmarked for redevelopment should be stabilized and secured.

Many disused industrial sites have historical contamination problems from decades of poorly controlled industrial activities. Examples of industrial contamination may include asbestos, lead and other heavy metals, chlorinated hydrocarbons, PCBs, and other chemical contaminants. Nuclear sites have the additional complication of potential radiological contamination. Removal of these materials is necessary to protect human health and the environment, and must be accomplished by trained personnel. The presence of contamination is an additional barrier to the redevelopment of facilities, but should not be seen as impossible to overcome. These contaminated industrial facilities and sites must be assessed on a case-by-case basis with regard to redevelopment and reuse options and their associated decommissioning.

Currently, conceptual decommissioning plans should exist for most nuclear facilities, but they may be limited to the achievement of release conditions and may not include possible redevelopment and reuse options. Such plans should also include the securing of facilities and sites after decommissioning until successful redevelopment and reuse. Emphasis should be on the identification of structurally sound buildings and property not to be demolished.

Redevelopment and reuse of former nuclear sites supports sustainable development since it combines socioeconomic development with conservation of natural resources such as land and maintaining community integrity. The identification of redevelopment and reuse options supports the continuity employment opportunities. The operators of nuclear and non-nuclear facilities have an ethical, if not legal, responsibility towards the employees and the local communities. This responsibility should not be seen as a burden, since it can be converted into a possible profitable action for the operators [23].

The fundamental environmental principles of Reduce, Recover, Recycle and Reuse (the ‘four Rs’) are integral to sustainability as well as to successful decommissioning. Applying these principles means minimizing radioactive waste and recovering, recycling and reusing materials, equipment, buildings and sites to the fullest practicable extent. Disposal should be the last option. Typically, over 90% of the volume of waste generated during the decommissioning of a nuclear facility has little or no radioactivity associated with it, and most of the remainder contains only very low levels of radioactive material. Thus, only a small percentage of waste material is regulated as low or intermediate level radioactive waste.

Policies for the long term protection of the environment stem from ethical considerations, in particular that the current generation should protect the environment for future generations; in benefiting financially and achieving higher standards of living from nuclear power, it must not harm the environment or leave a legacy of technical mismanagement for future generations. This is the basic concept behind sustainable development and combines environmental issues and socioeconomic priorities. These objectives are reconciled within the sustainable development principle. Briefly, this principle can be described as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs [25]. Reusing facilities/sites contributes to the overall concept of sustainability.

Public expectations attach high value to site reuse because of the potential for workforce re-deployment and local redevelopment. Commercially, the best reuse of a successfully decommissioned nuclear site may well be the construction of a new nuclear facility in its place, an option that may also be congruent with national needs and local resources. From a national perspective in many countries, nuclear power is gaining increasing policy support as a reliable source of affordable and cleanly generated electricity. From a local perspective, the replacement option draws on available skilled labour and infrastructure, and therefore likely to enjoy the local public acceptance common to communities familiar with nuclear power [26].

The location of any industrial facility to be decommissioned is an important factor that needs to be considered from a socioeconomic perspective. Most of the facilities that become obsolete or operational functions were modified are located in geographical areas already heavily populated and close to commercial districts. Older facilities are usually targeted for decommissioning. These facilities were originally constructed on the edge of a growing metropolitan area but are now in the centre of an urban area and are engulfed by city sprawl. The overall public sensitivity to the environment and possible discharges and pollution has increased significantly. Noise pollution, for instance, has become a contentious issue, especially if constantly generated. Water pollution in the case of facilities located adjacent to surface water bodies and visual airborne discharges are further examples of issues that cause negative public response. Industrial redevelopment around water bodies may not be supported by the public.

The reuse options of facilities located in the centre of urban areas must consider the public needs and perceptions before implementation of a redevelopment and reuse option. Arguments that the disused facilities were there first do not sway the public. Negative public sentiment has a major impact on a company or government entity when making decisions about where to commit their limited funding for upgrades and modifications. Buildings within urban areas may become obsolete for present-day uses, although remaining structurally sound. The fate of these buildings is in the hands of the owner and depends on his or her appreciation and sensitivity to public sentiment. The need to preserve historic buildings is an important part of maintaining the historic industrial character that forms a basis for future redevelopment. In this regard, it should also be noted that reused buildings and/or factories tend to be publicized and turn into tourist attractions, generating extra revenue for the owner (media coverage, tickets sold, etc). To this end, it is often convenient to keep signs of the former use, such as a historical façade.

The term ‘adaptive reuse’ is applied to situations where a facility or building is obsolete from in terms of its original purpose, but can be modified for a new function. If the facility has the right combination of location, architectural scale, and aesthetic or historical appeal, it can be an extremely attractive prospect for adaptive reuses options oriented towards the general public. In some cases, adaptive reuse of old industrial facilities and sites are being incorporated into urban renewal efforts. The opportunity to reuse obsolete facilities in the urban core supports sustainability and smart growth initiatives designed to focus redevelopment in inner cities in an effort to decrease urban sprawl. There are two basic factors that need to be considered when assessing the potential of adaptive reuse of an obsolete facility: (a) who currently owns it, and (b) what are the driving forces in creating a new use for the facility [27].

For a long time, regeneration was driven by a combination of political will and business economics. However, it has depended heavily on public money and has often been complicated by bureaucracy. More recently, experience has helped developers to tackle bureaucratic obstacles. Less public money is needed to back projects, as investors are becoming more attracted to regeneration projects as a sound place to put their funds [28]. Some examples are as follows:

- Kick-started by public money and tax breaks, development in London Docklands, UK is now driven by the private sector.
- In Milan, Italy, the Bicocca project transformed almost 100 ha of a tire and cables factories into a university, research laboratories, offices and residential accommodation. The redevelopment was undertaken by a daughter company of the former owners, Pirelli.
- The Hines European Development Fund (HEDF) has invested in partnership with two local developers in the regeneration of a factory site at Billancourt in Paris, where Renault cars were built until 1989. Hines plans to build more than 800 000 m^2 of mixed residential, office and commercial space.

As private finance moves in, are financial returns the only measure of success for regeneration projects? The creation of jobs in areas afflicted by unemployment is certainly a complementary measure. At London Docklands, the working population rose from none to 64 000.

The number of visitors attracted to a city is another important aim when regeneration schemes have financed cultural showpieces. The Guggenheim Museum was the result of a move by the Bilbao authorities to attract the Guggenheim Foundation to the city, when the traditional industries of shipbuilding and steelmaking collapsed in the early 1990s. Within two years following the museum opening in 2001, extra tax revenues had already covered the cost of bringing the museum to the city [28].

A comprehensive review of indicators for measuring change in the historic environment (and evaluating success of national redevelopment programmes) is given in Ref. [29]. The list includes:

— Public support;
— Tourism;
— Education;
— Awareness;
— Identification;
— Condition and loss;
— Investment;
— Planning;
— Access;
— Employment;
— Skills.

Reference [30] describes these indicators in detail.

Finally, it should be emphasized that the process of redevelopment and reuse of non-nuclear facilities and sites is more mature than the redevelopment and reuse of nuclear installations. The latter has been often hindered by remaining or suspected radioactive contamination (although this can be reduced to levels compatible with an adaptive reuse) and often by the nuclear stigma. This report describes both nuclear and non-nuclear applications, and identifies where the latter can be successfully applied to the nuclear sector. Appendix III provides further details on the redevelopment and reuse of industrial heritage.

3. PURPOSE

The purpose of this report is to disseminate information and lessons learned on new productive uses of nuclear facilities and sites at the completion of decommissioning and after restricted or unrestricted release from regulatory control. This is intended to leverage the value of assets (land, buildings and infrastructure) that can reduce the economic burden of decommissioning. In pursuing this approach, the report makes extensive use of redevelopment and reuse cases from the non-nuclear sector, since they are considered fully applicable in most cases to nuclear facilities and sites.

A second objective of this report is to demonstrate that planned redevelopment and reuse of the nuclear facilities and sites may facilitate the decommissioning process. More broadly, this report aims at counteracting the traditional negative view of decommissioning (the liabilities) by highlighting a more positive view (the recovery of assets). In this sense, it has a promotional nature. It does not address any safety implications, e.g. it does not touch on radiological criteria for restricted or unrestricted release of sites/facilities, although recognizing that such criteria have an important impact on redevelopment and reuse options. This information may be found in an IAEA report [31].

This report provides practical examples on a range of the advantages of redevelopment and reuse of facilities, describing both nuclear and non-nuclear cases. In fact, non-nuclear reuse has been a common practice long before nuclear reuse was considered. The emerging field of redevelopment and reuse of nuclear sites/facilities can benefit from the experience gained from redevelopment and reuse of non-nuclear sites/facilities. The actual reuse case studies provide lessons learned from both nuclear and non-nuclear examples. This task is a follow up to Redevelopment of Nuclear Facilities after Decommissioning (Technical Reports Series No. 444) (TRS-444) [30].

TRS-444 provides a conceptual framework for the reuse of nuclear facilities, focusing on factors, criteria and responsibilities associated with site reuse. It also provides some technical detail and background on the reuse of a number of individual decommissioned facilities and should be read in conjunction with this report. The information provided for individual facilities in TRS-444 has not been repeated here unless up-to-date information on reuse strategies for them has become known since its publication.

Finally, the report recognizes that redevelopment and reuse opportunities should be considered on a case by case basis. In a number of cases, demolition and greenfield release of the site may be the only available option, since redevelopment and reuse would be too costly or impractical. However, the information presented here demonstrates that redevelopment and reuse process deserves to be evaluated for most decommissioning projects.

4. SCOPE

This report covers generic experience and lessons learned from the nuclear and non-nuclear industry as illustrated by case studies involving reuse of the following:

— Power plants (turbine halls, electric stations and grids);
— Large industrial buildings and sites;
— Bunkers (buildings with thick walls and floors, subsurface facilities);
— Contaminated areas associated with other facilities (closed waste sites, broad areas of secondary contamination);
— Smaller buildings on multi-facility sites (small research reactors, laboratories, offices etc.);
— Other facilities (stacks, cooling towers, water towers, sewage plants);
— Marine, floating or offshore facilities (nuclear ships/submarines, oil-drilling platforms).

The report includes conclusions and recommendations, appendices, national annexes highlighting technical details of specific case histories and secondary annexes dealing with events that have occurred in the course of redevelopment and reuse projects that provide lessons learned.

5. GENERIC EXPERIENCE AND LESSONS LEARNED

The options for redevelopment and reuse of facilities, buildings and sites are mostly limited by the developer’s initiative, finances and long term care projections. Redevelopment and reuse of facilities, buildings and sites should always be considered an alternative to demolition.

There are numerous reuse options available for industrial facilities and sites, such as:

— Museums;
— Art studios;
— Offices;
— Residential units;
— Schools;
— Nuclear site development;
— Landfill, waste storage and repository;
— Industrial parks;
— A combination of the above.

Various aspects have a major impact on the choice of the final redevelopment and reuse options. Some of the factors that should be taken into account when considering redevelopment and reuse option are:

— Socioeconomic impact (job retention or creation, financial benefits, etc.);
— Decommissioning impact (scope of decommissioning work, waste generation, timing, regulatory issues, etc.);
— Environmental impact (conservation of greenfields, level of contamination);
— Stakeholder impact (public needs and demands and regulatory framework).

These factors vary in content for nuclear and non-nuclear redevelopment and reuse plans and are discussed in the following paragraphs. More detail on the decision making is given in Appendix II.

5.1. SOCIOECONOMIC IMPACT

The economic viability of a redevelopment and reuse option is critical to ensure success. The selected redevelopment and reuse option should provide the owner or developer with a reasonable return on investment and should generate sufficient income to ensure the long term sustenance of the facility and associated open spaces [32]. The value of the assets (land, infrastructure) in their redevelopment and reuse for new purposes is sometimes so high that it will significantly offset the cost of decommissioning. This was the case of the University Research Reactor cited in Ref. [30], where the land value increased dramatically due to expansion of the nearby city.

In many cases, there is little to gain in pure economic terms since nuclear and other industrial sites are often remote and the land remains cheap. Cases of increased land profitability may occur due to: expansion of nearby cities, promotion of attractions such as museums and business parks, or making use of existing infrastructure for new installations. In the UK, while there are sound financial grounds for redeveloping a few premises of high land value located within commuting distance of London (Harwell, Winfrith), most nuclear installations are dispersed widely around the British coastline. Still, the option of building new NPPs at existing nuclear sites is potentially profitable [33]. In a recent paper, the Nuclear Decommissioning Authority, as the owner of decommissioning sites in the UK, has been advised to maximize the commercial value of these sites, either for nuclear or non-nuclear development, as a means to alleviate the escalating cleanup costs [34]. Valuing nuclear sites for new buildings is difficult, but in general, the scarcity of supply will increase values of existing sites. According to a recent study [35], the nuclear development land could be worth $8–24 million per ha (£2–6 million per acre) for a typical 16 ha (40 acre) footprint pressurized water reactor (PWR) nuclear power station — about the same cost as prime residential development land in London. The total revenue from the land sale is estimated in the range of £80–240 million ($120–360 million) per site. These figures were confirmed by the recent auction of three UK Nuclear Sites. The auction raised £387 million ($580 million) [36].

A holistic reuse could include the conservation of the heritage value of the facility, but should not compromise the sustainability of the redevelopment and reuse option. The impact of successful redevelopment and reuse is experienced beyond the boundaries of the heritage asset itself and should aim at a socioeconomic boost for the community [32].

The redevelopment and reuse of a facility can have very positive socioeconomic impacts on a community:

- Property values are likely to rise with successful redevelopment.
- Employment issues are not affected to the same extent as they are by shutdown and decommissioning. Re-employment could be a driving force for redevelopment
- Educational opportunities are maintained.
- Sustained tax revenues and municipal income could even increase [23].

The impacts of the final shutdown of facilities, buildings and sites vary significantly between different industries. The impacts on the workforce are more severe when specialized labour is involved; its redeployment is not always easily managed. There can sometimes be a delay in the transitional phase before and after decommissioning, which could impact negatively on the staff required to perform decommissioning and redevelopment actions. The early communication and promotion of redevelopment and reuse options and the development of a strategy can have a significant positive socioeconomic impact on the workforce and sustainability of the local community [37].

It is vital to understand the facility, building or site in detail to determine the most viable redevelopment and reuse option. The economic, environmental, historical, archaeological and natural resources and other characteristics must be studied and known. These need to be aligned with stakeholder interest and the complete content of the facility, building or site to be reused [38].

For multifacility nuclear sites, it is vital to develop a total site redevelopment plan rather than allocate individual facilities for isolated reuse demands. A holistic approach should be assured by considering current and projected future demands in a redevelopment and reuse plan, thus ensuring that individual facilities are not allocated for redevelopment and reuse without consideration of the overall strategy as presented by the site redevelopment and reuse plan. It is important not to allow the redevelopment and reuse of a single facility on a multifacility site based solely on short term financial gain, because these outcomes are not easily reversed. With the recent increase in demand for nuclear research and development (R&D) facilities, the redevelopment and reuse of nuclear facilities for new nuclear options should be given preference due to the inherent advantages associated with a licensed site.

5.2. DECOMMISSIONING IMPACT

Redevelopment and reuse is likely to have an impact on the scope and extent of decommissioning including activities related to equipment dismantling and decontamination. For specific redevelopment and reuse scenarios, equipment could be required for similar or adaptive reuse. Reuse of equipment could result in a significant cost saving when compared with the cost of full decommissioning and reinstallation of new equipment [39].

For buildings and sites, the land and building value can be a significant asset for the owners. Traditionally, decommissioning is only viewed as a liability; however, the recovery of land and facilities standing on it may offset the cost of decommissioning, at least in part. This is now recognized in certain cost studies for decommissioning. Reference [40] assesses the land value in immediate and delayed dismantling scenarios.

When considering redevelopment and reuse options, the buildings should be inspected (e.g. facility design, materials of construction, and current condition) to evaluate whether they can be reused or should be demolished. Current building requirements, e.g. seismic, applicable to the specific reuse option might not be met by the old building, and it could be too costly to renovate the building to comply with current building codes.

Intended reuse should be a driving factor in determining the cleanup standards. The cleanup methodology should be aligned with the redevelopment scenario. For example, asphalt capping can be reused as a parking area and at the same time contain contaminated soil and prevent the leaching of contamination into groundwater or the migration of contamination to neighbouring areas [39].

Decommissioning should include all steps leading to the release of buildings, land, facilities and equipment for redevelopment and reuse. Approval of release criteria associated with a selected redevelopment and reuse option should be obtained early in the process to ensure the inclusion of the applicable criteria in the redevelopment and reuse strategies. Since it is not always possible to release a decommissioned site or facility, the redevelopment and reuse options may be limited due to remaining liability and ownership requirements [26].

Redevelopment and reuse options must ensure that no significant risk to the public or the environment develops during or after the implementation of the option. redevelopment and reuse options must also aim to reduce the associated liability. If contaminated material cannot be removed, the engineering controls such as capping the site should be combined with institutional controls to ensure that contamination is not disturbed and institutional control is maintained. Depending on the level of safety, such areas could also be considered for recreational reuse (e.g. golf course) [26, 41].

Once a site is decommissioned, it is intrinsically much safer than when it is in operation or abandoned in situ. The hazardous activities are stopped, hazardous material inventories removed and generation of process waste halted [26]. This safer environment should be communicated as an advantage associated with redevelopment and reuse strategy. The redevelopment and reuse option evaluation should not be obscured by the original purpose and current condition of buildings, sites and facilities.

It should be noted, in contrast, that dismantling activities may result in extensive damage to structures, making redevelopment and reuse problematic. One such case is the decontamination of graphite silos at the Vandellos NPP, Spain (Fig. 11).

5.3. ENVIRONMENTAL IMPACT [39]

An environmental impact assessment (EIA) or similar process is typically required for redevelopment and reuse projects and will ensure evaluation of all relevant factors. During the EIA process, hazardous materials, the extent of contamination and the future environmental impact with respect to the redevelopment and reuse options will be determined. An EIA is costly and time-consuming, but a focused assessment of the reuse options can improve the redevelopment and reuse process.

Decommissioning to various levels is required for redevelopment and reuse. The cost of decommissioning can be shared by interested developers of a redevelopment and reuse facility or site. In many cases, buildings are left abandoned due to lack of decommissioning funding. Not addressing environmental contamination can lead to

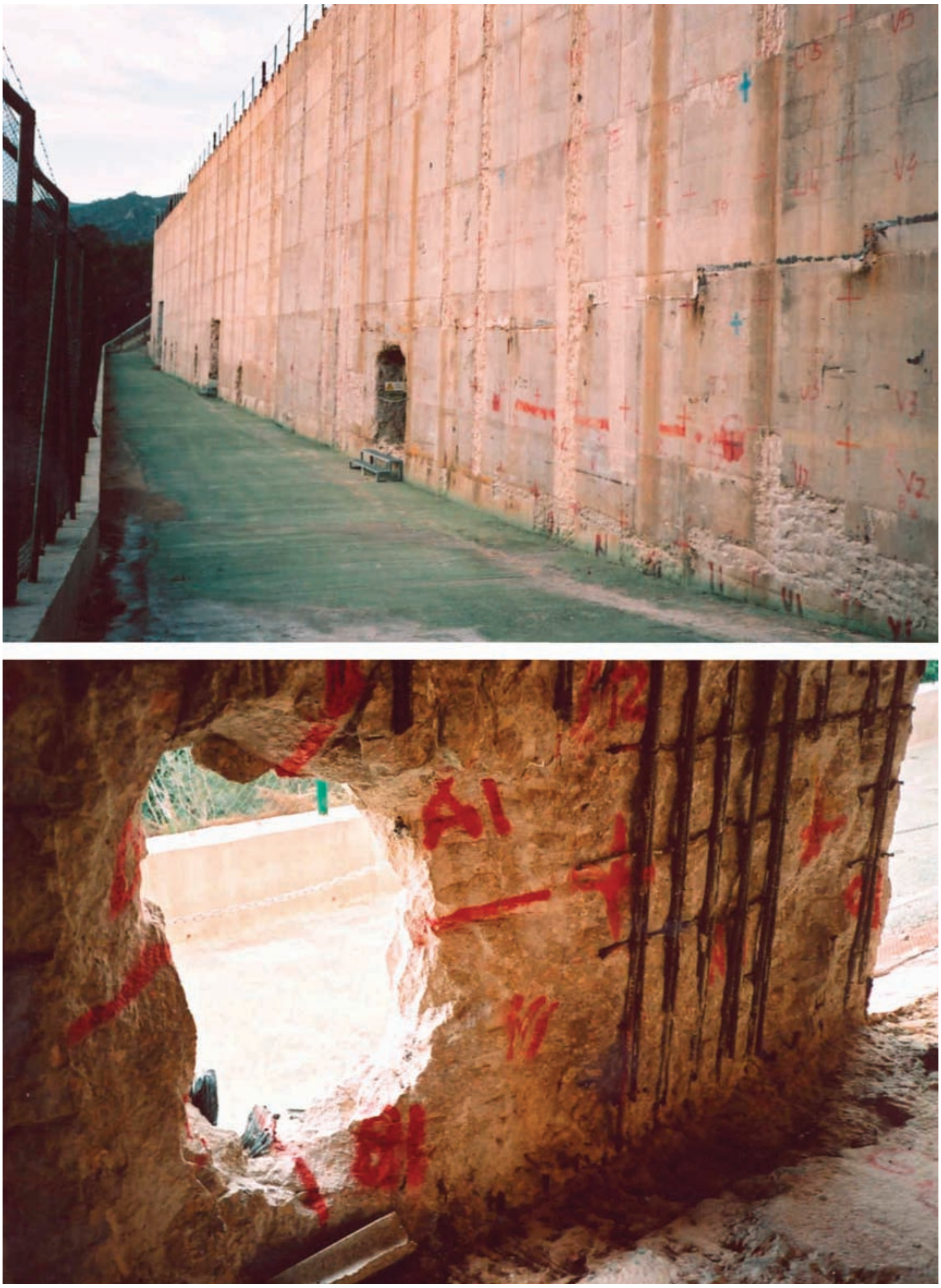

FIG. 11. As the result of extensive contamination of floors and walls, decontamination of graphite silo surfaces at the Vandellos nuclear power plant in Spain entailed removal of material in depth. In some cases, the entire thickness of the wall had to be removed (bottom).

migration of contamination, causing severe environmental impacts that lead to regulatory enforcement actions, bad publicity and costly cleanup later. The redevelopment and reuse of such a contaminated site will not easily attract the attention of developers. Abandonment of buildings leads to a worsening of problems, animal infestations, and safety hazards due to structural deterioration or release of hazardous materials.

5.4. STAKEHOLDER IMPACT (REGULATORY REQUIREMENTS AND PUBLIC INVOLVEMENT) [39]

Public concern over social issues can determine redevelopment options. The public's need for infrastructure, schools, residential property, business areas and recreational options should be recognized and considered in redevelopment and reuse options and strategies.

The regulatory requirements in the nuclear industry dictate the compilation of redevelopment and reuse options and strategies. The applicable authorization criteria and guidelines for the various phases, cleanup criteria and characterization methodologies and techniques, should be adhered to. Cleanup criteria would differ for a future industrial use or limited exposure scenario versus the more stringent requirements for public use or a planned use with an unlimited time of exposure. Early involvement of regulators is critical in the case of planned redevelopment and reuse. The viable redevelopment and reuse options should be approved or accepted by the regulators as part of the decommissioning strategy prior to decommissioning. Failure to obtain prior approval could result in a much higher decommissioning cost and/or the future redevelopment and reuse plans being jeopardized.

Redevelopment and reuse options are site specific, and the viability of the different options should be considered for each site. Some approaches or options may be viable from a construction viewpoint, but would not maximize the lifecycle potential of the site. Other approaches and options may present long term flexibility, but are costly and could be restricted by the site characteristics. The selection of a redevelopment and reuse option should consider the impact of each alternative in terms of the following key attributes; cost of option and the technical, operational, commercial, environmental and social objectives. The factors should be considered and weighted in accordance with their relative importance in a systematic multivariant analysis.

Redevelopment and reuse options should have a strong focus on safety for the protection of people and the environment. Such redevelopment and reuse options will build confidence among the public, regulators and other stakeholders.

The redevelopment of former nuclear sites will also require a high level of involvement of external agencies and stakeholders. The redevelopment and reuse phase will involve the stakeholders from the operational phase as well as additional community stakeholders. The additional stakeholders should include the potential new owners, tenants and applicable external agencies in the case of adaptive reuse. The economic and social redevelopment advantages should be communicated with stakeholders including the public at an early stage of decommissioning. Effective communications are required to build stakeholder confidence in the redevelopment process.

It would be desirable to develop near term guidance for a regulatory framework for redevelopment and reuse of nuclear sites; experience and lessons learned from the non-nuclear sector will help. Although each redevelopment and reuse option must be evaluated on a case by case basis, the need to identify uniform reuse guidelines and a framework typical to each industry is as important as uniform regulatory standards related to redevelopment and reuse. Uniform redevelopment and reuse options help to predict, plan and ensure effectiveness of a project**.**

5.5. GENERIC EXPERIENCES AND LESSONS LEARNED: THE NUCLEAR INDUSTRY

5.5.1. Redevelopment and reuse of nuclear facilities as new nuclear sites

One of the keys to successful sustainable redevelopment is to ensure future occupation or use of the redeveloped area. In most cases, the best use for a building or facility is the same for which it was originally designed. The most desirable option for redevelopment and reuse is therefore the reinstatement of the original use. This is especially important for nuclear sites and buildings, but it is also applicable to other industries. It is acknowledged that this is not always possible to achieve because not all original uses are currently in demand or necessarily appropriate. Adaptive reuse options have to be considered in cases where the original use is no longer viable. Due to the public perception and negative sentiment regarding nuclear applications, the idea of reusing nuclear sites for residential areas may be rejected. The reuse option of redeveloping the site into a nuclear site again, having the same use for it as previously, is more likely to be supported. The redevelopment and reuse of a nuclear site for similar nuclear applications has major advantages for the developers, as highlighted by the following:

- Sites already licensed and authorized could be a general benefit with respect to project risk, cost, time and effort. Normally, site permits with respect to discharge limits are already established and authorization already approved.
- There are existing stakeholder acceptance and established communication links.
- There are existing on-site and off-site emergency control arrangements.
- Site information such as demography, geology, hydrogeology, seismology, population density and floods is already available.
- Safety, health, environmental and quality management systems are approved and implemented (e.g. monitoring programmes for groundwater and air releases), reducing the initial level of investment of any developer [23].
- Inherent cost savings and the difficulty in securing decommissioned nuclear facilities and sites make the redevelopment and reuse option a viable alternative. If a decommissioned nuclear site can be reused for a waste repository or brownfield development, the cost of controls and security can be lowered and the historical liabilities can be shared.

Nuclear facilities have been redeveloped and reused as, inter alia, museums, natural gas power plants, waste storage areas, nuclear culture complexes, technological parks and renewable power generation facilities (wind energy).

Decisions regarding the reuse of nuclear facilities must be made on a case by case basis, with location and public acceptance playing a major role.

5.5.2. Aspects specific to nuclear sites that should be taken into account when compiling a redevelopment and reuse plan

Scope of decommissioning work (radiological release criteria or criteria for site delicensing)

The extent of decommissioning depends on acceptable residual activation or contamination levels for the reuse options (the typical brownfield versus greenfield argument). Selection of realistic options in terms of prevailing contamination levels and the extent of decommissioning are required. It is more profitable from a developer's perspective and more acceptable from the public's viewpoint to reuse nuclear facilities or sites as industrial sites rather than as residential areas. It is even more advantageous to redevelop a nuclear site into a more advanced nuclear site. In some cases, it is economically impossible in the short term to meet radiological release criteria for site delicensing; in these cases, non-nuclear reuse options are limited (restricted release options may however be considered) [23]. The reuse as a nuclear facility, waste repository and waste storage is a possible redevelopment and reuse option in cases where delicensing is not possible.

5.6. STEWARDSHIP

Stewardship or acceptance of responsibility is needed for ensuring long term protection of human health and the environment from hazards posed by residual radioactive and hazardous chemical substances. Planning for stewardship should be part of the decommissioning planning process, since cost and liability associated with stewardship may influence the final decision on decommissioning approach, degree of remediation and reuse of a site. If reuse is to occur, then the degree of contamination remaining must be compatible with the selected reuse option, and the new user will become responsible for most, if not all, of the stewardship activities and costs. A key action prior to transferring the site for reuse is the establishment of an information system that will preserve the date and location of remaining contamination and the reason for any associated institutional or physical control [23].

The stewardship of a nuclear site cannot be transferred without proper control arrangements; the national regulator's involvement is required. The regulator's involvement sometimes influences the decisions of developers on the reuse of the site.

Non-nuclear developers would prefer a cleared site or a site with restricted use rather than a fully controlled site. Sites and facilities that are under regulatory control are generally associated with delays in timescale and increased costs, which may influence the developer's willingness to redevelop the site.

5.7. RADIOACTIVE WASTE QUANTITIES

Due to today's stringent clearance criteria, it can be difficult to demonstrate that waste generated on a nuclear site can be cleared and may result in the unnecessary generation of larger volumes of radioactive waste. A redevelopment and reuse plan should address waste minimization objectives by optimizing reuse of buildings and structures, and hence preventing their demolishing and the unnecessary generation of radioactive waste [23].

5.8. AGE AND INTEGRITY OF FACILITY

The disadvantages of older and decommissioned nuclear facilities are natural deterioration of structures and degradation caused by decommissioning, e.g. removal of concrete from structures for decontamination purposes. Older facilities must be evaluated to determine whether they can be renovated in a cost effective manner to comply with current structural codes and requirements as well as operational standards [23]. Operational and maintenance costs may also be higher than similar comparable modern buildings. These are factors that can work against the choice of redevelopment and reuse.

5.9. LOCATION OF FACILITY

Nuclear facilities are normally sited at a distance from residential areas. If this is still the case, the remoteness can be an advantage for prolonged nuclear applications. If this is not the case, the risk involved related to an abnormal situation that might occur at a nuclear facility and current regulatory requirements will influence the nuclear redevelopment and reuse viability of such a site.

5.10. EXPERIENCE AND LESSONS LEARNED FROM NUCLEAR SITES

Effective communication with local stakeholders is essential to the success of a redevelopment and reuse project. The public will have understandable concerns regarding long term risk from any remaining contamination. It is important to involve non-radiological state agencies, both in the decommissioning and in the decision-making processes with regard to possible chemical contamination of a nuclear site, where the nuclear regulator focuses mainly on the radiological impacts [42]. An integrated approach to hazards and environmental impacts is recommended and could begin long before the facility is shut down. Periodic public meetings would allow stakeholders to express their concerns and have any questions answered.

Communication between radiation protection staff, the involved state agencies and the public must be effective. The use of technical terminology and jargon that can lead to confusion for non-technical stakeholders must be eliminated [42]. The public can easily misinterpret the potential risks of radiation, but generally responds favourably when given sufficient well-explained technical information.

The public and other stakeholders must be included in the decommissioning process in order to ensure that their needs are also recognized. This will lead to more broadly acceptable redevelopment and reuse plans.

The remoteness of specific sites has specific advantages for nuclear redevelopment. The redevelopment and reuse of existing NPP sites would offer the following important advantages if future NPPs or nuclear facilities are located on them [43]:

- There will be fewer locations subject to long term restricted use and periodic surveillance and maintenance.
- The burden and liability of long term care and final disposition of redundant NPPs will be eased.
- The overall environmental impacts due to construction, operation and decommissioning will be less than new construction at a greenfield site.
- The licensing and authorization of these facilities might be easier with regard to public concern and the regulatory framework.
- Due to time and money saved by not constructing new utilities, the current utilities can be upgraded at a lower cost.

- The current training facilities can be upgraded ensuring higher skills on existing and new facilities.
- Skilled and experienced human resources associated with the operation of existing facilities would be available.

Redevelopment and reuse options are influenced by the nuclear fuel cycle specific activities, buildings, facilities and sites (e.g. conversion, enrichment, fuel manufacturing, reprocessing). The type of contamination (radiological and chemical) differs for each phase. However, different nuclear sites may have similar radiological contamination and characteristics associated with typical facilities.

In mining applications, large volumes of low level radioactive wastes that also contain hazardous chemical substances and concentrated metals are normally present. Such sites are usually associated with a significant environmental impact such as contamination leaching into underground water or airborne as dust. This radioactive and hazardous chemical contamination should be considered in the development of reuse options and strategies [26].

Fuel manufacturing and reprocessing facilities have more complex radiological wastes to deal with (natural radionuclides, actinides and fission products), which should be considered in redevelopment and reuse applications. For isolated short lived radionuclides, the decay of radionuclides must be considered in the redevelopment and reuse. A redevelopment project may need to be delayed to allow decay of short half-life radionuclides to increase the viability of more redevelopment and reuse options. This could result in significant financial savings by not removing short lived waste as radiological waste, but allowing it to decay to clearable levels. Hot spots due to contamination by short lived radionuclides could be isolated (e.g. capped) for development at a later stage. An example of such an application is where a large area is contaminated with short lived radionuclides that can be covered and used as a parking area.

Regulatory standards for natural occurring radioactive material (NORM) facilities are also necessary for successful decommissioning and reuse. The regulatory levels for NORM need to be considered for the development of a waste management strategy for the decommissioning of a facility or site. The decommissioning cost can be reduced significantly if the regulator allows the use of the higher release criteria applicable to NORM for releasing the site for unrestricted use [42].

Examples of successfully redeveloped nuclear sites are described in Section 6.

5.11. GENERIC EXPERIENCES AND LESSONS LEARNED: THE NON-NUCLEAR INDUSTRY

5.11.1. The redevelopment and reuse of non-nuclear facilities

The redevelopment and reuse of redundant non-nuclear facilities and sites is generally regarded as more flexible and easier to accomplish due to a less restrictive regulatory framework and broader public acceptance.

When industrial sites are to be redeveloped and reused, the basic environmental information is often already available (e.g. demography, geology, hydrogeology, seismology, population density and flood levels, etc.). This could result in significant financial benefits and time savings. Site permits regarding discharge limits may be established and authorized since the monitoring information and programmes are available and implemented, e.g. for groundwater and air emissions surveillance.

The timely development of a redevelopment and reuse strategy has several financial and other associated advantages:

- It avoids abandonment of property, thus preventing vandalism. This will ensure that the property value is not influenced negatively.
- It ensures maintenance of buildings and structures by property owners.
- The early identification of redevelopment resources (e.g. financial, technical and corporate development) allows them to be made available at the end of a facility’s life.
- Knowing the potential impact that the redevelopment strategy may have on neighbouring facilities and areas allows for preventive measures to be put in place.

Adaptive reuse of urban facilities has high potential to support ‘smart growth’ initiatives, which focus development within cities to decrease sprawl. Development in cities, as opposed to suburbs or rural areas, helps contribute towards the revitalization of urban cores. Urban development allows opportunities for more efficient transportation and resource use in addition to avoiding negative impacts on the surrounding landscape [39].

There are several environmental benefits from the redevelopment and reuse of buildings:

- It reduces the raw materials consumed in construction.
- It avoids waste production by obviating demolition of the original structure.
- It reduces development pressure on open space by reusing land that has already been developed [39].

Older facilities have assets and infrastructure that can be reused, for example:

- An established electrical supply infrastructure;
- Airstrips, road, rail or sea access with offloading facilities;
- Office space;
- Established utility supplies (e.g. electrical, cooling water systems, steam supply and demineralized water supply);
- Developed security systems (cameras, fencing, etc.);
- Established underground features (e.g. vaults, tanks, pits, water supply systems, fire protection systems, sewerage systems and other waste retention systems). If the site is not to be reused, these underground features may have a major impact on decommissioning, but for a site that will be reused, they could have many benefits;
- Support services (e.g. catering, public transport);
- A local workforce with a high level of technical skill;
- Prestigious old and/or historic buildings.

The redevelopment and reuse of a facility can have a positive social influence on a community:

- Property values rise due to sustainable development.
- Employment issues are not affected to the same extent as shutdown and decommissioning; re-employment could be a driving force for redevelopment.
- The loss of educational opportunities is reduced.
- Tax revenues and municipal income are not lost and could even be increased [23].

5.11.2. Experience and lessons learned

The public is a primary stakeholder; the influence of its opinions and needs must not be underestimated. The public’s needs for residential, retail, leisure, hotel, educational, cultural, workshops, community, office space and storage areas must be recognized. These needs are examples of potential, viable redevelopment and reuse options for both heritage buildings and brownfield sites. When reutilizing historic sites, the redevelopment and reuse options should be demand driven rather than purely heritage driven.

Redevelopment and reuse of heritage buildings can play an important role in the future of towns, cities and rural areas by promoting sustainable development. The redevelopment of older buildings contributes to achieving sustainable development objectives by attracting tenants who would normally not be interested in this choice of real estate [33, 44].

Historic buildings have qualities that can enhance the overall town’s value — cultural, architectural or simply historical. Many historic buildings are popular landmarks, and the communities support redevelopment and reuse to save them.

Creativity and engineering skills can turn almost any heritage building or site into a new development area. The reuse of existing buildings and structures can be a cost effective and environmentally beneficial way of redeveloping brownfield sites. As development pressure on land and the cost of resources increases, these types of reuse projects will become more common [39].

Although the design and construction of new buildings involve large amounts of energy, water and materials, there are disadvantages to redevelopment and reuse of older buildings to consider. The initial design, engineering, maintenance and operational costs of older buildings are higher than that of comparable modern buildings. The maintenance of historical architectural value of heritage buildings limits future flexibility and changes to suit possible user or tenant demand. Appropriate control over, inter alia, public use areas, service access and modifications by tenants is required to preserve the character of the building in its setting. The access and floor plan may restrict use to one type of occupancy or result in incompatible tenants. Facilities management may be more complex if there are multiple occupiers. Older buildings have limitations that can restrict their reuse options, which may be caused by limited floor areas space, ceiling heights and distance between external walls and available services, such as electrical infrastructure.

The redevelopment and reuse of older buildings mainly for heritage purposes should be well planned and have a well developed implementation strategy, which should consider the following aspects [32, 44]:

— A scheme that is viable in terms of business, financial and heritage considerations;
— A clear building and site assembly strategy if needed;
— If known, the occupier's needs and demands, including the style of the accommodation in the building;
— The creation of a steering committee and procurement strategy to consider and implement proposals;
— A clear public and/or private sector funding strategy;
— A robust town planning strategy involving local stakeholders;
— Thorough planning to justify a planning base that addresses the full range of conservation, regeneration and other relevant planning issues.

Redevelopment and reuse planning should consider the following for successful development [32, 44]:

— Use quality based (not just price based) selection procedures to choose consultants and contractors.
— Provide reliable services by obtaining references of craftspersons and inspectors of previous work quality.
— Ensure adequate specifications and supervision are provided by consultants or developers.
— Draw lessons from other comparable projects and allocate adequate time in advance for all aspects of the work.
— Wherever possible, subject to market demand and the occupier's needs, opt for 'low tech', low intervention, sustainable alterations and fit-out for new uses.
— Understand cost implications of repairs and new work by seeking advice from suitably experienced cost consultants and/or by benchmarking costs on comparable projects.
— Bear in mind that overhead costs and professional fees tend to be higher than for comparable work on non-heritage buildings.
— Fully scope the project at outset and avoid 'scope creep' through effective change management.
— As a further way of avoiding scope creep, create prioritized and cost estimated 'wish lists' of scope items that can be introduced subsequently if funding permits or if tenders prove more competitive than forecast.
— Ensure adequate contingencies, preferably based on realistic, quantified risk assessments.

The redevelopment of brownfield sites carries risks directly related to past contamination of the site, including:

— Liability risk;
— Regulatory risk;
— Timing risk;
— Financial risk.

A developer, contactor or owner of a brownfield site faces the risk of contaminated soil, groundwater or contaminated neighbouring areas of which he/she will only become aware during his/her redevelopment actions. Undiscovered pre-existing contamination could become the new developer or owner's liability depending on contractual agreements and the regulatory framework.

The regulatory role in brownfield sites could become a major risk in the case of undiscovered pre-existing contamination. Once contamination is discovered, the regulator could stop redevelopment actions and require a comprehensive characterization survey to determine the extent of contamination.

If the site turns out to have undiscovered preexisting contamination, timing becomes a major risk due to required cleanup actions. Additional direct and indirect costs such as interest on loans (delay on income generated) could jeopardize redevelopment actions.

Financial risk is determined by the magnitude of preexisting contamination. The contractual agreement for a redevelopment of a brownfield area must always carry a risk to allow for possible cleanup actions. The magnitude of the risk is unknown, and if realized, it may change the viability of a redevelopment and reuse project. The implied financial risk associated with the uncertainty of unknown contamination may result in a developer's decision to develop new brownfield sites rather than redevelop existing brownfield sites.

Examples of non-nuclear redevelopment and reuse projects are described in Section 6. For further examples of non-nuclear redevelopment and reuse projects involving chemical contamination, see Appendix I.

6. PRACTICAL EXPERIENCE AND LESSONS LEARNED

This section provides case studies of redevelopment and reuse from the nuclear and non-nuclear industry. Each example describes the original use, the redevelopment scenario and the outcome. Note that many of these examples are in the planning or early stages of redevelopment; hence, the outcome may be different than originally anticipated.

6.1. REUSE OF POWER PLANTS (TURBINE HALLS, INFRASTRUCTURE AND GRIDS)

During the past few decades, the electric utility industry has experienced significant changes. One of the major demands for change was the public's view towards pollution and nuclear power generation. As a result of these changes, some older power plants have become obsolete; it is often too expensive to upgrade the current power plants to meet the new regulatory requirements. The location of the facility in a densely populated centre can result in the closure of an urban power plant. Negative public perception regarding a power plant in an urban centre could lead to its closure, even if it is able to meet the new operating standards and environmental requirements [45].

Although these old power plants may be obsolete from a power generation perspective, the proximity and other qualities of these ageing facilities provide potential for a new life unrelated to the electric utility industry. In some cases, adaptive reuse of old industrial facilities including power plants is incorporated into urban renewal efforts.

Power plants have a number of qualities that make them ideal for redevelopment. The design style of older power plants makes them attractive for reuse from an aesthetic or historical perspective. They were constructed with large turbine generator halls mainly because they were steam cycle based, which required large buildings. These large spaces present opportunities for a variety of reuse options [27, 45]. The large open spaces make old power plants ideal for conversion into museums and exhibit halls, but the options should not be limited to museums and heritage facilities.

Older power plants were equipped with a good infrastructure (e.g. railways, roads and water supplies used for cooling). The value of their land and buildings has increased significantly over time as industry and residential development grew around the sites. Older power plants may be an excellent financial opportunity for redevelopment and reuse.

The adaptive reuse decision is influenced by a combination of internal and external factors. An internal factor is the owner's vision regarding the redevelopment of the old power plant (e.g. development as offices, warehouse space, or selling the property for profit). External influences such as economic development groups, museum committees, businesses or government entities play an important role [45].

6.1.1. Reuse of power plants (turbine halls, infrastructure and grids): The nuclear industry

In the light of the ongoing nuclear revival, nuclear sites are likely to be reused for new NPPs [43] for the following reasons:

- — The number of locations committed to long term restricted use and periodic surveillance and maintenance could be limited.
- — The burden of long term care and final disposition of retired NPPs could be eased.
- — Overall environmental impacts from the construction and operation of the power plants could be reduced.
- — Time and money in completing licensing proceedings could be saved.
- — Existing sites are already licensed and tend to have local acceptance.
- — Existing infrastructure on the site supports new development.

However, some stakeholders are opposed to construction of new NPPs. In these cases, the site of a former NPP may be used for other purposes, especially for non-NPPs that take advantage of the presence of the electrical distribution system and other suitable infrastructure.

Fort St. Vrain Power Station, Colorado, USA [46]

Original use: Fort St. Vrain, Colorado, USA, was an NPP converted to a natural gas fossil fuelled power plant. The plant was America's only commercial high temperature, gas cooled reactor design. The NPP shut down in 1989.

Redevelopment: Complete defuelling and decommissioning of the main nuclear plant was completed in 1992. In 1996, it was converted to generate 130 MW of power burning natural gas and utilizing the old main steam turbine. By 2001, the plant was expanded to a total of 720 MW. This decommissioning strategy was endorsed by the US Nuclear Regulatory Commission (then the US Atomic Energy Commission) as early as 1974, in Regulatory Guide 1.86 [47]. (See also the Pathfinder NPP below).

Outcome: Fort St. Vrain Power Station was successfully decommissioned. Some of the original buildings and plant were reused for fossil fuelled power generation.

Maine Yankee NPP, Maine, USA [48]

Original use: Maine Yankee was a single unit 900 MW PWR that safely generated about 119 billion kW·h of electricity from 1972 through 1996. Located in Wiscasset, Maine the plant was Maine's largest generator of electricity. Maine Yankee was permanently shut down in August 1997 when it was no longer economically viable to operate.

Redevelopment: The power plant and reactor was fully decommissioned. A spent fuel storage facility remains on site. Concerning redevelopment and reuse, the following achievements are worth mentioning:

- — The creation of an upland marsh area;
- — The donation of 800 000 m^2 (200 acres) of plant property for conservation and environmental education;
- — The transfer of 1 600 000 m^2 (400 acres) of plant property now undergoing economic development.

A proposed Twin River Energy Center on the former Maine Yankee property would use gasification technology to produce up to 700 MW of electricity and up to 9000 barrels per day of diesel fuel. The new plant would create 200 full time jobs and help to restore the local tax base, which suffered during the decommissioning of Maine Yankee NPP.

Outcome: The local community rejected the above approach [49].

Pacific Northwest, B Reactor, Columbia River, Hanford, Washington, USA [50]

Original use: The B Reactor was the world's first large scale nuclear reactor and was originally part of the Manhattan Project. B Reactor was a major contributor to world history, science, technology and engineering. The reactor operated from 1944 to 1968.

Redevelopment: The B Reactor was part of the largest ever scientific, engineering and construction project (the Manhattan Project) and played a key role in ending World War II. These heritage values were highlighted through the reuse of Reactor B as a museum, forming part of American and world history. The museum will be a commercial undertaking and will be open for tours.

Outcome: The B Reactor Tour Route is free from hazards:

- The asbestos has been removed.
- The electrical system has been upgraded and emergency lighting installed.
- The ventilation system was improved to control radon levels.
- Fire protection improvements have been provided including emergency lightning and egress enhancements.
- It was confirmed that the exhaust stack meets seismic standards.
- Safe radiation levels are ensured through continuous monitoring.

The B Reactor has been recently designated as a US National Historic Landmark [51]. It currently holds up to 50 public tours annually. It is planned to increase public access to the B Reactor in response to growing public interest. Other Manhattan Project sites have already been designated as historic landmarks: Los Alamos Scientific Laboratory, the X-10 Graphite Reactor at Oak Ridge National Laboratory in Oak Ridge, Tennessee, USA, the Trinity Site in New Mexico, USA and the Chicago Pile 1, in Chicago, Illinois, USA.

Shoreham NPP, Long Island, New York, USA [52, 53]

Original use: After a three decade political battle, the Shoreham NPP was permanently shut down shortly after it went critical. Opponents of Shoreham, including the local government, argued at the time that Long Island could not be successfully evacuated in the event of a major accident. Shoreham never reached commercial operation and has sat idle since its decommissioning in 1994.

Redevelopment: A non-NPP was the most voiced option as the Long Island Power Authority (LIPA) convened in June 2008, the first meeting of a new Shoreham Advisory Committee established to find a use for the site. Over the past 14 years since the plant was mothballed, ideas for its use have been floated. Some suggested a ferry terminal for service to Connecticut; others recommended a non-nuclear energy generating plant. In addition, there were proponents of demolishing the distinctive dome to create a waterfront park. Because of opposition or inertia, nothing came of the proposals. Other ideas included a marina with restaurants, a boatbuilding factory, a museum or an educational facility, windmills or some form of renewable energy technology. The property is zoned light industrial, so it would have to be rezoned for housing. The only use that is not an option is another nuclear plant because this is prohibited by the statute that created LIPA. This facility could be used to generate electricity again, or its 240 000 m^2 (58 acres) waterfront site on Long Island Sound could become a ferry terminal or marina.

Outcome: Long Islanders, as taxpayers and utility customers, continue to pay off the billions of dollars in debt incurred in building and shutting down Shoreham.

British Nuclear Group, Calder Hall NPP, UK [54, 55]

Original Use: Calder Hall was opened in 1956 as the world's first commercial nuclear power station and ceased operation in 2003. The reactor and its associated turbine hall are currently in a preserved state awaiting removal of the nuclear fuel.

Redevelopment: The defuelling and dismantling of the four reactors and turbine halls are due to begin soon. A decision on whether to preserve one of the reactors for posterity needs to be taken and a feasibility study is underway. The design and condition of the reactor and turbine hall make it possible to convert them into a museum for future generations. However, the preservation of Reactor 1 at Calder Hall would be expensive and the expressed opinion is that some may see it as a distraction from the main decommissioning focus.

Outcome: The outcome is subject to further consideration; Calder Hall will either be decommissioned or partly converted for use as a museum.

Magnox South, Hinkley Point NPP, UK [56]

Original Use: Hinkley Point NPP (two Magnox type units) operated from 1965 to 2000. One of the most significant decommissioning activities to date has been the de-planting and refurbishment of the turbine hall.

Redevelopment: A huge space covering 3500 ft^2 (300 m^2), Hinkley's decommissioned turbine hall is the home of the Deplanting Mock-up Simulator (DMS), and it is planned that soon a similar one will be built at Sizewell A. The DMS model was created by a similar scenario based simulator built at Rocky Flats Environmental Technology Site in 2001. The DMS, which was opened in November 2007, is a decommissioning training facility that allows the staff to gain first-hand knowledge of the environments they will encounter through different decommissioning activities. It simulates conditions such as noise, heat, cold and working with live tools. Simulated experiences are created that can involve staff working at height, in trenches and within soft sided spaces.

Outcome: Initially, the DMS will help to retrain Magnox staff in de-planting and decommissioning activities, but is perceived to be of real value to all trainees, regardless of their experience.

Bohunice NPP, Slovakia [57, 58]

Original use: The A1 NPP (HWGCR) was operational from 1972 to 1977 and was shut down after an accident. The plant is undergoing progressive decommissioning. The V1 NPP (two WWER units) was shut down in 2006 and 2008 and preparation for decommissioning is ongoing.

Redevelopment: The turbine hall of the A1 NPP has been reused as a radioactive waste/metal treatment facility including facilities for the unrestricted release of metal wastes. Part of the A1 auxiliary building will be decommissioned to brownfield; other buildings will be transformed to on-site waste management systems. A redevelopment study for the V1 NPP indicated the following further options such as a gas power station, a technological park, a new NPP, renewable power sources (wind energy) and others (see Annex A.I–6.2).

Outcome:

The main objective is to use the infrastructure of the Bohunice site for nuclear or other purposes in order to preserve job opportunities.

Pathfinder NPP, USA

Original use: The Pathfinder NPP was shut down in 1967. Initial decontamination was completed soon after and the main nuclear plant put under care and maintenance.

Redevelopment: The turbines and generator were reused in 1992 to establish a gas electric generating plant on-site.

Outcome: The reuse option was not successful, and due to economic reasons, the gas plant was shut down in 2000. The economic viability of a reuse option is essential for sustainable redevelopment.

The nuclear components of the facility have been kept in safe storage and monitored (care and maintenance). There was residual radioactivity located within piping and equipment, and further decommissioning was completed in 2007 [59].

BR3 Reactor, Mol, Belgium [60]

Original use: Built at the end of the 1950s, this was the first PWR plant built outside the USA. The reactor has a small power output at 10 MW. The plant was started in 1962 and shut down in 1987. The facility has six main buildings.

Redevelopment: Decommissioning of the facility is currently under way. Reuse options for some of the buildings have been considered and proposals studied. The aim is to decommission the facility and remediate the site to greenfield, unless opportunities for reuse occur.

The main arguments that would support reuse applications are as follows:

- They provide services to the nuclear industry in the field of decommissioning (decontamination facility).
- They provide facilities allowing cold and hot testing of new dismantling or decontamination techniques.
- They provide cold and hot testing of new processes for the treatment and conditioning of waste.

Outcome: The reuse strategy is under discussion with stakeholders. The decommissioning cost could be affected significantly if a viable redevelopment and reuse option could be found and implemented.

Greifswald NPP, Germany [61, 62]

Original use: The Greifswald facility was used as a nuclear power generating station until operation was terminated in 1990.

Redevelopment: While the five NPP units are being dismantled, the rest of the site is being converted to a number of new applications, such as an industrial harbour, waste management facilities, power plants and factories. Some buildings were converted to new applications (see Annex A.I–4) (Fig. 12).

Outcome: The redevelopment process is intended to alleviate unemployment in an economically depressed region of the country, which depended on the operation of the NPP in the past. The decommissioning project is extended over a long period to allow for the development of alternative industries.

Gundremmingen NPP, Germany

Original use: Gundremmingen A NPP, Germany was shut down in 1977 and has since been under decommissioning; two more BWRs, Gundremmingen B and C, are in operation at the same site.

Redevelopment: Being in the decommissioning phase, Gundremmingen A provides the ideal infrastructure for decontamination and waste management in support of the other two units. A specific case is described in Ref. [63]. Condenser tubes from Gundremmingen B and C were decontaminated in the former turbine hall of the shutdown unit.

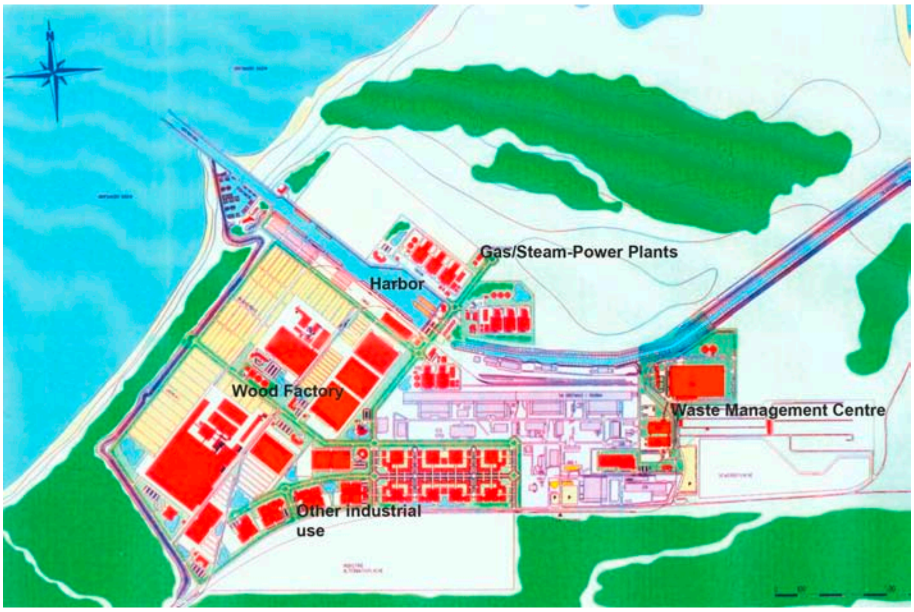

FIG. 12. Industrial redevelopment at the former Greifswald NPP, Germany.

Outcome: At a multiple facility site, integrating activities at the shutdown unit with the operation of other units is a convenient means to maintain the workers' skills and make use of infrastructure.

Piqua Nuclear Power Facility (PNPF), Piqua, Ohio, USA [64]

Original Use: PNPF operated between 1963 and 1966. PNPF was a 45.5 MW(th) organically cooled and moderated reactor.

Redevelopment: PNPF was decommissioned in 1969, and the reactor vessel complex, including the cavity liner and the space between the vessels, was backfilled with dry quartz sand.

Outcome: The City of Piqua uses the remainder of the facility as a motor pool and maintenance/storage area.

6.1.2. Reuse of power plants (turbine halls, infrastructure and grids): The non-nuclear industry

Most non-NPPs were constructed on the outskirts of a town or city. Over time, these facilities became engulfed by city development and are no longer isolated. Local governments strive to limit urban sprawl and eliminate inner city poverty and decay. Obsolete power plants can be a risk to the control of urban sprawl and a challenge for redevelopment. With the development of recent legislative and regulatory initiatives, and innovative risk management tools, the market for brownfield redevelopment is a strong motivation to encourage reuse of urban land. Environmental insurance is a valuable tool that can eliminate uncertainty and encourage many projects to proceed [45].

Power plants have solid structures and are usually situated along lakes and/or rivers or have large sources of water available. The buildings have large floor space and height, making them ideal for reuse options such as museums, aquariums, restaurants, offices, hotels, libraries, science and technology centres, arts centres, industrial manufacturing facilities and stations for public transportation systems. Any number of these options may be combined.

In the case of obsolete power plants, decommissioning should remove the power generating equipment and support systems, address any existing environmental contaminants, and leave a 'clean' shell of a building for a new function or adaptive reuse that is not related to power production. Typical environmental considerations for these older facilities include the presence of asbestos, metals based paints and coatings, mercury, and sometimes PCBs.

Redevelopment and reuse options influence the decommissioning endpoints, especially for museums or heritage facilities. In industrial museums, most of the equipment (e.g. power generators, control systems) are to be kept in the original state, and decommissioning includes cleanup actions and restoration options, but not necessarily the dismantling and demolishing of equipment and parts of buildings. The architectural scale and open spaces of former power plants are well suited for use as museums.

The following power plants were successfully redeveloped into museums, restaurants and hotels [27, 45]:

— Tate Modern Museum in London, United Kingdom [65];
— The Power Plant Museum in Toronto, Canada;
— The Power Plant Complex at Inner Harbour in Baltimore, Maryland;
— The Comal Power Plant in New Braunfels, Texas;
— The Seaholm Power Plant in Austin, Texas;
— The Centrale Montemartini in Rome, Italy [66, 67];
— The Museu de Electricidade in Lisbon, Portugal;
— The Musée d'Art et d'Industrie in Roubaix, France;
— The Neues Museum Weserburg and the Städtische Galerie im Buntentor in Bremen, Germany.

Some of these and other facilities are presented in more detail as case studies.

Tate Modern Museum, London, UK [45, 65, 68]

Original use: A conventional fossil fuelled power station.

Redevelopment: The Tate Modern, a high profile, world-class and renowned modern art museum converted the former Bankside Power Station, located on the south side of the River Thames. Attributes of the former

Bankside Power Station for redevelopment and reuse as a museum were its architectural distinction, its location opposite St. Paul's Cathedral (enabling the linking of the two by riverboat service and a new bridge) and the historical significance of the surrounding area. The Bankside Power Station, a very striking and distinguished building, provided over 33 000 m^2 (370 000 ft^2) of internal floor area, which is used for display and exhibit space, shops, cafes, an auditorium, education area and support areas.

Outcome: Tate Modern is a leading example of the reuse of a conventional power station building.

Lots Road Power Station, London, UK [69]

Original use: In 1902, construction started of the then largest power station in the world. The Lots Road Generating Station was designed to power most of the London underground. Styled as a classic American industrial building, it housed 64 boilers powering eight turbo-alternators, generating a total of 40 MW. In 1905, the turbines hummed into life, and conditions improved enormously for subway passengers who had had to put up with the smoke and soot from the steam locomotives. From 1965 to 1969, the entire plant was replaced by modern oil fired boilers and six new turbo-alternators, yielding a total output of 180 MW.

Redevelopment: The power station building will be converted into homes and shops as a reminder of this fascinating relic of London's industrial past. In addition, the local museum benefited from the opportunity to recover tools and materials, such as heavy duty industrial racking, several motor driven pumps, high pressure hose and pipe fittings, and floor plates and grids (Fig. 13).

Outcome: Lots Road is an interesting example of an ongoing industrial reuse project.

Centrale (Power Plant) Montemartini, Rome, Italy [66, 67, 70]

Original use: The power plant was started in 1912. It was built close to the Tiber River in order to have continuous availability of water and outside the city borders to be exempted from local taxes on fuel. Initially, power was 7000 kW; later on in 1924, it increased to 16 000 kW with the addition of steam turbines. In 1963, parts of the plant were shut down, and a few years later, the plant was closed (Fig. 14(left)).

Redevelopment: Centrale Montemartini's conversion into an Art Centre started in the 1980s. The transfer of hundreds of sculptures from the Capitoline Museums in 1997 marked the conversion milestone.

FIG. 13. Lots Road Power Station during conversion.

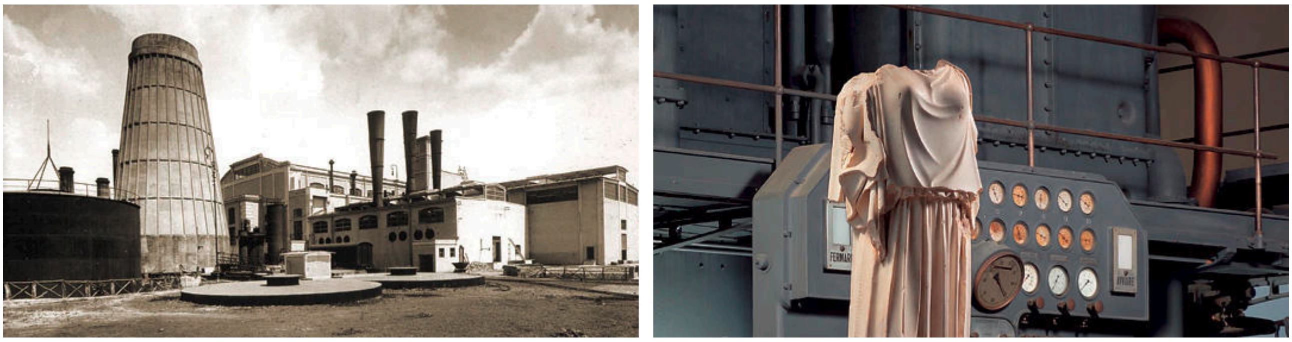

FIG. 14. Centrale Montemartini, Rome, Italy, during operation in 1924 (left); Centrale Montemartini, now a museum (right).

Outcome: Centrale Montemartini houses part of the Capitoline Museums' fine collection of ancient sculptures. Gleaming classical statues stand among rows of machinery; although the contrast is odd, it is also memorable and effective. The museum's habitual emptiness makes it all the more atmospheric.

The main gallery on the first floor is a lofty industrial space, dominated by two huge diesel motors constructed in 1933 by the firm Tosi, surrounded by lines of marble busts and statues as well as segments of temples and triumphal monuments (Fig. 14(right)).

The Sydney Powerhouse Museum, Sydney, Australia [71]

Original use: It was originally built to provide power to the electric tram system and continued to do so for over 50 years. Buses eventually replaced the electric tram system, and the power station was closed in 1963.

Redevelopment: The Sydney Powerhouse Museum opened in 1988. The Powerhouse Museum was built in and around the shell of the former Ultimo power station originally constructed in 1899–1902. The modifications for converting the facility into a museum included renovating the structure and adding a new building. The museum has over 25 exhibits that explore human achievement, science and technology, the decorative arts, and the everyday lives of Australians.

Outcome: The facility is now one of Australia's most distinguished museums.

A former NPP, Baltimore, Maryland, USA [45]

Original use: A power plant facility.

Redevelopment: In Baltimore, Maryland, this former power plant facility located on the east side of the City's Inner Harbour has had multiple uses since the original conversion. Historically, the power plant has been oriented to commercial uses, but the businesses located there have not always prospered. This is in spite of the overall popularity of the Inner Harbour and the proximity of the power plant to the outstanding National Aquarium. The power plant complex underwent additional renovations in 1995 to make the area more commercially viable. One of the high profile businesses brought into the power plant complex was the Hard Rock Café restaurant.

Outcome: An example of redevelopment of a power station facility for use other than a museum.

New Braunfels Power Plant, Texas, USA [72]

Original use: The power plant was originally built in 1921 and operated as an electrical generating facility until 1977.

Redevelopment: In New Braunfels, Texas, a power plant owned by the Lower Colorado River Authority is currently in the process of adaptive reuse. The facility is located adjacent to the Comal River and the popular Landa Park, both popular public recreational areas. The power plant equipment has now been dismantled and the environmental issues addressed, including primarily asbestos and metals based paint. The future use of the facility was determined by a request for proposal process in which any interested party was encouraged to submit a proposal for reuse of the facility.

Outcome: It is planned to be reused as a commercial complex with a hotel and restaurants open to the general public. The adapted reuse of the shell of this former power plant is expected to work well with the surrounding public recreational activities.

The Seaholm Power Plant, Austin, Texas, USA [27, 45, 73]

Original use: The Seaholm Power Plant main building was built in the 1950s using concrete and glass bricks in an Art Deco style. This main building has over 10 000 m^2 (110 000 ft^2) of floor space, with the turbine hall representing an estimated 2400 m^2 (27 000 ft^2) and a ceiling height of 20 m (65 ft).

Redevelopment: The Seaholm Power Plant is being decommissioned for future use, which is still undetermined.

The environmental considerations in decommissioning this facility are complex due to the presence of PCB, asbestos, metal based paint and mercury issues.

The driving force for its adaptive reuse has been a dedicated group of local citizens that see promise in converting the obsolete power plant into a new public use. This group envisages the architectural style, scale, location and ownership by the City of Austin Electric Utility as attributes for adapting this facility for a new public life.

Outcome: The ultimate future public reuse for the Seaholm Power Plant has not been determined, although there are various ideas. Leading examples include a museum, a science and technology centre, and a performing arts centre. Other suggestions include a hub or station in the planned public transportation system, or an aquarium. There is a possibility of combining a number of these suggested uses. The process for making the ultimate selection is ongoing. The adaptive reuse project at the Seaholm Power Plant presents an informative case study because the driving force for adaptive reuse has been the general public, the City Council has directed that the plant will be decommissioned. The future use has not been selected [73].

The citizens' group, Friends of Seaholm, campaigned to get the Austin City Council to direct the city-owned electric utility to decommission the plant. This decommissioning effort includes dismantling power-generating equipment and support systems, and addressing environmental concerns. Not knowing the future reuse of the facility, however, has created conflicts in the decommissioning process. For example, supporters of the idea for using the building as a science and technology centre have expressed a desire to keep significant portions of the plant equipment on-site for display purposes. These requests have included retaining items ranging from gauges and chart recorders to a turbine generator set and the steam boilers. Other interested parties want the equipment totally dismantled and removed, with only the clean shell of the building left remaining. Similarly, there was much debate on whether to demolish the boilers or develop an approach that would address the asbestos and metals based paint while maintaining the aesthetic profile of the facility. All of these discussions occurred concurrently with the electric utility committing to to decommission the power plant while expressing its desire to eliminate their future potential liabilities at the facility, such as leaving asbestos in place. This has created uncertainty during the execution of the decommissioning efforts.

Chester Waterside Station, Philadelphia Power Plant, Pennsylvania, USA [74, 75]

Original use: The Chester Waterside Station was originally a coal fired electric power plant located along the Delaware River.

Redevelopment: The massive power station, Chester Waterside Station, was transformed into a new world headquarters for a 21st century technology company. Conservation of old layout features was incorporated into the design that met the highest standards in architectural design, historic preservation and adaptive reuse. Prior to redevelopment, cleanup of chemicals, asbestos and lead was completed.

Outcome: Redeveloped into office space and the corporate headquarters of Synygy Inc.

Riga Contemporary Art Museum, Riga, Latvia [76, 77]

Original use: A conventional power plant.

Redevelopment: The power plant now houses the educational, media-related and production sections of the museum. The museum displays a variety of experiences, from video and research to public programmes and

FIG. 15. The Riga power plant now converted to a museum.

performances, organized around art without necessarily implying a direct confrontation with art objects. The exhibition space and the museum shop are located in an extended perimeter surrounding the power plant. The result is a single, continuous, neutral space with a flat roof and a glass façade, embedding the old in the new, making the power plant work for the museum in a utilitarian rather than symbolic way (Fig.15).

Outcome: Successfully redeveloped as a museum.

Old Power Plant Karlin, Prague, Czech Republic [78]

Original use: In the 19th century, the steam power plant was operated in the town of Karlin, not far from Prague; today it is a part of Prague.

Redevelopment: The power plant was converted into an administrative building.

Outcome: The refurbishment of an old industrial building with valuable architecture and property in Prague transformed into an administrative building.

6.2. REUSE OF LARGE INDUSTRIAL BUILDINGS AND SITES

The construction of new buildings and the development of new sites require a great deal of effort and resources. Redevelopment and reuse of large industrial buildings must therefore be specifically considered in view of the extent of inherent savings. The older industrial sites are brownfield sites with infrastructure such as roads, sewers and utilities. Redevelopment and reuse of large industrial buildings and sites specifically prevent additional exploitation of greenfield sites or previously undeveloped land (preservation of open space).

Redevelopment and reuse visions for large industrial buildings and sites include a new housing development, new industrial facilities, training facilities, educational and recreational facilities, and a hub for commercial business activities.

The following information is normally available for nuclear and non-nuclear industrial sites (brownfields) and should be studied and taken into consideration when developing redevelopment and reuse plans:

- — Current site conditions based on observations (information on prior activities at a facility);
- — Process knowledge and operational reports (types of activities performed during the life of the facility);

— Information on past maintenance practices and remediation actions (types of environmental issues associated with former processes);
— Building age and type of construction (indication of use of asbestos and metals based coatings, PCBs, etc.);
— Historical aerial photographs and as-built drawings (identifying outdoor storage areas, spills, and operations that are no longer visible);
— Previous environmental investigation and management reports;
— Regulatory agency inspections, reports and files (e.g. inspections, spill notifications and operations reports).

If redevelopment and reuse plans are developed at an early stage of decommissioning of an industry, valuable information can be gained by interviewing the senior facility staff to record historical processes, chemical storage, event, spills and any prior abatement activities and past maintenance practices. This information can give an indication of the condition of the buildings and the environmental contamination/pollution of the site.

6.2.1. Reuse of large industrial buildings and sites: The nuclear industry

Public concern and a lack of information on the nuclear industry and applications may influence redevelopment and reuse options of large industrial buildings and sites. Redevelopment and reuse of nuclear sites is often perceived negatively by the public, even in the case of NORM contamination. This emphasizes the importance of early stakeholder involvement and the establishment of cleanup standards and communication protocols. The relative risks associated with the nuclear industry must be communicated in order to convey positive perceptions and advantages of the industry as a whole and that of reuse of facilities and sites.

The actions of the nuclear industry with regard to redevelopment and reuse must focus on nuclear and non-nuclear hazards. The impact of historical chemical contamination may sometimes be worse than that of radiological contamination. Nuclear regulators as well as other regulators should be involved in the redevelopment plans of a site. Developers, on the other hand, could benefit by applying a proactive approach whereby all hazards are characterized, even if it is not prescribed by current regulations and standards.

Redevelopment and reuse options for nuclear industrial buildings and sites are influenced by the level of contamination. In some cases, the contamination levels are such that it will just not be feasible to decontaminate these facilities and sites to clearance levels. The redevelopment and reuse options would then be limited to waste depository, waste storage facilities or similar nuclear activities as previously practised in the facilities or sites.

Astra Research Reactor, Seibersdorf, Austria [79]

Original use: The ASTRA reactor was permanently shut down on 31 July 1999 after 39 years of successful operation. Cleaning and pre-documentation work started immediately thereafter, but no substantial work was performed. Actual decommissioning work began in January 2000. Work on the project was completed in October 2006 with the formal acceptance of the cleared building by the authorities. The project was officially terminated by the end of 2006.

Redevelopment: From 1999, the concept for decommissioning of the ASTRA Reactor was to reuse the reactor building as part of the intermediate waste storage facility on-site [30]. Nevertheless, under the authorization from 2006–2007, and considering the already advanced planning, it was later decided by the Austrian Government as owner to invest in further storage facilities within the enclosed controlled area, rather than indulge in expensive rebuilding of the reactor containment close to but outside the controlled area.

Outcome: After extensive discussions, the now empty reactor containment will be adapted to house inactive and cleared casks, and will be used for the interim storage of NORM waste until the legal requirements for a suitable storage facility are cleared. To fulfil this purpose, the ground floor will be renewed and new lighting installed. Still pending a decision of the owner, enlarging of the entrance door to a height of 4.2 m and installation of a basic ventilation system is also foreseen. The attached new building for clearance measurements will continue its inherited designation into the future.

No reasonable economical propositions were put forward for the reuse of the underground pump room. After unrestricted clearance was obtained, it was decided to demolish the structures including the decay and storage tank, and the basins of the cooling towers to at least a level of 0.7 m beyond ground level, to refill the cavities with suitable clean material and level the area to greenfield. The task was completed by the end of 2007.

Nuclear R&D site for a Science and Technology Park, Winfrith, UK [23]

Original use: In the early 1950s, the United Kingdom Atomic Energy Authority (UKAEA) developed a number of designs for civil NPPs. Winfrith South Dorset was identified as the preferred site for prototype installation. The basic layout of the site was to have a central administration facility with the individual reactors located around it. Over the years, a number of prototype reactors were constructed on the site.

From about 1990, work on the development of nuclear power was approaching its end and the last reactor operated by UKAEA was closed down in 1995 on the Winfrith site.

Redevelopment: Winfrith's vision is to create a pre-eminent science and technology centre. There are three main prerequisites to achieving this: decommission the facilities, delicense the land and attract tenants. Part of their reuse strategy is to attract tenants and address their nuclear related concerns. High quality radiological surveys are completed on radiological sites to avoid resurveying after occupation by a tenant. There are additional requirements associated with the nuclear site, such as security. Site safety systems are communicated to prospective tenants. Regulatory approval of tenants is based on the condition that their activities on-site should not have adverse effects on nuclear installations.

Outcome: Progressive decommissioning by the UKAEA allows for non-nuclear businesses to move in. It is important that any site decommissioning programme have a clear end point vision.

The main outcomes can be summarized as follows:

- There was deliberate planning for decommissioning as redevelopment.
- Key assets for redevelopment need to be protected as part of decommissioning planning.
- The site was decommissioned to partially greenfield, and some buildings and areas to partial brownfields.
- A specific reuse option should be planned for the short and long term.
- Remoteness of a site could be a disadvantage for redevelopment except for tourism related developments.
- By encouraging reuse, the operator is contributing to the economic and social development prospects of communities.
- Redevelopment may result in reuse of systems, including high value systems that would only have a low value after dismantling (scrap).
- Re-employment could be a driving force for redevelopment.
- Early intervention at the closure of facilities is necessary to keep key (marketable) employees for redevelopment.
- There was early recognition that the long term mission of site had changed.

IPEN-CNEN, Nuclear Fuel Cycle Facilities, São Paulo, Brazil [80, 81]

Original use: The Nuclear Energy Research Institute (Instituto de Pesquisas Energéticas e Nucleares, IPEN) is located on a campus of São Paulo University in an area of nearly 500 000 m^2, which is a very valuable, highly populated area.

The nuclear fuel cycle facilities contributed to technological development and personnel training, with transfer of the technology for institutions entrusted with the scale up of the units. At present, most facilities are shut down.

Redevelopment: In addition to the full release of some facilities as ‘green areas’ (priority programmes) for installation of new laboratories, some buildings will be used as interim storage facilities for equipment and wastes.

Outcome: The location is an important aspect determining the reuse of the space and buildings of the fuel cycle facilities. Decisions on the reuse of the different facilities have been made on a case by case basis. Decontamination and decommissioning to the extent of reintegrating buildings as new laboratories was necessary.

ENEA Saluggia Research Centre, Enriched Uranium Extraction (EUREX) reprocessing plant, Saluggia, Italy [82]

Original use: Reprocessing of nuclear spent fuel.

Redevelopment: After finishing the reprocessing campaigns in 1970–1983, the EUREX pilot reprocessing plant started a new phase, aiming at achieving a safe configuration for materials and irradiated fuel and radioactive waste conditioning.

In 1997, the CORA project was initiated for a vitrification plant for the high and intermediate liquid radioactive waste. The CORA plant will be hosted in some dismantled cells of the EUREX plant, reusing many of the EUREX plant auxiliary systems, duly refurbished.

Outcome: The reuse of contaminated cells and rooms from the former reprocessing plant for the housing of a new facility required extensive dismantling activities.

Nevertheless, in the end, the reusing will save money and construction time, and avoid constructing a new nuclear building on the site.

Santo Amaro Mill, São Paulo, Brazil [42]

Original use: Processing of monazite (contaminated with NORM).

Redevelopment: Removal of contaminated waste, decontamination and dismantling of equipment, decontamination of floors and walls, and demolition of buildings were undertaken. A radiological survey was performed after site cleanup to demonstrate compliance. The site was redeveloped into a residential area. Six high residential towers were constructed on the site.

Outcome: Five years after the facility had been released for reuse, the State established the regulations for contamination by conventional contaminants and the site had to be re-surveyed for non-radioactive contaminants. This experience highlights the importance and value of the involvement of non-radiological state agencies, both in the decommissioning and in the decision making processes.

Although international regulation would allow the application of higher dose levels for releasing the site for unrestricted use, the lack of national regulation for intervention and public anxiety led to the use of lower dose levels, resulting in higher costs. A legal base for clearance/release and intervention in the case of NORM contamination was necessary.

Decommissioning cost approximately $2 000 000 and the site was sold for $12 000 000 after decommissioning. This extremely profitable redevelopment and reuse case was due to the site being in central São Paulo.

Port Hope Conversion Facility (PHCF), Port Hope, Canada [83]

Original Use: Cameco is a Canadian company involved in activity related to the exploration, mining, milling, refining and conversion of uranium containing materials.

PHCF was initially established by Eldorado Gold Mines Limited in 1932 to process ore from Port Radium, Northwest Territories, into refined radium. The current building that houses the north UO_2 plant at the Port Hope facility was built in 1937.

The radium refining operation ran until 1939, when operations were suspended for a short period for economic reasons. In 1943, the company was renamed Eldorado Mining and Refining Limited, and in 1944, it became a crown corporation; the operation was then converted to a uranium processing plant. Operations were located in the area adjacent to the west side of the Port Hope harbour.

In 1953–1954, the radium circuit was removed and replaced by a solvent extraction circuit, which started producing high-purity uranium products in 1955. Yellowcake was refined into nuclear grade uranium trioxide (UO_3) for the US Atomic Energy Commission. The Canadian CANDU nuclear reactor programme was developing and the initial fuel design involved uranium metal. Thus, a uranium tetrafluoride (UF_4) plant was added to the site. The eventual CANDU design involved UO_2 rather than uranium metal; therefore, commercial production of natural UO_2 was initiated.

At present, the PHCF receives nuclear grade UO_3, for conversion to UF_6, or UO_2; these products are processed further off-site to provide fuels for light and heavy water reactor programmes, respectively. Cameco also produces depleted UO_2. In addition to these fuels, the PHCF is also licensed to manufacture depleted uranium metal components for use in a variety of industrial applications.

Redevelopment: Cameco Vision 2010 is a plan to clean up, modernize and improve the appearance of the Port Hope conversion facility. This is a large, long term investment in Port Hope that builds on work currently under way through the Port Hope Area Initiative to address historic low level waste (LLW) issues.

The project includes removal and long term storage of 150 000 m^3 of inherited waste materials, removal of two thirds of the site's 30 buildings, and construction of new buildings to improve the look and efficiency of the site.

In the fall of 2005, Cameco engaged Gartner Lee Limited to involve the community in shaping the project. Between November 2005 and January 2006, Gartner Lee conducted a series of targeted communications and community engagement initiatives, and then produced an independent advisory report with analysis of stakeholder ideas, opinions and advice.

Vision 2010 has now entered the schematic design phase where an architectural concept will be developed that addresses Cameco's requirements for the site as well as community concerns and wishes identified through the consultation programme. This will result in development of a preferred concept including a site plan, floor plans and building elevations.

Outcome: The redevelopment process is ongoing.

United Nuclear Corporation (UNC) Naval Products Facility, Montville, Connecticut, USA [64]

Original use: This 1 000 000 m^2 (240 acre) site was used for the manufacture of nuclear propulsion units for the DOE and the US Navy. The entire facility consisted of about 39 000 m^2 (430 000 ft^2).

Redevelopment: The facilities were decontaminated and decommissioned between 1991 and 1993. The land was then purchased by the Mohegan Tribe and now houses the Mohegan Sun Casino.

Outcome: The tribe has been able to use all but four of the original buildings for new activities**.**

CEA, Fontenay-aux-Roses Centre, Building 19 (NLF 58), France [84]

Original use: Laboratory of plutonium metallurgy studies used until the beginning of the 1980s (laboratory established in the ancient military building of the Chatillon Fort). The nuclear activities were restricted to a group of glove boxes.

Redevelopment: The glove boxes were sent for reuse in a new facility constructed in Cadarache or for volume reduction and disposed. The ventilated hoods and ducting were disassembled.

Outcome: After a check for the absence of contamination, the rooms were redeveloped in offices.

CEA, Fontenay-aux-Roses Centre, Building 52.1 (NLF 59), France [84]

Original use: A laboratory from plutonium fuels studies (1968 to the early 1980s), then laboratory of waste management studies (from the end of the 1980s to the middle of the 1990s).

Redevelopment: The glove boxes were either removed or recycled for reuse in a new facility constructed in Cadarache or sent for volume reduction and disposal. The ventilated hoods and ducting were disassembled. After checking for the absence of contamination, the rooms were redeveloped in offices.

Outcome: The ground floor laboratories were rehabilitated and transformed into a conference room.

CEA, Fontenay-aux-Roses Centre, Building 91/54 (NLF 5), France [84]

Original use: The halls and laboratories at CEA, Fontenay-aux-Roses Centre were used for chemical engineering studies on the irradiated fuel reprocessing, liquid extraction with the uranium solutions.

Redevelopment: Dismantling of the chemical engineering equipment included the analytical laboratories and the disassembly of the workshops and stores. The nuclear waste was displaced in a conventional waste zone. In the ground floor of the hall area, metal structures were constructed for storage of 200 L drums containing LLW. The old tank room located under the ground floor was reserved for the storage of 100 L drums containing alpha–Pu waste (ILW). The parts store and workshop was transformed into an area for the installation of measuring equipment (new gamma spectrometry equipment associated with a neutron measurement) and for the loading of the transport containers**.**

Outcome: This operation allowed a notable reduction of the redevelopment duration compared to a demolition of the buildings and a rebuilding. It allowed a reuse of the service runs left in place (ventilation, handling, etc.).

Barsebäck NPP, Sweden [85]

Original use: Barsebäck NPP consisted of two units, which were closed down in 1999 and 2005.

Redevelopment: Active decommissioning is planned to begin around 2020. In the meantime, new business is offered for other activities, including the Barsebäck Test & Maintenance Centre, offices, stores, workshops and sale of equipment. The site is open to training courses and research, and national and international organizations.

Outcome: During the ongoing period of care and maintenance, it will be possible to optimize technical and human resources.

6.2.2. Reuse of large industrial buildings and sites: The non-nuclear industry

There are many valuable large industrial sites in a dilapidated state. Changing these into new, economically viable industrial sites again poses significant architectural and marketing challenges. Redevelopment and reuse of these sites is needed to ensure that the built industrial heritage not only survives, but also prevents the development of new greenfield sites. The location of these abandoned industrial sites does not always imply that redevelopment and reuse options should be limited to industrial developments. There are numerous reuse options that include development of residential and business areas (office blocks). The industrial heritage of older industrial buildings gives a distinctive architectural expression that can be replicated in the newly built property.

There are ample examples throughout the world where cities have successfully turned old industrial waterfront buildings into thriving centres of arts, culture and commerce. These complexes have generated a new and exciting sense of place and history. The redevelopment plans should take into account existing infrastructure, stakeholder needs and demands, the location, and the integrity of the older buildings. One interesting category is the gasometers (gas holders) and associated gas production factories. There are a number of these worldwide; a comprehensive list of redevelopment projects are given in Ref. [86]. More detailed information is given below.

For further examples of completed redevelopment and reuse projects see Appendix I. Additional examples of successful redeveloped industrial facilities are given in Refs [87, 88]. Reference [89] is cited to show the impressive number and variety of redevelopment jobs that a company can perform in the USA, as described in the following.

Navy Pier, Chicago, IL, USA [90]

Original use: The Navy Pier was originally designed as a naval pilot training facility and used by the University of Illinois.

Redevelopment: The Navy Pier has evolved into a family entertainment centre. It also provides state of the art meeting space perfectly suited for small to medium sized trade shows. All of these elements combine to make Navy Pier Chicago's number one tourist destination, drawing more than eight million visitors annually. In 1989, the Metropolitan Pier and Exposition Authority were created by the state legislature to manage and operate both McCormick Place and Navy Pier. The Authority moved swiftly to redesign Navy Pier into one of the country's most unique exposition and recreation facilities.

Outcome: Navy Pier has evolved into a family entertainment centre.

Mill City Museum, Minneapolis, Minnesota, USA [91]

Original Use: Beginning in 1880 and for 50 years thereafter, Minneapolis was known as the ‘Flour Milling Capital of the World’. At the industry’s peak, the Washburn ‘A’ Mill was the most technologically advanced and the largest in the world. At peak production, it ground enough flour to make 12 million loaves of bread a day.

The city grew up around the mills, which received grain via rail lines stretching across the Northern Plains grain belt into the Dakotas and Canada. Trains also carried the milled flour to Duluth and to eastern US destinations for both export and domestic distribution. In 1870, the city’s population was 13 000; 20 years later, it had grown to nearly 165 000. After World War I, the milling industry in Minneapolis began to decline. As the industry moved out of Minneapolis, the old mills fell into disuse. The Washburn A Mill closed in 1965 and in 1991, it was nearly destroyed by fire.

Redevelopment: The City hired the Minneapolis Community Development Agency, to clean up the rubble and fortify the charred walls of the mill in the late 1990s. Shortly thereafter, the Minnesota Historical Society announced plans to develop the Mill City Museum (source: http://www.millcitymuseum.org/art-and-architecture).

Outcome: Redevelopment plans implemented to convert Minneapolis Mill into a Mill City museum.

Edenton Cotton Mill, Edenton, North Carolina, USA [92]

Original Use: The Edenton Cotton Mill was set up in August of 1898, and quickly became a mainstay in the local economy. The building is a handsome example of the large industrial complexes that were popular in North Carolina. The one million bricks used in its construction were made on-site with machinery leased from Edenton Brick Works. Between 1899 and 1923, more than 70 homes were constructed next to the mill for its workers and supervisors, creating what is now referred to as the Mill Village. In late 1995, shortly after closing the mill, Unifi Incorporated donated the 180 000 m^2 (44 acre) complex to Preservation North Carolina, and the task of restoring the property began (source: http://www.pacsir.com/cottonmill_condos.html).

Redevelopment: Today, the Edenton Cotton Mill and Village are listed on the National Register of Historic Places. Fifty-seven of the original 70 homes remain, 54 of which have been purchased by individuals or families who have restored them.

Outcome: The Edenton Cotton Mill has been redeveloped into a residential area with commercial development.

Konak Pier, Izmir, Turkey [93]

Original use: Built in several phases between 1875 and 1890, the original structure had housed the French Customs Building and a variety of other maritime facilities. The Export Warehouse designed by Gustav Eiffel and built in 1890, is historically Konak Pier's most important building. The structure was fabricated in Eiffel's workshop in Belgium, transported by ship, and constructed under the supervision of French engineers.

Redevelopment: During the 1980s, the Turkish Government initiated many economic reform efforts designed to transfer portions of state assets to the private sector for development. Private facility development was initiated under the label build-operate-transfer (BOT) in 1984. In 1996, the Konak Pier was privatized using the BOT strategy. Under this arrangement, private developers are allowed to recover their costs by operating a facility for a fixed time, in this case, a 25 year privatization period, before handing it back to the state. The developer, Izmer A.S., with assistance from ELS Architecture and Urban Design of Berkeley, CA, USA, as well as Enterprise Development Company (EDC), a subsidiary of the Enterprise Foundation, created by developer Jim Rouse, developed a plan for the site incorporating existing buildings. Turkish American Developers Salim Koyuncuoglu and his brother Suphi, using a public/private partnership technique developed during the Ottoman Empire, have rehabilitated and adapted a group of historic waterfront warehouses in Izmir into a 200 000 ft^2 (20 000 m^2) waterfront centre, Konak Pier, which is used for retail, dining and entertainment (source: http://www.oaklandnet.com/documents/9thAveTermVerFnl2.pdf).

Outcome: The restoration of the buildings has left structural elements exposed and unaltered, as well as revived the original skylights, which bring daylight into art exhibits along retail arcade walkways. A promenade along the pier's perimeter links cafes, clubs, restaurants and cinemas.

Torpedo Factory Art Center, Alexandria, Virginia, USA [94, 95]

Original use*:* The facility is located on the docks of the Potomac River in a renovated former torpedo factory built in 1918. At the time it was named the US Naval Torpedo Station. When fully operational, it was responsible for the manufacture and maintenance of torpedoes for the next five years. Work stopped and the facility served as a munitions storage area until World War II. Production on the Mark XIV, a submarine borne torpedo, and the Mark III aircraft torpedo then resumed at an intense rate. After World War II, the US Government decided to use the buildings for storage space: the Smithsonian stored art objects and valuable dinosaur bones, Congress stored documents, and the Military kept German war films and records in sealed vaults.

In 1969, the City of Alexandria bought the complex of buildings from the Federal Government. However, it was several years before an acceptable plan for their use was adopted.

Redevelopment: The Torpedo Factory Art Center is one of the largest and most successful visual arts centres in the USA. This creative alliance was begun in 1974 by a group of local artists and the City of Alexandria, Virginia. From 1982 to 1983, the building underwent a major renovation as part of the City's waterfront development plan. This building still serves as a non-affiliated retail and office space.

The Torpedo Factory building was gutted entirely, including all pipes, electrical units, windows and flooring. A second floor was constructed. Then a ventilation system and central air and heating, the artful spiral staircase and main staircase (Fig. 16) were also added The artist studios were built to address the specific water, lighting and electrical needs of each resident artist. A grand reopening celebration was held on 20 May 1983.

Outcome: Today, the Torpedo Factory Art Center is home to over 160 professional artists who work, exhibit and sell their art. Together with over 1000 cooperative gallery members and some 2000 art students, it draws artists from across the region and attracts visitors from around the world. The Torpedo Factory Art Center comprises the following:

— 84 artist studios;
— Six galleries: the Target Gallery (our flagship gallery), the Art League Gallery, the Enamelists Gallery, Multiple Exposures Gallery (photography), Potomac Fiber Arts Gallery and the Scope Gallery (ceramics);
— Two workshops: Fiberworks and Printmakers, Inc.;
— The Art League School;
— The Alexandria Archaeology Museum;
— Friends of the Torpedo Factory Art Center.

The Torpedo Factory Art Center is a working example of how the arts can revitalize a community and serves as a prototype for visual arts facilities throughout the world.

Fort Mason Center, San Francisco, California, USA [96]

Original use: The Fort Mason Centre used to be a military base for more than 200 years.

FIG. 16. The inside of the Torpedo Factory, main atrium.

Redevelopment: Fort Mason Center, located in the historic piers and buildings of Lower Fort Mason, offers a variety of activities of the highest quality suitable for all ages and interests. This former military base offers the opportunity to experience diversity in a unique environment, focusing on the visual and performing arts, humanities, education, ecology and recreation.

Outcome: The Fort Mason Center is an example of a successful redevelopment plan. The Fort Mason Center is a National Historic Landmark and part of the Golden Gate National Recreation Area, the Center houses about 30 non-profit organizations and is the setting for more than 15 000 meetings, conferences, performances and special events, attended by 1.5 million visitors each year.

Ford Assembly Plant, Richmond, California, USA [97]

Original use: The Ford Motor Company Assembly Plant was one of Richmond's important production sites in support of America's war effort during World War II. The assembly plant building stands today mainly untouched from when it opened in 1931. During its history, Ford converted the plant to war-time production in 1942, and then it was reconverted to a production plant of civilian autos and trucks in 1945. Ford closed the plant in 1955. The building therefore holds considerable potential for interpreting the stories of American workers on the home front during World War II. For this reason, the building will be one of the focal points in the National Park Service's new Rosie the Riveter/World War II Home Front National History Park being developed in Richmond.

Redevelopment: The rehabilitation/adaptive reuse plan for the Ford Assembly Building (FAB) & Visitor Education Center and the Oil House are in final negotiations. During World War II, this building was converted from an automobile to a tank production plant that processed 60 000 tanks plus other combat vehicles including Army trucks, half-tracks tank destroyers, personnel carriers, scout cars, amphibious tanks, lift trucks, snow ploughs and bomb lift trucks. FAB is listed on the National Register of Historic Places. Richmond has contracted with Orton Development, Inc. for rehabilitation of the building primarily for work/live adaptive reuse. The City has transferred title of the building to Orton. Based on compliance with the State Historic Preservation Officer, Orton will retain and stabilize the historic façades, roofline, craneway, the boiler room and other distinguishing historic features. Orton is willing to improve and provide space for 7000–9000 ft^2 (700–900 m^2). World War II Home Front Visitor Education Center in the craneway facing San Francisco Bay. FAB is 56 000 m^2 (561 000 ft^2) and 400 m long (a quarter-mile). The Visitor Education Centre and exhibits would provide all-weather, multimedia orientation and education programmes on the World War II Home Front themes in Richmond, the Bay Area and nationwide. The craneway, if properly designed for adaptive reuse, affords a prime indoor public space for events, celebrations, and residents and visitors on a scale previously unknown to the City.

Outcome: Rehabilitation under way.

The Oakland Terminal Building, California, USA [98]

Original use: The Oakland terminal was originally used as a terminal building.

Redevelopment: The Oakland Terminal Building is no longer in use. Qualified developers have been invited to submit proposals that would lead an interdisciplinary team to determine and implement reuse opportunities for the Ninth Avenue Terminal that will maximize its economic potential and historic importance, and complement other private and public development activities in the Oak to Ninth District in Oakland.

The proposal should suggest ways to allow for the Terminal Building to feasibly realize its full potential. The proposed plan for the Terminal Building (the 'Reuse Plan') should integrate into the urban waterfront setting of Oakland, recognizing the historical character of the building and setting. It should also fully integrate the building, site plan and access with the adopted project, and adaptively reuse the structure.

Outcome: The final redevelopment decisions for the Oakland Terminal are yet to be made.

The Toronto Gas Purifying House, Toronto, Canada [99] [100]

Original use: The Toronto gas purifying house was originally used to feed the lights of Edwardian Toronto, which is located south of Front Street between Princess and Berkeley.

Redevelopment: Two of its buildings now house CanStage's Berkeley Street Theatre and the rehearsal halls of the Canadian Opera company.

Outcome: Redevelopment to productive uses complete.

The Skyline railway building at Spittelau,Vienna, Austria [101] (Fig. 17)

Original use: Used as a railway bridge.

Redevelopment: The Skyline railway bridge at Spittelau was taken out of service and redeveloped into office buildings and shops. The railway line was built on an old bridge. This bridge now supports a 120 m long building with 12 000 m^2 office space, 2600 m^2 for shops and restaurants, and a garage for 220 cars.

Outcome: Redevelopment project complete.

The Gasometers in Vienna, Austria [102, 103] (Fig. 18)

Original use: Originally used as a gas reservoir.

Redevelopment: The Gasometers consisted of four gas tanks of each 90 000 m^3 and were part of the Vienna municipal gas works. During the redevelopment actions the historic brick exterior front walls were preserved. The preserved structures have found various new uses, such as:

- They are used in movies.
- They are used to host Gasometer-Raves. The sound in the large round structures reverberate and exhibite a special echo popular to ravers, and the term ‘Gasometer’ is well known in the scene.
- Each gasometer was divided into several zones for living (apartments in the top), working (offices in the middle floors), and entertainment and shopping (shopping malls in the ground floors). The shopping mall levels in each gasometer are connected to the others by skybridges.

Outcome: The various Vienna stakeholders recognized the importance of a well defined redevelopment option, undertook remodelling and revitalization of the protected monuments, and called for ideas for the new use of the structures. The Gasometers have now developed a village character of its own. A true sense of community has developed, and both a large physical housing community (of tenants) as well as an active virtual internet community (Gasometer Community) have formed (for further information, see Ref. [102]).

FIG. 17. The Skyline railway bridge, Vienna, Austria.

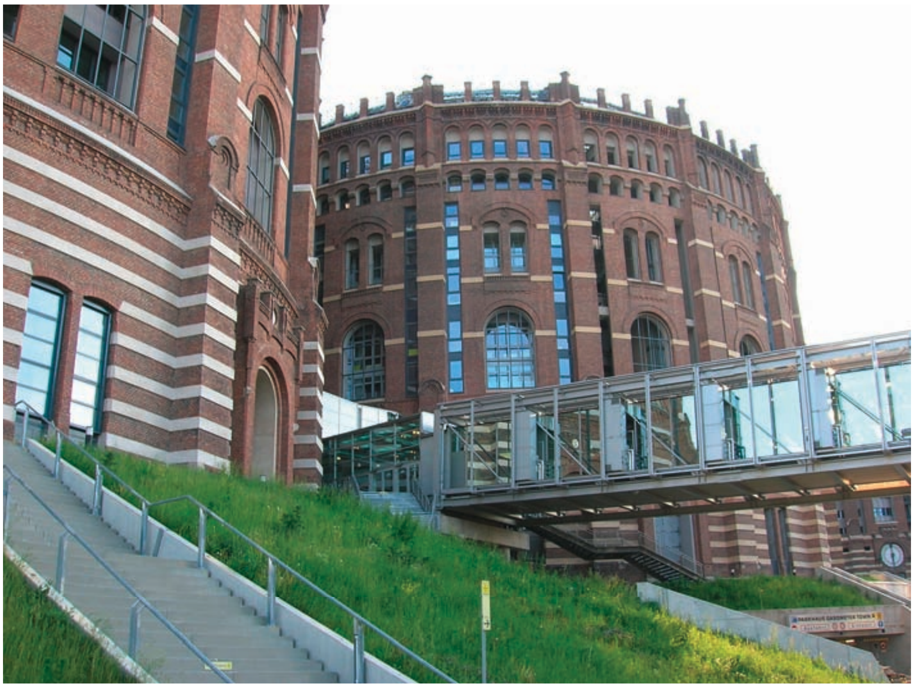

FIG. 18. Vienna Gas Holder, Vienna, Austria. The façade was left intact and the interiors were redeveloped into offices, shops and apartments.

The Gazi Factory, Athens, Greece [1, 104]

Original use: The Gazi Factory was founded in 1857 as a gas factory. It started functioning in 1862 and closed down its furnaces in August 1984.

Redevelopment: The factory was transformed into one of the top cultural centres of Athens after it closed down. Its many buildings, rooms and outdoor areas host a variety of events, such as concerts, exhibitions (art, comedy, multimedia, trash art, etc.) and special screenings.

Within its architectural space, one can see a real community, autonomous and self-reliant. The carpenter's shop, the smelting works, the machine works, the garage for the car repair works, the restaurant, the barber shop and the community clinic were just some of facilities offered by a well organized closed economy. The buildings have stonework of austere neoclassical morphology, with openings arranged by plinth work. The surface of the facets with cornices is varnished. The roof is wooden with skylights and is covered with Byzantine or French tiles and iron plates. The complex has been completely restored by the City of Athens.

Outcome: Today, the area of Gazi serves as an industrial park and a cultural centre.

The King Liberty Project, Toronto, Canada [105]

Original use: The site used to be an industrial manufacturing site with various different activities.

Redevelopment: The King Liberty Project in Canada entailed the redevelopment of 180,000 m² (45 acres) of former industrial manufacturing plants and rail yards situated along the central waterfront area of Toronto. The railway facilities were shut down in 1991 and the remaining industrial plants were closed soon after. The land was sold and redeveloped into a residential and retail village. A consultancy firm was appointed to oversee the urban design, landscape architecture and civil engineering services for the planning, design and implementation of parks, roads and infrastructure. The retail village and the first housing units were occupied in 2004. Some buildings were preserved and reused. The importance of the forested parks and walkway system were recognized as the key elements in the marketing of the property.

Outcome: The land was sold and redeveloped into a residential site and a retail village.

Lister's Mill, Bradford, West Yorkshire, UK [106]

Original use: Lister's Mill, also known as Manningham Mills, was the largest silk factory in the world.

Redevelopment: The redevelopment project of the process was a £100 million ($140 million) project and included the building of over a hundred residential apartments that were sold to the public. The developers' vision was to renovate the larger buildings and build striking new structures. Apartments, workplaces, shops and public spaces once more brought Lister's Mill back to life.

Outcome: This factory is now redeveloped into a residential and semi-commercial area.

The aluminium smelter Kinlochleven, UK [107]

Original use: The Kinlochleven factory was an aluminium smelter.

Redevelopment: The village of Kinlochleven was established in the early part of the 20th century. The North British Aluminium Company built the Blackwater reservoir, hydro-electric power plant and aluminium smelter. Due to the construction of the smelter, the Kinlochmore and Kinlochbeag was developed into a thriving industrial village known as Kinlochleven that housed the worlds largest aluminium smelters at that time, powered by hydro-electricity. A village was developed around the smelter with houses, recreational facilities, schools and churches, etc. The smelter employment peaked at well over 700 employees.

The aluminium industry and its smelting processes improved, and the viability of the Kinlochleven smelter was questioned as well as the sustainability of the community built around it. An announcement was made that the smelter would be closed at the end of the century. A working group was established out of a local partnership formed between economic development agencies, and the business community was established to investigate potential opportunities and recommend regeneration proposals for the village. The working group generated a ten point strategy that included short and long term development actions (e.g. various decontamination actions, environmental improvements, restoration and development of specific buildings to display the smelter history and provide new business space, etc.). In 1995, the total estimated cost, of this village Economic Enhancement Strategy was £7 825 000 ($11.7 million). Various issues needed to be considered, i.e. the Blackwater reservoir catchment land had to be managed to ensure economic development, but no community structures were in place with the ability or willingness to take over ownership and responsibility for the land. Due to all these issues, the Kinlochleven Land Development Trust (KLDT) was established to implement the strategy. KLDT has been successful both in securing funding for projects and in meeting the target outputs and timescales of funding partners. They had to deal with a number of complex problems involving contaminated land, listed buildings, leasing arrangements, drawing funding from a number of sources, and arranging cash-flow support from the commercial lenders (source: http://www.caledonia.org.uk/socialland/kinlochl.htm).

Outcome: KLDT's experience illustrates the importance of appropriate professional advice is used and available resources for offering guidance to a non-executive Board of Directors. The strong partnership approach adopted by all interested agencies and community groups, spearheaded by KLDT, was one of the main success factors of the Kinlochleven project, which implies that the communities played a part and shared responsibilities.

The redevelopment plans included typically:

- — The restoration of the laboratory building as a bunkhouse and camping site;
- — The redevelopment of the carbon bunkers in a 'Hill-Walking and Mountaineering Interpretative Centre';
- — The preservation of the 'The Aluminium Story';
- — The adaptive reuse of the old aluminium works into a brewery run by Atlas Brewery;
- — The development of an entertainment area, the Ice Factor, which includes the world's biggest indoor ice climbing facility, the UK's largest articulated rock climbing wall and a wide range of other facilities [108, 109].

Shropshire Ironbridge, UK [110]

Original use: Shropshire was Britain's first ironmaking centre. Various other industries developed in Ironbridge, ranging from decorative ceramic tile making to hand-painted porcelain and clay pipes.

Redevelopment: Ironbridge was declared a World Heritage site in 1986. The Ironbridge Gorge Museum Trust was established in 1967 to protect the heritage and remains of the Industrial Revolution for future generations.

Outcome: The Ironbridge area was redeveloped into a museum.

London Docks, London, UK [111]

Original use: Used as docks.

Redevelopment: The London docks, consisting of an old world of ships, wharfs, cranes and warehouses, have been replaced by shops, leisure facilities, offices, wine bars and expensive apartments. Wildfowl have now replaced steamships on the water. Most of the import docks were filled in when the docks closed, but a small part of the docks was retained as an attractive water feature.

Outcome: Redevelopment project complete.

From factories and warehouses to homes, UK [112], Germany [113], Italy [114] and Latvia [115]

Original use: Older buildings, created for the heavy industries of the past.

Redevelopment: Factories and warehouses, which were never intended for use as homes, became derelict as the manufacturing industries fell into decline and withered away. Now many of them have been converted into flats. Cases published in Ref. [112] include a match factory, an armoury and a metal refinery. In Germany, a granary was converted into an apartment hotel. Reference [113] describes single changes to the original structure and their motivations. In Italy, projects involving conversion of former industrial buildings and warehouses into loft apartments, offices and studios are reported in Ref. [114]. In Riga, Latvia, a plaster factory from the 19th century is now a fashionable residential address [115]. A number of examples of industrial mills being converted to apartments, their histories, technical issues and today's trends are described in Ref. [116]. Guidelines, pros and cons, and a number of actual examples of the conversion of rural buildings in the UK are given in Refs [117, 118].

Outcome: Factories and warehouses throughout the world have been redeveloped into homes. These buildings are often stylishly and solidly built landmarks, thus highly appealing to many buyers. In addition, because they were designed as practical working buildings, they are often on or near key transport links such as railways, canals or road junctions. The converted flats are usually spacious and open plan, with double-height ceilings and big windows.

Ditherington Flax Mill, Ditherington, UK [119]

Original use: A flax mill.

Redevelopment: The Ditherington Flax Mill was the first iron-framed building, and the techniques used in its construction make it the original skyscraper, which is important for heritage conservation and learning experiences. The construction dates from 1797. The construction technique was believed to be successful, but time has now revealed shortcomings: the iron beam supported at the centre bent and eventually cracked without warning. The Ditherington Flax Mill was abandoned in 1987 and slowly decayed through neglect, lack of investment and vandalism.

In March 2005, English Heritage officially bought the building at around £2 million, but the mill is still in a critical condition and architectural work is being performed to assess the state of the structure.

Outcome: The long term future for the flax mill looks a little better, but the final vision is still unclear. The building will likely have a variety of uses, including public access, residential and commercial.

Canvey Wick, UK [120]

Original use: Canvey Wick's was once the site of a huge oil refinery, built in the late 1960s.

Redevelopment: The preservation of Canvey Wick's past is important to the industrial heritage. In 1973, the global oil crisis brought an end to carefree motoring, and the resulting recession meant that the Canvey Wick oil refinery never opened.

Abandoned for decades, it became a brownfield site. The plan was to turn the place into a business park. However, before the bulldozers arrived, nature overwhelmed the site. Canvey Wick is now set to become a nature reserve for all the plants and animals that find refuge there. Canvey Wick, on the edge of the Thames Estuary, has been called ‘England's little rainforest’, and with good reason: due to its size, it supports a greater variety of species of plant and animal than any other place in Britain.

In addition to attracting many animals (some rare species), a natural reserve located close to large population centres attracts thousands of visitors and can be turned into a profitable industry.

Brownfield sites are ideal for this redevelopment, because they are often near cities and are generally unused.

Before reusing the site, the reserve had to be built, which is not always an easy task. At London’s Rainham Marshes, the first job was to clear away dumped cars, washing machines and fridges, and remove some particularly lethal chemicals. Then, the bulldozers were brought in to dig lagoons for wildfowl and wading birds, areas were landscaped and planted with reedbeds, and finally, a state of the art, architect designed visitor centre was built.

Outcome: Canvey Wick is one of many former industrial site in Britain to be transformed into a wildlife paradise. (See more cases in Ref.[120]).

Ruhr Valley, north-western Germany [121]

Original Use: Emscher Park in the Ruhr valley of north-western Germany is an excellent example of a brownfield redevelopment and reuse project. It was the centre of Europe’s steel and coal industries, which closed down over the past decades, leaving environmental damage contamination and unattractive brownfield sites. The decrease in steel and coal industrial development caused high unemployment and had a widespread negative impact on the economy and the environment.

Redevelopment: The State Government of North Rhine-Westphalia created a regional redevelopment approach — the International Building Exhibition (IBA), a State supported entity, at Emscher Park.

IBA’s projects illustrate the latest thinking in the ecological and economic regeneration of a former industrial region. Many of these innovative urban and architectural designs were fostered by IBA’s workshops, competitions and spatial planning guidelines. IBA was given a ten year mission to achieve the ecological, economic and urban revitalization of the Ruhr valley and the Emscher River through the creation of collaborative partnerships with local authorities, private industry, professional associations, environmental groups and citizens. Seventeen local authorities of the Ruhr area joined the building exhibition at its creation. Emscher Park’s development planning is guided by ecological principles that protect, increase and shape undeveloped areas. These objectives are realized by reusing old buildings rather than constructing new ones.

Their planning strategy contains the following fundamental elements:

— Re-using land to prevent additional exploitation of greenfields, or previously undeveloped land;
— Employing maintenance, modernization and reuse strategies for existing buildings to extend their life;
— Incorporating ecologically sound construction practices for both new buildings and adaptive reuse;
— Transforming the region’s production structure towards environmentally friendly production methods.

The approach was to devise an ingenious reuse strategy that preserves these enormous relics as museum pieces of its industrial past and promotes them as centres of cultural activities. The term ‘industrial monument’ captures the essence of the Emscher Landscape Park, where concerts are staged against the backdrop of a former steel plant’s framework, and people hike among the hills of reclaimed coal pilings.

Another guiding principle of IBA is ‘Baukultur’, literally translated as ‘the culture of architecture’. IBA has embraced the idea that building and site design are critical components of an environmental, social and economic regeneration strategy. IBA describes this process as ‘architecture organizing urban planning’. Rather than accept the haphazard, uncontrolled development that is typically considered urban sprawl, architecture offers the opportunity to direct urban planning. “Through architectural quality determined on a case by case basis and moderated by a qualified authority, one allows urban planning from the bottom up” (source: http://www.epa.gov/brownfields/partners/emscher.html).

To dismantle these immense iron and steel frameworks, the economic and environmental costs would be great due to the leftover rubble, steel and contaminated site.

Outcome: IBA developed and implemented approximately 100 projects on five sites in the area between the cities of Duisburg and Kamen.

Penn Field Army biplane and radio training base, Pennsylvania, USA [122]

Original use: The former Penn Field Army biplane and radio training base were used for a variety of purposes, e.g. the manufacturing of automobile parts manufacturing, furniture making and fireplace construction.

Redevelopment: Throughout the redevelopment phases, the developers chose not to tear down the old brick buildings, but instead built within them.

Outcome: Penn Field Army biplane and radio training base and is now redeveloped into a modern office space.

New Haven factory buildings, Connecticut, USA [123]

Original use: The New Haven factory consisted of different buildings that were part of a huge industrial block.

Redevelopment: Various redevelopment proposals have been suggested for the New Haven factory. It had been proposed to redevelop the two old factory buildings that were part of a huge industrial block owned by the Olin Corp into a rock climbing gym. An entrepreneur has been looking for an industrial space with high ceilings to build an indoor climbing gym with synthetic rock walls. The ceilings are 30 ft (9 m) high, which is space enough for a challenging upward pitch. The gym would occupy a fraction of the space in the back of the five storey building. The rest of the building has been partially renovated and is being leased out as office space.

Outcome: There is no outcome yet for the redevelopment of the new haven factory buildings.

Warehouse Row, Chattanooga, Tennessee, USA [124]

Original use: The Chattanooga Warehouse Row, originally known as the Old Stone Fort, included a large mound of stone used as a fortification during the Civil War.

Redevelopment: At the turn of the 20th century, the area was developed to a warehouse district. Developers soon transformed the eight aging buildings into an outlet shopping centre.

Outcome: Currently, the site is being further transformed to a destination shopping and dining venue. A detail of the centre is shown in Fig. 19.

FIG. 19. The redeveloped Warehouse Row, Chattanooga, TN, USA.

Fondazione Arnaldo Pomodoro, Milan, Italy [125]

Original use: The Fondazione Arnaldo Pomodoro in Milan was a former manufacturing industry for hydraulic turbines (Riva Calzoni).

Redevelopment: The building was converted to exhibition spaces for a Museum of Contemporary Art (Fondazione Arnaldo Pomodoro) (Fig. 20).

Outcome: The museum required vast spaces that could be provided by the former factory.

Factory building, Krakow, Poland [126]

Original uses: The Krakow factory building in Poland was used during World War II by Oskar Schindler as a hiding place for more than a thousand Jews during the Nazi Holocaust.

Redevelopment: This factory building is being turned into a museum commemorating the life of the German businessman. The Emalia Factory in Krakow is already partly open, and visitors can see Schindler's office. The museum will later have multimedia rooms narrating the story of Schindler's complex life as well as the stories of the Jews he managed to save, including survivor testimonies. The site will also house a library, cinema, restaurant and other facilities.

Outcome: This is a recent example where building reuse goes hand in hand with preservation of historical memories and the national sense of identity.

Zeppelin hangars converted into a central market, Riga, Latvia [127, 128]

Original use: Hangars

Redevelopment: In 1922, Zeppelin hangars located in Western Latvia were bought by the City Council after striking a deal with the Government. Five of these hangars came into full use in 1930 as the central market, such as for meat or fish. (Fig. 21).

Outcome: A good example of reuse of large civil structures.

McClellan Air Force Base, California, USA

Original use: US Air Force Base.

Redevelopment: The McClellan Air Force Base is one of the State funded military bases agreed on by the government to be cleaned up by private developers. It consists of 250 000 m^2 (62 acres) of industrialized area, which could be redeveloped for reuse. The US Government agreed on a land transfer of the McClellan Air Force Base to the local county, which will have authority over the reuse of the land. The county in return will lease the land to a private developing company. Currently, the private development company only leases uncontaminated portions of the complex to house various industries.

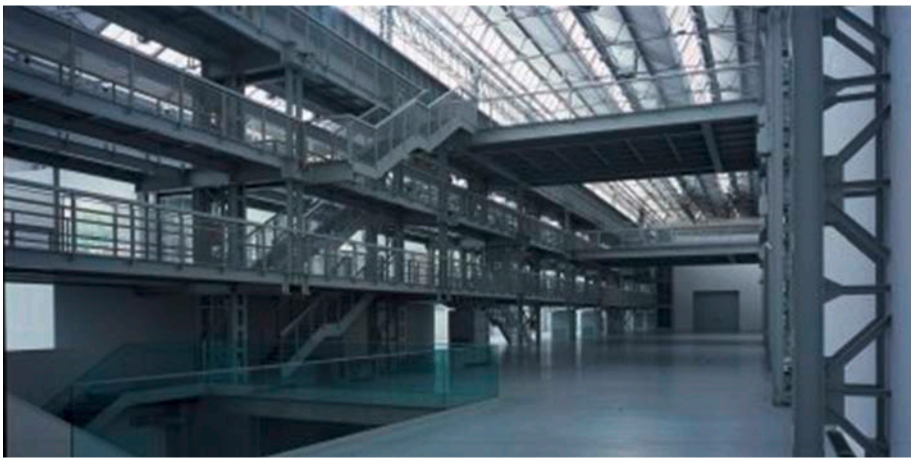

FIG. 20. Foundation Arnaldo Pomodoro, Milan, Italy: View of museum premises.

FIG. 21. Outside view of the former Zeppelin hangars, now Central Market pavilions, Riga, Latvia.

Currently, the land at McClellan Air Force Base greatly suffers from soil and groundwater pollution. Various cleanup actions have been performed and the up to date McClellan Air Force Base has attracted 170 business tenants with more than 13 000 employees.

Outcome: The proposed redevelopment action includes the construction of new office buildings and warehouses together with cleanup actions.

Coal mine and coking plant, Karolina, Ostrava, Czech Republic [129]

Original use: Karolina, established in 1837, was the oldest coal mine in Ostrava. In 1858, the coking plant was built and supplied with coal from the Karolina mine. In 1905, the power plan was constructed. The coking plant was shutdown in 1964, and the power plant, in 1974. In 1970, liquidation commenced of the industrial area in the centre of Ostrava City, where the mine, coking and power plants were located. By 1989, most of the buildings were demolished, except for two power plant buildings, which were retained as cultural monuments.

Redevelopment: Between 1999 and 2005, extensive decontamination of approximately 60 ha was completed as a result of toxic contamination. This resulted in 500 000 t of contaminated soil. In 2008, the redevelopment project started with a goal to convert this area into an integral part of the city centre through the construction of new facilities and infrastructure. The two retained historical buildings will be converted into cultural and education centres. The project is estimated to be completed by 2018.

Outcome: Reuse of historical buildings and valuable space in the centre of the city.

Department store, Palladium, Prague [130]

Original use: Since the end of the 18th century, an area close to the city centre was used as an army base. A block of dilapidated barracks on the site owned by the Czech Army had been abandoned since the second half of the 20th century.

Redevelopment: In 1996, the area was sold and the old historical buildings were converted into a department store. The reconstruction started in 2005 and was completed in 2007.

Outcome: Reuse of historical buildings as a department store.

Brownfield, Pilsen, Czech Republic [131]

Original use: A 180 ha zone in the central part of Pilsen was industrialized by SKODA between the late 19th century and the 20th century.

Redevelopment: Some buildings will be reconstructed and used for machinery production by SKODA, while the rest of the old buildings will be demolished. A new hall for industrial production will be constructed.

Outcome: Use of a brownfield site for new and refurbished industrial buildings.

Mine in Pribram, Czech Republic [132]

Original Use: The traditional mining area of Pribram consisted of many silver and non-ferrous metals mines. The first silver mines were established in the 10th century. The greatest development of the mining industry took place during the 18th and 19th centuries. In the 20th century, the mining of non-ferrous metals stopped; the mines were shut down in 1978.

Uranium mining started in Pribram after World War II and ceased in 1991.

Redevelopment: The mines and mining technology were gradually transferred to the mining museum established in 1955, which is the largest mining museum in the country.

Outcome: The former mining area in Pribram was converted into a mining museum.

6.3. REUSE OF BUNKERS (BUILDINGS WITH THICK WALLS AND FLOORS, SUBSURFACE FACILITIES)

Reuse of bunkers, rather than demolition, is typically more financially beneficial due to the high cost that would be incurred in demolishing these thick-walled structures.

6.3.1. Reuse of bunkers: The nuclear industry

Demolition of bunkers will increase the amount of radioactive waste for disposal, thus increasing the cost of decommissioning.

Würgassen NPP, emergency building (UNS), Germany

Original use: The building served as the independent emergency building (UNS) at the NPP Würgassen. The NPP was commissioned in 1971 and shut down in 1995 after it reached the end of its operational lifetime.

Redevelopment: UNS was converted to serve as a waste storage facility for the storage of decommissioning waste until a suitable waste repository would be available in Germany. UNS waste store became operable in 2005 after decommissioning the building. Redevelopment activities included the creation of waste storage chambers, the installation of hoisting equipment and the installation of control and security systems (Fig. 22).

Outcome: The waste store is in routine operation without any problems to date. The waste is retrievable and intervention is possible at any stage.

NPP Garigliano, Emergency Core Cooling System and Emergency Buildings, Garigliano, Italy [133]

Original use: The bunker was used for the Emergency Core Cooling System, refurbished in late 1980s (Fig. 23). The building, which formerly housed the emergency diesel generator, is being refurbished for similar purposes. The buildings formed part of the Garigliano NPP that is currently under decommissioning.

Redevelopment: The buildings have been redeveloped into radioactive waste stores.

Outcome: Both projects were intended to overcome the opposition of the local municipality to granting a building licence for new buildings to be used as waste stores.

FIG. 22. Würgassen NPP: Conversion of the independent emergency building into a waste storage facility.

FIG. 23. Garigliano NPP, Italy: The former ECCS building redeveloped as a radioactive waste store.

Underground Missile Silos and Vaults, USA [134, 135]

Original uses: Missile silos and vaults are subsurface structures that have been used for the housing missiles, including nuclear missiles, in a state ready to be launched, and storing weapons**.**

Redevelopment: Cold War relics are found across the country and reused in numerous ways, such as homes, for scuba diving, as schools, as storage facilities, and as museums.

In Holton, Kansas, the Jackson Heights School District was built on top of an old missile site using the underground labyrinth for eight classrooms and other uses.

Near Saranac, New York, developers have converted an Atlas missile silo into a multi-million dollar luxury home, complete with fibre optic lighting, marble baths and a whirlpool bath.

Outcome: Very creative and viable redevelopment and reuse scenarios have been implemented in underground structures. Some sites have environmental concerns such as contamination with hazardous substances, e.g. trichloroethylene (TCE). The Federal Government has sold most of the sites to the private sector, but other sites are owned by Federal agencies, state governments and other entities.

R1 reactor, Stockholm, Sweden [136]

Original use: Although not properly a bunker, R1 is a 30 m underground reactor hall, and its decommissioning and reuse may have similarities to actual bunkers. Sweden's first nuclear reactor, R1, was built in 1954 and closed in 1970. Measuring 12 × 12 × 24 m, the hall had not been used since a thorough cleanup of the radioactive rock.

Redevelopment: R1 reactor hall is now used as an experimental venue for art and media technology. The main research goal in planning this redevelopment was to explore how elements of new interconnected media technology, placed in a historical environment, could trigger emotional and artistic experiences. An interactive theatre was also built on the premises.

Outcome: A unique and successful experimental facility was established by the redevelopment of the underground reactor.

6.3.2. Reuse of bunkers: The non-nuclear industry

Czechoslovak defence fortifications, 1935–1938 [137]

Original use: Since the beginning of the 1930s, leading politicians of the former Czechoslovakia worked together with the Army Headquarters to build up an acceptable defence concept to enable the protection of the national borders in case of a surprise hostile attack. The reinforcements were subdivided into four stages depending on the danger to particular border sections. The end of the project was scheduled for after 1945. Only a part of the fortification was constructed before the start of German occupation in 1938. The fortification represented the largest construction project in Czechoslovakia: 10 000 small buildings and more than 250 big forts were built.

A part of the fortification was destroyed by the German Army during World War II. After 1946, the fortifications along the south and west borders of Czechoslovakia were logically integrated into the considerations of the newly formed political-military doctrine of the Soviet bloc.

From the 1950s, almost all remaining buildings were abandoned and became dilapidated.

Redevelopment: Some remaining buildings are used as museums of the fortification system.

Outcomes: Use of some buildings as museums of history of the Czech fortification system and World War II.

Germany's cold war bunker [138]

Original use: The bunker complex, which includes a maze of more than 17 km (more than 10 miles) of tunnel, is tucked into the rolling hills west of the former West German capital of Bonn. It was originally dug in 1903 as a train tunnel to France.

During World War II, the Nazis used slave labourers from the Buchenwald Concentration Camp to expand the tunnels, in which they hid rockets.

West Germany first made provisional plans for an emergency government bunker when it joined the North Atlantic Treaty Organization in 1955. But it was not until 1960 that work on the bunker began. By the time the $2.5 billion project was completed in 1972, it comprised 936 bedrooms, 897 offices and five small hospitals. If there had been a nuclear strike, it was equipped to provide for up to 3000 people — including the Chancellor, the President and other high officials — for 30 days.

The bunker ceased to be secret after Germany's reunification and the dismantling of the Warsaw Pact in 1991. The tunnels were abandoned in 1997, as Germany was making preparations to move its capital to Berlin.

Redevelopment: The German Federal Government made €2.5 million available to convert the bunker into a museum. Visitors can tour 200 m of the tunnels, which have been restored to their original condition and which house decontamination rooms, a meeting room for the president and a reconstruction of the apartment where the chancellor would have slept during an extended nuclear crisis.

Outcome: The new museum, the Government Bunker Documentation Center, is a memorial to Germany's division and the fear of a nuclear standoff that gripped the nation.

Kelvedor Hatch Secret Nuclear Bunker, Kelvedon Hatch, UK [139]

Original use: The bunker started as a Royal Air Force (RAF) Station and then as a civil defence centre. The facility was designed to house up to 600 military and civilian personnel during a possible nuclear attack.

Redevelopment: It has been used recently, as a Regional Government Headquarters, and for catering for dining, parties, conferences and film productions.

Outcome: Successful multiple and diverse reuse and redevelopment.

Nuclear Bunker, Sevelen, Switzerland [140]

Original use: A former nuclear bunker several metres below the ground was empty most of the time, except on rare occasions when the army used it for training courses. Maintenance costs were expensive.

Redevelopment: The bunker was converted to a low budget, basic hotel without television, windows and heating. In case of emergency, the hotel could be converted back into a nuclear bunker within 24 hours.

Outcome: Creative redevelopment of unused facilities (Fig. 24).

Antiaircraft towers, Vienna, Austria [103, 141–143]

Original use: The antiaircraft towers (or 'flak towers') were constructed around the Vienna City Centre starting in 1942 during World War II as a countermeasure against air attacks. In Germany, some flak towers were converted to residential places, but some are still abandoned (see Fig. 27). The towers were built to house anti-aircraft guns and to shelter thousands of civilians. Six towers were eventually built, each 40–60 m high and wide.

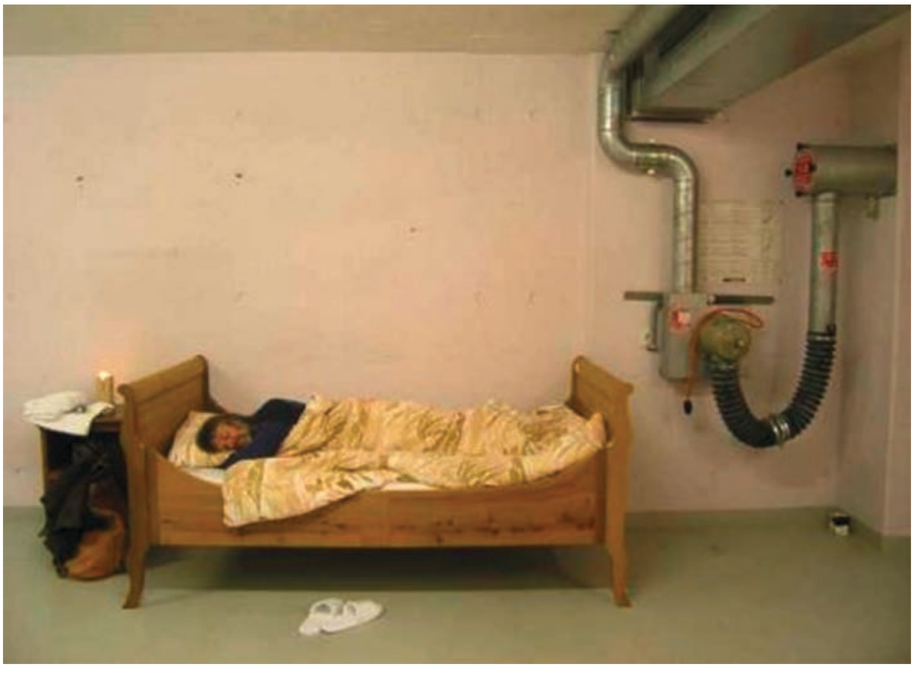

FIG. 24. From nuclear bunker to no-frills hotel: Sevelen, Switzerland.

Redevelopment: Four towers were left as monuments, one of which was turned into an aquarium (Fig. 25) and another into a garage and warehouse for objects of art (Fig. 26). For the latter, plans are being made to refurbish the building and develop it as the Contemporary Art Tower (CAT) of Vienna [144]. These redevelopments were prompted by the thick walls keeping interior temperatures constant and the reinforced floors capable of supporting great loads. In addition, an elaborate climbing wall has been installed on one of the exterior walls; publicity material boasts no less than 25 different routes up this unusual urban reproduction of an alpine rock face. Another tower bristles with myriad telecommunication aerials — tall buildings that can be defaced in this way are at a premium in today's urban environments (see Fig. 27).

Outcome: Following the war, engineers determined that the explosions necessary to bring down these towers (wall thickness is up to 3–4 m) might have severely damaged the surrounding buildings, so they were left in place and form part of modern Vienna.

Coalhouse Fort, East Tilbury, UK [145]

Original use: This is a Victorian coastal defence fort set in park land next to the river Thames. It was completed in 1874 to defend the approach to the capital against enemy invasions. The fort continued its role as a military establishment through two world wars.

Redevelopment: The aim is to make Coalhouse Fort a self-sustaining business by extending the opening times to the museum to become a heritage centre or by housing small business units.

Many people would have liked to demolish Coalhouse Fort with its scruffy appearance, but the cost alone would be huge. The fort is built of solid granite, brick and concrete, and would cost more to demolish than its original building cost. The Coalhouse Fort Project relies on volunteers for opening the fort to the public.

Outcome: A decision to preserve the Coalhouse Fort was made in view of its historical value and the cost of demolition. Historical value is a strong driver for redevelopment and reuse.

San Carlo Defence Bunker, Gotthard Pass, Switzerland [146]

Original use: Bunker San Carlo was one of the important defence emplacements in Switzerland.

FIG. 25. The Haus des Meer (literally House of Sea), Vienna, Austria, is a flak tower redeveloped as an acquarium.

FIG. 26. A flak tower redeveloped into a garage and warehouse for art objects in Vienna, Austria.

FIG. 27. The inside of the Humboldthain flak tower. (Source: www.uer.calocationshow.bmp).

FIG. 28. Bunker redeveloped into a hotel.

Redevelopment: Converted by a communications artist into a subterranean 4-star hotel ‘La Claustra’ as part of an interactive/spiritual/communications centre for tourists (Fig. 28).

Outcome: Unusual form of redevelopment.

6.4. REUSE OF CONTAMINATED AREAS ASSOCIATED WITH OTHER FACILITIES (CLOSED WASTE SITES, BROAD AREAS OF SECONDARY CONTAMINATION)

Most nuclear sites have broad areas that were used for waste treatment, storage or containment of effluent and contamination. These areas must be capped or otherwise remediated to prevent the spread of contamination beyond the boundaries of the facility. The redevelopment and reuse of such areas for the majority of cases will be restricted reuses. These areas can be redeveloped in landfills, wetlands, or low occupancy areas such as parking lots, golf courses or waste storage areas.

There are several reasons for which contaminated lands and mining sites make good locations for clean and renewable energy development, as listed below [147]:

— Many contaminated lands and mining sites offer large land surfaces and may be situated in areas where the wind and solar structures are less likely to be met with aesthetic opposition.

— These lands have electric transmission lines and capacity, and other critical infrastructure, such as roads, and are adequately zoned for such development. The avoided new infrastructure capital and zoning costs are often significant.
— Whether it is a long term lease or outright purchase, contaminated lands may have lower overall transaction costs than greenfields due to the relative ease of acquisition of large swaths of land from one or few owners, compared to the acquisition of greenfields from potentially numerous landowners.
— Redevelopment of brownfields for green energy production can help reduce the stress on greenfields for construction of new energy facilities.
— Many contaminated lands are in areas where traditional redevelopment may not be an option because the site may be remote, or may simply be saddled with environmental conditions that are not well suited for traditional redevelopment such as residential or commercial.
— Some contaminated sites such as industrial, manufacturing and mining sites were once operations that provided jobs for the local communities. However, once these facilities ceased operations, these communities were left with fewer jobs. The development, operation and maintenance of renewable energy facilities on these sites may reintroduce job opportunities.
— There are approximately 480 000 sites and almost 6 million ha (15 million acres) of potentially contaminated properties across the USA that are tracked by the Environmental Protection Agency. Cleanup goals have been achieved and controls put in place to ensure long term protection for more than 340 000 ha (850 000 acres). This opens many potential opportunities to develop renewable energy facilities on these sites; coordination and partnerships among federal, state tribal and other government agencies, utilities, the private sector and communities will help advance renewable energy production.

6.4.1. Reuse of contaminated areas: the nuclear industry

The following are examples of nuclear sites with broad areas that have been reused or considered for reuse.

Fernald Nuclear Site, Fernald, Ohio, USA [148]

Original use: Feed Materials Production Center in Fernald refined uranium for the nation's Cold War nuclear weapons programme. From the time it opened in 1951 until it closed in 1989, the Center processed 250 000 t (500 million pounds) of uranium and generated 750 000 t (1.5 billion pounds) of radioactive waste. This cause widespread contamination of the environment and ultimately resulted in the closure and decommissioning of the site.

Redevelopment: During a seven year process, 197 trains each removed 5800 t of contaminated soil in 60 railcars to a Utah dump site in the hills of southern Ohio.

In the final compromise, the Federal Government agreed to move 1.3 million t of the most contaminated waste to storage sites in Texas, Nevada and Arizona. Citizens agreed to place the rest (4.7 million t) in a landfill at Fernald.

The waste site resembles a long, fat worm. Filled with uranium laced soil, building parts and shreds of clothing, the landfill is 10 m (30 ft) deep, with another 20 m (65 ft) above ground, and is 1.2 km (three-quarters of a mile) long.

The landfill's outer wall of rock, plastic and clay is 3 m (9 ft) thick and sits 10 m (30 ft) above the aquifer. It is designed to last at least 1000 years.

When the site opens as a park, the landfill will be off-limits to the public. The remaining 3 700 000 m² (930 acres) will include hardwood forest; prairie and wetlands intended to recreate the area's natural environment before European settlers arrived in the early 1800s.

The conversion of the nuclear site into a park with the landfill option on the site out of reach of the public inspired the idea of similar revelations at nuclear facilities around the country to be investigated and developed.

Native bird species, not seen in the area for decades, have now been spotted at Fernald. The indigenous fauna and flora have been successfully restored.

The public's view changed dramatically, and the value of the property increased. People then moved back to the residential areas around Fernald since it was no longer a nuclear waste dump.

Outcome: The redundant nuclear site was first seen as a huge environmental liability and became an environmental asset.

Y-12 National Security Complex, S3 Ponds, Oak Ridge, Tennessee, USA [149]

Original use: These four unlined, 4000 m^2 ponds were used from 1951 to 1984 for the disposal of acidic, nitrate, metals and radiologically contaminated waste solutions produced by the Y-12 plant and other United States Department of Energy facilities. During their 33 year operation, about 9.5 million L (2.5 million gal) of nitric acid solution was annually discharged to the ponds. Other wastes included pickling and plating wastes, machine coolants, depleted uranium and technetium. Smaller quantities of organic compounds including acetone, chloroform and tetrachloroethane were also disposed of in the ponds. In 1984, the acid wastes in the ponds were neutralized, the nitrates were treated by in situ biodenitrification, and remaining liquids were pumped off and treated. Later that year, the S-3 Ponds were capped in compliance with the Resource Conservation and Recovery Act (RCRA) regulations.

Redevelopment: In 1988, the capped S-3 Ponds site was paved with asphalt and reused as a large parking lot.

Outcome: Converted to a parking lot for employees at the Y-12 National Security Complex.

6.4.2. Reuse of contaminated areas: The non-nuclear industry

Viaduc Daumesnil Railway, Paris, France [150]

Original use: A railway redeveloped for new uses. Rail traffic had stopped on the viaduct in 1969.

Redevelopment: Paris successfully converted Viaduc Daumesnil (railway) in the 12th arrondissement, near the Bastille, into a pedestrian walkway called the Promenade Plantée. The project as a whole helped revitalize the surrounding neighbourhood, inspiring new residents and businesses to come to the area [151]. The 5 km (3 mile) linear park, designed by Philippe Mathieu and Jacques Vergely, is lavishly planted and offers stairs and elevators for access. Retail spaces, designed by Patrick Berger, were created in the spaces under the masonry arches supporting the structure.

Outcome: A railway converted for reuse as a pedestrian walkway.

Bridge of Flowers, Shelburne Falls, Massachusetts, USA [152]

Original use: A bridge.

Redevelopment: The bridge was converted into a linear garden, on which more than 500 varieties of flowers, vines and shrubs are maintained between April and October. It has since come to serve as a centerpiece for the entire municipality of Shelburne Falls, as well as a renowned New England travel destination and therefore, an important economic base for the village.

Outcome: A bridge converted into a garden.

Holbeck Viaduct, Leeds, UK [153]

Original use: A former rail freight viaduct.

Redevelopment: The reuse of this former rail freight viaduct in Holbeck Viaduct, UK, is proposed as part of the Holbeck Urban Village redevelopment, a revitalization of a former industrial section of Leeds. The redevelopment project focuses on environmental sustainability in its mixed residential, cultural and commercial development.

Outcome: The architectural firm Bauman Lyons recently conducted a feasibility study and is working on a set of preliminary designs for the viaduct’s transformation.

Santa Caterina Market, Barcelona, Spain [154]

Original use: Santa Caterina Market is locked into the dense urban texture of Barcelona's Barri Gotic, close to the city's main medieval cathedral. Tenaciously occupying the same site since the 19th century, it is the oldest covered market in the city and its recent radical remodelling by Enric Miralles and Benedetta Tagliabue (EMBT) marks another stage in its long civic and commercial evolution. Plans for redevelopment were first mooted in 1997, since the market was languishing both commercially and civically. Although close to the city centre, it serves a relatively poor area, hemmed in by dense, dingy apartment blocks. Covered by a decaying pitched roof, the market's mess and stench had become a local eyesore and some thought it should be demolished, liberating a substantial parcel land for redevelopment.

Redevelopment: Through long conversations with politicians, planners and the board that operates the city’s markets, the EMBT competition winning proposal of 1997 evolved into a larger and more painstaking piece of bottom up urban regeneration that includes the design of new housing blocks and strengthening routes through the dense urban fabric.

Outcome: The original 19th century market was built on the remains of the eponymous medieval Dominican Convent of Santa Caterina that burned down in 1835. EMBT's scheme keeps the market's low arched walls on three sides, containing and defining the site. On the fourth south-east side, the orthogonal geometry is decisively fractured, as the new edge of the market dodges and weaves around a new public plaza and two new social housing blocks containing 59 low rent apartments for the elderly. Below ground, to minimize mess and disruption, is the ‘business end’ of things (see http://findarticles.com/p/articles/mi_m3575/is_1305_218/ai_n15891656/; http://www.arch.ttu.edu/courses/2006/spring/5605/391/CourseMaterials/santa%20catarina.pdf). Lorries deliver fresh produce to a busy loading bay, from where it is ferried to the main market hall by a system of goods lifts and porters.

The elderly and those in the surrounding blocks overlooking the building have possibly the best view of the revitalized Santa Caterina. Its roof is a fifth elevation that drapes and swells over the market hall like a coloured blanket or camouflage net. Extending the Catalan tradition of hectic mosaic ornament, it is clad in hexagonal ceramic tiles that make up a pixellated abstract pattern of fruit and vegetables. With some 300 000 tiles in 67 colours, covering an area of 5500 m², it was an intensive undertaking. Using computer simulations, models and practical tests, the difficulties of constructing such a vast surface were overcome by assembling single tiles into larger modules, so each colour coded hexagonal ‘pixel’ is made up of 37 tesserae.

Manhattan Railway, New York, USA [151]

Original use: The High Line was an urban railway route through Manhattan. A 1.5 mile (2.4 km) section has been redeveloped.

Redevelopment: Redevelopment is under way, driven by several community groups.

Outcome: Redevelopment as public open space under way.

Waste Dump, Oldham, Lancashire, UK [41]

Original use: An amphitheatre on the outskirts of Oldham, which received 1.8 million m³ of inert waste.

Redevelopment: The complex process to redevelop the Beal Valley landfill into a golf course took into consideration normal landfill management, ecological, agronomic and drainage issues together with water management and engineering concerns, while preserving the local floodplain and terrain and public services.

Outcome: The development is currently in the latter stages of the engineered fill construction, and final pre-golf course construction will begin later .

6.5. REUSE OF SMALLER BUILDINGS

6.5.1. Reuse of smaller buildings: The nuclear industry

The following examples describe the redevelopment and reuse of nuclear smaller buildings (e.g. laboratories, small research reactors, offices, etc.).

Instituto Venezolano de Investigaciones Cientificas (IVIC), Caracas, Venezuela [155]

Original use: Nuclear research reactor used for experimental applications until 1990.

Redevelopment: Suggestions were made to convert a portion of the facility (the site of a long retired nuclear research reactor) into a facility that could house a revenue generating commercial irradiator. A new irradiator was successfully installed. The closure of the reactor presented the Government of Venezuela with a financial dilemma. Demolition would cost approximately $35 million. Yet, to leave the reactor safely decommissioned and idle seemed a poor alternative, considering that the facility would continue to be staffed and maintained with no real return on investment. The suggestion of refitting IVIC with a larger, higher capacity irradiator capable of providing commercial scale irradiation services would solve many problems. The advanced irradiator increased business opportunities throughout the country. IVIC has three floors with a diameter of 25 m. The centre of the building housed the reactor core, leaving a 7–8 m wide space around the outside. Significant structural changes were impeded by safety requirements. Therefore, the irradiator was reconfigured to fit in the basement of the building and allocated part of the basement and also the first floor for storage. The irradiator company (MDS Nordion) stated, “it was the first time that they ever built a multilevel irradiator.”

Outcome: The IVIC’s new irradiator is a 12 box batch processor with a wide range of potential applications, from medical and surgical product sterilization to the treatment of pharmaceuticals, cosmetics and food. The new business centre — a centre of irradiation expertise — offers processing services,. Personnel from the facility will be able to share their knowledge of building and maintaining a sterilization plant.

Institute for Atomic Energy (IFA), JEEP 1 reactor, Kjeller, Norway [156]

Original use: Heavy water uranium research reactor, 450 kW t.

Redevelopment: Today, the reactor has been emptied of fuel and heavy water; the reactor vessel and the biological shield are not yet dismantled.

Outcome: The building containing the reactor is now used for housing a Co-60 irradiation facility.

Institute of Physics, Research IRT-M Reactor, Tblisi, Georgia [157]

Original use: Pool type research reactor in operation from 1959 until 1988.

Redevelopment: The IRT-M reactor was decommissioned in 2002, and the lower, high-radioactive part of tank (about 20 m^3) was covered with concrete. A low power nuclear facility (about 50 kW) was designed to be placed on top of the decommissioned (entombed) reactor inside the former reactor shaft. The concept included the reuse of the infrastructure of the IRT-M reactor.

Outcome: The new low-power nuclear facility with a new core and thermosyphon cooling will allow continuing research. However, a decision for the new facility has not yet been made.

EWA, Research Reactor, Swierk, Poland [158]

Original use: WWR-type research reactor in operation from 1958 to 1995.

Redevelopment: Decommissioning was completed in 1999. The main goal of facility decommissioning was the removal of activated and/or contaminated elements and materials, which constituted the integral parts of reactor technological systems. A preliminary study of the reactor facility has shown that various reuse options are available, as follows:

— Reactor concrete shaft can be used as a dry storage area for nuclear spent fuel elements.
— Hot cells can be used to encapsulate nuclear fuel elements and any other high radioactive waste.
— Hot cells can be used for material examination or for other work with radioactive material.
— The administrative laboratory building of the reactor can be used as the headquarters of radioactive waste management.

Outcome: Eventually, the start of spent fuel repatriation from Soviet design reactors to the Russian Federation may render the planned reuse of the reactor shaft obsolete. A similar case appears to be the AST-1 research reactor, Russian Federation. The reactor cavity is used as high level waste storage for the waste generated by decommissioning [159].

Korea Atomic Energy Research Institute, Reactors KRR-1 and KRR-2, Republic of Korea [160–162]

Original use: Research Reactors KRR-1 (TRIGA Mark-II) and KRR-2 (TRIGA Mark-III).

Redevelopment: The decommissioning of KRR-2 was complete at the end of 2005. The reactor rooms of KRR-2 have been used for the temporary storage of decommissioning waste, pending availability of a waste disposal facility. The decommissioning of KRR-1 was suspended pending a decision on proposed preservation as a museum and a nuclear culture complex. The strategy is foreseen as follows:

— All equipment inside the concrete bio-shield will be preserved.
— All external facilities (ventilation, cooling system, etc.) will be dismantled.
— Some new equipment will be installed.
— The reactor hall will be converted into an exhibition room after remodelling the building.
— A hard and safe glass window will be installed on top of the pool.

Outcome: Concerns of segments of the public (senior reactor operators) impeded the dismantling of KRR-1. A decision has now been taken to preserve KRR-1 as a national monument. which was based in part on survey polls and technical issues.

Argonne National Laboratory (ANL-East), Four Facilities, Argonne, Illinois, USA [64, 163]

Original use: Experimental Boiling Water Reactor (EBWR), Building 212 D-Wing Glove Boxes, Plutonium Fabrication Facility (Building 350), and Chicago Pile No. 5 (CP-5) Research Reactor Facility.

Redevelopment: The four facilities are being reused as follows:

— EBWR decommissioning was completed in 1996 and the facility is undergoing conversion/modification into a waste storage facility.
— Nine research laboratories containing 60 plutonium glove boxes in Building 212 D-Wing were fully released for unrestricted reuse. These have been reused for non-radiological research including an electron microscopy laboratory.
— The former Plutonium Fabrication Facility has been reused and is now designated as the US Department of Energy (DOE) New Brunswick Laboratory.
— Two support structures at the CP-5 Research Reactor Facility have been turned over to Facility Operations. One is being used as a road salt storage facility, and the other has been upgraded to store packaged hazardous waste awaiting shipment to a disposal site.

Outcome: DOE saved an estimated $3.6 million plus the cost of constructing a hazardous waste storage area by decommissioning and reusing these surplus nuclear facilities.

Oak Ridge National Laboratory (ORNL) Graphite Reactor, Oak Ridge, Tennessee, USA [164]

Original use: Constructed in 1943, the Graphite Reactor was used to prove the process for plutonium production during the Manhattan Project, and it was the first reactor to produce radioactive isotopes for medical uses. It was decommissioned in 1963.

Redevelopment: In addition to its listing in the National Register of Historic Places, the Graphite Reactor was also designated as a National Historic Landmark in 1966. Landmark designation is an official recognition of an historic property's national significance and is given to places where important historical events occurred. The Graphite Reactor received this special designation because of the national and international significance of its contributions to science and technology. The building now contains exhibits on the beginnings of the atomic age, reactor design, and current science and technology. It is open to the public via official DOE tours (Fig. 29).

Outcome: This historically significant building has been preserved and is open for tours.

Idaho National Laboratory, SPERT-I AND SPERT-III Reactor buildings, Idaho, USA [64]

Original use: Research reactors.

Redevelopment: SPERT-I reactor was decommissioned in 1964, and all equipment was removed in 1969. The building was used to house the Power Burst Facility plant protective system equipment. SPERT-III was decommissioned in 1980 and all reactor components removed. It now houses the Waste Experimental Reduction Facility.

Outcome: Reuse for new missions.

University of Virginia, Research Reactor, Charlottesville, Virginia, USA [165]

Original use: Research reactor.

Redevelopment: Decommissioning is almost complete. Renovation for other uses is expected shortly. One plan is to renovate the building into an engineering research lab complex to focus on interdisciplinary studies in information technology, biological sciences and nanotechnology.

Outcome: In progress.

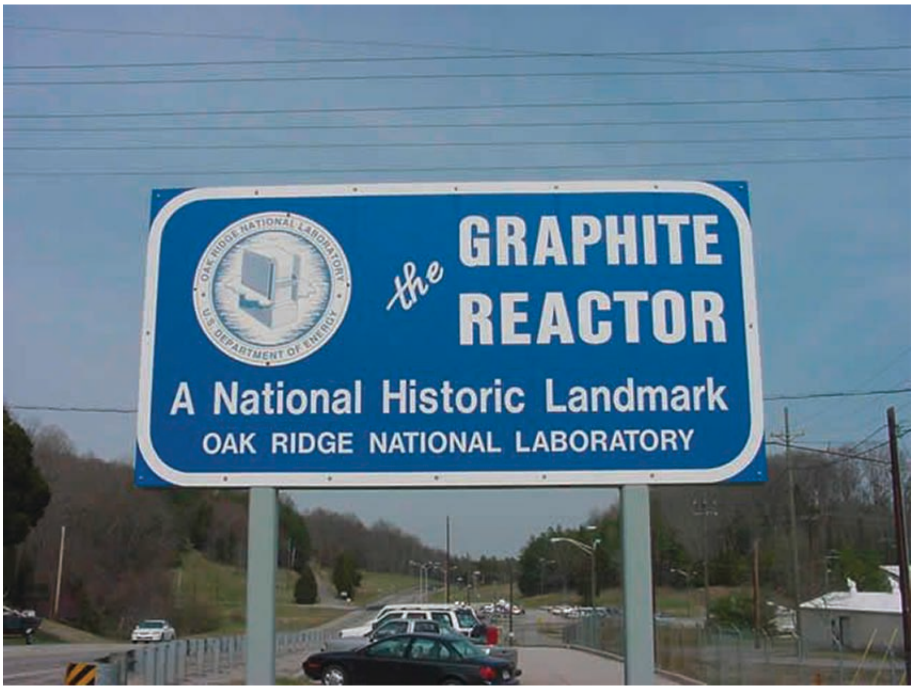

FIG. 29. A road sign to the Oak Ridge graphite reactor.

Queen Mary College, Research Reactor, London, UK [166, 167]

Original use: This tiny reactor was the first to be built for a UK university. It was commissioned in 1966 for the Department of Nuclear Engineering at Queen Mary College, where it was used for undergraduate experiments and postgraduate projects, and was deactivated in 1982.

Redevelopment: Following the completion of the decommissioning process, the Queen Mary's licence was officially de-registered by the Nuclear Installations Inspectorate in November 1983. The huge empty building, divided into two hangars, still stands; part of it is used by a waste disposal company.

Outcome: The area has no residual radioactivity and is available for reuse.

Dounreay, Boiler House, Thurso, Caithness, Scotland, UK [168]

Original use: Boiler house.

Redevelopment: Decommissioning began in 2006.

Outcome: Once decommissioned, the old boiler house will become a storage area for rock cores removed during hydrogeological tests.

Chalk River Laboratories, Pool Test Reactor (PTR), Chalk River, Ottawa, Canada [169]

Original Use: The 100 W PTR was used to measure the burnup of fissile samples from the National Research Experimental Reactor.

Redevelopment: PTR was defuelled in 1992. All PTR systems and structures will be removed for reuse or storage in Chalk River waste management areas.

Outcome: Atomic Energy of Canada Ltd plans to convert the PTR area into an active laboratory space.

Risø National Laboratory, DR-1 and DR-2 reactors, Risø, Denmark [170, 171]

Original use: Research reactors. DR-1 was dismantled in 2005 and the DR-2 reactor was dismantled in 2008.

Redevelopment: Following dismantling in 2005, the DR-1 reactor room was refurbished for use for wind generator experiments (Figs 30). However, the DR-2 reactor building and several structures will be retained for restricted nuclear use (material handling, waste buffer space, change rooms, etc.). The reuse of the building is intended to support ongoing decommissioning activities at Risø. Following a restricted use period of some ten years, the remaining part of DR-2 will be dismantled for unrestricted release. This is viewed in parallel with the completion of the Risø decommissioning programme (Fig. 31). The following structures in the Radioactive Waste Handling Facility are considered for use over the next ten years:

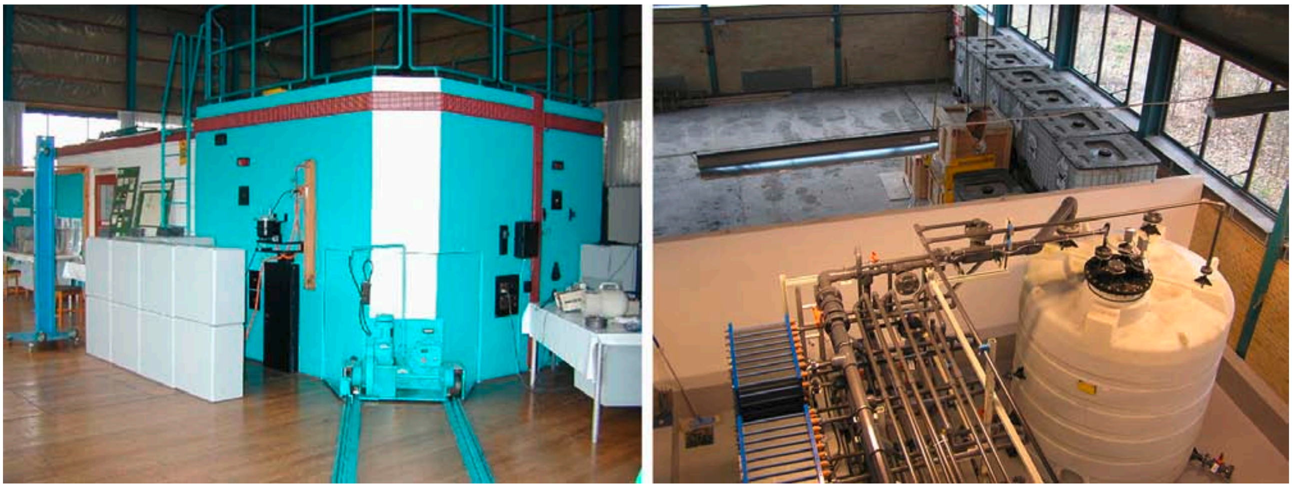

FIG. 30. The DR-1 reactor room (left) before and (right) after decommissioning.

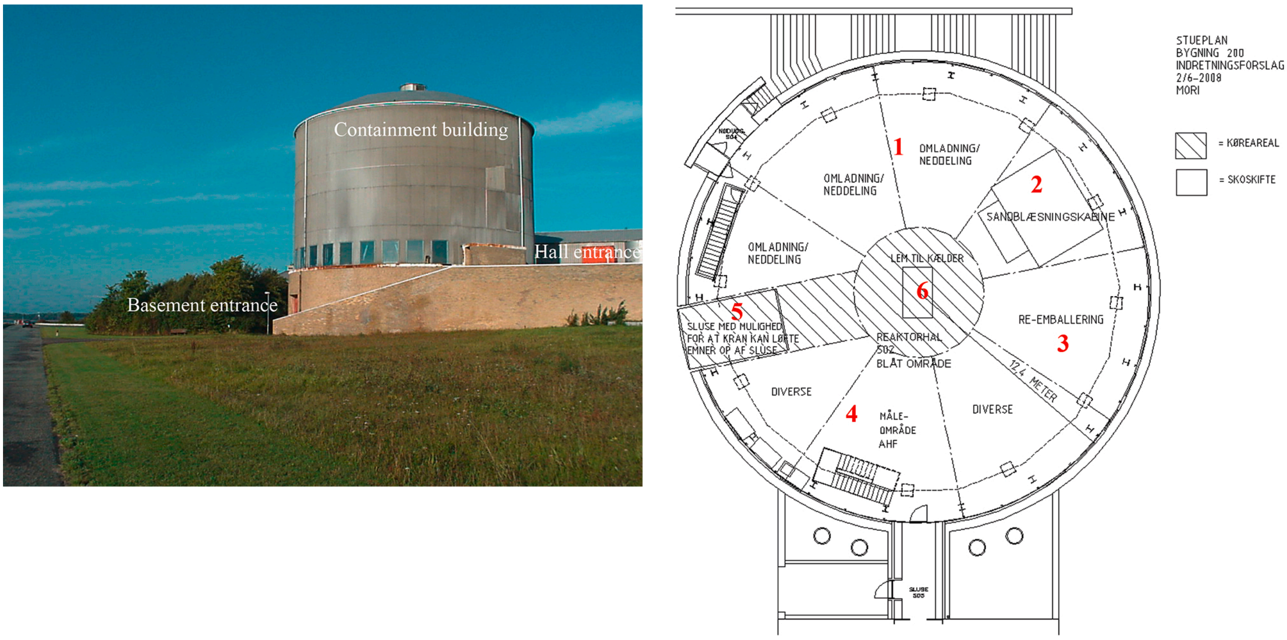

FIG. 31. The DR-2 reactor (left) and the planned reuse of the ground floor of the DR-2 reactor (right). (1: Loading and filling of drums and containers and downsizing of components; 2: sandblasting facility (decontamination cabin); 3: repacking of containers; 4: measuring control area; 5: lock and materials entrance bay (red); 6: basement opening with removable cover (centre of room).)

— Approximately 1 000 m^2 + basement;
— Crane with 15 t capacity;
— All support facilities in place (hygienic facilities, active tank, air pressure system, high voltage supply, ventilation and under pressure, etc.);
— Port opening allows for use of a 55 t truck.

Outcome: Planned activities include conditioning of waste, downsizing of equipment and backfilling of containers, etc.

Casaccia Research Centre, OPEC-1 and OPEC-2 Hot Cells, near Rome, Italy [172]

Original use: OPEC-1 Hot Cells operated from 1971 to 2000 carrying out handling and post-irradiation, mechanical, physical and chemical tests on nuclear fuel, devices and other materials from nuclear reactors. OPEC-2 Hot Cells were designed for operation on spent fuel, which was unsuitable to be managed at OPEC-1 due to size, activity and plutonium content. OPEC-2 was never operated on radioactive materials.

Redevelopment: Following licence termination, dismantling of internal structures, decontamination and surface coating, OPEC-1 is now authorized for storage of irradiated fuel; radioactive sources and waste used in its operational period. Following extensive layout changes, OPEC-2 will be used for storage of plutonium contaminated wastes and large radiation sources.

Outcome: Since OPEC-2 had never been operated in a radioactive environment, redevelopment of the premises, structures and systems has been much more extensive than at OPEC-1.

Salaspils Research Reactor, Riga, Latvia [173]

Original use: Research reactor.

Redevelopment: Decommissioning will be carried out to allow restricted release, since unrestricted release is prohibitively costly by the discovery of groundwater contamination (unrelated to reactor operation). It is proposed to install a cyclotron into parts of a research reactor facility being dismantled. There are still two variants under discussion which will affect the decommissioning project; to locate the cyclotron next to the reactor building or to locate it adjacent to another building (the garage), closer to the site fence.

Outcome: The location of the proposed cyclotron on the site of the reactor centre had several benefits over using an entirely new site, mostly in terms of space availability, access to hospitals, re-employment of skilled reactor specialists, and fewer limitations on the facility type and size (eventually resulting in scope upgrading from a purely medical facility to a multipurpose one). The target of restricted release is another factor militating for reuse of the Salaspils site for a new nuclear facility, i.e. the cyclotron.

Salaspils Research Reactor, Riga, Latvia [173]

Original use: Several small buildings, including the former central heating building.

Redevelopment: Several small buildings at the Salaspils site were converted to new purposes. One example is the former central heating building, which is now in use for monitoring the decay of short lived sources, e.g. iodine from hospitals, and might soon be used as a decommissioning waste storage facility.

Outcome: Access to the Baldone Waste Disposal Site in Latvia may become problematic due to public concerns. The Salaspils Reactor Decommissioning Project has needed to develop alternative waste management routes (Fig. 32).

East Tennessee Technology Park, Materials and Chemistry Laboratory (MCLinc), Building K-1006, Oak Ridge, Tennessee, USA [174]

Original use: Building K-1006 is a radiological/chemical laboratory, which was built to support the former K-25 Gaseous Diffusion Plant complex. In the mid-1980s, the lab was expanded to support the environmental restoration activities at East Tennessee Technology Park (ETTP). It then served from 1992 to 1997 as a DOE Environmental User Facility.

Redevelopment: In 1997, when the laboratory was declared surplus, it was made available for lease to the employee group who had operated it. It is now a commercial laboratory and the business is owned by former employees. The laboratory offers services in speciality environmental analyses, applied research problem solving pertaining to chemical process operations and industrial forensics. Only limited decontamination was necessary in order to reuse the laboratory for essentially the same purpose as it was originally. MCLinc refurbished major equipment items, which were subsequently transferred to the company by DOE.

FIG. 32. Former central heating building planned for use as a waste storage facility, Salaspils reactor, Latvia.

Outcome: Previous employees, including a core group of professionals, managed to effectively become owners and business partners. The long term fate of the facility remains a challenge because portions of the facility are radiologically contaminated. MCLinc has requested transfer of ownership of Building K-1006 under regulations detailed in 10 Code of Federal Regulations 770. If this request is not granted, the laboratory will be demolished under DOE's Accelerated Cleanup Plan.

Santa Susana Field Laboratory — Energy Technology Engineering Centre, Three facilities: The Sodium Reactor Experiment Containment building, The Nuclear Materials Development Facility and the DeSoto Avenue Fuel Fabrication Facility, CA, USA [64]

Original use: The Sodium Reactor Experiment Containment building was used for research reactor containment; the Nuclear Materials Development Facility for a plutonium fuels facility; and the DeSoto Avenue Fuel Fabrication Facility for fuel fabrication.

Redevelopment: The former Sodium Reactor Experiment Containment building is being used for storage of expensive equipment. The former Nuclear Materials Development Facility is being used for a laser R&D programme after being successfully decontaminated and decommissioned. The former DeSoto Avenue Fuel Fabrication Facility is now being used for the manufacturing of rocket engine components.

Outcome: Successful reuse of decommissioned facilities.

6.5.2. Reuse of smaller buildings: The non-nuclear industry

This section provides examples of the redevelopment and reuse of non-nuclear smaller buildings. A number of sugar mills and similar facilities were converted to other purposes [175].

The Bedlam Theatre, Edinburgh, UK [176]

Original use: Bedlam is housed in the former New North Free Church at the foot of George IV Bridge in Edinburgh. This building is on the site of the old city poorhouse and round the corner from the site of the city's first mental health hospital, hence the name. After the building was abandoned by the church, it fell into the hands of the University, which used it for various purposes including a furniture store and a school of nursing.

Redevelopment: In 1980, the Edinburgh University Theatre Company moved in after the building was converted for their use.

Outcome: Bedlam Theatre is a well known Edinburgh attraction.

The Mill, Naul, Ireland [177]

Original use: Naul was constructed as a mill. Various examples of the successful application of adaptive reuse, visible throughout Ireland, were industrial buildings such as watermills, redeveloped into dwellings or apartments, restaurants and craft shops. The changes implemented were not without significant architectural challenges, but in most cases, ensured the survival of industrial heritage. The focus in Ireland is on the inherent development potential of each village to provide sustainable rural communities.

Redevelopment: The village of the Naul is situated in the north of Fingal, which is in North County Dublin. This picturesque village still possesses much of its original streetscape. The refurbishment and reuse of the building, now known as the Seamus Ennis Cultural Centre, is a perfect example of what can be achieved by the refurbishment and reuse of original building stock. The aim of the Naul Project is to reuse an architecturally important industrial building while providing vital housing units within an existing site in keeping with the residential guidelines, and thus avoid urban sprawl, which is evident throughout the county. In the reuse of this building, the proposed river walk and seating area is a welcome addition for all its inhabitants to enjoy.

Outcome: The basis conservation principles (1964 Venice Charter and 1981 Burra Charter) are applied in Ireland. The redevelopment plans have been taken into consideration if an adaptive reuse option is accommodated within the building structure without leading to a significant loss of character of the building.

The Children’s Museum, Rome, Italy [178]

Original use: The structure was originally a bus garage.

Redevelopment: The garage was converted to a children’s museum, Explora. Ample use was made of existing windows allowing natural illumination of the exhibition space. The building is located in a historic villa, and the green spaces are perfectly suitable for a children’s museum (Fig. 33).

Outcome: Explora is the first Italian children’s museum, primarily designed for children, schools and families. Visitors can see exhibits dealing with the environment, communication, economy and new technologies.

Bonawe Iron Furnace, Scotland, UK [179]

Original use: Bonawe Iron Furnace is a relic from an industrial past that produced up to 700 tonnes of iron per year from 1753 to 1876. At its height, it was the centre of a significant settlement. The manager supervised as many as eight men producing the iron, and up to 12 more workers for the delivery of the charcoal and maintaining the site. The workers and their families, many from England, occupied the workers' houses still visible around the site. In addition, there were up to 600 tree cutters and charcoal burners employed for at least part of the year across a huge area of north Argyll, coppicing wood and converting it into the fuel for the furnace.

The centre of the process at Bonawe was the furnace itself. This was fed from the top with local charcoal, with iron ore from Furness, and with limestone from Lismore. The iron produced at Bonawe was either cast into rough ‘pigs’ for transport back to England and further processing, or was cast into cannonballs. In 1781, Bonawe produced 42 000 cannonballs.

Redevelopment: Bonawe today is set on a beautifully grassy slope facing north towards Loch Etive. The higher parts of the slope are occupied by the large charcoal stores and the ore shed, still stained red from the ore. The ore shed also houses a fascinating series of displays charting the history of the site and information about the iron making process.

But the heart of the site today, as during its productive life, is the furnace itself. The upper parts of this show what workers’ lives would have been like feeding the furnace, while the furnace itself can be seen from below via the hearth. Outside it is still possible to see the mill race from the reservoir to the south, together with the pit in which the water wheel sat until 1941 (Fig. 34).

Outcome: Bonawe is in the care of Historic Scotland and open to the public.

FIG. 33. Inside the Explora Museum, Rome, Italy. Note the structural elements remaining from the former garage.

FIG. 34. The Bonawe Furnace, Scotland, is now a museum.

6.6. OTHERS EXAMPLES (STACKS, COOLING TOWERS, WATER TOWERS, SEWAGE TREATMENT PLANTS)

When stacks have become part of the local landscape, public awareness raising may be important regarding the sensitivity on its removal. The public may also have safety concerns about an actual removal project [180]. Such factors may eventually lead to keeping the stack, possibly as a visitors' attraction. One example of public concern over stack removal is given in Ref. [181].

In additional to being site landmarks, stacks may present beautiful architectural elements (Fig. 35).

Cooling towers may present aspects similar to stacks.

Even a simple structure such as a stack is now reminiscent of former times, when industries were located downtown. With the industries gone, stacks remain as landmarks (Fig. 36).

To the best knowledge of the drafters, there are no published examples of reuse of nuclear facilities that can be mentioned here. It is felt, however, that the non-nuclear experience may also serve the purposes of the nuclear industry once radiological safety concerns have been removed.

In the non-nuclear sector, there are cases where stacks/chimneys were reused for other purposes, such as the former Whiskey Distillery Chimney, Dublin, Ireland, which was converted to a panoramic observation tower [182] (Fig. 37).

In Vienna, Austria, buildings used for distribution and storage of drinking water have been transformed into museums and exhibition halls. Noteworthy are the Wiener Wasserturm (Vienna Water Tower) and the Alte Schieberkammer (Old Installation Chamber). More details are given in Refs [183, 185] (Figs 38, 39). A number of conversions of water towers to homes are described in Ref. [186]; Figure 40 shows one impressive example.

Worldwide municipalities are faced with the problem of developing new advanced wastewater treatment facilities. It is becoming more complex and difficult to meet the new standards developed to operate wastewater treatment facilities. Due to the demand to improve the standards, the smaller and older facilities are continually phased out of operation. The potential availability of abandoned properties for reuse grows. Municipalities will have to deal with decommissioned facilities, which can become difficult and costly to demolish, but the transformation of these facilities can be done in a more cost effective manner, when redevelopment and reuse options are kept in mind [39].

FIG. 35. An old stack at the Řež Nuclear Research Institute, Czech Republic. Note the ribs as an interesting architectural element.

Smaller and older facilities to be decommissioned that are situated close together can be combined into one advanced new wastewater treatment facility such as the Monroe County wastewater treatment facility in the USA. Combining similar facilities into a single, newer, advanced facility will reduce capital costs by using recycled materials and will save operational cost by sharing resources and minimize utility uses. Redevelopment of a facility removes pressure from undeveloped greenfields, helping to preserve habitat and maintain open space. The Monroe County case is described below.

Wastewater treatment facility, Monroe County, New York, USA [39]

Original use: Wastewater treatment facility.

Redevelopment: In 1998, Monroe County consolidated two wastewater treatment plants, rerouting sewage from the Gates–Chili–Ogden Sewage Treatment (GCO) Plant in Scottsville, New York, USA to the larger Van Lare Wastewater Treatment Facility near the southern shore of Lake Ontario. In addition to reducing point-source pollution to the Genesee River and improving wastewater treatment efficiency, this move provided the major benefit of freeing up the 200 000 m² (50 acre) site of the former GCO plant to be used in an innovative adaptive reuse project for a long awaited, new centralized public works facility.

FIG. 36. Two stacks in downtown Vienna, Austria.

Monroe County sought to reduce expenditures and improve efficiency of operations by consolidating over a dozen previously scattered public works operations at nine sites throughout the county into one centrally located Interagency Public Works Facility, the new Monroe County Fleet Centre.

With respect to the construction of the facility, the county's goal was to reuse a decommissioned wastewater treatment facility by reusing and adapting as many of its structures and components as possible.

From 2001 to 2005, the county redeveloped 145 700 ft² (13 400 m²) of new building space on the site of the former GCO Plant, including 107 610 ft² (10 000 m²) of adaptively reused structures. The project used innovative design and construction techniques to maximize energy efficiency and to reuse structures and materials while solving difficult engineering challenges.

Outcome: The project included the following benefits:

- Environmental (energy efficiency; waste minimization; non-hazardous; sustainable land use; water discharges (such as stormwater runoff);
- Financial benefits (reduced capital and operating costs, increased tax revenues);
- Other benefits (employee benefits, productivity increases, enhanced reputation and improved customer relations).

6.7. REUSE OF MARINE, FLOATING OR OFFSHORE FACILITIES

Marine structures appropriate for reuse include ships, submarines, floating structures and oil drilling platforms.

FIG. 37. Dublin Distillery Chimney, now an observatory.

6.7.1. Reuse of marine, floating or offshore facilities: The nuclear industry

Reuse of nuclear facilities need not be restricted to land based facilities. Reuse of nuclear powered ships, submarines and naval structures is also practicable.

The NS Savannah, USA [187]

Original use: NS Savannah was the first nuclear powered cargo passenger ship, one of only four nuclear powered cargo ships ever built. It was built under a US Government sponsored initiative and launched in 1962. The ship was not commercially successful and was retired in 1972.

Redevelopment: In 1981, the ship was set up for display at the Patriots Point Naval and Maritime Museum near Mount Pleasant, South Carolina. It was used as a museum but did not attract sufficient numbers of visitors to enable refurbishment. It was dry docked and repaired in 1994 in Baltimore and then moved to the James River Merchant Marine Reserve Fleet near Newport News, Virginia. At this time, the ship still contained many of the primary nuclear systems in a defuelled state.

Outcome: The ship has been further refurbished and currently resides in Norfolk, awaiting further work and removal of the residual nuclear components. It has been designated a national historic landmark and may be preserved as a museum after the final removal of radioactive components.

FIG. 38. The Vienna Water Tower.

FIG. 39. The Vienna Old Installation Chamber.

FIG. 40. A water tower converted into a home in Vienna, Austria.

USS Nautilus, Connecticut, USA [188]

Original use: Launched in 1955, the USS Nautilus was the world's first nuclear powered submarine and the first to cross the North Pole, in 1958.

Redevelopment: The submarine was decommissioned in 1980, designated a national historic landmark in 1982 and converted into a museum in 1985. The ship is housed in the Submarine Force Museum, Groton, Connecticut, and except for the engine room, is fully open to the public.

Outcome: A nuclear powered submarine successfully developed as a museum.

The Lenin Icebreaker, Russian Federation [189]

Original use: The Lenin icebreaker entered service in 1957 as the world's first civilian nuclear powered vessel. It featured three OK-150 PWRs producing 90 MW each, but after operational problems including a partial core melt in 1965, the units were replaced by two OK-900 units producing 171 MW each. Lenin operated the Northern Sea Route until 1989, breaking ice for container ships to follow in its path.

Redevelopment: Lenin had previously been undergoing decommissioning at AtomFlot's facility about 2 km from Murmansk harbour.

Outcome: Lenin has been permanently docked in Murmansk harbour. The ship is expected to be converted to an information centre and Museum of the Arctic Region and the Development of the Northern Sea Route.

Otto Hahn ship, Germany [190]

Original use: The nuclear ship Otto Hahn was propelled by a PWR, which had a power rating of 38 MW t. Construction began in September 1963, with startup in August 1968 and shutdown in February 1979, after 64 532 effective full power hours [191].

Redevelopment: All nuclear fuel and operational wastes have been removed from the installation. All materials, equipment and parts of the nuclear installation in which activity remained significant despite decontamination were removed. The reactor vessel with inlets and outer shielding tank were removed in one piece. In all remaining parts, contamination has been reduced to acceptable levels. The installation was released for unrestricted use.

Outcome: The ship was reused with conventional propulsion.

6.7.2. Reuse of marine, floating or offshore facilities: Non-nuclear industry

Offshore oil and gas rigs, USA [192]

Original use: Oil and gas production platforms that had reached the end of their useful life or that have been damaged. For example, Hurricane Katrina destroyed 46 platforms and severely damaged 20 others, and Hurricane Rita destroyed 69 platforms and damaged 32 others. These storms also destroyed eight drilling rigs and another damaged 19 others.

Redevelopment: The USA has established a programme to enable the option of creating special artificial reefs from the platforms where appropriate. The options involve either complete removal, partial removal or toppling in place. The advantages are environmental: lower decommissioning costs and less risk to divers, especially in the case of damaged rigs.

Outcome: Oil and gas platforms have been reused as artificial reefs.

7. CONCLUSIONS AND RECOMMENDATIONS

There are numerous examples of successful projects where obsolete facilities have been converted into museums, libraries, office buildings, or commercial businesses such as restaurants. These projects can be carried out economically by following a focused assessment, planning, and implementation process, as described in this report [27].

In the coming decades, a large number of nuclear installations will reach the end of their useful lives and require decommissioning; many of them will be decommissioned in order to one. By recognizing and promoting the redevelopment potential of sites early in their 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 and land resources associated with the sites [23].

It would be desirable to develop near term guidance for a regulatory framework for the redevelopment and reuse of nuclear sites. Although each redevelopment and reuse option must be evaluated on a case by case basis, the need to identify uniform reuse guidelines and a framework typical to each industry is just as important as uniform regulatory standards related to redevelopment and reuse. In this context, it is imperative that nuclear and radiological safety assessments be formulated and incorporated in regard to decommissioning end points and redevelopment and reuse provisions.

7.1. REDEVELOPMENT AND REUSE PROCESS MODEL

This process model, shown in Fig. 41, presents factors and attributes that impact redevelopment options and implementation. In redevelopment and reuse option evaluation, the factors and attributes could be weighted and assessed in a multiattribute analysis to determine or justify the choice of a redevelopment option.

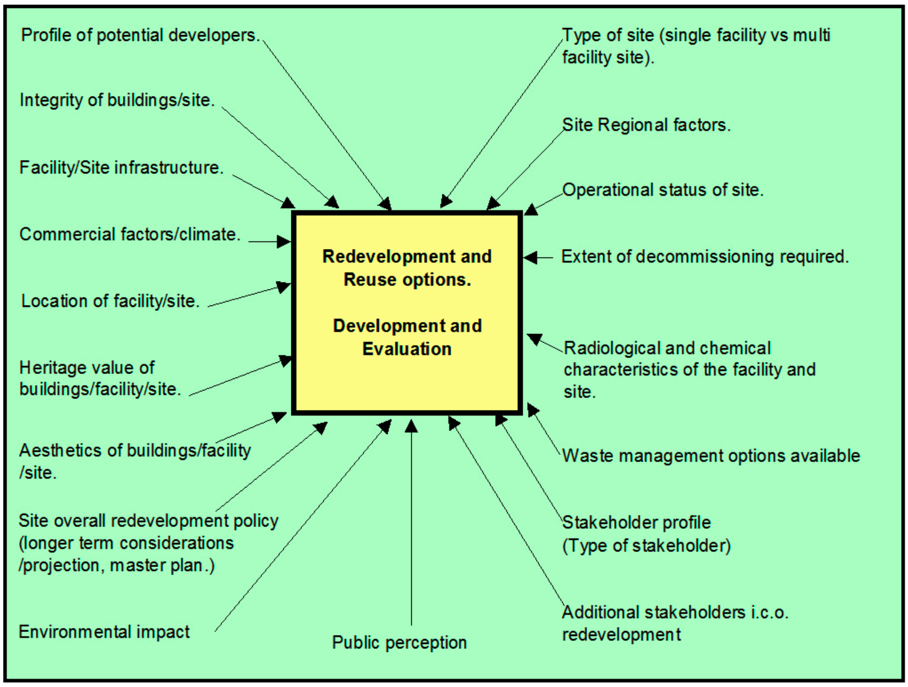

FIG. 41. Factors and attributes that impact redevelopment.

7.2. REDEVELOPMENT AND REUSE GOOD PRACTICE INDICATORS

Table 1 presents good practice indicators that should be applied to the various key performance areas of a redevelopment project.

7.3. FOLLOW-UP WORK

As stated above, redevelopment and reuse opportunities for nuclear facilities and sites are not yet fully investigated. It is vital that experience be collected and disseminated to potential users. One area needing further work is redevelopment and reuse for multifacility sites including facilities under construction, in operation, or being decommissioned.

TABLE 1. INDICATORS OF REUSE AND REDEVELOPMENT

	Key performance areas	Indicators
1	Financial/commercial	Redevelopment and reuse options are optimized in terms of: — Optimized commercial viability; — Optimized decommissioning costs and time schedule; — Redevelopment cost; — Sustainability factors; — Financial risks; — Return on investment.
2	Regulatory compliance	Regulatory requirements, including clearance/release criteria known and reflected in an approved regulatory compliance strategy redevelopment and reuse options covers: — The decommissioning and remediation of existing facilities and sites; — Redevelopment actions; — Construction and operations of redeveloped and reused facilities and sites (addressing compliance with the latest regulatory requirements).
3	Optimized resource utilization	Maximum use of: — Human resources; — Assets, including infrastructure (limited demolition); — Assets for similar purposes; — Assets for adaptive reuse purposes with minimized redevelopment actions; — Historical and aesthetic values of assets, which are evaluated and considered.
4	Stakeholder demands/involvement	— Early stakeholder involvement and an effective communication plan; — Stakeholder involvement in the development of redevelopment and reuse options — a reasonable consensus reached; — Stakeholder demands known, listed and addressed in redevelopment and reuse option evaluation; — Public perception known and addressed in the redevelopment and reuse strategy.
5	Safety and environment	Safety and environmental impact assessed and considered in the development evaluation and selection of reuse options. Impacts to be address in all project phases, i.e. decommissioning, remediation, redevelopment actions, operations and decommissioning of the redevelopment facility and site. The redevelopment and reuse option resulted in: — The reduction of historical hazards and environmental impact; — The reduction of historic waste liability; — Good waste management practice; — Demonstrable safety cases for the redevelopment and reuse options.

Appendix I

EXAMPLES OF REUSE —
US ENVIRONMENTAL PROTECTION AGENCY

US ENVIRONMENTAL PROTECTION AGENCY (EPA) [193]

Table I.1 on recycled superfund sites includes 133 sites in actual or planned use, 31 sites in continued use, and eight sites that are in restored use (172 total sites). 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 EPA has undertaken or has overseen the cleanup at the site, which has allowed it to be used productively during and after the cleanup. **Restored use** has occurred at a site when a pre-existing use has been halted during cleanup, and was resumed after the site was cleaned up. The numbers and primary uses of Recycled Superfund Sites are summarized in Table I.1. Information on original and post-redevelopment uses of selected sites is given in Table I.2, which is based on EPA information.

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

TABLE I.1. NUMBERS AND PRIMARY USES OF RECYCLED SUPERFUND SITES (http://www.epa.gov/oerrpage/superfund/programs/recycle_old/success/sites.htm).

Sites in productive use							
Primary use							
Category	Commercial	Residential	Ecological	Recreational	Agricultural	Governmental	Total
Actual use	64	3	16	15	3	10	111
Planned use	15	—	1	4	—	2	22
Continued use	25	2	—	—	2	2	31
Restored use	5	1	—	—	1	1	8
Total	109	6	17	19	6	15	172

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
			ALASKA	
Standard Steel & Metals Salvage Yard (US Department of Transportation), Anchorage, AK	NPL	Actual use	Scrap yard.	Parking and storage.
			ARIZONA	
Indian Bend Wash Area, Scottsdale/Tempe/Phoenix, AZ	NPL	Actual use	Groundwater contamination.	Student dormitory for Arizona State University and a portion of a state highway.
Phoenix Goodyear Airport, Goodyear, AZ	NPL	Actual use	Airport.	Prefabricated homes manufacturing (Cavco Company).
			CALIFORNIA	
Coalinga, Coalinga, CA	Deleted	Actual use	Asbestos processing area.	K-Mart and residential community.
CTS Printex, Inc., Mountain View, CA	NPL	Continued use	Circuit board manufacturer.	Circuit board manufacturer.
Del Amo Facility, Los Angeles, CA	Non-NPL	Actual use	Rubber plant.	Commercial complex.
Fairchild Semiconductor, Mountain View, CA	NPL	Actual use	Semiconductor solvent storage.	Commercial development of research and office facilities.
Firestone Tire & Rubber Co. (Salinas Plant), Salinas, CA	NPL	Actual use	Firestone Tire & Rubber Co. operated a tire-manufacturing plant. The site includes a 43 acre building on 256 acres of land.	Industrial park.
George Air Force Base (GAFB), Victorville, CA	NPL	Actual use	Military base.	Base Realignment and Closure (BRAC) facility; major cargo hub, planned prison, and police headquarters and training academy.
Lorentz Barrel & Drum Co., San Jose, CA	NPL	Planned use	Lorentz Barrel & Drum Co. recycled drums on this 5 acre site.	Planned parking lot for neighbouring sports venues.
McColl, Fullerton, CA	NPL	Actual use	Waste disposal facility.	Golf course and wildlife sanctuary.
Norton Air Force Base, San Bernardino, CA	NPL	Actual use	Military base.	BRAC facility; public/private mixed use.
Sacramento Army Depot, Sacramento, CA	NPL	Actual use	Military base.	BRAC facility; Packard Bell assembly/distribution plant; and Foodlink warehouses.
South Bay Asbestos, San Jose, CA	NPL	Planned use	Asbestos contaminated fill used in areas of city.	Planned R&D offices, retail, light industrial, restaurant uses.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
Treasure Island Naval Station (Hunters Point), San Francisco, CA	NPL	Actual use	Military base.	BRAC facility; San Francisco Police Department uses the site as a crime laboratory; artists and caterers lease several properties; at the dry dock, a metals-recycler dismantles Navy ships.
TRW Microwave, Inc., Sunnyvale, CA	NPL	Continued use	Semiconductor manufacturing.	Semiconductor manufacturing.
			COLORADO	
California Gulch, Leadville, CO	NPL	Actual use	Mining.	Tourism and recreational use
Denver Radium, Denver, CO	NPL	Actual use	Radium processing facility, then brick manufacturing facility.	Home Depot retail store.
Smuggler Mountain, Aspen, CO	NPL	Actual use	Silver and lead mines.	Homes and historic tour service.
Rocky Mountain Arsenal, Commerce City, CO	NPL	Actual use	Military base and manufacturing complex.	Wildlife refuge.
Central City Clear Creek, Central City, CO	NPL	Actual use	Mining.	Outdoor recreation, casinos, hotels, and restaurants.
Summitville Mine, Summitville, CO	NPL	Actual use	Abandoned gold mine.	Agricultural.
			CONNECTICUT	
Cheshire Ground Water Contamination, Chesire, CT	Deleted	Actual use	Plastic moulding manufacturing facility.	Automotive parts manufacturer.
			DELAWARE	
Army Creek Landfill, New Castle, DE	NPL	Actual use	Municipal and hazardous waste disposal facility.	Wildlife enhancement area and wetlands.
Delaware Sand and Gravel, New Castle, DE	NPL	Actual use	Industrial waste landfill.	Equipment storage.
Dover Gas, Dover, DE	NPL	Restored use	Coal gasification plant; then parking lot for museum.	A museum and parking lot.
E.I.Dupont Newport, Newport, DE	NPL	Continued use	Pigment manufacturer.	Pigment manufacturer.
NCR Corp (Millsboro Plant), Millsboro, DE	NPL	Continued use	Electronic component plant and later a credit card company.	First Freedom Centre — major credit card processing facility
New Castle Spill, New Castle, DE	Deleted	Actual use	Chemical storage and processing area.	New headquarters for the New Castle Department of Public Works.
Standard Chlorine, Delaware City, DE	NPL	Continued use	Chemical manufacturer.	Chemical manufacturer.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
Tybouts Corner Landfill, Wilmington, DE	NPL	Actual use	Sand and gravel operation accepted municipal and industrial wastes.	Wildlife habitat.
Wildcat Landfill, Dover, DE	NPL	Actual use	Disposal facility for municipal and industrial waste.	Wildlife habitat and wetlands.
			FLORIDA	
Alpha Chemical Corp., Galloway, FL	Deleted	Continued use	Polyester resin manufacturer.	Polyester resin manufacturer.
Cabot Carbon/Koppers, Gainsville, FL	NPL	Planned use	Wood treatment.	Planned Dodge dealership.
Cecil Field Naval Air Station, Jacksonville, FL	NPL	Actual use	Military base.	BRAC facility; computer based training software and technical manuals shop; and jet component repair shop.
City Industries, Inc., Orlando, FL	NPL	Actual use	Recycling and transferring station.	Sheet metal work, other industrial use.
Miami Drum Services, **Miami, FL**	NPL	Actual use	Drum recycling business.	Dade County maintenance and repair yard.
Northwest 58th Street Landfill, **Miami, FL**	Deleted	Actual use	Municipal landfill/incinerator.	Ecological reuse and hiking trails.
City Industries, Inc., **Orlando, FL**	NPL	Actual use	Recycling and transferring station.	Sheet metal work, other industrial use.
Miami Drum Services, **Miami, FL**	NPL	Actual use	Drum recycling business.	Dade County maintenance and repair yard.
Northwest 58th Street Landfill, **Miami, FL**	Deleted	Actual use	Municipal landfill/incinerator.	Ecological reuse and hiking trails.
Parramore Surplus, **Mt. Pleasant, FL**	Deleted	Continued use	Storage and distribution facility for [US?] Navy and Air Force surplus equipment.	Storage and distribution facility for Navy and Air Force surplus equipment.
Stauffer Chemical, **Tarpon Springs, FL**	NPL	Planned use	Phosphorus manufacturer.	Planned golf course.
Tri-City Oil Conservation, **Tampa, FL**	Deleted	Actual use	Waste oil collection and distribution centre.	Gas/service station.
			GEORGIA	
Luminous Processes, Inc., **Athens, GA**	Deleted	Actual use	Watch factory.	McDonald’s restaurant.
Marzone, Inc., **Tifton, GA**	NPL	Actual use	Chemical company.	Auto service company.
Monsanto Corporation (Augusta), **Augusta, GA**	Deleted	Continued use	Industrial facility.	Industrial facility.
Woolfolk Chemical Works, **Fort Valley, GA**	NPL	Actual use	Chemical plant.	Library and planned literacy centre.
			IDAHO	
Bunker Hill Mining, **Smelterville, ID**	NPL	Actual use	Mine, mill and concentrator, lead smelter, electrolyte zinc plant, phosphoric acid and fertilizer plant, cadmium plant, and sulphuric acid plants.	Native, coniferous forest; development of nearby ski area facilitated construction of a gondola on-site.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
			ILLINOIS	
Circle Smelting Corporation, **Beckemeyer, IL**	Proposed	Actual use	Zinc smelter.	Parking lot for local trucking company.
Dupage County Landfill/Blackwell Forest Preserve, **Warrenville, IL**	NPL	Actual use	Municipal landfill.	Recreation area with picnic and camping areas, trails, a lake and a 120 ft sledding and hiking hill.
Peterson Sand & Gravel, **Libertyville, IL**	Deleted	Actual use	Quarry.	Lake/outdoor recreation area that will include an educational centre, banquet rooms, boat launch, canoes, picnic area, swimming beach and hiking trails.
			INDIANA	
Columbus Old Municipal Landfill #1, **Columbus, IN**	NPL	Actual use	Landfill.	Portion of site used in expansion of major highway.
Continental Steel Corp., Kokomo, IN	NPL	Actual use	Steel scrap reclamation.	Just-a-Wee Floral Warehouse.
International Minerals Company, Terre Haute, IN,	NPL	Actual use	Chemical plant.	Little league baseball fields.
Southside Sanitary Landfill, Indianapolis, IN	Deleted	Actual use	Landfill.	Landfill; methane gas supplier to Rolls Royce jet engine factory.
Whiteford Sales and Service/National Lease (WSS), South Bend, IN	Deleted	Actual use	Truck washing and leasing facility.	Highway overpass.
			IOWA	
Aidex Corporation, Council Bluffs, IA	Deleted	Actual use	Pesticide production facility.	Equipment storage.
LaBounty Site, Charles City, IA	Deleted	Actual use	Manufacturer of veterinary pharmaceuticals.	Equipment storage for construction company
			KANSAS	
Arkansas City Dump, Arkansas, KS	Deleted	Actual use	Refinery/dump.	Restaurant; industrial park in continued use.
Cherokee County Cherokee County, KS	NPL	Actual use	Mining.	Wildlife enhancement area.
			LOUISIANA	
Bayou Bonfouca, Slidell, LA	NPL	Actual use	Wood treating facility.	Local government offices and equipment storage; boat landing and recreational area.
PAB Oil & Chemical Service, Inc., Abbeville, LA	NPL	Planned use	Oil field waste disposal area.	Planned driving range.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
			MAINE	
Bangor Gas Works, Bangor, ME	Non-NPL	Actual use	Coal gasification plant.	Shaw Supermarket; community park.
Loring Air Force Base, Limestone, ME	NPL	Actual use	Military base.	BRAC facility; public/private mixed use.
Saco Maine Municipal Landfill, Saco, ME	NPL	Planned use	Municipal landfill.	Planned community recreational centre.
			MARYLAND	
Chemical Metals Industries, Baltimore, MD	Deleted	Actual use	Precious metals recovery facility and gas station.	Neighbourhood park with parking area; Maryland Department of Environmental Protection field office.
Kane & Lombard, Baltimore, MD	NPL	Actual use	Landfill.	Golf driving range.
Mid-Atlantic Wood Preservers, Harmans, MD	NPL	Actual use	Wood treatment facility.	Parking lot for neighbouring industry.
			MASSACHUSETTS	
Army Materials Technological Laboratory (US ARMY), Watertown, MA	NPL	Planned use	Military base.	BRAC facility; planned yacht club, business centre, public park, and weapons research.
Cannon Engineering Corporation, Bridgewater, MA	NPL	Actual use	Waste disposal facility.	Propane distribution business.
Fort Devens, Fort Devens, MA	NPL	Actual use	Military base and training complex.	BRAC facility; public/private mixed use; warehouse and distribution centre; research and development facilities for several computer and graphics firms; a jobs corps centre; a wildlife refuge; and an army training site.
Fort Devens — Sudbury Annex, Sudbury, MA	NPL	Actual use	Military base and training annex to Fort Devens.	BRAC facility; wildlife refuge.
Industri-Plex, Woburn, MA	NPL	Planned use	Chemical manufacturer.	Planned Target retail store.
South Weymouth Naval Air Station (SWNAS), Weymouth, MA	NPL	Planned use	Military base.	BRAC facility; planned shopping mall and entertainment centre, office space, housing for the elderly housing, shelter for the homeless, a golf course, and a recreational and open space.
			MICHIGAN	
Allied Paper/ Portage Creek, Kalamazoo River, MI	NPL	Restored use	Paper mill.	Organic roofing material manufacturer.
Anderson Development Co., Adrian, MI	Deleted	Continued use	Specialty chemical manufacturer.	Specialty chemical manufacturer.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
Folkertsma Refuse, Grand Rapids, MI	Deleted	Continued use	Sanitary and industrial landfill; pallet manufacturer.	Pallet manufacturer.
H. Brown Company, Inc., Kent, MI	NPL	Actual use	Nonferrous metals reclamation.	Warehouse and light industrial complex.
Hedblum Industries, Oscoda, MI	NPL	Actual use	Automobile parts manufacturer.	Aircraft tool company.
Lower Ecorse Creek Dump, Wyandotte, MI	NPL	Continued use	Residential.	Residential.
Wurtsmith Air Force Base, Oscoda, MI	Proposed	Actual use	Military base.	BRAC facility; commercial use.
			MINNESOTA	
Boise Cascade/Onan Corp./Medtronics, Inc., Fridly, MN	Deleted	Continued use	Railroad tie and pole treatment until the 1960s; power generator system manufacturer and corporate headquarters of medical products manufacturer.	Power generator system manufacturer and corporate headquarters of medical products manufacturer.
General Mills/Henkel Corp., Minneapolis, MN	NPL	Actual use	Technical centre and research laboratories.	Business enterprise development facility supporting nearly 100 start-up businesses.
Koppers Coke, Oroville, MN	NPL	Actual use	Coking facility.	Hi-tech industrial park.
MacGillis & Gibbs Co./ Bell Lumber and Pole Site, New Brighton, MN	NPL	Actual use	Manufacturing plant.	Purchased by the City of New Brighton for public, commercial and industrial use.
NL IND Taracorp Golden Auto, St. Louis Park, MN	NPL	Actual use	Lead smelter.	Parking lot for adjacent hospital.
Reilly Tar &Chem (St. Louis Park Plant), Hennepin, MN	NPL	Actual use	Creosote production plant.	Park, apartment building, town homes.
Waite Park Wells, Waite Park, MN	NPL	Actual use	Burlington Northern Railyard.	City owned little league baseball fields; planned indoor recreation. facility, office warehouses and office buildings
Whittaker Corp., Minneapolis, MN	Deleted	Actual use	Industrial coating manufacturer.	Welding supply company.
Union Scrap, Minneapolis, MN	Deleted	Actual use	Lead battery recycler.	Parking lot for supply company.
			MISSISSIPPI	
Flowood Site, Flowood, MS	Deleted	Continued use	Manufacturing plant.	Manufacturing plant.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
			MISSOURI	
Fulbright Landfill, Springfield, MO	NPL	Planned use	Municipal landfill.	Planned walking trails.
Oronogo-Duenweg (Jasper Co), Jasper County, MO	NPL	Actual use	Mining.	Scrap metal recycling centre; Missouri Dept. of Transportation plans to use a portion of the site to construct a highway.
Times Beach Site, Times Beach, MO	NPL	Actual use	The City of Times Beach with widespread road contamination.	Waterfowl sanctuary; horseback riding.
Wheeling Disposal Service Co. Landfill, Amazonia, MO	NPL	Actual use	Industrial waste disposal facility.	Wildlife reserve.
			MONTANA	
Anaconda Company Smelter, Anaconda, MT	NPL	Actual use	Smelting operations.	Golf course.
East Helena, East Helena, MT	NPL	Actual use	Lead smelter contamination.	School constructed; planned residential and commercial areas; baseball field.
Milltown Reservoir, Milltown, MT	NPL	Actual use	Tailings pile.	Wildlife/ recreational/ educational area with a trail system including a foot bridge across a reservoir.
Silver Bow Creek, Silver Bow/Deer Lodge County, MT	NPL	Actual use	Mine.	Ball fields, wetlands.
			NEBRASKA	
Hastings Groundwater Contamination, Hastings, NE	NPL	Actual use	Contaminated groundwater; agricultural, industrial, and residential uses.	Treated groundwater used in cooling operations at local power plant and to water an area park; continued agricultural, industrial and residential uses.
Lindsay Manufacturing Co., Lindsay, NE	NPL	Actual use	Manufacturing plant; contaminated groundwater.	Treated groundwater redirected for crop irrigation.
			NEW HAMPSHIRE	
Pease Air Force Base, Portsmouth/Newington, NH	NPL	Actual use	Military base.	BRAC facility; 1110 acres National wildlife refuge; 3265 acres available to Pease Development Authority; commercial airport and high technology/corporate centre.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
			NEW JERSEY	
American Cyanamid Company, Bound Brook, NJ	NPL	Planned use	Industrial waste disposal facility.	Planned 6300 seat minor league baseball stadium and 700 000 ft of retail/hotel or office space.
Cooper Road, Voorhees Township, NJ	Deleted	Actual use	Midnight dumping area.	Residential.
DeRewal Chemical Company, Kingwood Township, NJ	NPL	Actual use	Chemical manufacturing.	Part of the site will be used as a bike path.
Lipari Landfill, Pitman, NJ	NPL	Actual use	Chemical waste dump.	Recreational area.
Vineland State School, Vineland, NJ	Deleted	Continued use	Unregulated incinerator and landfill located at school for mentally handicapped women.	School for mentally handicapped women.
			NEW YORK	
Kenmark Textile Corporation, Farmingdale, NY	NPL	Continued use	Textile dye, printing, and screening.	Textile dye, printing, and screening.
Love Canal, Love Canal, NY	NPL	Restored Use	Industrial landfill; residential.	Residential; light commercial industry
Marathon Battery, Cold Spring, NY	Deleted	Actual use	Nickel-cadmium battery plant.	Purchased by Hudson River Scenic Land in order to preserve wildlife area.
Old Bethpage Landfill, Oyster Bay, NY	NPL	Actual use	Landfill.	Waste transfer station, commercial methane gas supplier.
Rosen Brothers Scrap Yard/Dump, Cortland, NY	NPL	Planned use	Wire manufacturing and scrap yard.	Part of the site (5 acres) will be used for an access road to an intermodal rail facility.
SMS Instruments, Inc., Deer Park, NY	NPL	Actual use	Metal degreasing and refurbishing operations.	Kitchen, bathroom, and household utensils manufacturer.
Tronic Plating Company, Farmingdale, NY	NPL	Actual use	Electroplating and anodizing services.	Small businesses on the site.
Wide Beach Development, Brant, NY	Deleted	Continued use	Residential	Residential.
			NORTH CAROLINA	
Celanese Corporation, Shelby, NC	Partially Deleted	Continued use	Chemicals, fibres and plastics manufacturer.	Manufacturer of polyester resin and fibre.
			OHIO	
Bowers Landfill, Circleville, OH	Deleted	Actual use	Landfill.	Wetlands.
			OREGON	
Martin-Marietta Aluminium Co., The Dalles, OR	Deleted	Restored Use	Aluminium production.	Aluminium production.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
			PENNSYLVANIA	
Centre County Kepone, State College Borough, PA	NPL	Actual use	Chemical manufacturer.	Sidewalk, road improvements and storm piping system
Commodore Semiconductor Group Site, Norristown, PA	NPL	Restored Use	Semi-conductor chip manufacturer.	Prospective Purchaser Agreement with EPA enabled a new owner to reopen the bankrupt semiconductor chip manufacturing plant.
Crossley Farms, Hereford Township, PA	NPL	Continued use	Farm.	Farm.
Drake Chemical, Lock Haven, PA	NPL	Continued use	Specialty and chemical manufacturer.	Specialty and chemical manufacturer.
Enterprise Avenue, Philadelphia, PA	Deleted	Planned use	Unauthorized dumping ground for sludge, solvents, oils and resins.	Planned commuter runway at Philadelphia International Airport under construction.
Hellertown Manufacturing Co., Hellertown, PA	NPL	Actual use	Spark plug manufacturer.	Small manufacturer.
Kimberton Site, Kimberton Borough, PA	NPL	Continued use	Asphalt manufacturer.	Asphalt manufacturer.
Metropolitan Mirror and Glass, Frackville, PA	NPL	Continued use	Glass manufacturer until 1982; St. Jude Polymer began recycling plastic bottles in 1987.	St. Jude Polymer Co. continues to recycle plastic bottles.
Mill Creek Dump, Erie, PA	NPL	Planned use	Dump for foundry sands, solvents, waste oils, and other industrial and municipal wastes.	Planned golf course.
North Penn Area 12 Site, Worcester, PA	NPL	Planned use	Electric motor manufacturer.	Planned tool catalogue sales distribution operation.
Ohio River Park, Neville, PA	NPL	Actual use	Dumping ground for coke, cement, pesticides, coal tar, benzene, arsenic, mercury and phenols.	Sports-recreation centre with two indoor ice-skating rinks has been constructed and is in use; other recreational facilities are under construction.
Publicker Industries Inc., Philadelphia, PA	NPL	Planned use	Alcohol distillation and production.	Planned construction of a $250 million multi-purpose shipping terminal in the Port of Philadelphia expansion project.
Resin Disposal, Jefferson Borough, PA	NPL	Planned use	Landfill.	Methane gas collection facility and bird habitat.
Revere Chemical, Nockamixon Township, PA	NPL	Actual use	Metals reclamation company.	Migratory birds habitat.
Saegertown Industrial Area, Saegertown, PA	Partially Deleted	Continued use	Polymer manufacturing facility.	Polymer manufacturing facility.
Stanley Kessler (King of Prussia), King of Prussia, PA	NPL	Continued use	Welding wire manufacturing operation.	Welding wire manufacturing operation.
Westinghouse, Sharon, PA	NPL	Actual use	Electrical equipment manufacturer.	Sheet galvanizing plant; tubular products warehouse.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
Westinghouse Elevator Company Plant, Gettysburg, PA	NPL	Continued use	Elevator manufacturer.	Elevator manufacturer.
Westline Site, Westline, PA	Deleted	Continued use	Wood processing facility and chemical plant; the Westline Inn opened on-site in the 1950s.	Westline Inn — hotel, restaurant, and recreation area.
			PUERTO RICO	
Naval Security Group Activity, Sabana, PR	Deleted	Actual use and Continued use	Naval communications station; Public Works Department and Pest Control Shop area contaminated with pesticides.	Naval communications station; pesticide contamination area remediated and asphalt cap used for parking.
			RHODE ISLAND	
Davisville — NCBC, North Kingston, RI	NPL	Actual use	Military base.	BRAC facility; beverage warehouse, public works garage, plastic/metal recycling facility, plastic film manufacturing, current port and commerce park w/room for expansion.
Peterson-Puritan, Cumberland, RI	NPL	Actual use	Several manufacturing plants.	Prospective Purchaser Agreement with EPA enabled a new company to occupy a closed manufacturing facility at the site.
			SOUTH CAROLINA	
Carolawn, Inc., Fort Lawn, SC	NPL	Actual use	The Carolawn, Inc. site is an abandoned 3 acre waste storage and disposal facility that was owned by various companies until the Carolawn Company bought the site in 1977.	Turkey feed mill.
Independent Nail Company, Beaufort, SC	Deleted	Restored Use	Screw and fastener manufacturing.	Panel nail coating operation.
Lexington County Landfill, Cayce, SC	NPL	Actual use	Landfill.	Golf driving range.
Rock Hill Chemical Co., Rock Hill, SC	NPL	Actual use	Solvent distillation facility.	Automotive services.
			SOUTH DAKOTA	
Whitewood Creek, Whitewood, SD	Deleted	Actual use	Mining area and tailings dumps; residential properties; creek used for irrigation, watering livestock, and recreation.	Residential properties; creek used for irrigation, watering livestock and recreation.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
			TEXAS	
Crystal City Airport, Crystal City, TX	Deleted	Restored Use	Private airport and crop dusting operation.	Public airport.
French, Ltd., Crosby, TX	NPL	Actual use	Waste pit.	Management consulting firm and nature walks and fishing.
RSR Corporation, Dallas, TX	NPL	Actual use	Smelter.	Retail shopping centre.
			UTAH	
Monticello Mill Tailings, Monticello, UT	NPL	Planned use	Vanadium mill.	Planned golf course.
Pallas Yard, Murray City, UT	Proposed	Planned use	Freight railyard.	Planned commuter light rail.
Tooele Army Depot, Tooele, UT	NPL	Actual use	Consolidated maintenance facility.	BRAC facility; Detroit Diesel engine refurbishing plant.
			VIRGINIA	
Abex, Portsmouth, VA	NPL	Planned use	Railroad bearings casting plant.	Planned police and fire department headquarters and recreation centre
Atlantic Wood Industries, Portsmouth, VA	NPL	Continued use	Lumberyard.	Lumberyard and pre-stressed concrete operations.
Chisman Creek, Seaford, VA	NPL	Actual use	Disposal area for fly ash.	Recreational park facility with sports fields and walking trails.
Saunders, Chuckatuck, VA	NPL	Continued use	Lumber yard.	Lumber yard; plant nursery.
			WASHINGTON	
ALCOA (Vancouver Smelter), Vancouver, WA	Deleted	Continued use	Aluminium smelter and disposal areas.	Aluminium smelter.
American Crossarm, Chehalis, WA	NPL	Actual use	Smelter.	Light industrial park with wetlands.
Asarco Smelter, Tacoma, WA	NPL	Planned use	Smelter.	Planned amphitheatre.
Commencement Bay /Near Shore Tide Flats, Pierce County, WA	NPL	Actual use	Smelter.	Port redevelopment.
FMC Corp (Yakima Pit), Yakima, WA	NPL	Actual use	Pesticide formulations plant.	Metal fabricator.
Hanford Site 1100 Area, Benton County, WA	Deleted	Actual use	DOE nuclear complex.	Diesel locomotive maintenance company.
Northwest Transformer (South Harkness St), Everson, WA	Deleted	Actual use	Transformer refurbisher/manufacturer.	Public parking lot.
Pacific Sound Resources, Seattle, WA	NPL	Actual use	Wood treatment.	Part of container port expansion project.

TABLE I.2. NATIONAL PRIORITIES LIST (NPL): ORIGINAL AND POST-REDEVELOPMENT USES (cont.)

Site name and location	NPL status	Use category	Original use	redevelopment and reuse
Port Hadlock (US Na**vy,** Indian Island, WA	NPL	Actual use	Landfill.	Recreational beach access; fishing area.
Silver Mountain Mine, Loomis, WA	Deleted	Actual use	Precious metal extraction operation.	Cattle grazing land.
Spokane Junkyard, Spokane, WA	Deleted	Actual use	Junkyard.	Sports fields.
Wyckoff Co./Eagle Harbour, Bainbridge, WA	NPL	Actual use	Wood treatment, ferry navigation lanes, marinas, boat yards, and boat transit.	Portion of shipyard converted to parking lot for ferry traffic.
Toftdahl Drums, Brush Prairie, WA	Deleted	Actual use	Drum cleaning and re-sale operation.	Residential homes.
		WISCONSIN		
Northern Engraving Co., Sparta, WI	Deleted	Continued use	Decorative metal company/metal finishing.	Decorative metal company/metal finishing.
		WEST VIRGINIA		
Follansbee, Follansbee, WV	Final	Continued use	Coal tar processing plant.	Coal tar processing plant.
Leetown Pesticide, Leetown, WV	Deleted	Continued use	Beef & dairy cattle, operating landfill, pesticide disposal area, US Fish & Wildlife facility.	Dairy cattle, US Geological Survey facility (formerly US Fish and Wildlife).

Appendix II

CONCEPTUAL APPROACH FOR CHOOSING FUTURE LAND USE

This appendix is largely an elaboration of Ref. [194]. It provides a conceptual approach to determining the optimal use of a site/facility.

II.1. OBJECTIVES AND RESTRICTIONS

Remediation objectives and the technologies used to achieve them must be evaluated in terms of their potential impact on future land use. One of the overarching objectives is that the remediation not only improves the radiological situation, but also does not result in undue detriment to other properties of the site.

In practice, the possible land use depends on the degree of restrictions placed on it due to any residual contamination remaining. Restricted use (industrial or commercial) or unrestricted use (residential or agricultural) as targets influence the kind of technology to be implemented and level to which remediation has to take place. The degree of restrictions to be applied may also vary between areas forming part of a larger contaminated site.

Certain parts of a 'site' may not have received any contamination at all, and therefore could be turned to other uses without restriction. For example, it is estimated that only about 6% of the approximately 77 000 km^2 of land associated with USDOE activities are actually contaminated. Much of this land served as buffer zones around the facilities and owing to very restricted human access now supports thriving and valued eco-systems. This in turn may impose restrictions on alternative uses from a nature conservation point of view.

Information on pre-existing plans can be obtained from land management plans, land use decisions, zoning regulations, building regulations, or any other relevant spatial planning instruments available in the respective Member State. If future land use is unknown or undecided, a common assumption may be made for all remediation options. Land use, however, can also be a variable in itself for the decision making process, allowing for optimization within certain constraints, for example, the criteria justifying remediation.

Release of land for 'restricted use' implies reliance on the continuing existence and retention of institutional control. Such 'control' can take the form of signs warning the public against trespassing or other activities, of fencing in and imposing of planning restrictions, usually at the local, or even national level, to prevent and control alternate land use. The applicability, feasibility and efficiency of the respective measures may vary considerably from Member State to Member State, depending on the socio-cultural circumstances, how much respect administrative authorities are able to draw on and the economic circumstances. There are numerous instances where scarcity of available land, breakdown in governance or lack of communication has led re-occupation of contaminated land. Remediation options relying on institutional control need to be assessed with respect to their realistic sustainability.

Land use after environmental remediation can also be a public participation and community issue. The issue often is part of a broader transition in the local economy. The contaminated site may have been part of the operation of a major local employer, which no longer exists or has changed the market sector, with ensuing changes in employment levels and structures.

Chosen end-points for remediation and hence the amount and form of residual contamination can put restrictions on certain forms of land use. For instance, for a given set of environmental conditions, the residual contamination may be stable in the soil column; introducing irrigation, however, may lead to increased mobility of radionuclides. Hence, if such scenarios are foreseen, appropriate measures have to be taken.

A vast amount of experience has been accumulated, mainly in the context of revitalization of former industrial and commercial sites. Although planning procedures and requirements, and the related legal instruments will vary from Member State to Member State, some common general features and requirements can be observed, as indicated in the following paragraphs.

II.2. LAND USE AND REDEVELOPMENT PLANNING

A comprehensive planning strategy for the use or redevelopment of land needs to include an analysis of potential consequences from changes in land use, and strategies for maintenance (and possibly, improvement) of environmental quality. The planning needs to be based on a comprehensive process that involves stakeholder input during which ongoing and emerging site issues are identified.

II.2.1. Questions to Answer

A land use plan needs to answer the following questions:

(1) What property or part of the property is available for reuse or redevelopment?
(2) What is the most beneficial use of the property?
(3) How can the property be transferred to the future user(s)?

II.2.2. Structure of a Land Use Plan

A land use plan needs to include three basic components:

— A land use section, which identifies local property use characteristics, such as heavy industry, residential, light industry, and educational, and historic districts;
— An economic feasibility analysis of the land use plan, which includes both market analysis and fiscal analysis components;
— An infrastructure section, which evaluates the condition of both the utility and transportation systems on the property, and which projects both the capital improvement and annual operating costs that would be incurred in the course of the plan's implementation period.

A comprehensive land use plan might be structured as follows:

— *Regional Overview*: Provide the general context for government/owner and stakeholder discussions on-site issues and influences.
— *Site Conditions*: Address the evolution and general state of the property.
— *Planning Process*: Identify site development goals, the general planning process and methodology.
— *Planning Analysis*: Examine site development concepts in response to current site issues and trends.
— *Strategy*: Present plans for implementation of property transfer initiatives.
— *Master Plan*: A diagrammatic illustration of the planned long term development of a site.

In determining the most beneficial reuse, the plan needs to thoroughly examine possible uses of a property, their benefits, disadvantages and constraints on future use in the context of the property's specific characteristics. Ideally, the plan provides: a summary of the site and its facilities, including the estimated operational closure date, total property available for redevelopment, number of parcels to be released or planned for release; an environmental summary of current and future environmental cleanup and monitoring activities; and a statement of the general environmental condition of the property. In addition, depending on-site specific circumstances, the plan needs to cover:

— Marketing of facilities (buildings, transportation, and utilities) to new owners/users;
— Negotiation of property transfer or leases;
— Negotiation of care and custody agreements;
— Environmental remediation to enable the transfer of property;
— Acquisition of funding for continued conversion efforts (planning and implementation);
— Feasibility studies to assist in the successful implementation of specific components of the reuse plan, such as the creation of a heritage district or educational programmes;

— Retraining and re-employment of those who have lost jobs, directly or indirectly, as a result of the contamination;
— Creation of jobs in the community to replace the revenue lost directly through reductions in payroll taxes;
— Property taxes, as well as through indirect impacts, such as lost sales tax revenue;
— Reuse of the facilities on the property so that the local government might generate revenue to cover the costs involved in its newly acquired responsibilities of maintaining and servicing those facilities, such as the provision of police and fire services and municipal utilities such as water service;
— Using the property transfer as an opportunity to revitalize the local community; and
— Mitigating the impacts on the community at large, from both the business and the social service perspectives.

In the interest of the public, a most beneficial use of surplus land in government ownership is to be sought that reflects a balance among various goals, including maximum return to the taxpayer, wise land stewardship, adherence to community values, economic development, environmental protection, cultural and natural resource preservation, and aesthetic value. For some sites, the most beneficial use will be readily evident to all interested and affected parties (http://lts.apps.em.doe.gov/centeredevelopment and reuseeports/doc1/1_c.html).

For example, if a site is already industrial and can be reused to create jobs as an industrial area, the reuse determination is likely to be relatively simple. For other sites, where multiple uses are feasible and natural and/or cultural resources are present, determining the most beneficial use may be more complex.

The most beneficial use will depend on the site's particular traits, strengths and weaknesses, as well as the goals that the site, affected governments and communities, and other interested parties would like to fulfil through reuse. Therefore, the most beneficial use of one property at a site may be industrial reuse, while the most beneficial use of a different parcel of the same site may be as a recreational space or habitat preserve. Establishing the most beneficial use of a site requires a sound understanding of its specific features and legal and environmental status, and the reuse constraints that may be imposed. Information gathered through site assessments, environmental audits, cultural resource plans and other research must be considered when evaluating alternative future uses.

A useful way to begin the 'most beneficial use' determination is by conducting a property appraisal to assess a site's financial value. By analysing the property's specific physical and legal features, the area and infrastructure surrounding the facility, zoning, comparable properties and market needs, the appraisal suggests the highest and best use that would result in the greatest financial value. The market value reflects the expected financial return of the property given its most profitable and allowable use, based on data concerning similar uses in that community.

However, although appraisals are useful tools in determining market value, this financial appraisal does not capture a site's less quantifiable values, such as ecological diversity, cultural resources, and recreational opportunity. One must turn to the community and other affected and interested parties to ensure that these less tangible benefits enter into the most beneficial use determination. The environmental impact assessment (EIA) instrument would also provide valuable insight.

A number of important facts influence how the site can and may be reused. For example, the legal status of property and its environmental conditions may clearly limit the range of its future uses. In addition, reuse might be limited due to physical deficiencies of the facility, inadequate supporting infrastructure, or zoning not easily subject to modification.

On the other hand, a site may have attractive characteristics such as ecological diversity or cultural artefacts that need to be considered in the reuse determination. Some members of the public will be interested in preserving these resources, while others will see them as barriers to other types of development and reuse.

Deciding on the best use of a property will be more realistic and efficient if all affected parties are aware of these constraints and considerations from the beginning. Some property use limitations may be permanent, while other restrictions might be lifted in specific time frames. All interested parties need to understand the property's unique features, any constraints that limit reuse, and the rationale behind these limitations.

After the constraints on future use as well as the property's specific characteristics are fully understood, the range of possible uses, their benefits and disadvantages can be discussed. It may be considered which reuse alternatives have the greatest feasibility given current market conditions, the property appraisal, public support, and information about prospective users.

Affected governments and the public can be encouraged to express their interests in promoting economic development, preserving habitat or aesthetic value, or serving other goals through reuse. As the interested parties discuss the various uses, it needs to be evaluated how each reuse alternative fulfils one or more community values with a view to develop reuse options that potentially satisfy multiple interests. Ideally, this preferred use will strike a balance between various goals, including maximum return to the taxpayer, wise land stewardship, economic development, environmental protection, cultural and natural resource preservation, and aesthetic value. Community support is particularly critical in cases where institutional controls are needed to ensure a specific, limited use. A site may have multiple reuse alternatives with each option satisfying one or more particular values.

One interesting example of a consultation process and a methodology to choose the best practicable environmental option for the site end state has been published for the Dounreay site, Scotland, UK. As known, Dounreay has a great deal of obsolete nuclear facilities, including reactors, fuel cycle facilities, R&D facilities, laboratories and administrative buildings. The Nuclear Decommissioning Authority (NDA) has strategic responsibility for the UK's nuclear legacy. The NDA Strategy requires sites to review site end states in consultation with stakeholders. The five options selected for stakeholder assessment (Dounreay Stakeholder Group, DSG) and further screening were [195]:

— Minimal restoration of the site;
— Remaining a licensed site, cleared of redundant buildings;
— Restored site, with natural attenuation;
— Restored site, with early release of land;
— Maximum practicable restoration.

More detailed information on these options is given in [196]. Following extensive debate, the DSG's preferred End State for the Dounreay Site is Option 4 — Restored Site, with Early Release of Land, but this is conditional on the following [197]:

— NDA working more closely with all the agencies responsible for socioeconomic development to maximize the exploitation of the skills and assets of the Dounreay site, since the NDA has identified Caithness & Sutherland as a 'priority geographical area', as per DSG's wishes.
— The Enterprise Agency must consider site reuse as part of any regional development and regeneration initiatives.
— The NDA must not encourage the Dounreay site operators to accelerate decommissioning to such a level that future reuse of potentially suitable existing and planned infrastructure is effectively ruled out.
— The end state for the particle contamination issue and the End State for the neighbouring Vulcan site must be recognized within the chosen Dounreay End State.
— There must be some degree of flexibility in definition of the End State to ensure that the community can capitalize on any opportunities that may arise in the future. As a minimum, the End State should be reviewed routinely together with the NDA Strategy.

Appendix III

REDEVELOPMENT TO PRESERVE INDUSTRIAL HERITAGE

This section elaborates Refs [198, 201].

Industrial archaeology, which emerged as a discipline in the 1950s, was first concerned with interpretation of surviving physical evidence to understand past human activity. Later on, and for the purposes of this report, it was recognized as a preservation movement concerned with ensuring the survival of a significant proportion of the industrial monuments of the past. In the latter sense, 'industrial heritage' was coined and the two terms 'industrial archaeology' and 'industrial heritage' are often taken to be synonymous.

The traditional building blocks of heritage protection have been different types of assets: listed buildings, scheduled ancient monuments, areas of architectural and historic interest, or protected landscapes. Yet, it can be difficult to draw lines around what is important when a building sits in a landscape that is in turn part of a wider area. The idea of historic environment enables us to look at places as a whole. It also brings heritage closer to environmental thinking, since some of the same ideas about management, diversity and sustainability read across to a more environmental approach. Moreover, the wider values of the heritage should be recognized — as a learning resource, a social resource that involves people, as part of the environment and as a contributor to the economy. This is particularly important, since it signals a move away from heritage as a narrow, specialist interest, to recognizing that it is something that has relevance to many areas of modern life.

Nevertheless, the idea of a historic environment with broad-ranging social and cultural values as well as historical value raises a number of problems. How, then, can society function, the economy develop or people live their lives effectively if this is followed? The key lies not so much in what is protected, but in how change occurs. The challenge for anyone operating the system is rather one of how to manage change: how to ensure that what is important is kept for future generations, without compromising the ability of present generations to meet their own needs?

Adaptive reuse is the act of finding a new use for a building or area. It is often described as a process by which structurally sound, older buildings are developed for economically viable new uses. The recycling of buildings initially developed as a method of protecting historically significant buildings from demolition. Adaptive reuse is a form of rehabilitation, as a variety of repairs or alterations to a building that allow it to serve contemporary uses while preserving features of the past.

Adaptive reuse should always be favoured over demolition. There are countless reuse options available for industrial buildings. Some of the most popular conversions are of industrial buildings to museums, art studios, live-work units, offices, residential units, schools and retail, and increasingly are combining several uses together. Indeed, the only industrial buildings that have survived were those that were reused. It is not the scale or size that determines whether a structure survives, but whether it has been reused. The survival of cheap and flexible premises remaining after industries closed in the early 20th century acted as an incentive for new industries to move into the area. Instead of the area stagnating as it might have done, there were probably more new industries than at any other time, restarting the industrial cycle (Fig. 42).

If industrial heritage is seen as backward looking, as a drag on regeneration and economic development, and symbolic of decline and failure, then its future will continue to be questioned. Consequently, the key approach should relate to the focus of current regeneration programmes.

It is very difficult to overstate the negative impact of a derelict and unmanaged industrial building on an urban area and its population: it holds down economic value, reduces confidence, may attract anti-social behaviour, and gives a message of failure and a lack of care and responsibility. Moreover, there is a general negative public perception, and sympathy for demolition. While science and industrial museums continue to attract support, the wider industrial heritage is unlikely to match the current public perception of valued heritage without a sustained campaign of access and education. This will also need to challenge the prevalent view that the industrial period is one that is best forgotten or removed from view (other than in the safety of a museum). For example, the very concept of a museum should be changed. Industrial heritage sites transformed into museums are not only places of education and information, but also have an important symbolic value. Due to reconstructions of the past, museums are not places where memories are relived, but spaces for creating them. In newer industrial sites with reconstructed surroundings and machinery, grandparents can tell stories of 'the way we were' to their grandchildren and thus

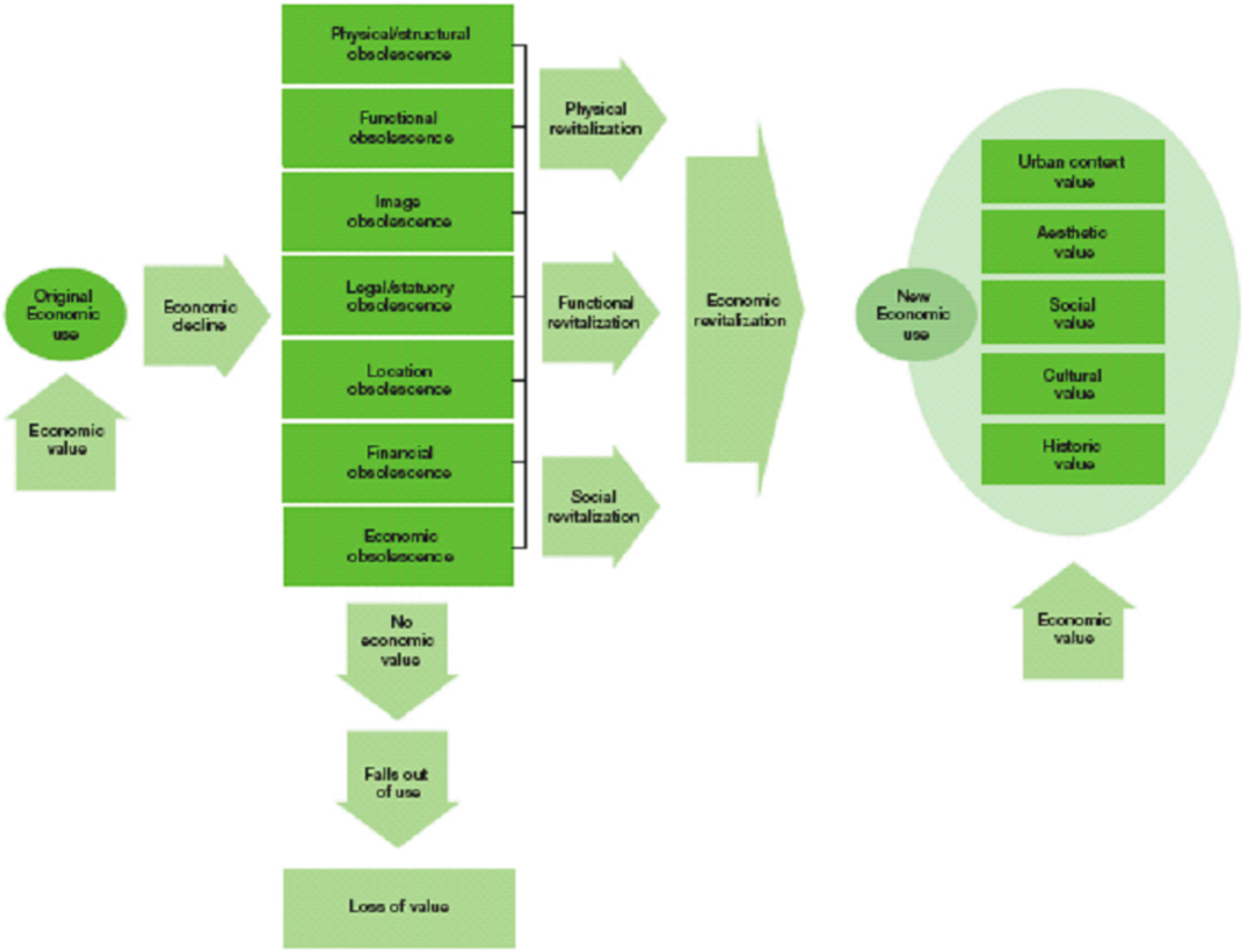

FIG. 42. The process of economic growth, decline and growth.

provide them with a direct link to a world that they never experienced. In addition, as heritage issues are forced ‘downstream’ in the change management process, the perception of heritage as a negative issue becomes reinforced, leading to less, rather than more, involvement. A better approach is to harness and integrate the historic environment at an early stage. In this way, the results can be both financially successful and deliver attractive redevelopment. In other words, the industrial landscape should be conceived as a living and functioning space, where protection is a form of managing the changes affecting the site, not a general list of restrictions and limitations.

In conclusion, today it is necessary to engage knowledgeably and confidently with the change process in order to open eyes to opportunities. Reuse of buildings and whole landscapes into new and productive uses while securing their integrity and their meaning in the landscape is one desired approach.

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Annex I

PROJECT CASE STUDIES

The examples provided in this annex address a wide range of redevelopment and reuse examples of decommissioning projects in several countries. This material is intended to illustrate how the issues described in the main sections of this report have been managed in actual project conditions. The aim is to provide general practical guidance to approaches that have had some success, rather than to present best practices for replication since they each have elements that will be specific to the project, site and national context in which they were undertaken. Further examples of lessons learned from project experience are presented in Annex II.

Annex A. I–1. Canada, Atomic Energy of Canada Limited (AECL), Chalk River Labs: Reuse and Licence Termination of a number of facilities at the Chalk River Labs to allow for refurbishment of the site

A.I–1.1. INTRODUCTION

Chalk River Labs is located along the Ottawa River in Ontario, Canada, approximately 200 km north-west of Ottawa. The site began construction in 1944 following the expropriation of approximately 1 500 ha of land. A number of research reactors were constructed at the site along with numerous nuclear labs, hot cells and administrative facilities in support of the research and development work planned for the site. Figure I–1.1 shows an aerial photo of the site and Fig. I–1.2 provides a map showing the site location.

The principal occupants of the Chalk River site are AECL employees with a strong presence from National Resources Canada (NRC) and other small research groups. The site is undergoing substantial changes with an emphasis on minimizing the impact of increasing the builtup area footprint in conjunction with site upgrades and new build projects. To accomplish this task, a number of refurbishment and decommissioning projects were planned. Decommissioning projects were initiated to make room for new development through a number of initiatives. The decommissioning mandate includes the removal of a select group of original deteriorating facilities to make room for new construction and to decommission other facilities to facilitate redevelopment and reuse of the available space.

FIG. I–1.1. Aerial view of Chalk River Laboratories, Chalk River, Ontario.

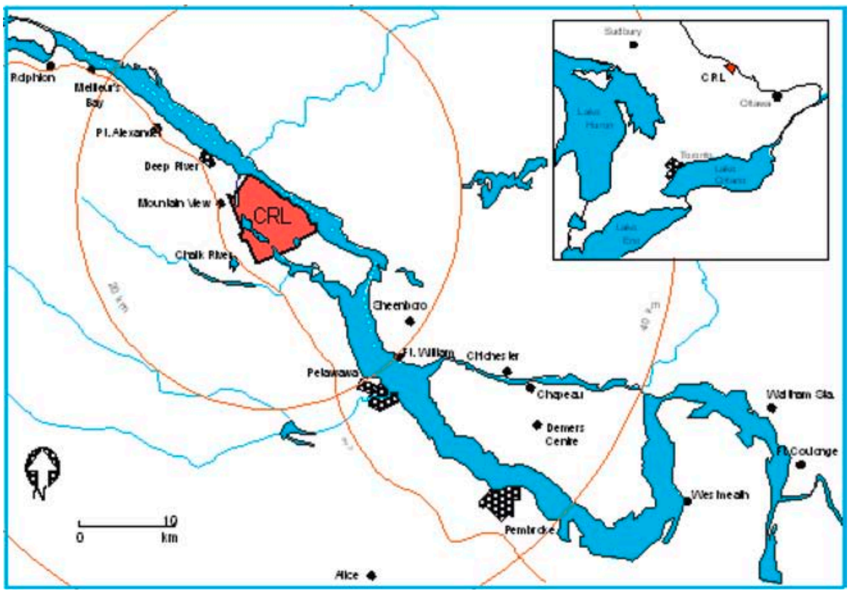

FIG. I–1.2. Location of Chalk River Laboratories, Ontario.

A.I–1.2. NUCLEAR SITE LICENCE

In Canada, the Canadian Nuclear Safety Commission (CNSC) issues nuclear licences. The licensees must demonstrate that it is safe to continue operations of the nuclear site and request a renewal of their licence. CNSC will issue a new operating licence for a specific period of time at which the licensee must demonstrate that it is safe to proceed with a licence renewal. A request to terminate a licensable activity must be submitted to the CNSC. Upon approval to proceed, it must be demonstrated that the licensable activities have ceased and the facility has been appropriately decommissioned.

Licence termination requires a demonstration that the land or previous activities presents a low risk and that the process can be used to support redevelopment because it results in a scrutinized validation of the property quality.

The nuclear site licence restricts the reuse of the land by anyone other than the site operator and thus licence termination is the key requirement to enable redevelopment. In the absence of a full licence termination for the site, a licence termination for the facility is possible and releases the facility for internal reuse by other on-site programmes.

A.I–1.3. USE AND REUSE OF BUILDINGS: CHALK RIVER LABORATORIES

Buildings at the Chalk River site have been used over time in a use and reuse cycle:

- *Original Construction* — The Chalk River site was constructed in the mid-1940s. Due to a shortage of steel as a result of the war, the primary method of construction was from the readily available resources of wood, concrete, brick and some steel. Many of the buildings at the Chalk River site were built as temporary facilities in support of the war effort. Following the war and the advent of nuclear power, the site expanded to perform research and development to support Canada’s nuclear programme.
- *Nuclear use* — A zone at the north end of the builtup area at the Chalk River site was designated as the active area. All facilities that handle radioactive materials are located in this area other than the waste management facilities.
- *Post-nuclear use* — Many buildings were partly decommissioned and then reused for different nuclear uses or for non-nuclear research. During this phase, the buildings were still on a nuclear licensed site, and management of the buildings and liability risk remained with the nuclear site operator. The buildings were used by the operator or leased to tenants in the nuclear and related industries. Some buildings were converted to offices for entirely non-nuclear usage.

— *Delicensing* — The presence of a nuclear site licence in the Canada heavily restricts the involvement of the private sector in site redevelopment. Delicensing of a number of buildings at the Chalk River site will be pursued following the completion of decommissioning activities. It has been possible to retain some low hazard buildings in a fully decommissioned state for continued reuse.
— *Refurbishment* — The Chalk River site developed a renewal project in the mid-1990s to begin the refurbishment of the site. The plan focused on facilities that were no longer safe to operate under their current condition, space requirements to continue growth of the various programmes, refurbishment of long term facilities, and the decommissioning of facilities to create new rentable space or a footprint for new construction.

A.I–1.4. PROGRESS WITH DELICENSING AND REUSE OF THE CHALK RIVER SITE

The Chalk River site plan has been revised a number of times over the past 15 years, but the focus remains on refurbishment of the site through strategic decommissioning, construction and renewal activities. The focus of the plan is to enhance the operation of the site, minimize costs and maximize the use of space.

Buildings that are licensed are decommissioned to a pre-determined end state and either removed or delicensed and returned to the site landlord for reuse.

A.I–1.5. EXAMPLES OF REUSE AND DELICENSING AND REUSE OF FACILITIES AT CHALK RIVER

Tandem Accelerator Super Conducting Cyclotron (TASCC)

The TASCC facility operated between the early 1960s through to the late 1990s. It was used to conduct basic nuclear physics experiments during its operation. The 4200 m^2 TASCC facility housed the accelerator, beam lines, target areas, control room and service areas. The building consisted of one main floor level with a partial second story and basement area. This facility was specially built to house the accelerator and beam lines, and is constructed of reinforced concrete and shielding of up to 1.5 m thick. Attached to the TASCC facility is a 1500 m^2, two-story office and laboratory facility with a partial basement constructed of wood with brick veneer siding. The TASCC facility was safely shut down in 1997 and prepared for decommissioning.

Following the TASCC shutdown, decommissioning was completed with the removal of all process systems, equipment and components, leaving a serviced concrete cavern. The former TASCC facility was delicensed and returned to Operations for reuse. This vast space was difficult to retrofit due to the odd angles and thick concrete walls. A number of small rooms were refurbished to house experimental loops, while larger areas with overhead cranes were used for fabrication shops, training rooms and laboratory space, and the former control/computer rooms were converted into office space and maintenance libraries. A project is currently underway to expand the footprint of this facility for new laboratory space.

The office section attached to TASCC was also retrofitted following the closure of the facility. A structural analysis of the building confirmed that the building was structurally sound, and plans were developed for modifying the 1940 vintage building. Extensive renovations were completed that included the gutting of the building to the outside walls, removing all former interior partitions. New electrical and mechanical services were installed, including an addition to the building to incorporate a fresh air and exhaust fan system. The building was converted into an open office concept to house staff from various groups on-site.

Building 610 — The Heavy Water Upgrading Plant (HWUP)

HWUP was originally constructed in 1967 to remove contaminants and upgrade the isotopic composition of AECL- and Ontario Hydro-owned heavy water to reactor grade specifications (greater than 99.75% D_2O), using an electrolytic process. The facility was expanded in stages in response to increasing demands. By 1971, it consisted of 114 cells in seven units, and an expanded cleanup section and storage tanks, pumps and piping had been installed to minimize the amount of drum handling. Upgrading operations were terminated permanently in 1998. The facility has been placed into a safe shutdown state (SSS) prior to it being turned over to decommissioning.

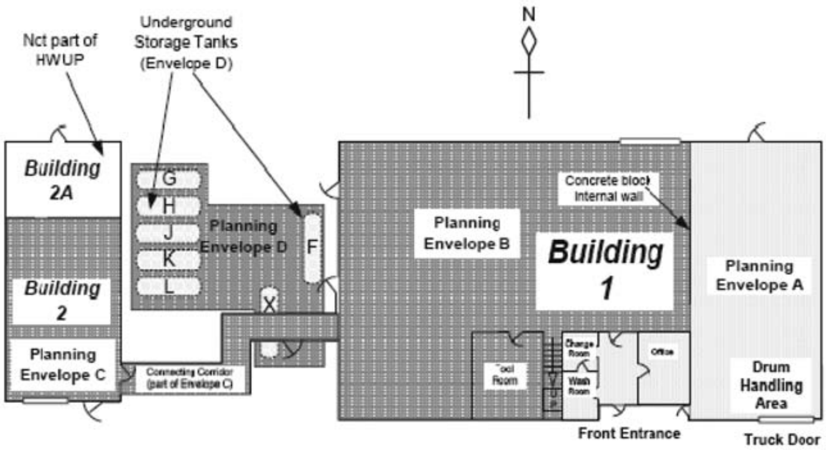

FIG. I–1.3. Building 610, Heavy Water Upgrading Plant.

HWUP is a single storey, pre-engineered steel structure with outside dimensions of 40 m frontage and 29 m depth, resting on reinforced concrete foundations. The building has a footprint of approximately 950 m^2 of unobstructed floor area and is classified as low hazard industrial occupancies. The term 'low hazard' refers to the non-combustible construction. The floor is designed for a live load of 4900 kg/m^2, making it appealing for reuse. The building is divided into two main areas: a drum handling/shipping/receiving area that can store up to 400 drums of heavy water, and a process area where the heavy water was cleaned and upgraded. A tool room and office area is located adjacent to the process area. A schematic layout of the building at the time of shutdown is illustrated in Fig. I–1.3.

The HWUP is in a SSS and is awaiting approval to proceed with decommissioning. The decommissioning phase of the HWUP will include the removal of all process piping, equipment, tanks, hazardous materials and associated operational equipment that was used for heavy water upgrading. The building will be decontaminated and delicensed in preparation for its next tenants. Although a final decision is yet to be made on the reuse of the HWUP building, the key contenders are a waste characterization and decontamination facility, a new tritium laboratory or office complex.

Pool Test Reactor (PTR)

The PTR was a low power, light water moderated, pool type reactor fuelled with high enriched uranium (HEU). Criticality was first achieved on 9 November 1957. The pool is roughly 4.5 m^2 by 6 m deep and contains approximately 125 000 L of water. The reactor core, submerged in water to a depth of 4 m, contained an array of typically 14 fuel rods surrounded by a graphite reflector. Reactivity control was by two adjustable in-core boron carbide absorber rods and a stainless steel fine control absorber rod in the reflector. Two additional in-core absorber rods provided emergency shutdown.

The PTR is located in one room within a larger facility. The PTR room is constructed with a steel frame and in-filled with wood; it is a single story high bay construction. The walls are lined with painted plywood and the ceiling is open to the wooden roof deck. A tile floor has been laid on a concrete slab on grade. A 6 m deep pool is located in the south-east corner of the room. The service trenches cut into the floor are generally 31 cm deep and covered with checker plate.

The PTR was designed and built to carry out reactivity studies on irradiated fuel samples and determine the absorption cross section of fission products. Reactor usage eventually shifted to testing and calibration of self-powered flux detectors on a commercial basis.

Although the PTR is described as a 10 kW reactor, the normal operating power of the reactor was approximately of 10 W, and its emergency trip level was set at 100 W. The PTR was first operated in November 1957, and was operated intermittently up until October 1990, when it was shut down and defuelled.

Final approvals are in progress to decommission the PTR. Decommissioning will include the removal of all reactor components, draining the pool, final survey and delicensing the facility.

Following decommissioning activities, the former PTR pool will be covered and returned to operations for reuse. The facility will be converted into a high bay laboratory utilizing the former pool for additional height to install loop systems or test sections for future research and development work.

A.I–1.6. CLEANUP AND REDEVELOPMENT AT PORT HOPE

The Port Hope Area Initiative is a community initiated environmental remediation project with a goal to clean up, develop and initiate long term management of historic low level radioactive waste in the local area. The waste resulted from radium and uranium refining corporation that operated from 1930 to the 1980s.

Two projects were launched under the initiative, the Port Hope and Port Granby Projects, which were broken down into three phases:

- Phase 1: The planning phase involving environmental assessments and regulatory review;
- Phase 2: The implementation phase involving facility construction and contaminated sites remediation;
- Phase 3: The post-closure phase involving ongoing monitoring and maintenance of the facilities.

Both projects are currently in Phase 1.

The Port Hope Project has proposed to build a new, engineered, above ground mound as a long term waste management facility. Existing waste at the proposed site will be excavated and placed in the mound. Other historic low level radioactive waste and specified industrial waste from various sites in the urban area of Port Hope will be removed and transported to the new facility. The facility is being designed to safely manage a capacity of two million m^3 of waste from the Municipality of Port Hope.

The Port Granby Project proposed to relocate 500 000 m^3 of low level radioactive waste and soils from the former Eldorado Nuclear Operation site to an above ground mound facility for long term management.

Both of these projects focus on the safe development of contaminated lands, protection of the environment and long term management of low level radioactive waste. The recovered wastes from these communities will be centrally stored with numerous areas cleaned up. Redevelopment of these areas within the communities is in progress.

Annex A.I–2. Reuse of facilities during and after decommissioning: plans and experience in the Czech Republic

A.I–2.1. INTRODUCTION

There are some obsolete facilities being decommissioned in the Czech Republic, mainly in the Nuclear Research Institute (NRI) Řež plc. The main goal is to decommission the facilities and eliminate a potential negative impact on the environment.

Some facilities will be reused after decommissioning, which can be advantageous for many reasons, for example:

- Old buildings can be used for accommodation of new workplaces (demolition is not necessary).
- It is not necessary to perform decontamination for unrestricted use when a new workplace with ionizing radiation is installed.
- Legislative and licensing — avoidance of siting of new facilities, etc.

Furthermore, financial resources can be saved when facilities are reused. Some examples of reuse of facilities after decommissioning are described in this annex.

A.I–2.2. REUSE OF DECOMMISSIONED FACILITIES IN THE NRI ŘEŽ

A.I–2.2.1. Special sewage system

The special sewage system was used for the transfer of liquid radioactive waste (RAW) from various facilities (research reactors, radiochemical laboratories) to a RAW processing facility. The system consisted of a stainless steel pipe network with a total length of 410 m, situated in an underground concrete corridor (see Fig. I–2.1). The integrity of the system had never been tested. The system was contaminated by fission and corrosion products, mainly by ^{137}Cs, ^{60}Co and ^{90}Sr. Leakage of wastewater from piping was identified as a significant risk to the environment.

The remediation procedure started with the removal of soil and opening the corridor. The pipes and other steel components (valves, fittings, etc.) were removed and sent for decontamination (see Figs. I–2.2, I.2–3). The total amount of contaminated metal parts was approximately 20 MT. Limited areas of the concrete corridor's surface were contaminated from small leaks. The contaminated surfaces were removed and processed as RAW.

A standard mechanical saw was used for segmentation of pipes before decontamination. The pipe parts such as joints and flanges and corroded parts were sent for conditioning. High-pressure water jetting was used for preliminary decontamination of pipes. Then, an ultrasonic bath with decontamination solutions was used. Decontamination was successful in most cases; some pipes were mechanically decontaminated by a special one purpose instrument (an abrasive rotating device). External contamination of pipes was measured by a standard

FIG. I–2.1. Shaft to the special sewage system.

FIG. I–2.2. Special sewage system during decommissioning, one pipe remaining.

FIG. I–2.3. Special sewage system during decommissioning, all pipes removed

FIG. I–2.4. New pipelines with monitoring system.

FIG. I–2.5. Installation of new pipelines.

contamination instrument and contamination inside the pipes was measured by a special tube detector. Approximately 90% of the pipes were released as clean for waste recycling.

The decommissioning started in 2004 and was finished in 2005. The old concrete corridor was used for installation of a new system equipped with a leakage monitoring system (see Figs. I–2.4, I–2.5). The financial resources were therefore saved when the old corridor was reused. Also, obtaining the necessary licence was easier: it was not necessary to ask for two licences (for decommissioning and operation), because the decommissioning of the old system and installation of a new one were carried out under one licence for reconstruction of a workplace with an ionizing radiation source.

A.I–2.2.2. Liquid RAW storage tanks (Building No. 211/3)

Three steel tanks are located in concrete underground bunkers (see Figs. I–2.6, I–2.7). The parameters of the tanks are as follows: length 9.5 m, diameter 3 m, weight approximately 10 MT, each with a capacity of 63 m^3 (see Fig. I–2.8). The tanks were originally used for collection of liquid RAW from a research reactor. The tanks had aged beyond their design life and were contaminated by fission and corrosion products, mainly ^{137}Cs, ^{60}Co and ^{90}Sr. Leakage or spillage from these tanks was identified as significant environmental risk.

According to the original project plans, the remediation procedure would consist of decontaminating and dismantling the tanks and processing the RAW. Then, new tanks for storage of liquid RAW would be installed. This process would require partial building demolition to access the underground bunker.

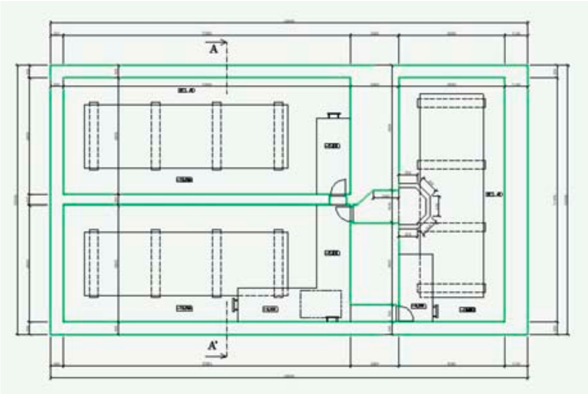

FIG. I–2.6. Underground floor with the tanks.

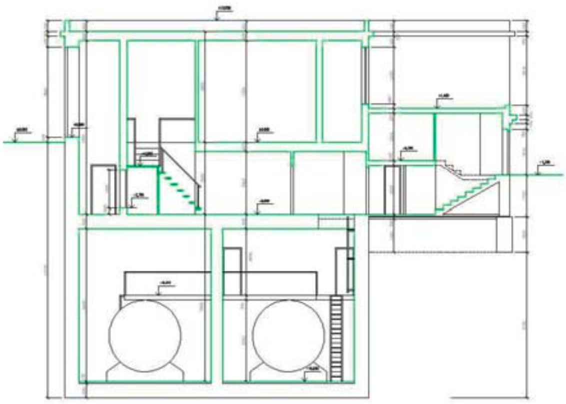

Fig. I–2.7. Section of the building.

Fig. I–2.8. Storage tank.

A new concept was developed and is being implemented. The tanks are being decontaminated (see Fig. I–2.9) and after the investigation of the tanks' integrity, a polyethylene lining is being installed inside the tanks. Two layers of the lining are installed (see Fig. I–2.10) so that the space between them can be monitored for the presence of water. This method is in use in the chemical industry. The reuse saves the resources that would have been needed for segmentation, RAW processing and installation of new tanks. The reuse was also advantageous from the perspective of improved radiation and industrial safety.

FIG. I–2.9. Tank surface after decontamination.

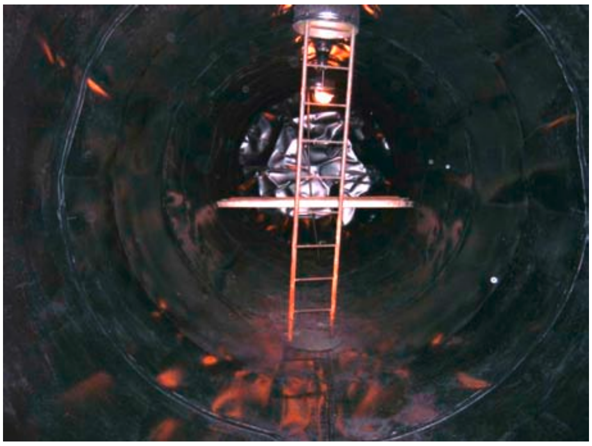

FIG. I–2.10. Polyethylene lining inside the tank.

A.I–2.2.3. Decontamination of a semi-hot cell

The semi-hot (or warm) cell was used for experiments in the field of reprocessing of spent fuel. The cell was heavily contaminated. The semi-hot cell, made from cast iron with a thickness of 100 mm, was partially decontaminated in the past and then its internal and external surface was covered with coating to prevent the contamination from spreading. The coating was first partly removed by a paint remover and then blasted with dry ice for decontamination (see Fig. I–2.11). Dry ice blasting was also used for decontaminating building surfaces for removal of contaminated coatings. A small amount of secondary RAW was generated and dispersion of contamination was limited.

The semi-hot cell is now used for other research activities (Figs I–2.12, I–2.13). Financial resources were saved because it was not necessary to decontaminate the cell to the levels for release into the environment or to segment it and process it as RAW. In addition, the cell is fully usable and no new cell had to be installed. The reuse was also advantageous from the point of view of improved radiation and industrial safety.

A.I–2.2.4. Decay tanks (Building No. 211/5)

The decay tanks have been in use since 1961. The tanks were designed for storage and decay of concentrated short lived RAW, but also RAW containing long lived radionuclides was shipped there. The building is submerged in the ground on three sides (see Fig. I–2.14). It contains two cylindrical tanks (length 9.5 m, diameter 3 m, weight approximately 10 MT), each with a capacity of 63 m^3. The decay tanks are made from structural steel jacketed by

FIG. I–2.11. Removal of coatings.

FIG. I–2.12. Dismounting of lid.

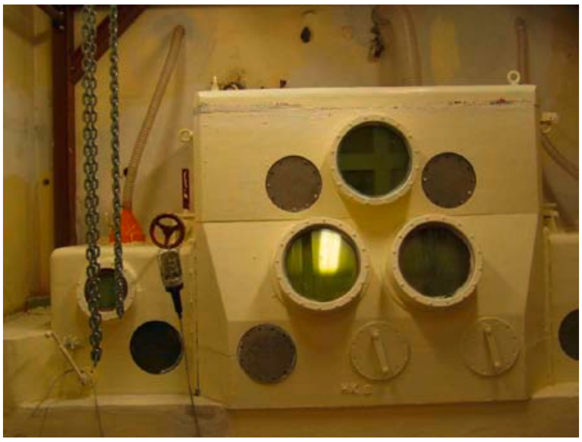

FIG. I–2.13. Semi-hot-cell ready for installation of renovated manipulators.

stainless steel inside the vessel. They are placed into two separate concrete bunkers located partially below ground. A building with tank inlet pipes and ventilation equipment are located above the bunkers.

The tanks not only contain liquid RAW; tank B also contains solid RAW. The main identified radioisotopes are ^{60}Co and ^{137}Cs. However, the presence of ^{239}Pu is also assumed. The solid RAW consists of tins with irradiated metallic samples and residues of spent fuel. The maximum dose rate is above the pile of solid RAW (hundreds of mGy/h). The leakage from the tanks and direct irradiation from in situ material were identified as significant risks to the environment and/or to employees.

FIG. I–2.14. Uncovered bunkers.

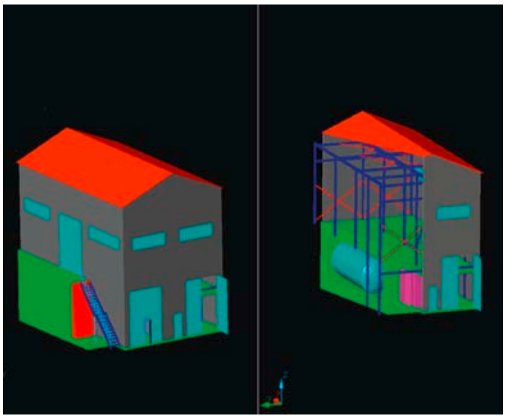

FIG. I–2.15. New workplace design.

FIG. I–2.16. New hall.

A hall above the decay tanks was built (see Figs I–2.15, I–2.16) after the previous building located above the tanks was demolished. A special remote-controlled manipulator will be installed into the tank inlet. The control room of the manipulator will be placed in front of the bunker. The liquid RAW from the tanks will be removed. The liquid from tank A (with lower activity) will be transported via a special tank to a plant for liquid RAW processing. The liquid from tank B (with higher activity) will be solidified on-site with a specially developed cementation unit. Solid RAW will be removed to a shielding container and transported to a hot cell facility for processing. The tanks

FIG. I–2.17. Storage carousels.

FIG. I–2.18. Lifting the shielding lid.

will be decontaminated by a high-pressure water jet and abrasive blasting. The tanks will be dismantled by special segmentation equipment. The decontamination water will be either released into the environment or disposed as RAW. The building will be decontaminated.

The possible use of the building is being discussed now in NRI. It is a massive structure located in a new hall with auxiliary technology. Decommissioning of the concrete structure would be very expensive. The building will be probably used as a storage site for irradiated materials. The final decision will be made after the tanks' removal and checking of the integrity of the concrete structure.

A.I–2.2.5. Decommissioning of storage carousels

The carousels located in two buildings were used for storage of ionizing radiation sources. The sources were stored in a steel drum placed in concrete shielding. The drum was covered with the shielding lid made from cast iron with a thickness of 100 mm. Below the shielding, there were several plates with storage nests. The carousels were equipped with the devices for rotating the plates and for manipulating the stored sources.

Four carousels were located in the first building (see Figs I–2.17, I–2.18). The carousels were used very rarely and were not contaminated. It was decided that the building would be used for accommodation of a new hot cell. Because demolition of the carousels could cause loss of integrity of the building, it was decided to leave the carousels on-site. They were covered with a concrete layer and a new floor laid down (see Fig. I–2.19), and a hot cell was installed in the building. The carousels will be decommissioned in the future together with the hot cell.

FIG. I–2.19. Building after reconstruction with new floor over carousels.

FIG. I–2.20. Storage drum.

FIG. I–2.20. After shielding demolition.

In the second building, the only carousel has been completely decommissioned. The contaminated upper shielding lid made from cast iron was cut before carousel decontamination. The storage drum was decontaminated and removed (see Fig. I–2.20). The concrete shielding was demolished (see Fig. I–2.21). The room is now used as a laboratory.

FIG. I–2.21. Reloading site before reconstruction.

FIG. I–2.22. Stored RAW.

A.I–2.2.6. Reloading Site (Building No. 211/6)

The Reloading Site was initially constructed as a temporary reloading site to handle conditioned RAW, but later was used also for storage of various RAW before treatment (see Fig. I–2.22). RAW is stored in eight concrete boxes each with dimensions of 5.5 × 8 × 4 m (1400 m^3 total capacity). The bases of the boxes are 4 m below ground level and are drained to four closed sumps. The building has a steel roof.

The total volume of stored RAW is approximately 600 m^3 (see Figs. I–2.23, I–2.24). An incomplete inventory is available, which only provides a general description of the RAW contained in the boxes. The RAW is contaminated mainly with ^{137}Cs, ^{60}Co and ^{90}Sr. Leakage of liquid waste in boxes, wash-off of contamination from RAW by rainwater and direct irradiation from in situ material were identified as significant risks to the environment and/or to employees.

The new hall above the Reloading Site was constructed in 2004 and contains a crane and auxiliary technology (see Figs I–2.25, I–2.26). RAW will be sorted and transported for processing (segmentation, decontamination and conditioning). The treatment of RAW will be performed in 2009–2014. The building will then be decontaminated and used for storing new RAW after reconstruction, which will be also advantageous from the point of view of industrial safety.

FIG. I–2.24. Old VVR-S research reactor vessel.

FIG. I–2.25. Building No. 211/6 — Reloading site with a new hall.

FIG. I–2.26. Building No. 211/6 — interior view of the reloading site with a new hall.

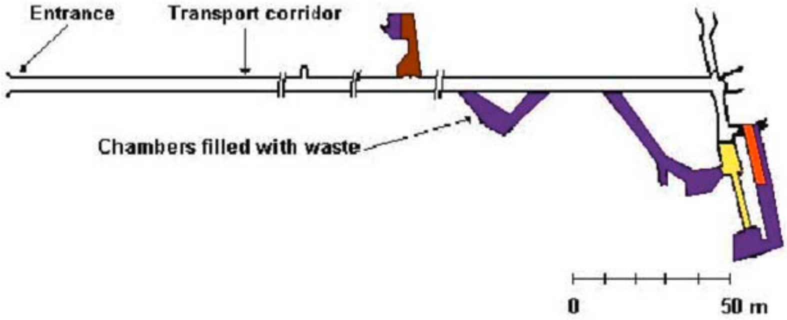

FIG. I–2.27. Cross-section of the Bratrstvi Repository.

A.I–2.3. OTHER EXAMPLES IN THE CZECH REPUBLIC

A.I–2.3.1. Radioactive waste repositories

Old mines were used after adaptation as disposal sites for institutional RAW in the Czech Republic. Other reuse cases are presented in this section.

A.I–2.3.2. Bratrstvi radioactive waste repository [A.I–2.1]

The Bratrstvi RAW repository was developed by adaptation of a gallery in a former uranium mine. Five chambers were adapted for RAW disposal with a total volume of nearly 1 200 m^3 (see Fig. I–2.27). The repository started operation in 1974.

A.I–2.3.3. Hostim radioactive waste repository [A.I–2.1]

The Hostim RAW repository was in operation in 1959–1964. It was built in 1959 in the Alkazar limestone mine near the village of Hostim by adaptation of two galleries in 1942–1944 (see Fig. I–2.28). The total volume of the two galleries was about 1 690 m^3. The repository contains low and intermediate level RAW. The operation of the repository was terminated in 1965.

A.I–2.3.4. Richard RAW repository [A.I–1, A.1–2]

The Richard RAW repository covers a small part of the abandoned Richard I, II and III mine complex composed of over 40 km of galleries and crosscuts. Limestone was being extracted within the Bidnice hill as early as the mid-19th century from a limestone seam about 5 m thick, situated 70–80 m beneath the ground.

In 1943–1944, the site was chosen for the construction of both an underground plant for Auto Union A.G. Chemnitz, a German automobile company (producing components and parts for the HL230 Maybach engine) and a factory for Osram. The project was code named Richard. The workforce — consisting of miners, builders, electricians, plumbers and various other workers — were prisoners from a nearby work camp and also from the Terezin Concentration Camp. The construction of only a small number of factory halls was eventually completed and used by Auto Union.

By the end of the war, construction work had still not been finished, with individual parts of the project at different stages of completion, from fully completed factory halls to underground galleries only just widened out. After the removal of all the equipment at the end of 1945 and the beginning of 1946, the Cizkovice Cement and Lime Company took over the site to resume limestone production. A vast new system of galleries was created during the next 15 years. For economic reasons, deep mine excavation being so much more expensive than open-cast mining, the mine was eventually closed. From 1964, the site has been used as a repository of RAW.

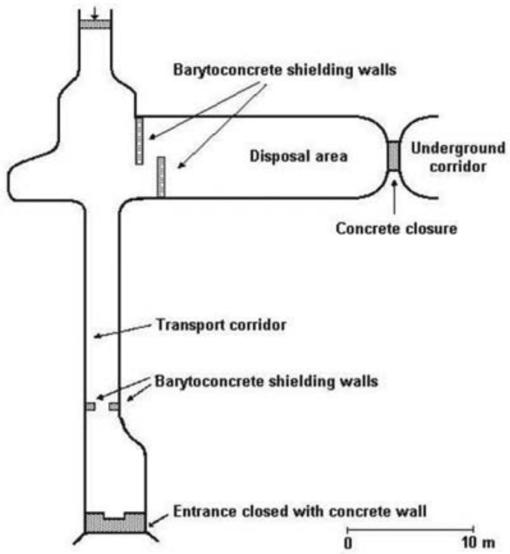

FIG. I–2.28. Cross-section of the Hostim repository.

FIG. I–2.29. Radiochemistry building in the Radium Line workshop.

A.I–2.3.5. Radium Line [A.I–2.3.4]

The Radium Line workshop was established in the area of the Richard RAW repository near Litomerice in the Czech Republic in the 1970s (Fig. I–2.29). The workplace was designed for the production of special sealed radionuclide sources with ^{226}Ra ('radium needles'), which were used for radiotherapy (Fig. I–2.30).

When production was terminated in the middle of the 1980s, the workplace was left without any decontamination work or removal of ionizing radiation sources. NRI obtained the contract for decommissioning of the Radium Line and started the decommissioning in 2003.

The biggest sources of radiation were the boxes for radium needles production (production boxes) with a maximum dose rate of 6 mGy/h on unshielded parts (Fig. I–2.31) and some RAW with dose rate up to 13 mGy/h. The dose rate of the rest of the workplace was up to 1.4 mGy/h. Surface contamination in the workplace ranged between one and thousands of Bq/cm^2 of alpha contamination. A further problem was air contamination by ^{226}Ra and its daughters. Monitoring of the workplace, environment and personnel was carried out in accordance with a monitoring plan. The use of protective equipment was determined according to need.

At first, easily removable objects and some collected RAW (laboratory equipment, furniture, etc.) were removed to gain more space for the following activities. RAW with a high dose rate was then put into shielded storage containers and removed. This reduced the dose rate in the workplace. Laboratory equipment (heaters, sink, etc.) was then removed.

FIG. I–2.30. The initial state in the production room.

FIG. I–2.31. Production boxes before dismantling.

FIG. I–2.32. Production boxes during dismantling.

The most hazardous operation was the dismantling and conditioning of the production boxes (Figs. I–2.31, I–2.32). The large amount of equipment, the remainder of the original sources of ^{226}Ra and lead shielding parts were removed from the boxes. The decontamination of inner surfaces of the boxes by wiping was then completed. A centrifuge was removed from the production boxes and put into the lead shielded disposal container (the dose rate on centrifuge surface was up to 4 mGy/h). External lead shielding of the production boxes was removed. The boxes were conditioned by cementation in a non-standard disposal container. The plexiglas boxes were dismantled and transported to the NRI for processing.

FIG. I–2.33. Production room after decontamination.

FIG. I–2.34. New laboratory (former production room).

When the rooms were empty, the remaining decontamination of the workplace was undertaken. The ceiling and floor roofing were taken away. Grinding off the walls and a part of the floor was necessary because of the high contamination levels (see Fig. I–2.33). Tanks for liquid RAW and the ventilation system were removed. Decontamination of contaminated areas was completed in the surroundings of the workplace of the Radium Line.

RAW was characterized and put into transportation packages in the workplace to avoid leakage of the contamination during the transport. Most of the RAW produced during decommissioning was processed in the NRI. Conditioned RAW was disposed in the Bratrstvi RAW repository.

Decommissioning was successfully completed during 2003 and 2004 for unrestricted use. The radiochemistry building was then reconstructed and the workplace was then used as a laboratory for measurement of low activities as a support for the repository operation (see Fig. I–2.34). This was the proof that the decommissioning of the Radium Line was successful.

A.I–2.3.6. Old heating station, NPP Dukovany

There was an old heating station on the location of the NPP Dukovany used as a source of heat before the plant was put into operation. The station was then put out of operation.

The station was reconstructed and then used for accommodation of technology for measurement of waste before release into the environment (see Fig. I–2.35).

FIG. I–2.35. The heating station after reconstruction with the measurement technology.

A.I–2.4. CONCLUSIONS

It has been demonstrated that the old facilities can be reused for other purposes, thus saving financial resources. The reuse can be also advantageous from the point of view of improved radiation and industrial safety. In some cases, the licensing process is easier to accomplish by upgrading and reuse of existing facilities when compared to licensing of new facilities.

Annex A.I–3. Project: Decommissioning and reuse of licensed nuclear facilities at the CEA Centre, Fontenay-aux-Roses, (CEA-FAR) France

A.I–3.1. INTRODUCTION

CEA-FAR is the CEA's oldest facility and is situated in the southern suburbs of Paris. It was opened on 26 March 1946 to host the first French atomic pile, which was named ZOE, and first went critical on 12 December 1946. The first laboratories were installed in existing buildings on the site.

In the early 1950s, a number of nuclear facilities to be used for R&D work were built within the perimeter of the centre. This included the construction and operation of a pilot plant facility for the reprocessing of spent nuclear fuel.

As space was restricted, all these installations were decommissioned and demolished to enable the construction of more modern second generation facilities. The Pu Pilot Plant for irradiated fuel reprocessing (the prototype of the Marcoule UP1 Plant) was used from 1953 to 1958. The dismantling of the equipment from the Pu Pilot Plant, the demolition of the buildings and the removal of the grounds to constitute a uniform platform were completed at the end of the 1950s. This operation made it possible to release the grounds on which building 18 was built, and also buildings 91 and 52. These buildings were constructed during the 1960s within the framework of the development of the CEN-FAR programmes.

In the late 1950s and early 1960s, in addition to ZOE (NLF 11), which remained in service, the following second generation facilities were built: radio-metallurgy installations (NLF 58 and 59), radiochemistry and chemical engineering installations for the reprocessing of spent fuel (NLF 57) [A.I–3.1], and installations for the treatment and interim storage of solid and liquid waste (NLF 34 and 73), which were required for pursuing the research programmes. These latter buildings are currently being cleaned up and dismantled.

ZOE was closed down and partly dismantled in the 1970s to former IAEA Stage 2 and the research areas around the pile were transformed into a museum.

The facilities shut down and dismantled in the 1980s were plutonium metallurgy installations NLF 58 and 59. The glove boxes in NLF 58 and 59 were transferred to another facility at the CEA Centre at Cadarache or dismantled in the CEA's waste treatment installations on-site. Following removal of the equipment, the interiors of the buildings were cleaned up and the premises thus became reusable as offices for conventional work. NLF 59

(RM1 and RM2) underwent phased dismantling. After cleanup, the RM1 premises were reused as offices, a conference facility, a lecture room and an amphitheatre.

A.I–3.2. PRELIMINARY DISMANTLING OPERATIONS

With the agreement of the French safety authority DGSNR (today ASN), it was decided to denuclearize CEA-FAR by blanket decommissioning of all the NLFs there. This programme led to altering the perimeter of the NLFs [A.I–3.2] and to carrying out the following dismantling in advance.

Building 53, the liquid waste treatment plant (STEL), was built in the early 1960s and was in service from 1964 to 1994. It was used to concentrate LLW and ILW by evaporation. Its cleanup and dismantling was carried out in four phases beginning in 1997: (a) evaporator cleanup and dismantling, (b) tanks cleanup and isolation, (c) tanks dismantling, and (d) evaporator hall clearing. (Figs I–3.1 to I–3.4). The site work lasted for 55 months. On completion of the work in the tank area, a new waste package interim storage area was created. (Fig. I–3.4).

Building 54 (interim storage of material and equipment from Building 18) and Building 91 (testing hall with laboratories for chemical engineering pilot plants — thorium and uranium containing less than 1% of isotope-235) were constructed between 1962 and 1966. The dismantling of the equipment in Building 91/54 consisted of

FIG. I–3.1. Liquid waste evaporator, building 53.

FIG. I–3.2. Tanks room, building 53.

FIG. I–3.3. Dismantling work in the tanks room, building 53.

FIG. I–3.4. Tanks rooms after dismantling and transformation in storage area.

dismantling of the apparatuses, pulsed columns, evaporators, tanks, piping and pumps as well as the steel decking and structures, and partial cleanup of the masonry. This operation required more than 15 000 person-hours of work over two years (Figs I–3.5 to I–3.7). The work on fitting out Building 91/54 consisted in: preparing Hall 91 for interim storage of waste drums (1500 drums of LLW on the ground floor and space for 100 drums of alpha/plutonium waste in the basement); converting the laboratories into offices; and creating bays in Hall 54 to install a waste-drum measuring plant and for loading waste drums into transport containers (200 L LLW drums into Type IP2 containers and 100 L alpha/plutonium waste drums into Type RD 39 casks) (Figs I–3.8, I–3.9).

A.I–3.3. THE FUTURE OF THE CEA, FONTENAY-AUX-ROSES, FRANCE

CEA-FAR, France's birthplace of nuclear energy studies, has also become a centre dedicated to the study of life sciences — Project d’assainissement des laboratoires et démantèlement des installations nucléaires (ALADIN) du genie nucleaire au genie biologique. These activities, like the MIRCEN project, are installed in new or existing facilities.

Building 32/33 was the location of the first Tokamak nuclear fusion experiment. After dismantling the experimental equipment, the building was completely disassembled — floors, partitions and tower were taken down. Only the structural members remained to allow the construction of interiors for new use by MIRCEN, a

FIG. I–3.5. Dismantling work in the tanks room, building 91.

FIG. I–3.6. Support structures being dismantled, building 91.

FIG. I–3.7. Chemical engineering hall after dismantling, building 91.

FIG. I–3.8. LLW drums interim storage, building 91.

FIG. I–3.9. Measurement of LLW drums, building 54.

biological studies laboratory for research on neurodegenerative, hepatic, cardiac and infectious diseases, and the use of imaging techniques for treatment evaluation.

A.I–3.4. DISCUSSION OF REUSE FACTORS

The ability to reuse buildings that housed nuclear activities depends on whether they are to be reused for a nuclear, non-nuclear or external programme, among other factors. The reuse of buildings remains possible if, like the one in this case study, the new facility does not require specialized structural elements to support facilities such as hot cells with massive concrete shielding.

The possibility of reuse is directly related to the initial nature of the installations. For example, it is easier to reuse laboratories, halls or empty rooms in a reactor building than rooms specially designed to house a process involving tall equipment, galleries and piping for radioactive solutions.

The reuse of buildings 53 and 91/54 for the interim storage of waste containers is an example of successful reuse. Storage surfaces were in use one year after the end of dismantling work. The demolition of these buildings and the construction of new buildings could not have been accomplished in this time period. Furthermore, the cost savings of rehabilitating old facilities for waste storage was considerable. The reuse also supports the ongoing programme of decommissioning several facilities on the site, because it is necessary to have interim waste storage locations to absorb production peaks of waste containers during dismantling or to accommodate temporary interruptions of waste container transport to centralized storage.

Having the interim storage option in a reused facility will make it possible to reduce the costs of final cleanup by allowing concomitant decommissioning activities.

Annex A.I-4. Decommissioning of Greifswald NPP (KGR), Greifswald, Germany: Reconstruction of the former turbine hall into a manufacturing site for large ship components

A.I–4.1. INTRODUCTION

The Kernkraftwerk Greifswald (KGR) site is located in the north-east of Germany, at the Baltic Sea.

At the time of the unification of the German states in October 1990, the Kombinat ‘Bruno Leuschner’ incorporated almost all East German nuclear facilities, which included the power stations in Greifswald and Rheinsberg, the construction site in Stendal, as well as the disposal site in Morsleben. Directly after the unification, operation and all construction work were stopped. Serious efforts were made to restart some units in Greifswald or to use the site for new nuclear and/or conventional power plants. However, a decision was finally made to decommission all plants, mainly due to a lack of political acceptance and secured financial basis.

On the site in Greifswald, there are eight reactor units of the Russian PWR WWER-440. (The basic data are given in Table I–4.1) The units 1–4 are of the model 230 and the units 5–8 of the more recent model 213. The reactors are constructed on a double unit basis, i.e. two reactors are arranged in one reactor hall with supporting mechanical equipment and secondary systems together. There is only one turbine hall (with a length of 1.2 km, a height of 40 m, and a width of 35 m) for 16 turbines. The site layout is shown in Fig. I–4.1.

The decommissioning preparation started immediately after shutdown of all operating units in 1989/1990 and the decommissioning licence was applied for in June 1994 and issued a year later in June 1995.

In parallel with the decommissioning activities, a major objective is to create and support a new future use of the site in Greifswald in order to give the employees and the region new employment opportunities. Under this framework, successively different site areas and building structures have been exempted from the atomic law for industrial reuse.

A.I–4.2. SITE REUSE — STRATEGIC ISSUES

The reuse of the KGR site for industrial and energy production purposes is one of the most important initial key decisions made after shutdown of all five operating NPP units. Immediately after this decision was made, a separate project in the KGR decommissioning project work breakdown structure was added, the Site Remediation and Reuse Project.

TABLE I–4.1. BASIC DATA ON THE REACTOR UNITS IN GREIFSWALD (KGR)

Unit	Type	Power MW(**e**)	Operation	Shutdown	Produced energy (GW·h)
1 KGR	WWER-230	440	1973	18 Dec. 1990	41.321
2 KGR	WWER-230	440	1974	15 Dec. 1990	40.040
3 KGR	WWER-230	440	1978	28 Feb. 1990	36.028
4 KGR	WWER-230	440	1979	2 June 1990	32.077
5 KGR	WWER-213	440	1989	29 Nov.1989	240
6 KGR	WWER-213	440	Ready for commissioning		
7 KGR	WWER-213	440	Building erected, major components installed		
8 KGR	WWER-213	440	Building erected, major components installed		

FIG. I–4.1. The Greifswald site.

FIG. I.4–2. Bird's eye view of the newly built industrial harbor.

FIG. I–4.3. Plan of gas delivery station for the Baltic Sea pipeline.

After cleanup of the site areas and conventional buildings categorized as non-contaminated, the site development began. The planned industrial area is approximately 120 ha and includes a rail system suitable for complete trains up to 360 m.

One of the first actions was the construction of a new industrial harbour with 7 m draught (see Fig. I.4–2) as a key element for the future site development. Additional industrial redevelopment projects can be seen in Figs I–4.3 and I.4–4. See also the biodiesel plant in Annex II.

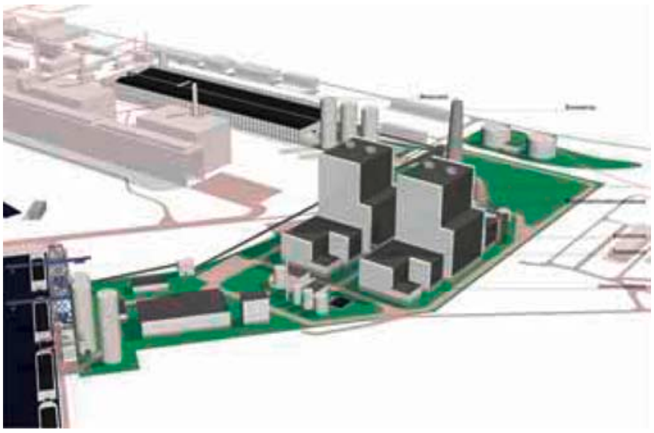

FIG. I–4.4. DONG Energy — Coal Power Plant Units, 2 × 800 MW.

A.I–4.3. DELICENSING OF THE TURBINE HALL

As described in Annex II Case 2: Site Reuse Procedure, a special step by step release procedure has been implemented, based on the principles shown in Annex II under special delicensing circumstances for the turbine hall.

The building structures of the turbine hall were categorized as non-contaminated in the context of the basic licence for decommissioning of the KGR site, issued in June 1995. Thus far, the regulatory body has approved a relatively easy delicensing procedure for the turbine hall.

After the dismantling of all components of the turbine hall (see below 'Reuse of the turbine hall'), a company directive, agreed between EWN and the authorities, was implemented for the release of the building structures including the foundations. In this directive, the measurement programmes are described (chosen measurement points). The measurements were taken with standard procedures used by qualified personnel. After evaluation of all measurements, no values were above the agreed limit values (0.1 Bq/cm^2, 0.01 Bq/g); therefore, the turbine hall could be released for industrial reuse.

A.I–4.3.1. Reuse of the turbine hall

Dismantling the turbine hall

The dismantling approach was to dismantle unit by unit based on physical location and accessibility as follows:

— Generator transformer units;
— Turbine and condenser;
— Big vessels (pre-heaters, feed water tanks);
— Small technological equipment (small pipes, pumps, drives, valves);
— Steel components;
— Instrument and control equipment;
— Building structure (concrete parts).

For dismantling, the planned strategy had to be changed. The initial dismantling planning strategy was to dismantle all the components and then cut them in pieces on location, with radiation measurements to be taken in the free release measurement facilities. The new dismantling strategy was to remove all equipment in pieces as large as possible and to store in outside buffer zones under controlled ventilation conditions. If the material is categorized as suspected or contaminated material, as described under the decommissioning licence, the material was brought to the controlled area for prioritized dismantling.

After the permission for free reuse was received by the authorities, the turbine hall was leased to a private company, MAB GmbH, for manufacturing large ship components (Figs. I–4.5 to I–4.8).

Reconstruction of the turbine hall

As a precondition for reuse in order to lease the hall, it was necessary to carry out extensive infrastructure upgrades, including construction of new heating and electrical utilities, reconstruction of turbine hall cranes and the addition of fire protection measures, new hall accesses, new roads for hall access and transportation corridors to the harbour.

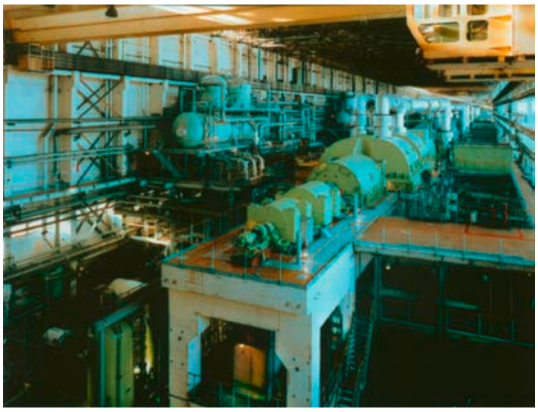

FIG. I–4.5. Turbine hall — before dismantling.

FIG. I–4.6. Turbine hall — after dismantling.

FIG. I–4.7. Turbine hall — under industrial reuse.

FIG. I–4.8. Turbine hall — big ship components.

A.I–4.3.2. Outcome

The large turbine hall of the Greifswald NPP (one hall to house 16 turbines for all eight units on the site) was completely emptied, and half of it was reconstructed for reuse as a manufacturing site for large ship components by the private company MAB GmbH, as illustrated in the photographs below. The other half is used by a big crane producer, Liebherr. Both companies were interested in reusing these huge halls because they perfectly met their requirements, especially with respect to capacity.

The new production started only one year after the planning start for reuse by MAB. The complete time schedule was as follows:

— Start of planning work	June 2006
— Start of construction work	Aug. 2006
— Start of commissioning	Apr. 2007
— Start of production	Sep. 2007.

The costs were partly borne by the Land Mecklenburg/Vorpommern to support the creation of new jobs in this poor region of Germany, which at the time had an unemployment rate of 20–25%.

One of the most important successes was an agreement between the decommissioning operator (EWN) and the authorities on an easy and fast procedure for the release of the turbine hall from the atomic law.

Annex A.I-5. Conversion of an ex-transuranicum laboratory building into a RAW processing facility, Serbia

A.I–5.1. INTRODUCTION

From 1993 to 1994, a building previously designated for the handling of transuranium elements in the Vinca Institute of Nuclear Sciences, Belgrade, Serbia, a laboratory for transuranicum elements (LATRANSA), was used for the production of Fumitoxin (aluminium phosphide, or AlP). The fumitoxin production process was based on synthesis from pulverized aluminium and red phosphorus as the principle reactants. A third party ran the process, and due to inadequate performance, the process was terminated. A considerable amount of Fumitoxin pellets and partly reacted mixtures were left stored in glove boxes, which represented a hazardous waste and prevented the use of the LATRANSA building for any other purpose.

Fumitoxin is formulated as a mixture of AlP and ammonium carbamate (NH_2COONH_4). When exposed to the atmosphere, the humidity in the air reacts with water (hydrolyzes), giving off a poisonous gas phosphine (PH_3) and an inactive powder of aluminium hydroxide ($Al(OH)_3$).

The project included the cleanup of the building so it could be refurbished and reused for other purposes.

A.I–5.2. DECONTAMINATION [I–5.1–I–5.3]

The first stage of decontamination involved the deactivation of the stockpiles of Fumitoxin materials in the building. This was achieved using a process to mix small amounts of the pellets/powder in reaction vessels with large quantities of detergent solution. The resulting inert waste was characterized and disposed of (Figs I–5.1–I–5.5).

The next stage of decontamination included the surfaces that had become contaminated with Fumitoxine. This included complete removal of wall and ceiling coatings using manual methods and grinding. The decontaminated surfaces were then resealed for future uses.

Workers in full protective clothing decontaminated the glove boxes used for storage of the Fumitoxine. Filters were decontaminated and all gaskets serviced for reuse. The glove boxes were returned to a condition suitable for reuse.

Residual reactant wastes such as aluminium flakes and phosphorus were sorted, repackaged and size-reduced before being dispatched for recycling.

A.I–5.3. REFURBISHMENT [I–5.4]

The building refurbishment incorporated the following major activities:

FIG. I–5.1. Fumitoxine in glove box in LATRANSA.

FIG. I–5.2. Fumitoxine reaction vessels with reaction mixture inside.

FIG. I–5.3. Removal from glove boxes.

FIG. I–5.4. Mixer preparation and testing.

FIG. I–5.5. Waste after Fumitoxine deactivation.

— Removal of roof asbestos sheeting, water proofing materials and thermal insulation materials;
— Removal of lightning protection system;
— Installation of new roof that consisted of water proofing, thermal insulation and a metal roof cover;
— Installation of new lightning protection system;
— Disposal of wastes from the refurbishment.

A.I–5.4. REUSE

The LATRANSA building will be reused as a low level (LL) and medium level (ML) RAW processing facility.

A.I–5.5. CONCLUSIONS

A programme of chemical decontamination was completed in a formerly designated transuranicum laboratory building, formerly used for Fumitoxin production in 1993–1994. The building has been refurbished for use as a LL/ML RAW processing facility.

Annex A.I–6. A1 NPP Decommissioning, Slovakia

A.I–6.1. INTRODUCTION

The first pilot NPP in the former Czechoslovakia was A1, which was built at Jaslovske Bohunice near the town of Trnava. An NPP with a capacity of 143 MW(e), it was commissioned in 1972 and operated with interruptions until 1977. A KS-150 reactor with natural uranium as fuel, D_2O as moderator and gaseous CO_2 as coolant was installed in the plant.

The first serious accident associated with refuelling occurred in 1976, when a locking mechanism at a fuel assembly failed. The core was not damaged during that accident and after reconstruction of the damaged technology channel, the plant resumed operation.

The second serious accident (level 4 according to the International Nuclear Event Scale) occurred in 1977, when a fuel assembly overheated, causing release of D_2O into the gas cooling circuit. This accident was attributed to human error during replacement of a fuel assembly. Subsequent rapid humidity increase in the primary system resulted in damage to fuel elements in the core, and the primary system was contaminated by fission products. Internal reactor structures were also damaged. Radioactive contaminants penetrated into parts of the secondary system by leaking through steam generators. The radiation impact on and around the plant site was below specified limits for both events.

Based on a technical and economic study of the difficult equipment repairs needed to restore plant operation, and also due to the policy decision to discontinue further construction of gas cooled reactors in the former Czechoslovakia, a decision was made in 1977 to terminate plant operation. The decision to proceed with the A1 plant decommissioning was issued in 1979.

Beginning in 1981, decommissioning proceeded with disassembly of equipment from the secondary system (process equipment in the machine hall, turbines with auxiliaries, feed water tanks, diesel generator station, pumps, cooling towers, electric equipment). At the same time, other systems were disassembled, which included turbine generators with auxiliaries, gas systems, oil systems and other equipment and systems in the main production building and in nearby buildings (Fig. I–6.1).

FIG. I–6.1. A1 NPP reactor hall.

A.I–6.2. CASE: REUSE OF SOME BUILDINGS OF THE A1 NPP FOR RADIOACTIVE WASTE TREATMENT AND STORAGE

Between 1996 and 1999, all nuclear fuel was removed from the plant, establishing conditions for the implementation of the initial phase of A1 decommissioning during 2008. Project of the A1 NPP Decommissioning — Stage I included the main project groups as follows [I–6.1]:

- Protection of the Environment;
- Main Generation Building;
- Radioactive Waste Treatment and Conditioning;
- Technical Support.

The following buildings of the A1 NPP are presented as good examples of redevelopment and reuse for RAW processing technologies:

- Machine hall: Following disassembly of the original equipment, new RAW treatment technologies were installed and commissioned;
- Main generation building: A vitrification facility was installed and commissioned;
- Several A1 NPP auxiliary buildings: These were modified for use as storage facilities for very low level wastes such as contaminated soil and concrete.

Technologies for segmentation of metallic waste (thermal and hydraulic cutting), decontamination of metallic waste (sand-blasting and high-capacity electrochemical decontamination) as well as technology for heat/ventilation/air-conditioning filters treatment are in operation in the former machine (turbine) hall of the A1 NPP (see Figs I–6.2–I–6.5]. A facility for the unrestricted release of metallic material has also been established there [I–6.2].

A vitrification facility, including storage facilities for vitrification products, is in operation in the A1 NPP main generation building in rooms where the original A1 NPP facilities were dismantled (Fig. I–6.6). High level liquid waste generated from the cooling of spent nuclear fuel is being vitrified.

Some of the A1 NPP buildings and rooms, originally equipped with plant operating equipment, are now being used for decommissioning after the dismantling of the original equipment. In this case, the NPP facilities are reused for other nuclear activities such as RAW processing to support decommissioning of the plant.

FIG. I–6.2. Machine hall during operation of the A1 NPP.

FIG. I–6.3. Thermal cutting.

FIG. I–6.4. Blasting facility.

FIG. I–6.5. High capacity decontamination facility.

A.I–6.3. CASE: RECONSTRUCTION OF THE A1 NPP HOT CELL

The hot cell was used during and after operation of the A1 NPP for inspections of irradiated nuclear fuel after its retrieval from reactor. All A1 incidents were analysed on the basis of results obtained by inspection of fuel in the hot cell (97 heavily damaged fuel elements were examined). Segmentation of selected parts of steel reactor components was also performed there.

A significant radioactive inventory, including alpha nuclides, accumulated in the hot cell in the 1970s and 1980s, and a decision to dismantle or renovate this facility needed to be made.

FIG. I–6.6. Vitrification facility.

FIG. I–6.7. Reconstructed hot cell.

The decision to renovate the hot cell was based on the fact that no other similar facility in Jaslovske Bohunice plants was available. The main benefits for reuse of the facility are its massive reinforced concrete construction, suitable internal infrastructure, available handling and transport equipment and technological linkage to the other A1 NPP facilities. The hot cell was decontaminated and reconstructed in 2003–2004 and its operation was resumed.

A.I–6.4. OUTCOME

The renovated hot cell can now be used for manipulation with spent sealed sources, highly activated materials, and management of non-standard RAW and other HLW from the A1 NPP decommissioning (Figs I–6.7, I–6.8). The hot cell is now a national resource supporting Slovakia’s industries and nuclear medicine.

FIG. I–6.8. Reconstructed hot cell control room.

FIG. I–6.9. Historical view of the A1 NPP after its completion (cooling towers on the right side).

A.I–6.5. CASE: THE POTENTIAL REUSE OF THE FORMER SITE OF THE A1 NPP COOLING TOWERS

The A1 NPP cooling towers were located in front of the main generation building. The towers were demolished in the 1980s after the operation of A1 NPP was finally terminated (Figs. I–6.9, I–6.10).

A.I–6.6. OUTCOME

The site of the former cooling towers is now used as a storage site for very low level contaminated soil. The current intent is to use this site for construction of integral storage for the A1 NPP decommissioning. Construction of a new nuclear unit in Jaslovske Bohunice on this site is under consideration from a technical, managerial and political perspective.

FIG. I–6.10. Demolition of the A1 NPP cooling towers.

Annex A.I-7. South Africa: Necsa redevelopment and reuse

A.I–7.1. OBJECTIVE

The objective of this report is to share the experience gained from the decommissioning and redevelopment of redundant Necsa buildings in order to assist in the compilation of a holistic future redevelopment and reuse plan for the Necsa site. This report aims to ensure optimization of decommissioning and redevelopment actions.

This report also aims to facilitate timely and efficient completion of decommissioning projects in that it highlights alternatives for effective redevelopment and reuse of buildings currently in a decommissioning phase.

A.I–7.2. SCOPE

The report includes background information on the Necsa site, and covers the current Necsa decommissioning and redevelopment situation and the lessons learned from previous decommissioning and redevelopment projects. It includes past decisions and methodologies followed during the development of the initial decommissioning strategy and the current view on the development of a new site decommissioning and redevelopment and reuse plan.

This report lists the new productive uses of buildings after the completion of a decommissioning project and after restricted or unrestricted release from regulatory control and how anticipated reuse of facilities may affect the decommissioning projects (appendix to this Annex).

This report supply information to assist in the compilation of a holistic Necsa site redevelopment and reuse plan and strategy.

The project of the initial uranium enrichment facility redeveloped and reused into a storage area for RAW is discussed as a single redevelopment project.

A.I–7.3. INTRODUCTION

The South African nuclear programme started in 1948 and focused on research and development in the nuclear field. The history of Necsa can be traced back to 1961, when the first separation of uranium isotopes started. Necsa is situated on the farm Pelindaba in the North West Province in South Africa, approximately 1280 m above sea level. The area has a view over the Magalies Mountains and the Hartbeespoort Dam. In the early 1970s, a pilot uranium conversion plant and a pilot uranium enrichment plant were constructed on the Necsa site. The enriched uranium was used as fuel for SAFARI-1, the research reactor at Necsa. A semi-commercial uranium enrichment

FIG. I–7.1. View of the eastern part of the Necsa site in the 1980s. The uranium enrichment facility is still in production.

plant and a fuel manufacturing plant were commissioned in the late 1970s to supply fuel for the Koeberg NPP near Cape Town. Currently, the research reactor is used for the generation of radioactive isotopes for industrial and medical applications. Various other research projects were initiated and buildings constructed on the Necsa site to accommodate the different projects. Figure I–7.1 gives a view of the Necsa site during operation.

The uranium conversion and enrichment research and production projects were terminated in the early 1990s, due to costs. This decision resulted in closure of a number of facilities and buildings on the Necsa site that became redundant. The South African nuclear programme of the 1970s to the mid-1990s has left the country with liabilities with regard to redundant, radioactively contaminated equipment, buildings and RAW. In 1999, Necsa was established as a public company according to the Nuclear Energy Act, but is still wholly owned by the state.

Similar to nuclear programmes worldwide, Necsa also experienced a nuclear winter, which enforced the implementation of short term decisions regarding decommissioning. An initial decommissioning strategy was compiled, aiming to return the Necsa site to greenfields, entailing the final disposal of waste, demolition of all buildings and its remediation to conditions prior to any development. This strategy is currently challenged because demolition is no longer considered a final decommissioning phase. Shutdown and decommissioning is viewed as a starting phase of an redevelopment and reuse opportunity for each available building on the Necsa site.

Redevelopment and reuse of currently licensed facilities at Necsa can prevent the development of greenfield sites into brownfield sites. An example of such a development is the siting of the fuel plant of the Pebble Bed Modular Reactor (PBMR) in the facility previously used for the manufacturing of PWR fuel on the Necsa site. As the demand for nuclear facilities increase (nuclear renaissance), the redevelopment and reuse options for the Necsa redundant buildings (some currently occupied by outside tenants) are considered.

The decommissioning of Necsa buildings is the responsibility of the Nuclear Liability Management (NLM) Department. To date, NLM has decommissioned several buildings, made available for redevelopment and reuse by Necsa as well as non-Necsa tenants, for reuse as chemical facilities, production of pharmaceuticals and mechanical workshops, etc.

Note: One of the main decommissioning and redevelopment projects that has been successfully completed by NLM is the redevelopment of the former uranium enrichment facility into a RAW storage facility. This project is discussed in more detail in Section A.I–7.7.

A.I–7.4. NECSA DECOMMISSIONING, REDEVELOPMENT AND REUSE: HISTORY AND FUTURE

Necsa is a multi-facility redevelopment and reuse similar to other research sites worldwide. It is recommended that multi-facilities should not considered isolated redevelopment and reuse options for individual facilities, but should adopt a holistic approach, by considering current and projected future redevelopment demands.

The new redevelopment and reuse plan currently in development for Necsa is aimed at nuclear applications and the promotion of nuclear redevelopment projects above non-nuclear-related projects. The ‘nuclear winter’ (approximately ten years from 1991 to 2001) led to many buildings becoming redundant when the nuclear fuel cycle projects were terminated. Due to uncertainty of the future of the nuclear industry, an initial redevelopment and reuse strategy had to be developed in order to ensure a positive socioeconomic impact on the workforce and the local community. Necsa was therefore forced to invite non-nuclear industries to lease some of the redundant buildings and areas with the main focus on short term financial gain.

The Necsa site is currently licensed, and the knowledge to licence facilities is well established within the corporation. Licensing sites for the development of nuclear and radiologically related projects is time consuming and the redevelopment and reuse for non-nuclear-related projects on the Necsa site will not be promoted to the detriment of the development of nuclear projects. Currently, all available buildings not occupied by non-nuclear projects are considered for nuclear redevelopment, because they are ideal for the siting of nuclear projects due to building characteristics. The new redevelopment and reuse plan aims to allocate previously licensed buildings to similar or the same nuclear projects as housed originally in the specific building and thus meeting most of the design requirements. With the recent increase in demand for nuclear facilities, the redevelopment and reuse of previous nuclear facilities have inherent advantages, which is well recognized in the new redevelopment and reuse plan.

The redundant buildings on the Necsa site (some radiological contaminated) were handed over to the Decommissioning Department (NLM). Various buildings were successfully decommissioned and reused. Necsa gained experience in the decommissioning of buildings to clearance levels because various buildings were leased to non-nuclear tenants. The buildings decommissioned to clearance levels enable the removal of these buildings from the nuclear licence and the buildings become available for redevelopment and reuse for non-nuclear applications. Since the removal of facilities from the licence was time-consuming, Necsa included this removal authorization into the original decommissioning schedule. Decommissioning costs and the reuse of equipment could not be optimized due to uncertainty in the nuclear future.

Due to the uncertainty of the nuclear future at that stage, individual facilities on the Necsa site had to be allocated for redevelopment and reuse without considering an overall site redevelopment and reuse strategy and plan. There are various other buildings on the Necsa site that are currently in a decommissioning or a care and maintenance phase that will now be evaluated to ensure the optimization of decommissioning costs and a nuclear based redevelopment and reuse.

Currently, there are conceptual decommissioning plans for most nuclear facilities, which will be explored to include possible redevelopment options. Conceptual decommissioning plans shall also aim to include the securing of facilities and sites (transition phase) after initial decommissioning until successful redevelopment and reuse. Emphasis shall be on the preservation of buildings and infrastructure in order to keep them structurally sound and operable.

Nuclear facilities require specialized labour, whose redeployment will be optimized in the new redevelopment and reuse plan. Due to the complexity of the facilities, some of the specialized labour force was retained for decommissioning purposes. As a result of the long nuclear winter, no development in the nuclear training was performed for over a decade. Today, the aim is to transfer the current knowledge to the new generation through the redeployment of skilled staff.

Necsa did not adopt a generic decommissioning strategy for all the redundant buildings, due to the diversity in historical contamination (chemical and radiological). In order to ensure the optimization of decommissioning projects, the projects are assessed and evaluated on an individual basis. These assessment processes are time consuming and costly, but are essential to ensure safe decommissioning of the facilities. Several of the historic buildings have asbestos and other chemical contamination. The decommissioning of these facilities poses a potential health risk to workers and requires special decommissioning equipment and protection.

The location of facilities to be decommissioned is an important factor that needs to be considered during the development and evaluation of redevelopment and reuse options. Necsa aims to allocate adjacent buildings or facilities that have related processes and requirements. Utilities and process equipment can be shared and its uses optimized (e.g. effluent handling systems and building stacks).

The Necsa site and facilities have the following specific infrastructure and attributes, with financial benefits/advantages that will be considered during the evaluation of redevelopment and reuse options:

— Well established and documented electricity supply to facilities (drawings and certification);
— Well developed roads, which ensure safe on-site transfer of radiological material between facilities;
— Well developed road network to main destinations in support of off-site transport.
— Office space;
— Well-established utility supplies (e.g. cooling water systems, steam supply and demineralized water supply, etc.);
— Well-developed security systems (cameras and fencing, etc.);
— Although well established support features (e.g. vaults, tanks, pits, water supply systems, fire protection systems, sewerage systems and other waste transfer/redevelopment and reuse systems), may have a major negative impact on decommissioning, it could have many benefits for a site that will be reused;
— Support services (e.g. catering, maintenance workshops);
— A partly ‘captive’ local workforce with a high level of technical skill living within a radius of 100 km from the Necsa site;
— Sites already licensed and authorized that could be a general benefit with regard to project risk, cost, time and effort;
— Stakeholder (public) acceptance and established communication links;
— On- and off-site emergency control arrangements;
— Available site information such as demography, geology, hydrogeology, seismology, population density and floods, etc.;
— Approved and implemented safety, health, environmental and quality management systems (e.g. monitoring programmes for groundwater and air releases), which would reduce the initial level of investment of future developers.

One of the disadvantages of decommissioned radiological contaminated facilities is the deterioration of structures caused by specific decommissioning actions, e.g. removal of concrete. The regulatory requirements and compliance with current structural codes (e.g. seismic) as well as operational standards may not be met by the decommissioned facilities, and the renovation of such buildings might not be cost-effective. Continuous operational and maintenance costs due to operating technical specifications applicable to nuclear facilities may be higher for the old buildings and reused systems. If, however, similar contamination is caused by the planned new projects, the integrity of the existing systems will be evaluated and upgraded, rather than dismantled, decontaminated and replaced. Reuse of equipment could result in a significant cost saving when compared with the cost of full decommissioning and re-installation of new equipment.

The removal of contaminated ventilation ducting, underground pipelines and drains, inter alia, may be very costly, and if required, it may not be viable to redevelop these older buildings. In such cases, the construction of new buildings that comply with the current legislation and standards should be considered. The time involved in obtaining decommissioning approval and the actual time required for decommissioning might jeopardize the redevelopment of a facility, and the construction of a new building may become the preferred option.

The new Necsa redevelopment and reuse plan will address waste minimization objectives by optimizing the reuse of buildings and structures, hence preventing the demolishing of structures and the unnecessary generation of RAW.

A.I–7.5. SAFETY ASSESSMENT AND ENVIRONMENTAL IMPACT STUDIES

Environmental impacts have been assessed and are currently managed in a fragmented manner due to the timeline of developments on the Necsa site. A consolidated Environmental Impact Assessment (EIA) must be performed as part of the Necsa overall redevelopment and reuse strategy and plan. Although an integrated EIA will be costly and time-consuming, a focused assessment of the reuse options will improve the redevelopment and reuse process and identify the total Necsa project impact.

In view of the requirement to consider all external events, the mutual impacts of facilities need to be assessed. Redevelopment of project-specific safety cases including safety assessments need to be performed, in which the impacts of all neighbouring facilities are analysed. The results of such safety analyses could have a significant impact on the outcome of the redevelopment and reuse options and decision making.

FIG. I–7.2. Aerial view of population distribution around Hartbeespoortdam, close to Necsa, in 1970.

FIG. I–7.3. Aerial view of population distribution around Hartbeespoortdam, close to Necsa, in 2007.

A.I–7.6. STAKEHOLDER IMPACT (REGULATORY REQUIREMENTS AND PUBLIC INVOLVEMENT)

The Necsa site is close to the Hartbeespoortdam area. The current public profile has changed significantly from a rural smallholding type of residential area in the 1970s, when Necsa just started high class residential and commercial developments. Figures I–7.2 and I–7.3 are aerial photographs indicating the difference in the development profile. Harbeespoortdam is one of the fastest development areas in South Africa. The initial site justification based on demography, geology, hydrogeology, seismology, population density and floods, etc. could not project the level of development as experienced since 2000. Overall public sensitivity regarding environment concerns has increased. The public's positive perception and support is required for the successful implementation of redevelopment and reuse options and plans. Its early involvement in the development of an redevelopment and reuse strategy is important.

The need to improve communication between radiation protection staff and the public has been recognized, and major improvements have been made to eliminate confusion. Public perception is inclined to overestimate the risks associated with a nuclear installation. Decommissioning plans and the redevelopment and reuse options should have a strong focus on safety for the protection of workers, the public and the environment. Such redevelopment and reuse options are likely to build confidence of the general public and other stakeholders.

The early involvement of the National Nuclear Regulator (NNR) during the planning of redevelopment and reuse and their acceptance of the Necsa site redevelopment and reuse options and strategies is important. The

FIG. I–7.4. Uranium enrichment facility in operation.

applicable NNR authorization criteria and decommissioning guidelines for the various phases (e.g. cleanup criteria, characterization methodologies and techniques) should be identified and addressed in the redevelopment and reuse strategy and plan. The viable redevelopment and reuse options should be approved by the NNR as part of the decommissioning strategy prior to decommissioning. Failure to obtain prior approval could result in higher decommissioning costs, which could jeopardize redevelopment and reuse plans. The holistic approach and complete picture of redevelopment and reuse projects should be made available to the NNR. The NNR has emphasized at various instances that they require an overview of the complete picture of new projects prior to approving individual phases of the project. In this light, it is also recommended that the NNR should be supplied with a proper redevelopment and reuse strategy and plan prior to completing individual decommissioning projects related to the redevelopment and reuse projects.

Redevelopment and reuse strategies should consider all hazards including radiological and chemical hazards, thus involving the NNR and other regulators in the acceptance of the redevelopment and reuse plan and strategy.

A.I–7.7. URANIUM ENRICHMENT FACILITY REDEVELOPED INTO A STORE

A.I–7.7.1. Uranium enrichment facility history (1977–1995)

The uranium enrichment facility was constructed in the late 1970s and enriched uranium at enrichment levels of 3.25–3.90%. The enriched uranium was used for PWR fuel production. In 1994, it became clear that the enrichment facility would not be cost-effective on an international scale. Operation of the uranium enrichment facility was terminated in 1995. Figure I–7.4 shows the enrichment plant during operation.

A.I–7.7.2. Uranium enrichment facility decommissioning (1995–1999)

Once the decision to terminate the enrichment facility was made, decommissioning of the facilities commenced. Some delay in the decommissioning project was experienced due to the licensing of decommissioning activities. Although the decommissioning project technically commenced a day after the facility was shut down, the licence to decommission the uranium enrichment facility was obtained at the end of 1995. The rate of decommissioning improved with experience and better planning in terms of labour equipment and use of the decontamination facility. The decommissioning project was completed about 1999 (Figs I–7.5, I–7.6).

Although redevelopment was not specifically considered during decommissioning, the following main lessons learned from decommissioning impacted on redevelopment and reuse of the facility are:

- Specific plans were implemented to ensure a positive morale among workers who had to shift from operation to decommissioning. Many of the workers successfully completed the decommissioning phase and were redeployed in the reuse application, thus ensuring that nuclear expertise would be retained.
- Efforts were made to limit radiological risks associated with the decommissioning actions by minimize radioactive inventories prior to shutdown.

FIG. I–7.5. Decommissioning scrap and possible recyclable material and equipment separated during decommissioning.

FIG. I–7.6. Uranium enrichment facility after decommissioning.

- During decommissioning, the building structure and general utilities were maintained to a level that allowed the successful reuse of the facility after decommissioning.
- Decommissioning is a multifaceted task and involves various disciplines and roles (e.g. operators, radiation protection specialists, decontamination specialists, mechanical and electrical engineers, project management and waste management) for the design of such facilities. Redeployment of such experts supported redevelopment and reuse.
- The initial chemical cleaning facility (used to clean components during construction of the uranium enrichment facility) was converted to a maintenance service facility after construction and was easily converted to a decontamination facility.

A.I–7.7.3. Redevelopment and reuse of the decommissioned uranium enrichment facility

Decommissioning and historical waste were stored in various interim storage facilities throughout the Necsa site. This caused logistical and security problems, and resulted in inconsistent pre-disposal waste management practice. In order to improve pre-disposal management practice, it was necessary to consolidate all waste in a single waste store. The decommissioned uranium enrichment facility was identified as a suitable facility and redeveloped into a radiological waste store. The facility was redevelopment and relicensed in accordance with the Necsa project approval process. The safety case of the store included specification of specific waste acceptance requirements aligned with specific design and lay-out features. Pre-disposal waste management actions and the demonstration of compliance with waste acceptance requirements were necessary for the transfer and acceptance of waste to the store. This resulted in improved and more consistent waste management practice (Fig. I–7.7).

The waste storage facility was equipped with a drum scanner for the characterization of waste required for further predisposal waste management and final disposal of waste (Fig. I–7.8).

FIG. I–7.7. Two views of waste stored in the decommissioned uranium enrichment facility.

FIG. I–7.8. Drum scanner used to characterize waste drums.

A.I–7.7.4. Conclusions

The redevelopment of the uranium enrichment facility to a RAW store was a relatively simple project, which was completed within time and budget. The main reason was that the available safety systems were far more advanced than the systems required by the new waste store redevelopment use.

APPENDIX TO ANNEX A.I–7

This appendix describes a number of redevelopment and reuse cases at Necsa.

Example 1.

The former chemical cleaning facility utilized for the cleaning of zirconium tubes also housing an oil purifying facility was decommissioned and the building reused to house semi-conductive, fluorine related chemical facilities and a chemical maintenance workshop. These facilities manufacture products such as NF_3; WF_6 and organic (fluorine related products).

The building is equipped with a high integrity building ventilation system, which serves the plant area with an individual building stack and utility network that includes steam, chilled water cooling water and demineralized water. The building is also equipped with a vault fitted with a separate ventilation system.

This building was ideal for redevelopment options, and the initial layout capital cost for the chemical facilities constructed inside the building was influenced by the availability of existing systems.

Example 2.

Part of the former PWR fuel manufacturing facility is partially decommissioned and will be reused as the Pebble Bed Modular Reactor (PBMR) fuel manufacturing facility. The building is not fully utilized at the moment, but the future development of the building is in the planning stage. The facility is equipped with a ventilation system, a building stack and an effluent handling system. Uranium was previously used in the facility, and the ventilation and building stack still have traces of uranium contamination; the ventilation might be upgraded without requiring full demolition of the current ventilation. The building is still under nuclear licence.

Example 3.

The remainder of the former PWR fuel manufacturing facility is reused as PBMR laboratory and R&D facilities. Laboratories and R&D facilities have been established for the development of manufacturing and quality control methods for nuclear fuel for the PBMR. The work is being carried out under contract for PBMR (Pty) Ltd.

The following four laboratories have been established:

— Kernel production;
— Coated particle production;
— Fuel sphere production;
— Quality control.

The building ventilation system stack is shared with two neighbouring buildings, but all the utilities are separately supplied by the main utility supply facility. The building and ventilation system were historically contaminated with uranium and the decommissioning did not require demolition of the ventilation system.

Example 4.

The zirconium ingots casting facility was decommissioned and redeveloped to house a non-radiological process, i.e. a surface fluorination chemical facility and non-radiological workshops. The chemical facility was originally designed, commissioned and operated by Necsa’s chemical division. A private company was then established to operate the facility as a (Pty) Ltd.

Example 5.

The former cleaning facility, used for cleaning of scrap zirconium tubes, was decommissioned and is currently housing a fluorine gas production facility and a small XeF_2 production facility.

Example 6.

Former office and halls used for the laser development project have been redeveloped into a training centre. The building is equipped with a building ventilation system with no scrubbing system for off-gases, and hot cell training will be conducted to accommodate future training needs.

Example 7.

The Hot Cell Complex is currently developed into a medical isotope production facility, which is used for examining post-irradiation, locally manufactured fuel elements.

The radioisotopes production facility is focused on the production and marketing of nuclear technology based products, used principally in the fields of health care, life sciences, industry and mining. Products are distributed across five different continents to customers in more than 50 countries including the USA, UK, Australia and major European and Asian nations.

Example 8.

The facility was used for UF_6 transfer to and from cylinders, and will now be utilized as a de-heeling facility: Residual UF_6 is removed from 12 t UF_6 cylinders in order to decontaminate and recycle redundant UF_6 cylinders.

Example 9.

The prototype testing facility for enrichment equipment such as the testing of turbines for compressor balancing was redeveloped into a special alloy manufacturing facility. The building is equipped with a good ventilation system and required very few changes for the new application.

Example 10.

The former food irradiation building was redeveloped into the cyclotron and medical isotope production facility. The building is well isolated from other buildings and is equipped with good shielding.

Example 11.

The original chemical cleaning facility used during the construction of the uranium enrichment facility and other research facilities was redeveloped more than once. After construction of the uranium enrichment facilities, the chemical cleaning facility was converted into workshops that served the various facilities. During decommissioning of the uranium enrichment facility, the chemical cleaning facility was again redeveloped into a decontamination facility.

The facility has been equipped with good ventilation and other relevant process-related systems. Additional criticality safety arrangements had to be put in place during use as a decontamination facility.

Annex A.I–8. UKAEA, Harwell site decommissioning and redevelopment

A.I–8.1. REUSE AND LICENCE TERMINATION OF THE UKAEA, EASTERN ZONE HARWELL, TO ENABLE REDEVELOPMENT AS A SCIENCE AND INNOVATION CENTRE

A.I–8.1.1. Introduction

Harwell is located in the Thames Valley, UK, in a rural setting near the Berkshire Downs, midway between Oxford and Newbury. UKAEA Harwell was the first significant nuclear research site in the UK. The site was opened in 1946 on the site of a WW II Royal Air Force (RAF) airfield. Several research scale nuclear reactors and many radiochemical facilities were operated at Harwell.

Today, Harwell is a multi-occupancy and multi-ownership site, part of which is undergoing decommissioning with a view to redevelopment. Part of the campus is a nuclear licensed site (Fig. I–8.1).

A.I–8.1.2. Nuclear site licences (UK)

In the UK, a significant number of nuclear installations with plant such as nuclear reactors are licensed under the Nuclear Installations Act [I–8.1]. Once the land has been licensed, termination of the licence in whole or part is not simply a matter of demonstrating that the licensable activity has ceased.

Licence termination involves a demonstration that the land presents a low risk and the process can be used to support redevelopment, because it results in an in-depth validation of the land quality. The nuclear site licence restricts the reuse of the land by landlords other than the site operator, and hence licence termination is the key requirement to enable commercial redevelopment.

FIG. I–8.1. The Harwell campus.

A.I–8.1.3. Use and reuse of buildings, Eastern Zone, Harwell

Buildings in the Eastern Zone have been used over time in a use and reuse cycle:

- *Original use.* Some buildings date from the 1930s and were constructed by the RAF for military use. These buildings are often brick built to a high architectural standard. The land was originally used for agricultural.
- *Nuclear use.* Many of the original RAF buildings were reused for early nuclear research; other buildings were built through the 1940s to the 1980s specifically for this purpose.
- *Post-nuclear use.* Many buildings were partly decommissioned and then reused for different nuclear uses or for non-nuclear research purposes. During this phase, the buildings were still on a nuclear licensed site, and management of the buildings (plus liability risk) remained with the nuclear site operator. The buildings were used by the operator or leased to tenants in the nuclear and related industries. Some buildings were converted to offices for entirely non-nuclear usage.
- *Delicensing.* The presence of a nuclear site licence in the UK heavily restricts the involvement of the private sector in site redevelopment. Delicensing of the Eastern Zone is now being pursued to enable unrestricted reuse of the land. Most buildings with a previous nuclear use have been removed as part of this process, but it has been possible to retain some low hazard buildings in a fully decommissioned state for continued reuse.
- *Redevelopment.* In the future, the Eastern Zone will be developed as a science and innovation campus using a joint venture development between the government and the private sector.

A.I–8.1.4. Progress with delicensing and reuse of the Eastern Zone

An objective has been agreed for the final end state of the Harwell site with local stakeholders, regulators and the government. The agreed end state is that the whole site will be returned to a land quality standard suitable for unrestricted reuse. This will take many years to achieve; for example, current plans indicate that most of the site will not be cleared until around 2030. The work will proceed in phases.

For areas of the site that are licensed, interim reuse of certain buildings is possible. The buildings are decommissioned to an interim status suitable for the intended reuse and then used, often by tenant organizations with the site operator as landlord. This interim reuse provides an income stream during the phase prior to full decommissioning funding becoming available.

An example of interim reuse is given in Appendix I to this Annex.

The intention is to redevelop the eastern part of the campus in the near term. Plans for commercial redevelopment have been agreed with local and/or national government, and a private sector partner has been brought on board to bring about the investment. The following areas are in the process of licence termination to provide the land for this development.

— ETSU Area 5 ha, delicensed 1992;
— Pilot Area 7 ha, delicensed 2006;
— North Gate Area 5 ha, delicensing case submitted, pending approval;
— Eastern Facilities Area 5 ha, delicensing case submitted, pending approval. (Fig. I–8.2).

A.I–8.1.5. Delicensing criteria

The most recent example of licence termination in order to achieve a land quality suitable for unrestricted redevelopment was the Pilot Area.

The licence termination involved:

— A historical survey of records and maps/drawings;
— Radiological and chemical surveys of the land;
— Building/drains surveys;
— Investigation/remediation of anomalies;
— Preparations of the delicensing case;
— Formal submission to the Nuclear Installations Inspectorate (NII) Regulator;
— NII verification surveys;
— Clarifications/discussions;
— NII approval;
— Marking of the new boundary;
— Issuance of a licence variation.

The UK regulatory authorities clarified licence termination in a policy issued in May 2005 [I–8.2]. The current criteria are:

— Additional risk of death to the individual meets a risk criteria of 10^{-6}/a for any foreseeable use (equivalent to 10–20 μSv/a);
— No RAW (as defined in the UK by the Radioactive Substances Act [I–8.3]) left on the site.

At Harwell, the delicensing criteria have been demonstrated by comparison of residual activity levels with the levels set in IAEA Safety Standard Series No. RS-G-1.7 [I–8.4].

Therefore, in the UK, licence termination has been implemented in order that a land quality will be suitable for unrestricted use. This does not leave open the possibility for the reuse of the land for less restrictive purposes unless the nuclear site licence is retained. While limited interim reuse is possible with a nuclear site licence still in place, the regulatory requirements and costs generally discourage commercial redevelopment unless the licence has been terminated.

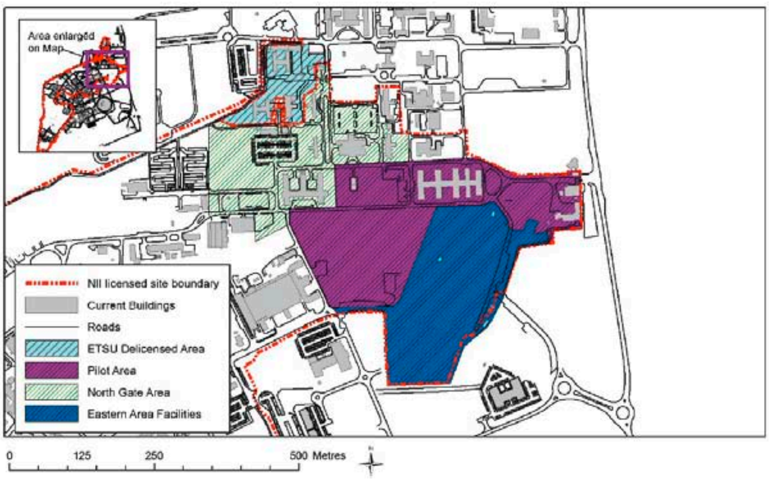

FIG. I.8–2. Current delicensing areas, eastern part of the Harwell site.

A.I–8.1.6. Examples of reuse in the Eastern Zone

Prior to any consideration of delicensing and redevelopment of the Eastern Zone, it has been normal practice at Harwell to reuse buildings beyond their original intended use. Some examples from the Eastern Zone are given in Appendix II to this Annex. A detailed example of a particular case history of reuse of buildings at Harwell is given in Appendix III.

A.I–8.2. DELICENSING AND REUSE OF BUILDINGS IN THE PILOT ZONE

The Pilot Zone was selected as the first modern example of licence termination for future redevelopment at Harwell, because the land was in a commercially attractive part of the site and the area had been used for a wide range of facilities.

The area had been used for 43 buildings from 1946 to the present, ten of which had a radiological use. Radiological uses included laboratories, active workshops, uranium fabrication and liquid waste stores. The original structures were all demolished except for six buildings, which were converted for office use; it was demonstrated that they were delicensable without demolition. (Figs I–8.3–I–8.5).

B329 is an example of a building that was retained throughout the entire history of the Harwell site and that has been cleared for reuse post delicensing (see Appendix IV).

In order to delicence the Pilot Zone and release it for future commercial redevelopment, a programme of surveys was undertaken, including:

FIG. I–8.3. The Pilot Zone in the 1950s showing early nuclear research use.

FIG. I–8.4. The Pilot Zone in 2005 after all decommissioning was completed.

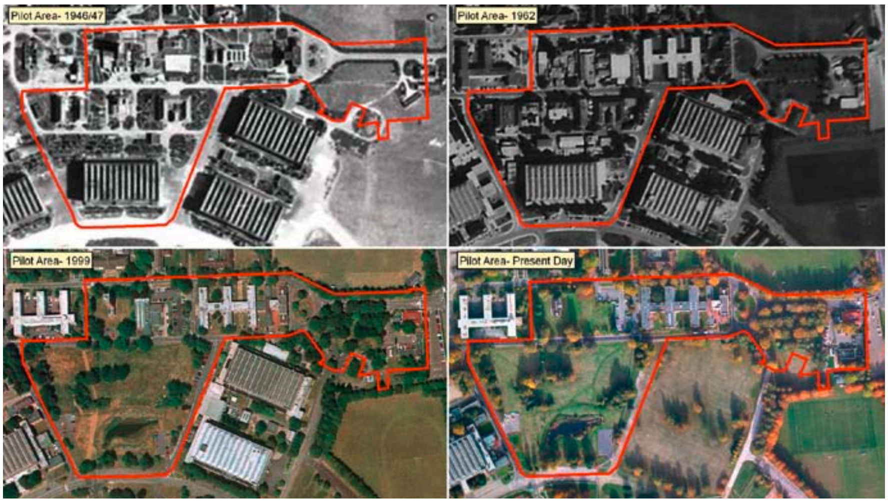

FIG. I–8.5. The Pilot Zone over time showing use, interim reuse and final clearance.

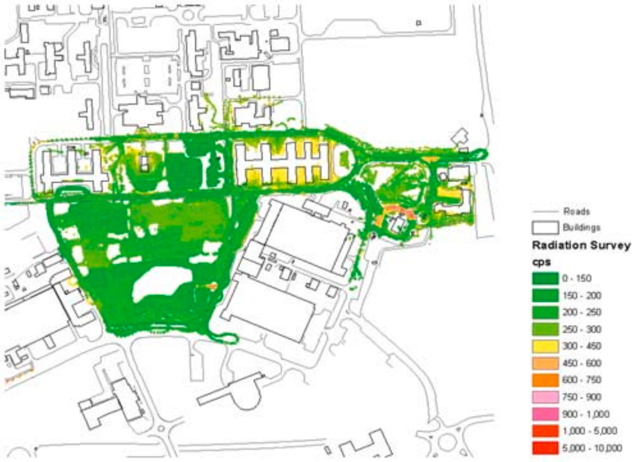

FIG. I–8.6. Example output from open area gamma surveys of the Pilot Zone (260 000 readings on a nominal 1 m grid at waist height using a sodium iodide probe).

— Internal and external surveys of all remaining structures;
— Gamma surveys of all open land;
— Intrusive sampling on a 23 m grid to 3 m depth;
— Drains surveys and decommissioning

The results of the surveys were compiled into a delicensing case and submitted for regulatory approval. All results and records were entered into a geographical information system and database. The database was used to support due diligence research carried out by the private sector land developer prior to commercial redevelopment (Fig. I–8.6).

The Pilot Area was delicensed in 2006.

A.I–8.3. OUTCOME

At the time of writing, the Pilot Area and the other areas in the Eastern Zone are under progressive delicensing and negotiation for transfer to a private sector/government joint venture development partner. The land is planned for redevelopment as a science and innovation centre.

The Eastern Zone demonstrates that buildings with nuclear uses can be reused for other nuclear and non-nuclear uses during the period of site licensing and can then be finally demolished or, in some cases, reused through to licence termination. Subsequent to licence termination, the land and reused buildings can be beneficially redeveloped.

A.I–8.4. DISCUSSION

The key factors for reuse of a building with nuclear usage are:

- The cost and practicability of cleaning the building for the potential reuse;
- Confidence created among stakeholders through decommissioning and survey that the building is suitable for the intended reuse;
- The demand for reuse applications from the site operator or other parties willing and able to work from within a licensed nuclear site;
- The timescales and intention to eventually clear the licensed site to a particular end state;
- The practicability of delicensing the building intact versus the requirement to remove the building to create confidence in the delicensing case. Relevant issues are: the degree of building strip-out required to ensure removal of contamination, the potential for underlying land and drains contamination, and the presence of non-nuclear chemical contamination, in particular the hazards from asbestos;
- The value of the building to the redeveloper on the delicensed land in the context of the redevelopment master plan.

At Harwell, the initial emphasis was on reuse of buildings on the licensed site while the site was operational, and there was demand from the site operator and others. As the site has progressed to a purely decommissioning status, the emphasis has shifted to final clearance of structures in preparation for licence termination and subsequent land redevelopment by the private sector. Nonetheless, it has been possible in some cases to reuse a building from an original RAF use through nuclear and post-nuclear uses, and to ensure that the building is delicensed to become a seed structure for future redevelopment.

The lessons learned from Harwell is that reuse of buildings from the nuclear industry can play a valuable part in the lifecycle of a nuclear site through to final licence termination and redevelopment.

APPENDIX I TO ANNEX A.I-8

BUILDING 146: AN EXAMPLE OF INTERIM REUSE AT HARWELL

Building 146 was constructed by the RAF in the 1930s as a Sergeants’ Mess. It was a single storey brick structure with a floor area of 860 m^2. By 1946, the building was modified to include radiochemical laboratories and incorporated an extensive ventilation system in the roof space. The building contained fume cupboards and glove boxes for a wide range of nuclides including alpha hazards (Fig. I–8.7).

The building was refurbished in the 1980s with the removal of all laboratory equipment, the covering of original floor surfaces and the sealing of the ventilation system. The building was reused for offices by a nuclear security regulator until 2006. During this period, the building contained some low level contamination fully sealed to prevent harm to the occupants. Final decommissioning involved removal of residual contamination and of the ventilation system and demolition/land remediation. This is an example of a building with a significant nuclear usage that was reused prior to final demolition. The building could not, however, be kept intact for delicensing, because removal of the ventilation system and soft fabric structures destroyed it. It was also necessary to remove contamination in the building cavities and below ground structures/drains (Fig. I–8.8).

FIG. I–8.7. B146 in the 1960s.

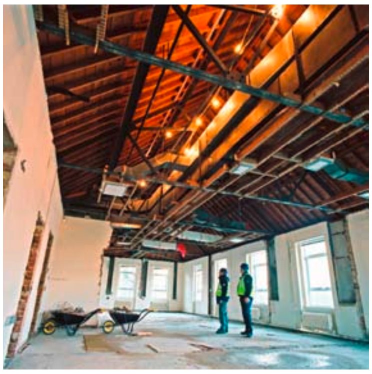

FIG. I–8.8. B146 prior to removal of the ventilation system during final decommissioning.

FIG. I–8.9. B401.4 pending demolition.

APPENDIX II TO ANNEX A.I-8

EXAMPLES OF BUILDING REUSE, HARWELL, EASTERN ZONE, BUILDING 401.4 (FIG. I–8.9)

Nuclear use. A zero energy and subcritical pile test facility (1954), later a remote handling test facility (1964), and finally, a facility for radiation tolerance testing of electronic systems (1992).

Post-nuclear use. Cleared for use as a storage building, and most recently, used by a tenant for sensitive record storage (2005).

End state. It will be demolished prior to licence termination because the building is in poor condition, has no market value to the developer and has extensive asbestos cladding materials.

FIG. I–8.10. Hangars 7 and 8 prior to decommissioning.

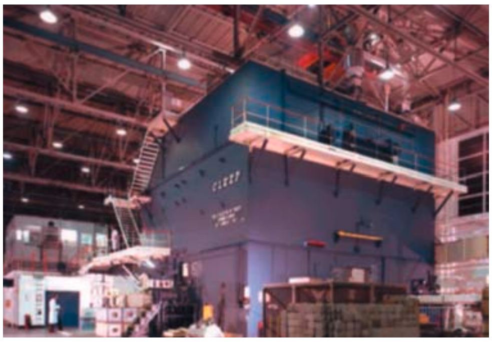

FIG. I–8.11. The GLEEP reactor in Hangar 8.

FIG. I–8.12. The area after decommissioning.

HANGARS 7 AND 8 (FIG. I–8.10)

Pre-nuclear use. Constructed by the RAF for WWII military use as aircraft hangars.

Nuclear use. Hangar 8 was used to house the GLEEP graphite moderated reactor (the first reactor in Europe) (Fig. I–8.11). Both hangars were used for early research experiments with accelerators and cyclotrons.

Post-nuclear use. Hangar 7 became a centre for chemical hazard research and waste experiments.

End state. The hangars were demolished and the land remediated to enable licence termination. The delicensing case is currently under consideration by the regulator. The hangars could not be delicensed without extensive strip out and there was no market for their reuse (Fig. I–8.12).

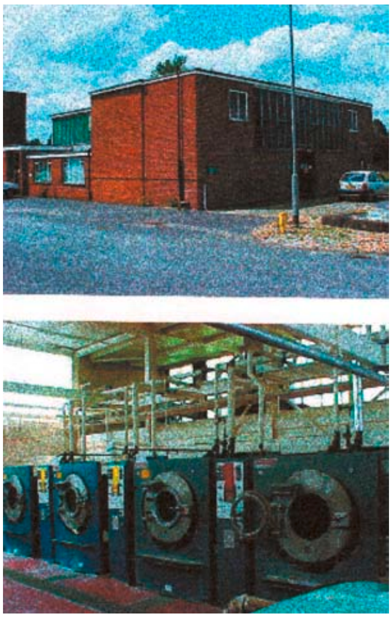

FIG. I–8.13. B413 in reuse as an active laundry.

APPENDIX III TO ANNEX A.I-8

HISTORY OF REUSE OF B413 AT HARWELL

Building 413 was constructed in 1955 to house a Chemical Cleaning Plant. The plant was used to degrease metal components and to provide surface treatments. The components to be treated were required for nuclear irradiation experiments and fusion research.

The building is single store and has a gross floor area of 635 m^2.

Large quantities of solvents and metal pickling solutions were used in the facility and numerous spillages occurred.

In 1970, the eastern end of the building was converted for use as the site's active laundry and the western end was converted for use a radiological calibration facility. The building was used for work with radioactivity for 30 years (Fig. I–8.13).

In 2000, the active laundry was decommissioned, which involved removal of the laundry plant, floor surfaces and ventilation systems. Significant areas of low level radiological contamination were discovered under floor surfaces and removed. The floor was extensively characterized by core drilling and surveyed.

The floor was found to have been extensively damaged by historical spillages of corrosive chemicals. This complicated decontamination, and the floor in one end of the building was completely removed in 2003 and replaced.

At this time consideration was given to complete removal of the building. The considerations in favour of removal were:

— The building had no long term redevelopment use as part of the site master plan.
— The building could have liabilities associated with radioactivity and chemical spillages underneath the substructures that could only be dealt with after complete removal.

The considerations in favour of conversion were:

— The cost of conversion was relatively low given that the decommissioning cost had been partly incurred and would in any case eventually have to be completed.

FIG. I–8.14. Building 413, the ex-active laundry area being concrete core drilled after removal of the contaminated floor surface.

— There was a use for the building that would result in rental income for a period prior to final removal.
— The building was not in a current delicensing area and hence did not need to be removed for licence termination purposes.
— The underground liabilities were not mobile, as evidenced from nearby groundwater monitoring.
— There was interest from tenants to reuse the building and the reuse proposal was compatible with the building structure in a way that would not complicate later decommissioning.
— The cost of conversion would be met by the future tenants and was not high.
— The prospective tenants were already based at Harwell and were within the nuclear industry; hence, there were no issues of blight from previous nuclear uses.
— The tenants were nuclear industry companies that could be trusted not to interfere with residual contamination in the building.
— The regulatory authorities had no concern with reuse of the building.
— The building could not be decommissioned fully at the time because of funding priorities.

In 2003, the building was converted: the active laundry end of the building was converted for use as the site carpentry workshop and the other end of the building was released to a new tenant for use as a calibration facility in line with previous similar uses.

Prior to reuse, the building was cleaned up to a standard acceptable for safe reuse, but not necessarily completely clean for free release. Any residual contamination was identified, fixed and sealed. Some residual contamination was locked into the roof structure and underfloors. The land is probably contaminated below the building. There are also asbestos liabilities in the building that are maintained in a safe state during use and will be removed prior to demolition (Fig. I–8.14).

The building is currently being used for these purposes and will be decommissioned after 2010 by complete removal.

This building is typical of many at Harwell that have been converted for different uses over their lifecycle, often involving both nuclear and non-nuclear uses. In fact, there are very few buildings on-site that were only used for one purpose.

Eventually, most buildings have to be demolished in order to demonstrate achievement of licence termination criteria and to free up the land for redevelopment. Some buildings can be retained through licence termination because they have had low hazard uses.

The advantages of reusing B413 were:

— Rental income was provided in the period prior to final demolition;
— There were few additional costs;
— It helps with maintenance of liabilities in the period prior to final demolition.
— In the case of the site carpentry workshop, the cost of building a purpose built facility was avoided.

FIG. I–8.15. B329 circa 1960.

APPENDIX IV TO ANNEX A.I-8

B329 — This is an example of reuse through licence termination, Harwell (Fig. I–8.15).

Pre-nuclear use — This brick built two storey building was constructed in the 1930s to serve as the RAF headquarters.

Nuclear use — The building was extended in 1948 and used for site administration.

Post-nuclear use — The building has been leased to a tenant for use as an administration building.

End state — The licence has been terminated for the area of land containing the building. The building was surveyed in order to delicence without demolition. It will become a seed facility for redevelopment of the area.

Annex A.I–9. Reuse of decommissioned nuclear facilities of the East Tennessee Technology Park, Oak Ridge, Tennessee, USA; East Tennessee Materials & Energy Corporation

A.I–9.1. INTRODUCTION

East Tennessee Materials & Energy Corporation (M&EC) was established in 1998 to provide waste treatment and materials management services to support the United States Department of Energy (DOE) in treating legacy waste from the Oak Ridge Reservation. The M&EC facility is located in Oak Ridge Tennessee at the Department of Energy's East Tennessee Technology Park (ETTP) (formerly the K-25 site). Originally, a joint venture between PDC, a small business, and Perma-Fix Environmental Services, M&EC became wholly owned by Perma-Fix in 2000. This enabled Perma-Fix to provide the capital to undertake decontamination and construct the waste treatment facility.

Today, the M&EC treatment facility occupies approximately 10 000 m^2 (110 000 ft^2) of the centre and south bays of Building K-1200 and a portion of Building K-1023. It also controls additional room for expansion in the K-1200 North Bay plus office space, staging areas and support facilities. The complex is occupied under a long term lease arrangement from DOE and the Community Reuse Organization of East Tennessee (CROET) (Fig. I–9.1).

The ETTP site began as one of the facilities built by the Manhattan District of the Army Corps of Engineers as part of the 'Manhattan Project' — the massive, all-out effort by the USA to build an atomic weapon to defeat Axis forces in World War II. ETTP, originally referred to as the Oak Ridge Gaseous Diffusion Plant, used a 'barrier-type' technology to enrich uranium. As a result of processing activities performed at the site, hundreds of ageing facilities were contaminated with radioactive and hazardous substances including uranium, heavy metals, solvents and PCBs.

FIG. I–9.1. East Tennessee Materials & Energy Corporation, Inc. (M&EC) facility.

In 1996, DOE-ORO began recognizing that former facilities could be reindustrialized or converted for future purposes. Although the ETTP site was undergoing cleanup under CERCLA and would be for some time, opportunities for leasing were available provided that DOE used the provisions of CERCLA 120(h) to safely enable others to use the site. CROET was tasked with developing and subleasing the property and equipment owned by DOE at the ETTP site.

The buildings occupied by M&EC were developed at the site during the Cold War era to support experimental work on gas centrifuge technology for uranium enrichment. After the centrifuge project was terminated, the North Bay was left relatively clean and contamination was light in the Center Bay of K-1200; however, the South Bay was significantly contaminated with classified material and remains a security area.

A.I–9.2. DECONTAMINATION AND PREPARATION FOR REUTILIZATION

The three-bay K-1200 building was ideal for M&EC's purpose due to the large open areas and tall overhead spaces. Through a contract with DOE, the Perma-Fix M&EC facility agreed to perform demolition activities for the radiologically contaminated facilities (K-1200 Center Bay and the K-1200 South Bay 'L Area') in exchange for a favourable lease arrangement.

Upon signing the lease agreement in 1998, M&EC commenced decommissioning the former nuclear facility buildings to the stage where new construction could occur. The demolition activities included the removal of equipment and dismantling of structures associated with the R&D gas centrifuge programmes housed in these facilities. Free release criteria were achieved for the K-1200 Central Bay, but South Bay remained restricted use only. In addition to demolition activities in these areas, the work scope included: the removal of equipment and structures; the relocation of equipment to other ETTP facilities for future use; the cleaning of equipment and other structures to facilitate declassification; the redefinition of the facilities to an unclassified condition; decontamination/cleaning of equipment and materials to promote unrestricted, free release under DOE Order 5400.5/10 CRF 835; and segregation/packaging of waste materials (low level hazardous, mixed) in compliance with Nevada Test Site Disposal Cell Waste Acceptance Criteria.

The demolition work associated with the other non-radiologically contaminated facilities under lease (K-1023, K-1009, K-1010, K-1052, K-1200 North Bay) also involved the dismantlement of structures (mezzanines, platforms, large structural steel), computer facilities, and spin test facilities with 12 inch thick, steel reinforced concrete walls. Removal of utility services (electrical, fire protection, HVAC systems, etc.) was also part of these demolition activities (Fig. I–9.2).

Work performed under the DOE contract for the K-1200 South Bay facility was classified at the 'Secret Restricted' level and required an active Q clearance and an established 'need-to-know' for all personnel involved in

FIG. I–9.2. Facility fully decommissioned and ready for new construction.

FIG. I–9.3. Facility during construction phase.

project work. M&EC has a DOE approved FOCI, which allowed the performance of this work at this level. The project had a DOE-approved security plan that entails the safeguards and security requirements for the work being performed.

In order for Perma-Fix to construct a fully permitted and licensed waste treatment facility, all of the above activities had to be performed in order to prepare the areas for new construction.

A.I–9.3. CONSTRUCTION AND OPERATION OF THE NEW MIXED WASTE TREATMENT FACILITY

New construction of the custom built mixed waste treatment facility began in January 2001, with full scale commercial waste treatment operations commencing nine months later. A unique design feature was the construction of a ‘building within a building’ to enable easy routing of large volume air ductwork and high capacity electric cables, as well as to provide containment for M&EC’s process equipment. The M&EC facility was specifically designed and constructed for treatment of DOE’s most difficult wastes; currently, M&EC processes mostly mixed waste streams unsuitable for land disposal in one of the nation’s most comprehensive treatment facilities (Fig. I–9.3).

M&EC has seven permitted storage units with a combined capacity of nearly 750 000 gal (4000 m^3) and over 30 permitted tanks and miscellaneous treatment units capable of managing a wide array of waste matrices. There are three main processing enclosures, which are maintained under negative air pressure with high efficiency particulate air (HEPA) filters for radioactive contamination control.

Enclosure 1: Various pretreatment unit operations include drum sampling, free liquid removal, waste removal, material sorting, and size reduction. A drum conveyor moves wastes through the various removal and sizing operations. In addition, Enclosure 1 houses treatment equipment to stabilize or solidify hazardous wastes using reagents appropriate for the waste constituents requiring treatment.

Enclosure 2: The process contained in this enclosure employs a 3 000 L, oil heated, vacuum assisted, thermal desorption unit. This unit separates volatile and semi-volatile organics, including PCBs, from solid wastes. The desorbed components are condensed as liquids using a water cooled heat exchanger. Solids and organic liquids are

FIG. I–9.4. Facility upon completion of construction.

stabilized, packaged and sent off-site for disposal. Low-organic aqueous liquids are typically transferred to Enclosure 3 for wastewater treatment.

Enclosure 3: This enclosure contains M&EC's advanced water treatment system, designed to treat radioactive aqueous waste streams with organic and/or inorganic constituents. The wastewater treatment system consists of a series of collection and treatment tanks (12 000 gal each, approximately 45 m^3), smaller activated carbon adsorption units and resin columns. The treated water can typically be discharged to the on-site sewage system.

The M&EC facility has a separate, dedicated area for sorting, size/volume reduction, certification, and packaging of low level radioactive (non-mixed) wastes, allowing cost-effective options for large volume, bulk solid RAWs.

Extensive contamination of environmental media by mercury releases has created one of Oak Ridge Reservation's most problematic waste streams. A dedicated area of the M&EC facility, with its own air handling and filtration system, provides treatment of large volume, mercury contaminated wastes (>260 ppm) using a proprietary amalgamation/stabilization process. An adjacent room contains a patented amalgamation process for treating elemental mercury wastes.

Over the past seven years, without incident or injury to plant personnel, the public and the environment, the Perma-Fix M&EC facility has successfully made a wide variety of complex wastes safe for disposal and subsequently shipped over 18.2 million lb of treated waste that meets all regulatory standards for disposal (Fig. I–9.4).

A.I–9.4. BENEFITS TO THE DOE AND THE COMMUNITY

Perma-Fix M&EC offers DOE and private clients a cost-effective solution to managing some of their most challenging mixed wastes. Had the option of sending their huge quantities of these wastes to M&EC's treatment facility not been available, DOE would have been forced to build its own waste-treatment complex at an estimated cost approaching $100 million. Now it is able to dispose of its extensive stored inventories, gaining approval of state and federal regulators.

Perma-Fix Environmental Services boosted the local economy with investments in local facilities in Oak Ridge and Kingston, Tennessee. In 2001, Perma-Fix acquired the M&EC and the Diversified Scientific Services, Inc. facilities and opened Perma-Fix Operational Headquarters.

Since 2001, Perma Fix has grown to provide 178 East Tennesseans with jobs and spends over $12 million annually on local employee compensation, with salaries well above the regional average. Between the three facilities, Perma-Fix invests an additional $9 million back into local businesses within East Tennessee.

In addition to making a positive impact on the local economy, Perma-Fix is also praised for their safety standards when dealing with the treatment and disposal of nuclear waste.

A.I–9.5. CHALLENGES ENCOUNTERED AND OVERCOME TO ACHIEVE REUSE

The conversion of a gas centrifuge technology R&D facility to a modern mixed-waste treatment facility was not without significant challenges, some technical and even more bureaucratic.

Vapour intrusion testing. Because the facilities are located on a National Priorities Listsite, the U.S.Environmental Protection Agency (EPA) required that buildings must undergo vapour intrusion testing in order to be reutilized. In the case of M&EC, the EPA would have mandated drilling holesinto the facility floor, thus compromising containment of the waste handling and processing areas. To date, M&EC has been able to avoid having vapour intrusion testing performed in their facility.

Utilities. Because ETTP is undergoing a site wide decommissioning and demolition process, utilities are subject to interruption and removal. When the ETTP steam plant was decommissioned, CROET substituted package steam plants at the M&EC facility; their ownership has subsequently been taken over by M&EC.

The water, sewage and electrical systems are in the process of being acquired by the City of Oak Ridge from CROET. The City no longer uses the ETTP sewage treatment plant; instead, sewage is pumped to a package plant at a nearby residential development. However, Oak Ridge's pretreatment standards are different from those of DOE, so M&EC must ensure that its process wastewater discharges comply with them.

Electrical service was provided by feeds from a variety of poorly documented sources. As other site buildings slated for demolition were taken off the grid, power was occasionally lost at M&EC because supply lines had been run from these facilities to the K-1200 complex. Maintaining sufficient electrical power to run the process equipment has been a continuing challenge for M&EC as it expands its operations. Currently, lines run from three different providers.

Continuity of operations. In 2002, DOE adopted a new approach to addressing the contamination problems at ETTP. The Accelerated Cleanup Program changed the focus from the reuse of site facilities under the reindustrialization programme to decommissioning and demolition (D&D) of all contaminated facilities. Across the site, many of CROET's industrial tenants had their leases terminated and were required to move out of their facilities, which were to be torn down by 2008. However, Perma-Fix M&EC had invested $45 million in decommissioning and decontaminating K-1200 and constructing their facility. Perma-Fix M&EC's ten year lease has since been extended, allowing it to remain at ETTP.

In order to better control the future of its facility, Perma-Fix M&EC began planning in 2003 for acquiring ownership of the building. In December 2004, it submitted to DOE a request for transfer of ownership of the facilities. The company proposes to buy out its lease with CROET and request the D&D money earmarked by DOE for final D&D, approximately $13 million (although this job is currently estimated to cost at least $15 million). DOE has been able to transfer free-release or uncontaminated buildings to CROET, but transferring a building with possible remnant contamination to a private entity is more challenging, largely due to restrictive requirements, both internal to the agency and by the EPA. M&EC is working through the transfer process with DOE. A similar situation impacts another heavily invested company in reutilized space on-site, and a third company is also interested in acquiring its industrial space.

A.I–9.6. LESSONS LEARNED

Reusing a government-surplus nuclear facility can have many unforeseen difficulties, as illustrated by the haphazard nature of ETTP's development over time and consequent issues with utilities, especially electricity. Larry McNamara noted that there is a steep learning curve for engineering around the radioactive aspects of a former nuclear facility. The reuse of such a site is much easier for nuclear applications than non-nuclear. Unless a company has internal radiological and engineering expertise, they must deal with contractors or consultants, a situation that has the potential for increasing costs beyond the available budget. Fortunately, Perma-Fix was able to draw on the experience and expertise of its facility in Gainesville, Florida (USA) to engineer M&EC.

Because much of the decision making at ETTP is based on national policy and annual appropriations by the US Congress, there is uncertainty regarding what upper level DOE managers, both in Oak Ridge and at headquarters in Washington, DC, will mandate regarding the facility. DOE can and has shifted policy directions abruptly, with little regard for site tenants or the concerns of its stakeholders. This element of risk is difficult to plan for and may require political or legal intervention.

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Annex II

LESSONS LEARNED

The following examples present lessons learned from redevelopment and reuse projects including where redevelopment and reuse options turned out to be impracticable. Some brief technical details are provided for each decommissioning project, which feature a description of the problems encountered in redevelopment and reuse options envisaged. The situations described are typical of the difficulties that can arise in redevelopment and reuse at decommissioned facilities/sites. The information presented is not intended to be exhaustive. The reader is encouraged to evaluate the applicability of the lessons learned to his or her specific decommissioning project. A categorization of the cases illustrated is given table.

Reuse of power plants (turbine halls, infrastructure and grids)	No. 14
Reuse of large industrial buildings and sites	No. 3, 4
Reuse of bunkers (buildings with thick walls and floors, subsurface facilities)	No. 12, 13
Reuse of smaller buildings (small research reactors, laboratories, offices, etc.)	No. 1
Reuse of stacks, cooling towers, water towers, sewage treatment plants	No. 5, 9, 11
Legal, regulatory and licensing issues	No. 2, 7, 8, 10
Miscellaneous	No. 6

Case 1: Undefined reuse for a brachytherapy facility, Cuba [A.II–1]

Problem encountered. An old brachytherapy facility, which was located in a large hospital, was shut down and for a variety of reasons kept closed for more than ten years. In addition to a lack of funds, there was no motivation for reusing the site.

Solution found. Once a potential reuse of the site had been decided upon, the ‘new’ users became active and insisted that the directorate of the institution provide the necessary funds for decommissioning. This was achieved and the decommissioning was performed taking into consideration the intended future use of the installation.

Lessons learned. Immediate decommissioning is the best solution for small facilities. Decommissioning should commence immediately after operations cease in order to make full use of the available personnel who operated and maintained the installation. The decision on the facility reuse accelerated the interest in having it decommissioned. The reuse of the site compensated for the negative impact of the facility being shut down. Some systems and utilities of the old facility were reused in the new one.

Case 2: Site Reuse Procedure, Durch die Energiewerke Nord GmbH (EWN) — Kernkraftwerk Greifswald (KGR), Germany

*Problem Encountered***.** The last step in executing a decommissioning project is site cleanup to levels that do not require licensing. This provides the opportunity to reuse the overall area for industrial activities (brownfield) or to remediate the site to greenfield conditions. The reuse of the site, e.g. to construct new industrial facilities, can normally start only after an exemption from the atomic law is issued by the authorities. This procedure is complicated and consumes an enormous amount of time. To create new industrial sites in a timely manner on a former nuclear site, a practicable solution must be devised for the release of land parcels and individual facilities.

*Solution Found***.** For the EWN site, exemption from the atomic law was achieved using a practicable reuse procedure, the ‘step-by-step partial area free release procedure’, support the site's reuse plan. This enabled early construction of a biodiesel plant at the EWN site [A.II–2] (Fig. II–1).

FIG. A.II–1. Greifswald NPP, Germany: Biodiesel plant construction.

FIG. II–2. New free release centre.

FIG. II–3. Former warm workshop (during construction).

Lessons Learned. At the EWN site, a step by step exemption procedure for areas within the site was the solution to expediting exemptions for those areas from the atomic law. A flexible approach was created in close cooperation with the regulatory authorities that would allow exemptions to be issued for individual parcels.

Case 3: Reuse of former auxiliary buildings for decommissioning execution EWN–KGR (Kernkraftwerk Greifswald), Germany

Problem encountered. For execution of decommissioning, waste and materials handling is an essential issue. For a project such as the EWN site, different treatment stations must be implemented. This required new facilities for storage, conditioning, and packaging of decommissioning wastes.

Solution found. Former auxiliary buildings found a new use during and for decommissioning. For example, the former spare parts storage was reutilized as a free release centre and the former warm workshop was turned into a new treatment and decontamination centre (see Figs II–2–II–4).

FIG. II–4. New treatment and decontamination centre.

Lessons learned. While performing the decommissioning and the dismantling activities, construction of new buildings is expensive, and it can be complicated to obtain the necessary licences. During the planning phase, when strategic decisions must be made, the reuse of existing operational or auxiliary buildings should be considered to save time and budget.

Case 4: Building redevelopment and reuse complicated by asbestos, Harwell, UK

Problem encountered. A building used for materials research that included radiography and neutron techniques was decommissioned and intended for reuse.

Before reuse, it became clear when commencing that the asbestos legacies in the building could not be maintained in a safe state due to deterioration of the building fabric. The result was the release of asbestos materials as debris.

The reuse was prevented and the building was stripped of asbestos legacies. After the strip out of asbestos, the building was no longer usable and was rescheduled for demolition. Fig. II–5 illustrates various phases of this project.

Solution found. The cost of reuse became prohibitive due to asbestos legacies and the building could not be reused (Fig. II–5).

Lessons learned. When considering reuse of a building, non-nuclear issues such as asbestos may be as important, if not more so, than the nuclear legacies.

When considering reuse of a building the asbestos, issues should be surveyed prior to reuse and an assessment made of whether the asbestos can be maintained or requires removal. Removal of the asbestos may render the building unusable if the asbestos is an integral component of the building structure.

Case 5: redevelopment and reuse complicated by drains legacy, UK

Problem encountered. A complex nuclear research site with hundreds of buildings utilized a network of drainage systems, developed over decades, to connect the buildings to a central liquid effluent treatment plant.

The drains included:

— Local soakaways;
— Networked industrial effluent systems, which were nominally non-radioactive;
— Old generation active drains with no secondary containment;
— Modern active drains with secondary containment;
— Rainwater drains.

Problems included:

— Generations of successive drains and delay tanks had been installed with no decommissioning of old systems.
— Drains sometimes collapsed or were leaking.
— Inactive drains had been used for active effluents by mistake.

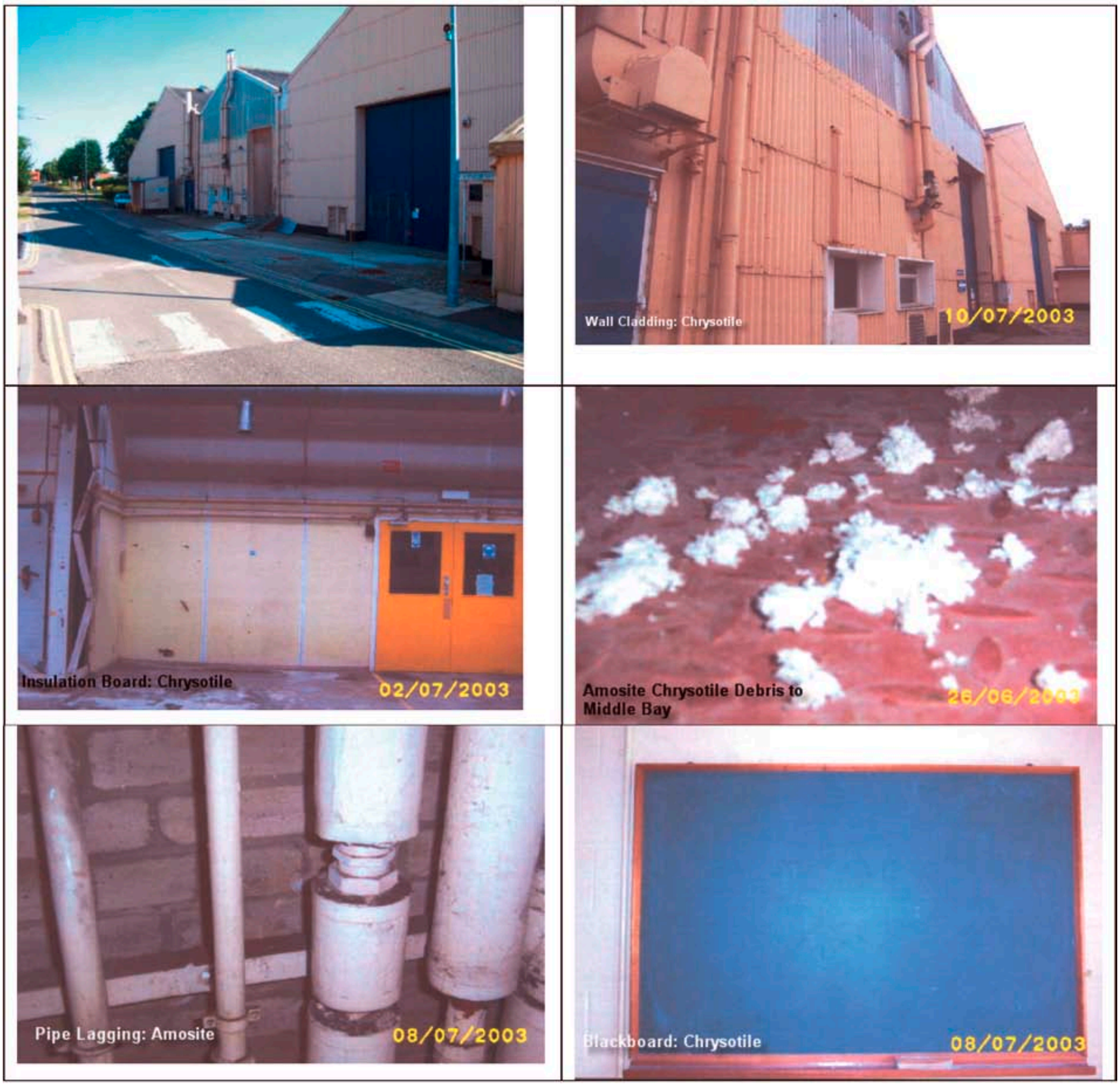

FIG. II–5. The building at Harwell that could not be reused due to asbestos hazards.

— Not all drains were recorded on site drawings.
— Some drains had been decommissioned but there were no records kept.
— Some drains had been grouted in situ with inadequate survey records to justify the drain being left.
— Rainwater was ingressing into drains creating additional effluent.

Solution found. A programme of drains decommissioning was established to enable site redevelopment. The remaining buildings requiring drainage were isolated with dedicated systems. The remaining network of drains was decommissioned so as to regain confidence in the eventual land quality.

— Drains detection and mapping;
— Use of a geographical information system to record and map progress;
— Flushing of drains;
— Contamination monitoring using a pipe crawling robotic probe;
— Removal of collapsed sections;
— Grouting in situ of all cleaned drains to avoid unnecessary excavations.

Lessons learned. Progressive decommissioning of redundant systems during the phase of site operations is beneficial to the redevelopment and reuse of the site.

Record keeping is very important in order to justify the final land quality status.

Drains may be suitable for reuse (the rainwater drainage system was reused on this site) or may have to be decommissioned. Decommissioning may not require excavation and removal if grouting in situ can be justified.

Case 6. Information needed for property transfer, Hanford Site, USA [A.II–3]

Problem encountered. During the turnover of property in the 3000 Area of the US DOE Hanford Site, some problems were encountered in the implementation of the transferedevelopment and reuseedevelopment efforts. There needed to be a better and clearer definition of information needed to facilitate the property transfer and plans for future redevelopment.

Solution found. The 290 000 m^2 (71 acre) area with about 15 buildings situated on it was transferred to the local property transfer authority for turnover of facilities to the local authority for redevelopment. The lesson learned here should allow for a more timely and efficient turnover in the future. In this case, 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 occur:

— There should be some transition period to the new owners when the current ones are still available for consultation and to resolve any confusion over actual conditions at the site.
— There should be strong effort to transfer detailed, accurate records on utility locations, especially those underground. Otherwise, it could be more expensive than planned to locate and repair those sites which, due to poor recordkeeping, are damaged in further site development activities.
— There should be a detailed site assessment performed on any environmental conditions left at the site at the time of turnover.
— There should also be a turnover of information on the site telecommunication system and transfer of information on utilities billing costs to assist with the redevelopment.

Case 7: Benefits of using realistic scenarios to demonstrate compliance with unrestricted release requirements, USA [A.II–4, A.II–5]

Problem encountered. Two good examples of the use of realistic scenarios are the Nuclear Fuel Services (NFS) site in Erwin, TN and the FMRI, Inc. (Fansteel) site in Muskogee, OK. The staff from the NFS site used a combination of two realistic scenarios to determine radionuclide specific derived critical group levels (DCGLs). The licensee demonstrated that the shallow, contaminated groundwater would not be used as a drinking water source in any case. The licensee then demonstrated that the most likely use of the site at licence termination was as an industrial site. It also acknowledged that there was considerable suburban development in the area. The licensee performed dose calculations for the facility using an industrial scenario, as well as a suburban resident scenario. The licensee then chose the lower (more conservative) DCGL value of the two scenarios for each specific radionuclide identified on the site. These values are less restrictive than the calculated DCGLs for the default residential farmer scenario.

Solution found. At the Fansteel site, the licensee proposed an industrial land use scenario for dose estimation. The site is bounded on the north by the Port of Muskogee and industrial operations on the east by the Arkansas River, on the south by US Highway 62, and on the west by the Muskogee Turnpike. In addition, there is a coal fired power plant across the Arkansas River. The NRC staff confirmed future development plans in the areas surrounding the site, including planned expansion of the Port of Muskogee onto the land currently owned by FMRI, and reviewed the proposed scenario and dose analysis. The NRC staff concluded that the industrial land use scenario was appropriate for dose calculations.

Lesson learned. These cases studies are examples of the application of NRC's realistic scenario approach to analyse reasonable foreseeable land uses for the property and still demonstrate compliance with the unrestricted release requirements.

Case 8: Approach for realistic scenario analyses at the Kiski Valley Water Pollution Control Authority (KVWPCA) site, USA, including scenarios for reasonably foreseeable on-site and off-site land uses [A.II–4, A.II–6, A.II–7]

Problem encountered. At the KVWPCA site, NRC staff provided the results of its own dose assessment to support a recommendation to the Commission of no further decommissioning action (SECY-04-0102). The Commission approved the staff's recommendation, including the application of the realistic scenario approach for this site. The dose assessment included a range of potential scenarios, both reasonably foreseeable land use scenarios (abandoned in place and offsite disposal) and less likely uses that were also assessed to bound the uncertainty associated with future land use.

Lessons learned. This case study is an example of the application of NRC's realistic scenario approach to analyse reasonable foreseeable land uses, less likely land uses, and off-site uses after licence termination.

Case 9: Utilities transfer at East Tennessee Technology Park (ETTP), Oak Ridge, Tennessee, USA

Introduction

The City of Oak Ridge, Tennessee, is in the process of taking over the utilities at DOE's ETTP. ETTP, the former K-25 Gaseous Diffusion Plant site, was the first complex for uranium enrichment using the gaseous diffusion technology. DOE is in the process of demolishing most of the production and support facilities as a first step towards environmental cleanup of the site. What remains will include two large decontaminated gaseous diffusion plants (K-31 and K-33), several office buildings, two or more private industrial operations, possibly a portion of the historic K-25 building, and cleared foundations. The objective is to clean the site to industrial risk standards and then turn it over to an industrial development corporation or private industry for reindustrialization.

In addition to making ETTP available as an industrial park, residential development on a large scale is occurring on the opposite side of the Clinch River from ETTP. Rarity Ridge is a high-end lakeside residential community being built by a private developer. Both facilities are several miles removed from current developed areas of Oak Ridge. In order to support the new development and future industrial clients, Oak Ridge must take over the electrical system, the water system, the sanitary sewer system, the fire station and the roads at ETTP.

The water treatment and distribution system is a high priority for acquisition by Oak Ridge because it will provide water to Rarity Ridge as well as to industrial clients at ETTP. Currently, this system draws from an intake at Grassy Cove, part of the backwater of Watts Bar Reservoir on the Clinch River. The City plans to use this source until a water line from the City-owned plant at Y-12 National Security Complex (previously transferred from DOE) is completed to the site. The City will then switch sources but plans to maintain the current intake permit.

The City's plan for the ETTP sanitary sewer system is to abandon the sewage treatment plant. A new pump station has been installed to move sewage over to the Rarity Ridge development where a new package sewage treatment plant will process the raw sewage. The clean effluent will then be discharged to the Clinch River under a National Pollutant Discharge Elimination System permit.

This case study will concentrate on the problems encountered during acquisition of the water and sewer systems, how they were resolved and the lessons learned.

Problems encountered

Problem 1 — Too many decision makers

The transfer of the water and sewer utilities turned out to be much more difficult than the City anticipated. Jim O'Connor, the Oak Ridge City Manager, noted that the agreement was 'ever- changing'. Some issues needed to be raised to the attention of upper management within DOE. The title transfer package for the water treatment plant required review by DOE headquarters in Washington, DC. Initially expected to be finalized in March 2008, the transfer was completed in May 2008.

Complicating the transfer is the fact that although the water and sewer systems are owned by DOE, they are leased by CROET). CROET has contracted with OMI, a subsidiary of the engineering firm CH2MHill, to operate and maintain these systems. Consequently, OMI has all of the technical information necessary to facilitate inspection and transfer, but was unable to deal independently with Oak Ridge because of their contractual relationship with CROET. Although CROET controls the utilities, no CROET representative was directly involved in transfer negotiations. Instead, the DOE took the issues requiring CROET decisions to that organization outside of discussions.

Additionally, because the transfer is concurrent with the D&D work, the City of Oak Ridge also must interface with DOE’s environmental cleanup contractor, Bechtel Jacobs Company (BJC). This is particularly important in that when a building is demolished, the water and sewer lines need to be properly terminated.

Problem 2 — Interim water source issues

The settling ponds next to the Grassy Cove Water Treatment Plant were found to be contaminated. These ponds contain sediment routinely flushed from the flocculating tanks at the water treatment plant where solids are settled out of the raw water. Record keeping was poor, and it is likely that contamination resulted from radionuclides discharged upstream of the intake from historic operations at Oak Ridge National Laboratory. The settling ponds will not be transferred to the City.

Staffing the Grassy Cove water plant requires adding three new City employees until the water supply is switched to the Y-12 plant. This cost is a significant addition to the utility's budget.

Problem 3 — Issues

Several years ago, former ETTP employees raised concerns that cross-connections between the fire suppression water system and the potable water system may have introduced contamination into the latter. At the time, BJC researched the issue by consulting as-built diagrams and maps, and concluded that at the time, there were no cross-connections between these systems.

Upon initial inspection by the City of Oak Ridge, the water lines appeared to be oversized. It was later found that smaller lines run inside some of the larger lines. This has raised concern that the distribution system may be undersized for support of future industrial customers in that area.

Because buildings were generally constructed hastily, water supply was connected in unusual places, sometimes from other buildings instead to a water main.

At this time, the water flow substantially exceeded the quantity of sewage being treated. Some flows and/or leaks had not been identified. Much of the apparent loss can be attributed to make-up water for the fire-suppression water supply system, quantities used for dust suppression for demolition activities and on the haul road, and other industrial uses.

Problem 4 — Determining the condition of the sanitary sewer system

Many of the sewer lines at ETTP date back to the beginning of the time when the site was built as part of the Manhattan Project in the 1940s. They had not been cleaned for years, and many were clay tile that had reached their 50 year expected life span. As part of the transfer, DOE agreed to pay the City’s cost to clean and televise the lines in order to determine their condition. However, due to the OMI labour contract, no one else was allowed to televise the lines. This caused significant delays in accomplishing this action. Eventually, the labour issues were resolved, and the City of Oak Ridge personnel performed the work.

One administrative requirement for meeting the industrial risk standards at ETTP is that no excavation or penetration can take place more than 3 m (10 ft) below ground surface without the prior written approval of DOE and the state and federal regulators. Some of the sewer lines are as deep as 7.6 m (25 ft). For any deep excavation, DOE must first be called, and if there is radiological contamination above cleanup guidelines, then DOE’s contractor BJC must carry out the excavating. DOE has assured Oak Ridge that they are working to eliminate this requirement within the City's easements. The data collected to date indicate that this will be possible. In addition, BJC is confident that the contaminant plumes of concern do not affect the utilities or roads.

A further issue that arose with televising the lines was the possible presence of a ‘secret’ situation in portions of the sewer line close to the buildings. Security requirements were such that the televising would have to stop at a specific point or the film would be confiscated. It took three or four meetings to determine how to televise the lines without possibly compromising secrets.

Although radioactive contamination was a potential concern, none was found in the sewer lines. BJC health physicists monitored the televising operations, but in one instance of suspected contamination, only radon was reported.

Solutions found and lessons learned

Solution 1 — Involve all decision makers, anticipate delays

In general, there were so many elements of the current water and sewer systems under the control of different entities that arriving at final decisions proved to be a much bigger challenge than the City of Oak Ridge had anticipated. Regular meetings involving City Utility staff and representatives from DOE, BJC, and OMI proved very helpful. The lack of direct participation by a CROET representative, the need to raise some issues to the attention of upper management, and review of the water treatment plant title transfer by DOE Headquarters all contributed to the need for more time than anticipated to iron out legal and technical details. For similar projects, all key decision makers should be involved in regular joint meetings, and the project schedule should be sufficiently flexible to accommodate unanticipated delays.

The contract between OMI and CROET, and OMI's labour contract complicated the transfer of necessary information and delayed completing of the televising of the sewer lines. Timelines must be flexible to account for contractual issues outside of the control of the new or prospective owner.

Solution 2 — Budget for interim measures

Despite the unexpected presence of contamination in the Grassy Cove settling ponds, the water treatment plant was transferred to Oak Ridge. The ponds remain DOE property.

The City needed to add new employees prior to generating additional revenue from the enlarged distribution system. Budgets are always tight in the best of times, which puts additional strain on the utility. The City needed to anticipate that costs would arise due to lack of immediately available supply infrastructure, and budget a reserve fund accordingly.

Solution 3 — Be prepared to implement various solutions for technical issues, including administrative controls

To maintain consistency in discontinuing service to buildings being demolished, BJC agreed to cut the utility lines where they entered the mains. This prevented cross-contamination of the potable water system and ensured that the sewer system remained intact.

The City identified several connections that needed to be valved off where the fire suppression water supply system connected to the potable water system. All such connections now have new meters with 'backflow preventers' in place.

In order to prevent yet undiscovered cross-connections from introducing pollutants into the system, the City is placing meters with backflow preventers at the boundary to the non-transferred parts of the system. Consequently, whoever owns/leases these areas — either DOE or CROET — is the responsible party for any problems in that portion of the distribution system. This will help isolate areas with leaks or other large discharges of water outside of the sewer system.

Some water lines may have to be replaced to serve facilities with water lines tied to buildings scheduled to be demolished or where service lines prove to be undersized. This will involve additional effort by the City. The situation illustrates that some nuclear facilities, particularly those that were built hurriedly, may have atypical distribution systems, a problem that needs to be anticipated.

Solution 4 — Negotiate payment and technical assistance to assess technical issues

Televising the lines after cleanout enabled the City of Oak Ridge to determine that the 60 year old trunk lines are in relatively good shape, that they are lined and are not cracked. The cost of cleanout and televising was covered by DOE, which enabled the City to conserve its budget.

Instead of transferring the entire sewer system at once, the transfer will be undertaken in three or four sections. This will allow City Utility employees to bring key sections that serve current customers — those given highest priority for completed televising and repair — under City operation.

DOE will remain liable for any contamination in the vicinity of sewer lines. The agency will also provide technical assistance through its contractor BJC for access to lines in excess of the administrative 3 m (10 ft) excavation limit. Because site cleanup is not yet complete, the City will need to work closely with DOE on access issues to ensure the safety of its employees and its compliance with all the terms of the transfer agreements.

Case 10: Safety in redevelopment and reuse (Nuclear Lake, USA) [A.II–8]

Problem encountered: One challenge associated with the prospective reuse of a site after decommissioning is proving that the site is safe for reuse, especially if the site has not been cleaned up in accordance with present-day clearance values or if buildings or other structures remain on the site. No new owner will want to accept liability for possible future cleanup. A case in question is Nuclear Lake, in New York State, near where there used to be a nuclear fuel testing and research facility containing a research reactor and fuel handling cells. The facility was closed in the 1970s and decommissioned. The buildings were decontaminated as part of the decommissioning project, but not demolished. The land changed hands several times, and it was ultimately donated to the National Park Service for public recreation purposes. In the 1980s, members of the public discovered that there was residual plutonium at the site, especially in and around the old fuel research building from which a plutonium release had occurred during an incident when the building had been in operation. Since the records of the first decommissioning project were not available, a great deal of time was spent on determining the location of the plutonium contamination.

Solution found. A second decommissioning project was carried out and the site was again released for unrestricted use. At the end of the second decommissioning project, all the buildings were removed and the site remediated to park-like conditions. The area is now part of the Appalachian Trail system and the public has unrestricted access to it.

The original owner of the site was no longer in business, so a subsequent owner — not the current owner — was called on to pay for the remediation (the second decommissioning project). This owner, a very large corporation, was willing to pay, so legal actions were not necessary. The issue could have come before the courts, and reuse of the site might then have been restricted for a long time.

*Lessons learned.***:** One lesson learned was that it is important to make sure that the criteria for the release of a site are fully understood. Another lesson was that limits may change in the future, so one should document the results of final surveys and ensure that the records are maintained in an accessible location and form.

Case 11: Reuse of decommissioned sewage system, NRI Řež plc, Czech Republic

*Problem encountered***.** A new sewage system was planned to be installed to replace a decommissioned pre-existing one. Initially, it was planned to request a licence for installation of a new sewage system after decommissioning the old system and termination of the operational licence. However, significantly more licensing documentation would have to be prepared for installation of a new facility. This would also be more time-consuming.

*Solution found***.** After a discussion with the regulatory body, a new solution was proposed — to ask for the licence for reconstruction of the sewage system. The original concrete corridor was used for installation of new pipelines instead of excavating a new system. This solution was fully in accordance with the legislative requirements.

Lessons learned. At times, it is a mistake to choose the first obvious solution without evaluating other options. In this case, the alternative solution initially did not seem as simple as the first one but turned out to be better, because the licensing effort was considerably less burdensome and less excavation was needed. Open discussions with the regulatory agency was helpful in understanding what options would be acceptable.

Case 12: Reuse of liquid RAW storage tanks, NRI Řež plc, Czech Republic

*Problem encountered***.** Old liquid RAW storage tanks beyond the design life were scheduled for decommissioning and replacement by new storage tanks. This proposal would have been expensive as the tanks would have been cut into segments and the RAW processed. Also, the subsequent installation of new tanks would be expensive. The project would require partial building demolition to obtain access to the underground bunker in which the tanks were located.

Solution found. The tanks were decontaminated, and after the investigation of the tanks' integrity, a polyethylene lining was installed inside the tanks. This is a proven method used in the chemical industry for renovation of tanks used for storage of chemicals or toxic materials. This approach saved the resources that would have been required for tank segmentation, RAW processing and installation of new tanks. It was also advantageous from the point of view of radiation and industrial safety.

Lessons learned. Creative thinking is important in all decommissioning activities. Experiences acquired from different fields, in this case the chemical industry, can be applied to solve problems associated with nuclear facilities.

Case 13: Reuse of storage bunkers, NRI Řež plc, Czech Republic

Problem encountered. Tanks located in underground storage bunkers and containing highly RAW are currently being decommissioned. Initially, it was planned to construct a new hot cell facility above these storage bunkers for RAW removal and processing. This proposed action would require partial demolition of the roof of the bunkers. Then, the tanks and bunkers would be decommissioned. The construction of the hot cell facility and the demolition of the bunkers with a wall thickness of 1 m would be very expensive.

Solution found. A new procedure was proposed. The bunker itself will be used as the hot cell and will be equipped with a special single purpose manipulator for the removal of stored RAW. The construction of a new separate hot cell facility will not be necessary, and the roof of the bunker will not be destroyed. The bunker/hot cell will be reused for storage of radioactive material.

Lessons learned. Nuclear facilities can often be reused for other nuclear purposes due to the presence of attributes such as thick shielding. In this case, creative reuse of a facility avoided a difficult and expensive demolition and resulted in a facility that had broader use than originally anticipated.

Case 14: Conflicting interests in reuse of NPP site, Sweden

Problem encountered. Barsebäck Units 1 and 2 were closed down permanently on 30 Nov 1999 and 31 May 2005, respectively, after a political decision. Both units have been under care and maintenance since their shutdown dates. The operator intends to defer dismantling until a repository for decommissioning waste is ready (around 2020) [A.II–9]. The local municipality finds that the timespan covered by the decommissioning plan is absurdly long. The municipality declared that the NPP land must be completely remediated and that the building permit was only for NPP production. The land must be remediated to greenfield status and the municipality does not want an empty power plant shell to remain that would spoil the visual and physical environment. Instead, they want to develop a seaside housing estate with a marina and harbour, in cooperation with the landowner. However, the landowner maintains that the site is good for power production due to the presence of transmission lines, harbour and roads [A.II–10].

Lesson learned. Conflicting interests between stakeholders may be a significant issue in the redevelopment and reuse of nuclear sites.

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ABBREVIATIONS AND ACRONYMS

CANDU	Canada Deuterium Uranium
CEA	Commission of Atomic Energy (France)
DOE	Department of Energy (US)
ECCS	emergency core cooling system
EIA	environmental impact assessment
EPA	Environmental Protection Agency (US)
ETTP	East Tennessee Technology Park (US)
EUREX	Enriched Uranium Extraction (Italy)
MW(th)	megawatts (thermal)
NDA	Nuclear Decommissioning Authority (UK)
NEA	Nuclear Energy Agency (OECD)
NECSA	Nuclear Energy Corporation of South Africa
NORM	naturally occurring radioactive material
NPP	nuclear power plant
NS	nuclear ship
OPEC	Hot Operation Laboratory (Italy)
PCB	polychlorinated biphenyl
PWR	pressurized water reactor
RAF	Royal Air Force (UK)
RCRA	Resource Conservation and Recovery Act
UKAEA	United Kingdom Atomic Energy Authority
UO_2	uranium dioxide
UO_3	uranium trioxide
WWER	water-cooled water-moderated electricity-producing reactor

GLOSSARY

The source for all definitions is the IAEA's Radioactive Waste Management Glossary, 2003 Edition, except when marked with asterisks: (*): IAEA Technical Reports Series No. 444; (**): consultants.

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.

adaptive reuse.** The act of finding a new use for a building (or area). It is often described as a process by which structurally sound older buildings are developed for economically viable new uses.

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.

clearance level (or criteria). 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 their 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. This does not apply to a repository or to certain nuclear facilities used for mining and milling of radioactive materials, for which closure is used.

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.

demolition.* Clearance and removal of a structure in order to achieve greenfield or carry out the redevelopment plan.

greenfield.* 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 that support development, including street lighting, sewers, flood control facilities, water lines, gas lines and telephone lines, etc.

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.

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.

operation organization (operator). The organization (and its contractors) that undertakes the siting, design, construction, commissioning and/or operation of a nuclear facility.

redevelopment.* Planning, development, replanning, redesign, clearance, reconstruction or rehabilitation of all or part of a project area.

reuse.** The use of a facility or building for a purpose other than that for which it was originally intended and/or used, following the termination of its original use has ceased; or the reuse for the original purpose but under new circumstances.

redevelopment plan.** Any new construction on a site that has pre-existing uses on the site, such as the redevelopment of an industrial site into a mixed use development, or the redevelopment of a block of townhouses into a large apartment building.

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 those lost by the closure of the former facility, and saving previously undeveloped land from being used for industrial purposes.

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, or under investigation for its suitability for, a nuclear facility (e.g. a repository). 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.

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.

unrestricted use. The use of equipment, materials, buildings or the site without any radiologically based restrictions.

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Consultants Meetings

Vienna, Austria: 17–20 March 2008; 2–6 February 2009

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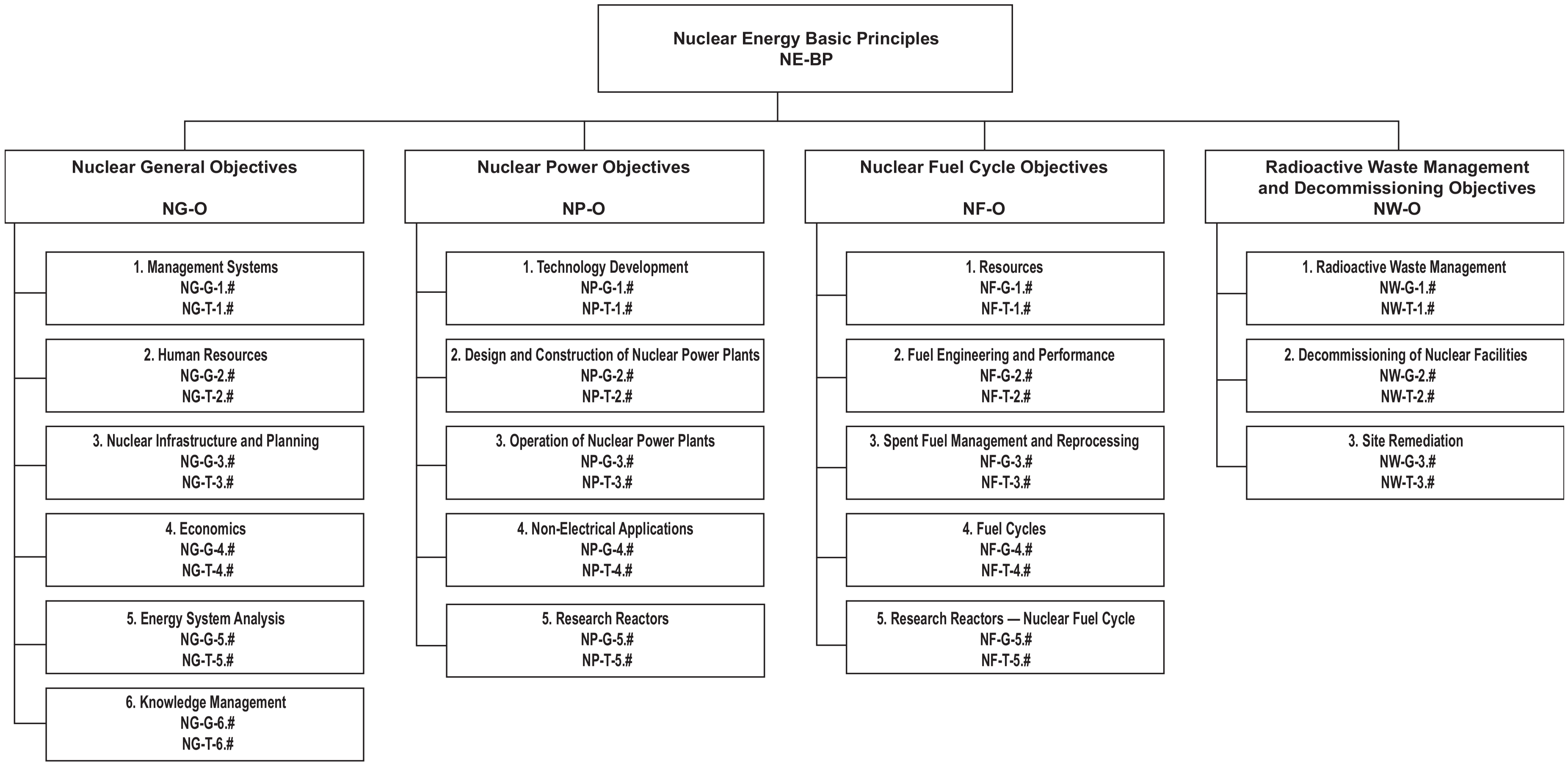

Key

BP: Basic Principles
O: Objectives
G: Guides
T: Technical Reports
Nos. 1-6: Topic designations
#: Guide or Report number (1, 2, 3, 4, etc.)

Examples

NG-G-3.1: Nuclear General (**NG**), **G**uide, Nuclear Infrastructure and Planning (topic **3**), **#1**
NP-T-5.4: Nuclear Power (**NP**), Report (**T**), Research Reactors (topic **5**), **#4**
NF-T-3.6: Nuclear Fuel (**NF**), Report (**T**), Spent Fuel Management and Reprocessing, **#6**
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ISBN 978–92–0–100210–5
ISSN 1995–7807