Technologies for Decommissioning: Status & perspectives of the Italian industry

Roberto Adinolfi,
Associazione Italiana Nucleare
1. Decommissioning in Italy and in other European countries
2. What kind of opportunity for the Italian Industry
3. ANSALDO commitment to DW&M
4. Main technology aspects:
   - Decontamination processes
   - Waste Retrieval and Conditioning
   - Storage containers
   - Dismantling
5. Conclusions
DECOMMISSIONING IN ITALY

- The National Program, launched in 1999, aims to bring all nuclear sites in Italy to the green field.
- It includes 4 nuclear reactors (1 PWR, 2 BWR and 1 GCR), plus 4 facilities linked to Fuel cycle R&D. Recently SOGIN also got the task to dismantle an experimental reactor on the JRC site at Ispra (VA).
- The Program is financed through a levy on electrical tariffs: such a mechanism provides in principle a more reliable founding source than other countries.
- The Program encompasses not only the dismantling activities, but also the closure of the fuel cycle and the final storage of LILW, for a total value of 7.2 € billions.
- Dismantling is currently estimated at 26% progress.
- Completion of the program is planned at 2035.
TECHNICAL DISTRIBUTION OF SOGIN EXPENDITURES

- Plant dismantling and site restoration: 38%
- Fuel reprocessing: 26%
- Site care and maintenance: 14%
- Technology Park and National Repository: 13%
- Plant dismantling (typ.):
  - Trattamento rifiuti rad.: 14%
  - Edifici non N.I.: 20%
  - Edificio Reattore: 7%
  - Ripristino Sito: 29%
  - Pm & supporto Decom: 13%
  - Invio a deposito naz.: 4%
  - Post-operation: 13%
Figura 22 - Numero di reattori elettronucleari che si troveranno annualmente in fase di smantellamento nel mondo
• In addition to reactors, decommissioning will also cover a number of fuel manufacturing and reprocessing facilities & research reactors.
• In Europe, the largest decom program is in UK, Germany market is going to increase because of early retirements, France will follow.
• Even if the Italian program is only a fraction of European total expenditure, it includes many different types of plants and facilities, thus allowing for a broad experience to be gained, possibly before other countries.

Tabella 1 - Investimenti in decommissioning, trattamento e gestione combustibile esausto e realizzazione impianti di smaltimento rifiuti nucleari (mld.€ 2012)

<table>
<thead>
<tr>
<th></th>
<th>2013-2020</th>
<th>2021-2030</th>
<th>2031-2040</th>
<th>2041-2050</th>
<th>2050+</th>
<th>Totale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europa Occidentale (1)</td>
<td>27,9</td>
<td>111,1</td>
<td>33,2</td>
<td>6,3</td>
<td>0,0</td>
<td>178,5</td>
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<tr>
<td>Europa dell'Est e Russia (2)</td>
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<td>53,2</td>
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<td>11,3</td>
<td>24,3</td>
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<td>Stati Uniti</td>
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<td>5,3</td>
<td>48,1</td>
<td>63,5</td>
<td>3,1</td>
<td>122,6</td>
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<td>11,7</td>
<td>90,0</td>
<td>57,8</td>
<td>157,3</td>
<td>338,2</td>
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<td>Altri (4)</td>
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<td>9,3</td>
<td>3,2</td>
<td>4,7</td>
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<tr>
<td>TOTALE</td>
<td>76,2</td>
<td>194,1</td>
<td>193,7</td>
<td>142,1</td>
<td>189,5</td>
<td>795,5</td>
</tr>
</tbody>
</table>

Note
1) Paesi inclusi: Belgio, Finlandia, Francia, Germania, Olanda, Svezia, Spagna, Svizzera, UK,
2) Paesi inclusi: Armenia, Bulgaria, Lettonia, Repubblica Ceca, Romania, Russia, Slovacchia, Slovenia, Ucraina, Ungheria
3) Paesi inclusi: Cina, Corea del sud, Giappone, India
4) Paesi inclusi: Argentina, Brasile, Canada, Sud Africa, Pakistan
A decommissioning program involves many kind of technologies, like:

- **Decontamination** of steel components, as well as of concrete structures
- **Retrieval** of wastes in various forms, mainly through remote handling, or even robotics
- **Conditioning** of wastes of different nature (e.g., sludges, resins, etc.)
- **Storage** containers for various activity levels
- **Dismantling** equipment for irradiated/contaminated components of various type

Even if many technologies have been developed in the past to cope with operational wastes, a D&D program poses further requirements, like:

- Minimization of **final waste volumes**
- Minimization of **secondary wastes**
- Waste forms adequate for **final storage**
• While in the early years SOGIN was quite open to jointly develop with the industry innovative solutions, specifically addressing the needs of D&D, more recently the preferred approach seems to be the request for proven solutions from the suppliers.

• Such an approach, mainly dictated by the public procurement regime as presently structured in Italy, could easily lead to an increasing difficulty for the Italian industry to respond.

• These difficulties can be addressed either by:
  ▪ Partnering with int’l companies with proper experience on similar problems, or
  ▪ Investing on R&D, where there is room and opportunity for new solutions, more specifically applicable to large D&D programs.

• This second approach requires a longer range planning, not favoured by the continuous shifting of plans.

• A proper combination of the two approaches seems to us, Ansaldo Nucleare, the most adequate response.
The nuclear operators strategy for the management of radioactive waste from NPP has gradually shifted to an increased emphasis on volume reduction and waste stabilization, due to the increasing cost of interim on-site storage and final disposal.

ANSALDO is fully committed to the development of innovative and more effective solutions for decommissioning and radwaste management, with a specific focus on the declassification of the radioactive waste category, down to the free release, and on minimization of final storage requirements.
DECONTAMINATION PROCESSES

THE PHADEC TECHNOLOGY

ANSALDO has been working for many years on the development and optimization of innovative processes for the off-line decontamination of metallic waste to be down classified or free-released.

The drivers for identifying the most suitable decontamination technology have been:

- Volume Reduction of the final radwaste to be disposed of
- Low production of secondary waste & Low Environmental Impact
- High Decontamination Factor
- Plant Modularisation
- Minimization of radiation dose commitments.

The selected solution was the PHADEC technology (PHosphoric Acid DEContamination), developed in partnership with BNG from Germany, which had already applied it at Gundremmingen, under a Development Program agreed with SOGIN.
AN INSIGHT INTO THE PHADEC

THE PROCESS AT A GLANCE: RECYCLE AND REUSE

- **Chemical and Electro-Polishing** decontamination with Phosphoric Acid
- **Recycling** of Phosphoric Acid by adding oxalic acid, precipitate the dissolved iron as iron oxalate
- **Reuse** acid for decontamination by extracting the iron oxalate & vaporization
- Thermolysis of iron oxalate by heating the iron oxalate (transformed into iron oxide for final storage)
The facility, successfully installed at Caorso NPP (Piacenza, Italy), represents the second application at industrial scale of this off-line patented decontamination process (the first-of-a-kind plant is still in operation at KRB plant in Gundremmingen).

It will be used to decontaminate materials from the Reactor Building.
KEY FIGURES ON PHADEC

- Low production of secondary waste (dry iron oxide powder), ca. 2 % wt. of the treated materials, suitable for storage; this waste can be either stored in special containers or conditioned with cement;

- Very low environmental release, both chemical and radioactive, due to high efficiency filtration & CO catalytic conversion into CO₂;

- High Decontamination Factor, theoretically infinite depending on the treatment time (average decontamination treatment time is 4 hours per batch, which could offer a Decontamination Factor (DF) of about 10² up to 10³);

- Plant Modularisation;

- Unrestricted free release of the decontaminated material;

- Minimising personal dose / collective dose;

- Easy management of the plant and minimum operational costs.
Ansaldo Nucleare is continuously striving to develop new products that could bring relevant outcomes in terms of “volume savings”, further improving its portfolio of technologies.

In this respect we have identified and developed, at laboratory scale, a method to directly vitrify metal waste coming from decontamination of nuclear components, with phosphoric acid.

Previous research showed that the glass produced does not need any further conditioning treatment, with major volume savings of the final waste compared with alternative and more traditional methods.
The process includes the following major steps:

- Dissolution of the contaminated metal parts by using phosphoric acid
- Oxidation of the iron ions in solution
- Precipitation of the phosphate salts of iron by electrochemical means
- Separation of the precipitated sludge
- Thermal vitrification treatment

The final waste form will be a LILW iron phosphate glass, suitable for final disposal; this comes from the direct vitrification of the radioactive waste sludge (no additives are needed, however small quantities could be used to further improve the process).
EXPECTED BENEFITS

Our project aims to develop an innovative and sustainable technology that will:

- reduce the waste generated during dismantling of nuclear facilities: it is estimated that the treatment of ferrous waste with METALGLASS would result in a reduction of the final waste volume of 75%, compared to the final product of the technologies currently used for treating metal waste (e.g. residue from PHADEC, after conditioning with cement)

- produce a more stable form of the non-recoverable waste to be disposed: direct vitrification of the radioactive sludge results in a glass product that does not require further treatment as already suitable for final disposal, and avoids using further products for waste encapsulation (e.g. cement)

- reduce radwaste management costs

- reduce needs of raw materials (the radioactive precipitate will not be incorporated into a new conditioning matrix - e.g. cement, bituminous or others - as the precipitate will be vitrified)
LECO is the plant designed and currently delivered by Ansaldo Nucleare (originally together with Techint in the frame of ACTEC Consortium) for the Retrieval, Conditioning and Temporary Storage of Latina Magnox Sludges.

In this case, the main issue was related to the design and testing of the retrieval system, which required extensive testing upfront.

The plant has been fully assembled and tested in cold conditions by the end of 2017.
Retrieval of MAGNOX sludge from an underground tank by using an electro-pneumatic machine, manually handled by an operator in radiologically safe conditions.

The machine consists of a suction nozzle connected to a vacuum tank and a high pressure device for sludge fluidization before retrieval. A gripper for solid waste is also included.

The machine reaches all the zone of the underground tank in safe condition.
Latina LECO (2)
Assembly of mock-up

Gripper for solid waste handling
As addressed before, a relevant number of major dismantling projects will be completed all over Europe in the next decades. This will entail an increasing demand for containers, both for LLW (Low Level Waste) and for ILW (Intermediate Level Waste).

ILW containers will be requested, for instance, to dispose of the activated metals from dismantling.
THE PRESENT ANSALDO EXPERIENCE

Since 2005 ANN has devoted many efforts to the design, qualification and supply of containers for Low Level Waste (LLW) as well as for the qualification of Final Waste Packages (FWP). These are the Italian containers for the future Near Surface National Repository.

These thin walled containers are of various materials (carbon and stainless steel), shapes (cylindrical and prismatic) and sizes (440 liter, 2.6, 5.2, 10.8 cubic meters) according with the applicable Italian regulation. They are IP-2 classified and the maximum content of radioactivity is up to 1e+10 Bq of Cobalt 60.

So far, ANSALDO has supplied about 1.000 containers (mostly CP 5.2).
AN INSIGHT INTO THE QUALIFICATION APPROACH

- Waste Form Qualification
  - Compression resistance Test / Thermal Cycle resistance Test / Water Permeability Test / Biodegradation Test / Waste Encapsulation Test / Radiation resistance Test / Water Immersion Test / Gas Generation Test / Gas Permeability Test

- Container Qualification
  - Degradation resistance Test/ Gas Leakage Test

- Package (container plus waste form) qualification
  - Stacking resistance Test / Drop resistance Test / Penetration resistance Test / High Temperature resistance Test

Rome, March 21, 2018
Concerning ILW there is a growing and cross interest, particularly for solid waste, on the use of “special containers”, due to some doubts on the long term stability of the conditioned waste form; the major downside is the cost, when compared to “standard containers”.

The interest for “special containers” could be higher also where a geological repository does not exist (a late-definition of the waste acceptance criteria could determine a need of repackaging, normally harder when the waste has already been encapsulated).

“Special containers” are manufactured by few companies, like GNS, ROBATEL, CROFT. It is noted that the market is poor of prismatic containers (type B qualified); this is definitely an area of interest for the development of new products.

The number of manufacturers of “standard containers” is higher (they are upgraded LLW containers, generally classified as IP-II/IP-III waste packages).
ILW CONTAINER – Product development

After reaching a noteworthy experience on LLW containers, ANN is aiming to develop containers for ILW disposal.

Our current strategy addresses the design, prototype construction and qualification of:

- One dual purpose cask (“special container”), cylindrical shape, for transport and storage of ILW, for disposing of activated waste with high dose rates. It should be relatively small (effective volume of 500 l) and built with a wall thickness of around 160 mm and an additional lead shielding up to 100 mm. For Cobalt-60 a maximum value of $1 \times 10^{13}$ Bq is expected to be handled.

- One dual purpose IP-II/IP-III prismatic container (“standard container”), consisting of a steel box, properly equipped with an inside shielding structure (either in lead or heavy concrete). This will be developed starting from our achievements on CP5.2. These containers could also be used for activated waste disposal.
A high number of dismantling projects have been launched all over Europe in the last decades; most of such projects concern the demolition of civil works or the dismantling of either non-contaminated or slightly contaminated systems.

Notwithstanding the above, several major decommissioning projects are being delivered. Jose Cabrera (Zorita - Spain) and Greifswald/ Wurgassen/ Stade/ Gundremmingen-A (Germany) are just a few significant examples, providing a lot of information about technologies to be deployed, as well as Clients orientations and disposal constraints.

The dismantling strategy, that various countries follow, is strongly influenced by local key drivers, although there are some shared international positions and good practices arising from NEA and IAEA.

Nuclear experience is deemed as a necessary requirement for companies willing to tackle these challenges (i.e. primary circuit dismantling), but it is not enough.

The use of equipment commercially available is good practice but quite often bespoke solutions are to be designed and utilised.
The availability of either proven or tested cutting technologies is of fundamental importance. Testing & qualification on mock-up have to be done prior to the execution phase on site, in dedicated facilities.

Similarities between the reactors are a lever that some nuclear players are using, to achieve a predominant position.

RVI segmentation projects are not just cutting. Special handling and manipulating tools (turn table, lifting tools, stands, etc..) have to be designed, qualified and manufactured.

At least for PWR, BWR and VVER, underwater cutting of the reactor internals seems to become the reference option. Removal without segmentation (waiting for decay) is possible but after all less probable. Concerning the RPV, the scenario is more uncertain; either underwater or dry cutting are viable approaches; removal without segmentation is also possible.
• The Italian D&D program represents an opportunity for the Italian Industry to develop competences and skills in view of a growing European market in the next decades.

• To achieve this goal, our industries shall focus on specific skills required to operate in the nuclear field, starting from proper certification.

• Partnerships with technology providers can be pursued to speed up the time to market, but properly considering the specific features of the Italian facilities and, even more, the need to properly interact with a single Customer, SOGIN, with its own views and its constraints.

• However, there are also good opportunities to develop some proprietary technology, considering the still limited experience with extensive decommissioning programs and then the space for cost effective improvements.
Thanks for your attention