Summary and conclusions

Last year, in its introduction to its annual report, the CNE gave an overall picture of the results from the research carried out in the context of the 1991 law by the CEA which is conducting research for line 1 and 3, and by the Andra, for line 2. This overview has put into perspective the research conducted since 1992 on long-lived and high activity waste management (ILW and HLW). In it, the CNE had assessed, line per line, results obtained at that period as regards the 2006 deadline. This overview also mentioned the need to continue certain research, beyond 2006, in order to complete current experiences and to extend others until their concrete realizations. Finally it mentioned the research areas not covered until now in relation with waste management that depended on law (radiation protection, sociology, economics).

In December 2004, the CEA published two synthesis reports listing all the results obtained so far on partitioning, transmutation, conditioning and long-term storage. These reports present all the research conducted by the CEA in collaboration with a wide national and international scientific community. The CNE has assessed this research in details since 1994 in its ten annual reports. In the present report, it can therefore provide a global assessment of all the results achieved so far on lines 1 and 3. The Andra has not yet given the CNE its synthetic report on the research that it has been leading, as well as in the context of large national and international programmes, but it provided many preliminary documents. Besides, the CNE remained very vigilant concerning the continuous progress of the knowledge acquired in Bure and the preparation of experiments to come. In the present report, it assesses both recent results obtained in Bure and all the results acquired so far concerning line 2.

The overall picture established last year contains most of the CNE assessment. It is used here and completed taking into account new elements brought to the knowledge of the CNE by the scientists in charge of research by law.

Line 1 - Partitioning

In its 2004 synthesis the CNE has summarised its assessment on advanced partitioning as follows: *globally, French research on partitioning has been innovative and has reached*

results sufficient to envisage an industrial implementation. It ranks at the best international level.

However the CNE outlined that the demonstration of the advanced partitioning technical feasibility was late compared to the schedule originally announced by the CEA. This demonstration is an important step which, after the scientific feasibility successfully achieved in 2001, opens the way to demonstrations on industrial pilot plants. It requires the implementation of new chemical engineering facilities in active environment in Atalante, that first of all have to be unquestionably operated. The trial runs of these facilities were completed at the beginning of 2005 and the actual experiments are in progress. The CEA is confident in their achievement but it is not expecting full results on advanced partitioning processes tested on their technical feasibility before mid 2006. At the end of 2005 the file on advanced partitioning technical feasibility will only be able to provide partial results. The CNE notices that the proof of technical feasibility may not be totally established at that date.

A long way remains to be covered to develop advanced partitioning up to the industrial level, in parallel to the transmutation systems and considering their requirements and availability. New orientations for transmutation incline to examine other paths in the way actinide partitioning of spent fuel could be approached. In any case, advanced partitioning experiments should be continued after 2006, to gradually reach a demonstration of industrial-like feasibility. However, an anticipated implementation of advanced partitioning compared to the deadline of the implementation of transmutation would create problems of how to store the separated elements over a few decades. The first studies by the CEA on such a storage outline certain difficulties.

To conclude, the CNE confirms its previous assessment on research conducted on advanced partitioning that opens concrete prospects.

Line 1 - Transmutation

Concerning transmutation the assessment by the CNE in its 2004 synthesis had been as follows: *in 2006, there will be no decisive arguments to take any decision of a scientific, technical or industrial nature on transmutation. In any case, any strategy in this respect will engage France, in close international co-operation, into a long R & D process during several decades, with the uncertainty inherent to the great present nuclear projects.*

Information gathered last year confirmed this assessment.

Conclusions on the transmutation possibilities in critical reactors remain unchanged. Plutonium and minor actinides multi-recycling in PWRs is a technically very difficult operation and with poor performances. The scientific feasibility of transmutation of minor actinides (except Curium) in a fast neutron flux has been experimentally established on pins placed in assemblies in the core of the Phénix reactor for the field acknowledged by the experiment. In order to be effective, transmutation must be continued over much longer periods than those of an irradiation cycle and so implies several recycling operations of the radionucleides to be transmuted. The demonstration of the technical feasibility will require several long tests on pins, then on the scale of an assembly. The CEA places great hopes on the gas-FBR, selected in the *Generation IV* international programme and chosen by the CEA, but this reactor is still only a concept. The CNE has no appreciation element concerning its feasibility and its transmutation performances.

Sub-critical Accelerator Driven Systems (ADS) are potentially interesting because they would allow the destruction of minor actinides while avoiding the complication of the fuel cycle in power reactors. Theoretical and experimental studies have been conducted for over ten years (Europe, USA, Japan). The global report on the PDS-XADS project aiming at the construction of an experimental "XADS" demonstrator has just been established. The "technical locks" concern the components of the reactor, the fuel and the cycle facilities. The emergence of these facilities could, according to the CEA, happen around 2045.

The study of fuels and targets for transmutation, a common theme to all transmutation systems, is one of the strong points of the research the CEA has been conducting for a long time but the technical feasibility is acquired only for the oxide-based fuels that have a low minor actinide content (for PWR, Na-FBR). Experiments to test higher concentrations or new compounds are being carried out or programmed.

The serious difficulties inherent to minor actinide transmutation, that occur in relation to the manufacturing, the irradiation and the reprocessing of targets or fuels that support transmutation, soundly arouse added interest for the thorium cycle which highly reduces the production of higher actinides. But the restarting research on the thorium cycle, that had been interrupted 30 years ago, would deserve a more important effort than the present one.

In the present state of knowledge, only the soluble fraction of technetium, among the long-lived fission products, could be transmuted.

Finally transmutation is hardly possible for already vitrified actinides. Vitrified packages retrieval is not technically impossible but it would lead to complex and heavy operations. The status of vitrified packages is virtually sealed as ultimate waste packages. Then these packages are addressed to geological disposal, together with ILW waste packages on which there is no status ambiguity.

Therefore, today as regards transmutation, we do not have at our disposal a system where the technical feasibility in a context of transmutation has been demonstrated. A long way remains to be covered. Transmutation is a hope depending on machines that do not exist at present, whether they belong to the generation IV reactor systems or the ADS one(s).

Line 2 – Deep Geological Disposal

In its 2004 synthesis the CNE has summed up its assessment on line 2 research in three points: research concerning the Bure site, possibilities open by this research and links between disposal and long-term storage.

For research concerning the Bure site, it wrote : *To conclude, the Bure site is marked by the presence of favourable characteristics and the absence of unfavourable prohibitive characteristics considering the present state of knowledge. A list of scientific questions still to be studied can be made. Andra's programme for the remaining time is relevant and dense, even if some experimentation and observation periods are too short to achieve results before 2006. Excepting new elements resulting from this programme, the Parliament should received in 2006 sufficient data to decide or not to continue exploring the site and the area in view of the possible creation of a deep repository.*

Results achieved this year have been marked by the end of the reconnaissance drilling programmes, by the drilling of the shafts and the first ten meters or so of the underground laboratory galleries. The drilling of the experimental alcove down 445 m made it possible to launch a series of observation and data acquisitions on the characterisation of the Excavated

Damaged Zone (EDZ) close to the potential sealings of a shaft, and on the delayed behaviour of the massif following the drilling of a shaft. However the analysis of the damaging and the mechanical behaviour of the argillites in the laboratory and disposal site conditions should be more deeply explored. Research conducted in the experimental alcove will also enable to complete the permeability and pressure measurements and to set up the diffusion experiments and sampling for waters and gas analysis. The experimental programme planned in the gallery drilled at 490 m in the Callovo-Oxfordian target layer , should be conducted according to the Andra's provisional calendar, until the end of 2006.

The CNE's assessment concerning the possibilities open by research in the Bure site was the following : *We can estimate that at the term of the law in 2006, there will be no serious obstacle that would prevent the Legislator from adopting the principle of deep geological disposal of long-lived waste in the studied area. The qualification of the rock is on its way to be acquired and the qualification of the sector will have to be confirmed once the works in 2006 are finished. But nevertheless there will remain technical questions of mining engineering and materials that will have to be answered in good time.*

On this point the CNE has been given the results from the 27 drillings that have been made. The results of the vertical or directional drilling campaign carried out in the Bure sector has brought a wealth of information in particular on the host layer and on the site. The examination of all the data allowed to improve the geological and hydrological model of the sector and to retrieve through vertical or horizontal core sampling 4,2 km of rock, 2,3 km of which in the Callovo-Oxfordian. These samples have been at the start of many laboratory works involving, besides the Andra's contractors, the French and European scientific community. The researchers involved have implemented the most modern techniques, particularly for prospection logging, tests in the drillings and geo-chemical analysis of the waters. They have interpreted the data according to the rule book using the latest knowledge and methods from science.

The Callovo-Oxfordian argillite layer shows a remarkable lateral continuity and homogenous composition and structure that exclude a lateral change (like switching to a sand or silt bed). The drillings positioned to understand the seismic anomalies interpreted with uncertainty have shown the absence of faults and has attributed these events to coralline episodes during sediment deposit. For the Callovo-Oxfordian, all the results prove - the long time of residence of the argillite poral waters - the low permeability of the rock - a remarkable

stratigraphic and mineralogical regularity, as well as the absence of conductive fractures in the studied area. The permeability measurements made on samples have shown extremely low values. Finally, water samples taken in the aquifers situated above and under the layer have shown very different water ages, which is coherent with the theory that there is no significant connective flow inside the argillite and that the layer is not crossed by waters.

At the scale of the transposition area of around 200 km^2 studied by the Andra, the works done allow to propose a geological model on which the argillite properties studied in depth on the site level, can be transposed. The continuity and the homogeneity of the geological layers are good, the hydraulic gradients between the aquifers have been confirmed as being low and no major fault has been identified during seismic survey or drilling.

If to date no prohibitive element for the setting up of a disposal site has been displayed, many research programmes still remain necessary to qualify the Bure sector. Preliminary results will be acquired before 2006 through the experiments launched in the galleries, but these will have to be confirmed and defined in the long term. In situ experiments implemented in 2005 in the underground laboratory, the analysis of the mechanical and thermal behaviour of the rock and of the EDZ, the study of the behaviour of the gases generated by the repository and their impact on the migration of the radionucleides require several years of continuous follow-up. Nevertheless in December 2005 the Andra should be able to present sufficient scientific elements to enable the Legislator to make a grounded judgement as for the pursuit of wide scope works.

In any reconnaissance in underground environments, bad surprises cannot be totally ruled out. It will be essential to complete the research conducted in the underground laboratory by detailed geological studies covering the site envisaged for disposal. Therefore such a large-scale plan will have to be carried out step by step, with a succession of meetings allowing to take stock of what has been acquired, to assess the uncertainties that remain and to define the research and running strategy of the following phase if the decision is taken to continue. Each step could last three to five years, enough to enable an optimum control of the benefits and short enough to rapidly detect the difficulties that could arise.

Finally last year the CNE had drawn the attention on the interdependence between storage and disposal by writing: *A question of management strategy remains also to be examined. The extent of the repository depends on the inventory of the waste to store and the time*

allocated for their cooldown. Therefore it is necessary to define the storage duration of the thermal packages and particularly those containing spent MOX, if their disposal was decided.

The CNE notes that the repository concepts and architecture proposed by the Andra are considerably clarified in comparison to those presented in the 2001 file. They better take into account the layer characteristics (thickness, mechanical strength, retention properties), they envisage only two types of pits and propose a modular tree-structured design which allows a rational layout of plugs and takes reversibility into account. In this respect the CNE recalls that in 1998 upon the government's request, it gave a favourable advice on reversibility. The repository concepts and architecture must remain modifiable along with the progress of knowledge in an engineering environment.

On the other hand, the CNE notes that it has not been presented with any detailed study concerning storage duration optimisation of thermal packages.

Simulation is a necessity to study repository behaviour on a scale of millenniums and in particular radionucleides migration. Research conducted by the Andra for the past few years in this field have led to a good standard simulation programme, the results of which will be presented in the « 2005 Argile » file.

To conclude, the CNE confirms its previous favourable assessment on research conducted in Bure within the line 2 of the law. The confinement qualities of the Callovo-Oxfordian argillite are comforted by the last observations in situ in the laboratory and by the results obtained on the core samples taken in the geological layers at the Bure site. The results of the first experiments and measurements in the laboratory will be available end of 2005, as planned on the calendar.

Line 3 – Waste conditioning

In its 2004 synthesis, the CNE had made a positive assessment of the research on primary conditioning of rough waste from reprocessing, assessment that it is renewing. Clearly the present manufacturing of primary industrial packages of ILW and HLW waste and their industrial storage are under control. The CEA and the manufacturers have effective facilities at their disposal to characterise any radioactive waste package. The short or long term

behaviours of waste and spent fuel packages in various situations have been reasonably established. Research is opening good prospects for new conditioning, if it became necessary (high temperature poured glass and ceramics). However it is necessary to continue the research to consolidate some results, particularly on the resistance of some glass materials and on the confinement possibilities offered by ceramics, in order to possess a wide selection of conditioning means to confine long-lived radionucleides on the long term.

The CNE considers that the research in line 3 that leads to the making of primary industrial waste packages has taken this technology to maturity. It also gives concrete prospects to adapt these solid waste forms to future waste and waste not yet conditioned.

Line 3- Long-term storage of primary waste packages

The assessment that the CNE had made in its 2004 synthesis on long-term storage research was subdued. It was formulated as follows *: The possibility for a storage to last beyond a century has not been proved. Therefore the CNE is led to express an opinion stemming from his thoughts: a limited storage time, in conditions similar to recent and advanced industrial storage seems to be the optimum solution, followed by a transfer – if possible without reconditioning – into a disposal site, as soon as the latter will be authorised by the safety authority. Disposal reversibility, if it is assured, would make it possible to bring corrections to the initial project of waste package management for still several decades.*

The elements provided to the CNE concerning long-term storage (ELD) give the following added information.

Long-term storage (roughly 300 years) of waste primary packages or spent fuel assemblies placed in canisters, or their disposal in a geological formation, requires the realization of long-lasting containers. Containers for such ELD/disposal double purpose have been designed by the CEA which has made them into technological demonstrators. The durability of these containers remains to be established. This is being done for metallic containers and remains to be done for concrete containers. The CNE examined these demonstrators in January 2005. It notes that it does not know precisely the specifications imposed to the constructor for these objects, nor the tests to be carried out in order to characterise all their

properties, tests that will have to be done in a near future. Therefore the CNE cannot evaluate their capacity to fulfil the functions they must ensure in the long term.

The storage of primary waste packages is possible for roughly a hundred years in industrial facilities recently built next to reprocessing plants. These facilities are not seemingly a concern. Vitrified waste is stored in dry conditions. All vitrified packages coming from the reprocessing of spent fuel from the present reactor plants could be stored (possibly up to a century) with extension and maintenance works of the existing industrial storage facilities. For their part, spent fuels are stored in pools, waiting for their reprocessing, for one or several decades.

Sketches of long-term surface or sub-surface storage facilities have been proposed and a new experimental facility for the real size study of the natural cooling of the storage facilities has been realised. The durability of the concrete forming the civil engineering works of the storage facilities, cannot be guaranteed (in the usual engineering meaning) beyond about a hundred years, whether it is vis-à-vis a temperature around 80°C, thermal cycles or interactions with the surrounding natural environment. However the CEA, after having progressed in its study of concrete deterioration, believes that this delay can be overtaken. The study of the civil engineering works has only been drafted. Since nobody can really say if concrete can last beyond a century, this implies that for a longer period, an active surveillance and, if necessary, a rebuilding of the facilities must be envisaged. There is another difficulty of a different nature : the existence of a radioactive material storage needing a constant monitoring and maintenance, demands a continuity in the social structure.

Sub-surface storage is a discreet facility, resisting to natural or accidental external aggressions. But for any detailed study it will be necessary to take into account the features of the application sites. The fabric of a sub-surface storage should be done by digging inside a geological formation that has been proved stable.

The main purpose of storage is to ensure the compatibility between waste management processes with very different time scales, from a decade to centuries. It can also be considered as a way to differ management decisions, but then it initiates a process of transfer of responsibility upon future generations.

To conclude, research conducted within line 3 of the law is not completed, except for the industrial storage of present reprocessing waste. The current programmes on storage and disposal containers must be continued. In order to go further than generic studies on long-term storage facilities, it would be suitable to select a potential storage site.

General conclusion

The CNE reminds that a summary of its assessment of the results acquired in the three lines of research has been presented to the parliamentary Office during public hearings on 20, 27 January and 3 February 2005.
The CNE will publish its global assessment report in January 2006. It will then evaluate, in accordance to its mission, the results that could be presented to it during the year 2006.

The 2004 overview included two assessments on the whole research, that the CNE takes up this year :

The documents that will be submitted to the Parliament in 2006 by the actors of the law should provide the Legislator with the technical elements enabling him to select a global waste and spent fuel management strategy.

The CNE outlines that long term technical and scientific research associated to the objectives chosen by the Parliament will be necessary and that it will have to be conducted in an international, particularly European, framework.

The CNE considers that it is in the line 2 that the most significant advances have been achieved during last year. Information collected by the Andra will enable the public authorities to select the principle of deep geological disposal for ultimate waste, if they so wish.

Chapter 3 - Line 1 – Partitioning and transmutation

3.1 Summary

The partitioning and transmutation of actinides and even of main long-lived fission products form a whole part of a global cycle which will have to involve plants to separate these elements, to develop new fuel or transmutation targets and fast neutron reactors for transmutation. Its implementation is far off because it requires a long pursuit of research within a strategy that remains to be defined. Research carried out within the framework of the law has allowed getting over a few important steps and identifying those to come.

The success of the CEA is to have established the scientific feasibility of americium and curium partitioning with processes that use a new robust extracting molecule (a diamide called DMDOHEMA) comparable to the molecule on which is based the Purex extraction process of uranium and plutonium from spent fuel. The demonstration of the technical feasibility of three processes for this partitioning is under way, tests have started in the Atalante facility. The Commission is waiting for the final results in 2006 in order to assess them. The partitioning of the main long-lived fission products (iodine, technetium, caesium) has been tested, although perspectives are hardly encouraging concerning their transmutation.

As far as the transmutation systems are concerned, we must make a difference between the scientific feasibility, then the technical feasibility of the transmutation systems for two operating modes: operating with "standard" fuel and operating with fuel or targets dedicated to transmutation. We must also make a difference between transmutation by a homogeneous mode, which can lead to the stabilization of the inventory via multi-recycling, and transmutation by a heterogeneous mode in targets that leads to an advanced destruction of minor actinides with only one recycling.

The pressurized-water thermal-neutron reactors (PWR) of the present nuclear power equipment and of the future reactors (EPR) could be used for plutonium and minor actinides multi-recycling but with great difficulty. Two possibilities are then open: either the possibility of innovative accelerator driven systems (ADS) as an addition to a power equipment using standard fuels, or the possibility of electricity-generating or "dedicated" fast neutron reactors (FBR). An ADS system includes a fast neutron reactor where the concentration in minor

actinides, namely americium, can be high, for a greater transmutation efficiency. The FBR would multi-recycle plutonium and minor actinides (or would transmute them once-through). They can come as a substitute or a complement to a PWR equipment. Thorium fuelled thermal neutron reactors which would produce hardly any minor actinides, could also be envisaged. The ADS is the main transmutation system for which theoretical and experimental studies have been carried out for over 10 years (Europe, USA, Japan). These studies, that produced many results, have identified the "technological locks" to be removed; programmes are under way (5^{th} and 6^{th} European FPs). The scientific feasibility of transmutation has been established experimentally for a Na-FBR (Phénix), already proved with standard fuels. The demonstration of the technical feasibility will first require tests the scale of an assembly. The gas-FBR selected in the *Generation IV* international agreement and the study of which is supervised by the CEA, is still, however, a concept to be developed. The Commission has absolutely no appreciation element at its disposal concerning its feasibility and its transmutation performances.

The study of *fuels and targets for transmutation* is one of the strong points of the research led by the CEA for nearly twenty years. The technical feasibility is only proved for oxide-based fuels with a low minor actinides content (for PWR,Na-FBR). Research is extended to the same types of compounds, with a higher minor actinides content (ADS, FBR). As a second priority and for innovative reactors, other materials like nitrides, carbides and metallic alloys are being experimented.

The CEA has carried out detailed studies on three contrasted scenarios, until 2100, on future deployment of new transmutation systems, by making hypotheses on dates for the industrial availability of chemical partitioning of minor actinides and systems that contribute to transmutation, and also on the consistency of the nuclear power equipment. These studies of scenarios shed a light on the potentiality of different transmutation cycles, in the context of a transition towards a future using nuclear energy on the long term. These studies should, in the future, better take into account the prerequisites for the deployment of these systems: on one hand, a more realistic agenda of the availability of industrial tools, on the other hand the global strategic and energetic context in which these scenarios are placed (for example the possibility to make coexist some ADS with a standard FBR equipment). Finally, the impact of these scenarios on the storage and disposal characteristics remains to be studied.

The key question of curium management demands much deeper work than the current one, if a second recycling is envisaged. The Commission considers that the theoretical advantages

of the thorium cycle in terms of long-lived waste are important enough to justify a detailed study of this cycle, beyond the basic studies carried out on molten salt reactors by the sole CNRS. The technical and scientific feasibilities remain to be demonstrated, although experimental reactors have already been operating in the USA.

To conclude on Line 1, the Commission considers that the CEA has made major scientific breakthroughs in the chemical partitioning of minor actinides and in confirming the use of oxides fuels as transmutation support for minor actinides. However, for transmutation, we do not have at our disposal to date a system for which the technical feasibility in a transmutation environment, has been proved. There is still a long way to go, both for partitioning and transmutation.

Chapter 4 - Line 2 –Disposal in deep geological formation

4.1 Summary

The evaluations of the Commission on research carried out in Line 2 are not final yet since important investigations in the Bure laboratory are still under way and essential results are expected from the *in situ* experiments that started in January 2005. Moreover, the Commission has not yet received the final reports from the Andra. It is only in its global assessment report, planned for the beginning of 2006 that the Commission will analyse and assess the totality of the elements provided by the Andra.

The investigations and measurements already made on the Bure site during programmes of geo-physics, vertical and deviated drillings, during the drilling of the shafts, the alcove and the deep galleries, and from the already made measurements on core samples or *in situ,* clearly show on one hand, the absence of signs of totally unacceptable defaults, and on the other hand, many favourable features of the Callovo-Oxfordian argillite to host geological disposal facilities : horizontal continuity of the host layer, homogeneity, absence of conductive fractures , low permeability, high retention capacity of the clays, reducing environment, suitable mechanic setting, small potential gaps between the aquifers surrounding the layer, very low water velocity within these aquifers.

These last few years, the Andra has done a remarkable work in many respects, by widely mobilizing national and international competences, and by efficiently preparing the tests to

be carried out in Bure, namely in the Mont Terri laboratory in Switzerland. The means already implemented in Bure are exceptional in terms of volume and quality. The Commission considers that, taking into account the oral presentations and the intermediate files that were brought to its knowledge, the Andra has identified the main scientific and technical problems.

The architecture proposed by the Andra for possible disposal facilities has been considerably simplified compared to the one presented in the 2001 Argile file. It better takes into account the characteristics of the layer (depth, strength); it is considering to have only two great types of pits; it suggests a modular, tree-structured design that enables a rational layout of the plugs. The question of reversibility is correctly dealt with. All the same, this architecture must remain modifiable with improvements in the knowledge of the environment and in the safety analysis.

The plugs that seal the pits, galleries and shafts form essential elements of disposal safety. The Andra has correctly assessed their importance. The targeted objectives in terms of water tightness are difficult to reach and their feasibility will have to be proved. The case of the shafts has to be thought about in priority, these works being the first ones to be submitted to authorization.

The study of the EDZ (excavated damaged zone by the drilling around the galleries) benefits from the experience that the Andra has been able to gather on the subject in Mont Terri in Switzerland in view of the programmed tests in Bure in 2005. It will not be possible to solve completely this important question in 2005 and its study should continue after 2006, being careful to bring the synthesis of the studies and the positioning of the scientific issues up to the best international standards.

The production of hydrogen by the steel corrosion could seriously question the image admitted so far of how a repository functions after it has been closed. The Andra has given this problem a great deal of thought for the past few years. This effort must be continued because it is still too early to draw firm conclusions.

Before the end of 2005, the Andra will have produced a report critically assessing the waste disposal possibilities in another rock, namely granite, and maybe will have shown the advantages and disadvantages of this kind of environment, in the geological context of France.

The encouraging impression given by the investigations already carried out on the Bure site must still be confirmed, by completing a research programme in the underground laboratory on the one hand, and on the other by doing more studies on the surface and by digging new shafts that will enable the reconnaissance of a sufficient area for a possible repository through galleries. The Commission recalls that during this phase, the disposal project could be seriously modified or even abandoned in view of the results of the investigations.

However the Commission believes that the probability of the reconnaissance process to be completed is not insignificant in view of the knowledge already accumulated. The Commission has questioned the level of scientific information that should be put together so that a possible decision concerning the implementation of a repository could be made with full knowledge. The needed information should include:

- The assessment of a research programme in the underground laboratory ;
- The assessment of the survey for a repository potential site and the related studies such as 3D seismic, drillings, shafts and underground galleries.

Chapter 5 - Line 3 – Conditioning and long-term storage

5.1 Summary

Significant advances have been made in the last decade on waste production minimization and on on-line conditioning of spent fuel processing waste. The primary packages of present waste are adapted to industrial operational storage. The CEA, in co-operation with the manufacturers, has conducted a remarkable scientific programme on waste package characterization, and on UOX and MOX behaviour, and vitrified waste packages. Those items contain nearly all the radioactivity produced in nuclear reactors. For spent fuel, very conservative models have been proposed to simulate its behaviour in dry storage and in geological disposal. The study already under way, of the long-term consequences of helium release in fuel (especially MOX) must imperatively be completed. As for the vitrified waste packages, a robust operational behaviour model in a geological disposal can be used for calculating the release of radionucleides in various conditions. The study of long-term alteration mechanisms must nevertheless be continued to enable this operational model to be consolidated (particularly to take the packages environment into account). The study of vitrified waste more heavily loaded in minor actinides, particularly in curium, will have to be realized in order to avoid increase in the number of the present packages when high burn-up

fuel or MOX will be reprocessed. In this respect, technological developments aiming at producing high-temperature poured glass are under way. Several ceramic materials for the conditioning of minor actinides and some separate fission products have been designed and produced in the laboratory in the prospect of implementing advanced partitioning. The experimental assessment of their properties has begun. However we are far from all the knowledge accumulated on vitrified waste.

Long-term storage (ELD) of primary packages of waste or spent fuel, or their disposal in a geological formation requires long-lasting containers. The design of double-purpose (ELD/geological disposal) containers for ILW waste and spent fuel, and the technological demonstrators have been completed by the CEA. The results of a technological testing programme now under way are being expected. The durability of these containers remains to be proved by experimental results and models. A study of the containers durability is under way. The container prototypes will follow.

Industrial storage is possible during about a hundred years in the storage facilities recently made for primary packages of waste produced in reprocessing plants. Models of long-term surface or sub-surface storage facilities have been proposed. An accurate simulation of thermal packages cooling remains to be done. For the civil engineering works, the durability cannot be guaranteed (in a « commercial » meaning) beyond about one hundred years. Sub-surface storage has the advantage to be resistant to some external aggressions, but a deeper study of it would mean taking into account the specificities of application sites, to be selected according to a stability criterion that would be more demanding than the one proposed by the CEA. So far, the study of civil engineering works has only been drafted.

To conclude on line 3, the Commission considers that the conditioning of waste concerned by the law results in robust, well characterised primary packages of ILW and HLW. It has been possible to propose operational models to simulate the behaviour of spent fuel and reprocessing waste packages in geological disposal. However, the full understanding of the alteration mechanisms of spent fuel and waste packages requires the continuation of research. The conditioning of waste primary packages and of fuel canisters, for storage and disposal purposes has been the object of recent developments which have not yet managed to establish the containers durability. The present industrial storage of waste primary packages could be prolonged over roughly a century, if necessary. For vitrified waste packages, it enables the reduction of the thermal load in the geological repository. ILW waste, considered as ultimate waste, has no alternative other than geological disposal :

there is no technical justification to store them before their disposal. Storage over longer periods, even in specially built facilities, and the feasibility of which remains to be established, would require permanent monitoring and heavy maintenance interventions, even a regular rebuilding of the facilities. Long-term storage in itself cannot be a long-term management strategy; it would weigh too heavily on future generations.