



Estimation of Expenses for Low and Intermediate Level Radioactive Waste Repository Project in Croatia up to Site License Acquisition

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ABSTRACT

The expenses needed for development of low- and intermediate level radioactive waste (LILW) repository project in Croatia include: (a) preliminary activities, (b) preparatory activities, and (c) preparing of environmental impact study. *The first group of expenses* are referring to the project leading activities, project plan updating, build-up of required infrastructure, preparing of licensing documentation, site investigations, data acquisition programme, pre-operational radio-ecological monitoring, modelling, safety analysis (first iteration) and public related activities. *Preparatory activities* are referring to purchasing of land for repository and preparatory activities for carrying out of on-site investigations, while third group of expenses are related to preparation and validation of *Environmental impact study*. It was found out that about 50 % of total expenses refer to build-up of infrastructure. Additional 25 % finances are related to radio-ecological monitoring, site investigations and development of calculations and models, while remaining 25 % of total estimated sum is expected to be spent for repository safety assessment, public relations, purchasing and preparing the on-site terrain for construction, etc. It was calculated 607 EUR per m³ of LILW to be needed up to site license acquisition. According to the world-wide practice, by extrapolating of additional expenses necessary for construction of the repository and acquisition of operational license, it comes out the cost of 1,723 EUR per m³ of LILW for shallow-ground and 2,412 EUR per m³ of LILW for tunnel repository. The estimated expenses for Croatia are within the span of expenses for the same purpose in the countries considered. Expected duration of the project performance up to acquisition of the site license is 4 years and 3 months.

1 INTRODUCTION

There are some significant facts to be accepted while considering experiences of other countries in the field of LILW repository development: (a) total expenses for LILW repository build-up and licensing are much higher than those needed for construction and licensing of facilities characterised by similar technical complexity; (b) final specific expenses (i.e. finances needed for disposal of 1 m³ of LILW) significantly vary from country to country even when applied similar technical repository designs; (c) in spite of a dozen LILW repositories currently operating in Europe, establishment of each new repository presents – as

it shows the international practice - a project to be repeatedly done *'ab ovo'*. However, it is not influenced by technical reasons since:

- there exist international conventions and recommendations on LILW disposal
- there is remarkable technical support by international organisations and specialised agencies (European, in particular) in the field of LILW disposal available
- information on LILW is widely accessible
- there are a few tested LILW disposal technologies to be applied
- there is an extensive documentation on LILW disposal site investigations and a long-term safety assessment widely available
- quality assurance and quality control (QA/QC) standards for LILW disposal are among the most rigorous in the world.

There are two main reasons for complexity of the LILW disposal project, including also demands for investments in every single stage of the repository lifetime (preparation for construction, licensing, build-up, operation and closure):

- specific national legislation and regulation in the field of LILW disposal and ionising radiation protection that vary from country to country
- remarkable differences world-wide in acceptance of LILW disposal by public and local community, in particular.

It should be admitted that build-up of LILW disposal facility represents in most of countries the 'once in a lifetime' project. That is why it often faces with pressures to provoke a very conservative, in many cases ecologically and economically unjustified requirements, in spite of its rather simple and well-tested technology. Consequently, total expenses necessary for LILW disposal facility construction might be assessed remarkably high. In addition, every estimation of expenses should be considered as very rough, since e.g. in the case of only one repetition of LILW repository site selection process (that could be provoked by quite political reasons) and repeatedly applied *public relations programme* to another local community, can double the planned expenses. It is obvious that duration of the repository project development would be in that case also significantly prolonged.

The presented estimation of expected expenses that are necessary for acquisition of LILW repository site license in Croatia is very rough. It does not include expenses needed for physical construction of disposal facility, auxiliary buildings and possible de-mining of the site area¹. It is related only to those activities that are indispensable for repository site license acquisition.

All presented expenses are based on the estimated expert engagement for every single project activity involved that is 5,000 EUR for 1 man-month.

Presented estimation of expenses necessary for LILW repository site license acquisition has been worked out in accordance with available documentation on LILW repository project in Croatia, developed by APO Ltd.

2 BACKGROUND

2.1 Structure of Project Activities

There are following elements of the complete LILW repository build-up project in Croatia :

- development of relevant legislation and regulations
- defining of administrative competencies and identification of authority body
- licensing

¹ It is possible that mines have been remained in the area after the war is ended.

- characterisation of LILW for disposal
- repository site selection process
- development of repository technical design
- development of safety analysis of the repository and environment
- LILW transportation safety
- economic justification of the repository construction and operation
- public related issues (including general public and relations with local community)

All of these substantial project components are considered in the paper.

2.2 Brief Project History

The estimation of expenses for the repository project, as it is presented here, *does not include finances that had already been spent during the past project activities*. That is why it seems important to point out the basic milestones in the project history, as well as the results of project activities realised in the past. The project in Croatia began in 1988 when Croatian and Slovenian governments – due to joint ownership over the Nuclear Power Plant Krško (NEK) – established Common Co-ordinating Body to manage radioactive wastes generated by NEK. In the same year the repository site selection methodology, including both exclusionary and comparative criteria, was defined (they were officially announced in ‘Narodne novine’, the official gazette of Croatia, No. 78/1992). Thus, exclusionary screening of Croatian territory and subsequently accomplished comparative analysis of potential areas resulting in selection and validation of 34 potential sites, were done in the period 1993-1995. After additional analysis, four sites – Papuk, Psunj, Moslavačka gora and Trgovska gora – were proposed as most perspective in 1996. Finally, one of them – *Trgovska gora* mountain in Banovina Region of Croatia – was included into the actual Physical Plan of Croatia which came into force in May 1999 (‘Narodne novine’, No. 50/1999). It has also been achieved some progress in the fields of the LILW repository safety assessment (preliminary safety assessment report), development of the repository technical design (shallow ground or tunnel disposal alternatively) and public relations issues (information to general public, contacts with potential local community). The repository is designed to receive 18,000 cubic metres of LILW.

3 ESTIMATED EXPENSES FOR PRELIMINARY ACTIVITIES

Preliminary activities comprise a few groups of the project related actions, starting from the project leadership and co-ordination, up to on-site researches, radio-ecological monitoring of ‘the zero-state’ at the site and first iteration of the safety assessment including relevant data acquisition programme. As distinguished from past project events which were resulting predominantly from deskwork (i.e. analysis of the already existing relevant documentation prepared mostly for other purposes), almost all of the following project activities are related to on-site field explorations that includes detailed terrain prospecting, thematic mapping, development of models and calculations, laboratory analyses, defining and construction of some infrastructure systems, etc. The estimated expenses for each group of the project preliminary activities will be shortly explained in the following text.

3.1 Project Leadership and Co-ordination

Project leadership and co-ordination refer to organising and controlling of all project activities needed for acquisition of the site license. That is why this activity lasts throughout

the project, i.e. 4 years and 3 months, and requires an expert engagement of 76 man-months in total (presumably 2 experts per 38 months). Hence, the foreseen expenses for this activity are totally *380,000 EUR*.

3.2 Project Activity Plan Update

Due to some significant modifications in the project performance that have become relevant since the last activity plan update, particularly in definition of critical paths, it is necessary to re-establish activity plan and in details elaborate duration and logic connections of some more important activities. Calculations show that an engagement of three experts by three months each would be realistic. It makes altogether 9 man-months, i.e. *45,000 EUR*.

3.3 Defining and Physical Performance of Some Infrastructure Systems

Due to considerable civil engineering works, such as designing and physical construction and/or re-construction (plateaux, site access roads, electric power transmission lines, water supply network, sewage system, telephone lines, etc.), these activities are the most expensive of all considered. It roughly covers even more than 50 percent of all planned finances, i.e. *5,750,000 EUR*: 1,900,000 EUR for re-construction and completion of the site access road; 670,000 EUR for construction of transmission lines; 1,680,000 EUR for build-up of water-supply system and 1,500,000 EUR for development of telecommunications. Duration of these activities is assessed at 24 months, i.e. two years total.

3.4 Licensing for Site Investigations

It is assumed that acquisition of site license for performance of detailed site investigations would cost some 2,000 EUR. The solution of juridical and proprietary issues referring to the land purchase for construction of LILW disposal facility would cost additional 2,500 EUR, while acquisition of building permit for site investigations is assessed to be about 6,000 EUR. Since expenses for changes and modifications of the Physical plan at county and local community levels will not be cheaper than 8,500 EUR, it is realistic to estimate the total cost for this group of investments at *19,000 EUR*. Licensing process is expected to last 6 months.

3.5 Site Investigations

This activity group includes a wide span of various site-related surveys, from geology up to land cover issues and demography. Different kinds of thematic mapping, laboratory work and development of some specific models and calculations make methodical basis for performance of site investigations necessary for acquisition of the repository site license. The estimated cost breakdown by particular investigations is as follows:

▪ geology (petrology and stratigraphy)	180,000 EUR
▪ hydro-geology	55,000 EUR
▪ engineering geology	70,000 EUR
▪ tectonics and neotectonics	35,000 EUR
▪ geomorphology	40,000 EUR
▪ hydrology	55,000 EUR
▪ pedology	18,000 EUR
▪ soil mechanics	120,000 EUR
▪ geochemistry	165,000 EUR
▪ geophysics (surface techniques: geoelectricity, refraction, reflection)	90,000 EUR

▪ demography	15,000 EUR
▪ land cover analysis	5,000 EUR
▪ development of GIS related database	50,000 EUR
▪ acquisition and interpretation of satellite and aerial photographs	27,000 EUR

The resulting total cost for all planned site investigations needed for site license acquisition is *925,000 EUR*. The investigations are expected to last about 26 months altogether.

3.6 Data Acquisition Programme

Data acquisition programme makes an indispensable step for accomplishing the first iteration of safety assessment. It is necessary to collect all available site specific (or generic, at least) data and quantify the obtained information to be applied in corresponding codes and calculations. It will be necessary to hire two experts for 8 months each, i.e. total engagement would be 16 man-months or *80,000 EUR*.

3.7 'Zero-State' Monitoring

The main purpose of the near-field and far-field monitoring programmes is to ensure reliable data on state of the environment at the site before start-up of the repository in order to check possible environmentally related changes during the repository's operation (in particular, in post-closure period). There are four zero-state monitoring programmes necessary to be undertaken synchronously during the period of three years (36 months) before the repository starts operating (there follows also the cost-breakdown):

▪ seismological monitoring	165,000 EUR
▪ hydro-meteorological monitoring	645,000 EUR
▪ radio-ecological monitoring of rocks, soils, water and air	130,000 EUR
▪ monitoring of radionuclide migration through food chains	320,000 EUR

All planned monitoring programmes involved cost totally *1,260,000 EUR*.

3.8 Development of Models

Development of models represents establishing of a series of sophisticated calculations to simulate more or less realistic events or scenarios that would be based on strictly defined characteristics of the geosphere, hydrosphere and atmosphere at the repository site. There are four models to be developed during the 17-months period. Each model demands engagement of experts as it is given below, and utilisation (purchase) of necessary equipment. The total cost of *610,000 EUR* is related to development, i.e. construction of the following models:

▪ hydro-geological model (20 man-months + equipment)	135,000 EUR
▪ hydraulic model (22 man-months + equipment)	162,000 EUR
▪ geochemical model (15 man-months + equipment)	108,000 EUR
▪ model of radionuclide migration (27 man-months + equipment)	205,000 EUR

3.9 Safety Assessment – First Iteration

After Data Acquisition Programme (see the section 3.6) is completed, first iteration of the safety assessment is planned to last about 1,5 year (18 months). It requires engagement of five experts (one expert for databases and parameter analysis, one expert for modelling and simulation, one hydrogeologist, one geochemist and one expert for LILW) during a one-year

period and three additional experts for two months each to prepare the final report. In addition to this 81 man-months (405,000 EUR) some 100,000 EUR should be added for purchase of necessary hardware and software, so that the final complete cost for safety assessment is *505,000 EUR*. Result of the first iteration of safety assessment is preparation of the document containing basic information necessary for completion of Environmental Impact Study.

3.10 Public Relations Programme

Activities related to increase public trust and co-operation for the project realisation encompass a series of actions to inform and educate the public on possible environmental impacts of the repository and measures to be undertaken for preventing them. Preparation and implementation of the Public Relations Programme are related to a number of actions such as identification of target groups, issuing of publications (periodicals, brochures, books, videotapes etc.), introduction of sponsorships for ecologically relevant actions, etc. Thus, the members of target groups should be acquainted with LILW disposal safety related practice at such installations. However, the incentives to local community are legally separated from these issues and are not included into this estimation of possible expenses. Total cost of publicly related actions to be activated during the 36-months period is assessed to *370,000 EUR*.

4 ESTIMATED EXPENSES FOR PREPARATORY ACTIVITIES

Preparatory activities consist of (a) ground purchase for disposal facility siting, and (b) preparing of site area for construction of disposal and auxiliary facilities. Both groups of activities are supposed to last 12 months. Although, it is expected some 15-20 hectares to be sufficient for complete repository in-door area, purchase of 30 hectares for disposal area along with surrounding protection belt would be preferable. Since it seems realistic to calculate some 5,000 EUR for one hectare of area, the total cost for the ground is 150,000 EUR. Preparation of that area would cost some 750,000 EUR, so that total estimated expenses for preparatory activities reach *900,000 EUR*.

5 PREPARATION OF ENVIRONMENTAL IMPACT STUDY

Environmental impact study (EIS) for LILW repository will be based on considerably wider standard format than it is prescribed by 'Code of Practice on Environmental Impact Assessment' ('Narodne novine', No. 59/2000). Due to complexity of possible environmental impacts, preparation of the study requires engagement of various experts such as physicists, chemists, biologists, technologists, geologists, experts in physical planning, etc.). Besides the preparation of the study itself, the work of members of the Expert Commission for EIS Evaluation, nominated by the Ministry for Environmental Protection and Physical Planning, should be considered as well. Hence, the total cost includes engagement of 14 man-months for preparation and 3 man-months for evaluation and validation of EIS. Therefore, it is necessary to ensure *85,000 EUR* total for this activity. It is reasonable to expect 13 months to be enough for completion and validation of EIS.

6 OVERVIEW OF TOTAL ESTIMATED COST FOR NEEDED ACTIVITIES

In accordance with the above mentioned, it follows the cost-breakdown of all estimated expenses needed for LILW repository site license acquisition (Table 1).

Table 1: Overview of total estimated expenses for LILW repository site license acquisition

Activity	Man-months engaged	Estimated cost (EUR)
<i>Preliminary activities</i>		
Project leadership and co-ordination	76	380,000
Project activity plan update	9	45,000
Infrastructure systems built-up	460	5,750,000*
Licensing for site investigations	3	19,000
Site investigations	130	925,000
Data acquisition programme	16	80,000
Monitoring of 'zero-state'	176	1,260,000
Development of models	84	610,000
Safety assessment (first iteration)	81	505,000
Public relations programme	55	370,000
<i>Preliminary activities – total</i>	<i>1.090</i>	<i>9,944,000</i>
<i>Preparatory activities</i>		
Purchase of ground for repository siting	18	150,000
Preparation of site area	80	750,000
<i>Preparatory activities – total</i>	<i>98</i>	<i>900,000</i>
<i>Environmental impact study - total</i>	<i>17</i>	<i>85,000</i>
<i>All expenses estimated</i>	<i>1.205</i>	<i>10,929,000</i>

* The cost includes all expenses reasonably expected: designing, constructions and work hours for personnel engaged

Total cost of activities needed for acquisition of LILW site license in Croatia is estimated to 10,929,000 EUR. With regard to 18,000 cubic metres designed capacity of the repository, it comes out the specific cost of 607 EUR per cubic metre of disposed LILW up to the stage of LILW site license acquisition. Total manpower engagement is estimated to 1,205 man-months, while additional finances are referring to cost of ground for siting, necessary equipment, administrative and other services, etc. As it is apparent from the cost-breakdown, 52,6 % of all expenses considered are related to planning, designing and construction of necessary infrastructure. Other remarkable expenses are those related to monitoring programmes of 'zero-state' (11,5 % of total cost), site investigations (8,5 %), preparation of the site area (6,9 %) and development of models (5,6 %). These five individually listed activities altogether make roughly 85 % of all expenses estimated.

7 COMPARISON OF ESTIMATED EXPENSES WITH PRACTICE IN OTHER COUNTRIES

The obtained specific cost per 1 cubic metre of disposed LILW up to the stage LILW site license acquisition is 607 EUR. This sum is significantly lower than a mean value when compared with corresponding costs for LILW repositories in other countries, as it comes out from the following list of specific costs (per 1 cubic metre of LILW) [1]:

- Loviisa (Finland) 1,740 EUR/m³
- Wellenberg (Switzerland) 1,737 EUR/m³
- Olkiluoto (Finland) 1,221 EUR/m³
- Rokkasho (Japan) 1,315 EUR/m³
- Konrad (Germany) 1,193 EUR/m³

▪ <i>Croatia (estimated)</i>	607 EUR/m³
▪ Belgium (planned)	410 EUR/m ³
▪ Uveghuta (Hungary)	233 EUR/m ³
▪ El Cabril (Spain)	220 EUR/m ³
▪ Udvari (Hungary)	183 EUR/m ³
▪ SFR (Sweden)	176 EUR/m ³

It is necessary to remark that the share of expenses needed for LILW repository until the site license acquisition considerably differs from country to country, varying within the span of 15-40 % of total LILW repository project. For this reason, but also due to the factors such as differences in LILW disposal quality (including safety aspects), organisational and regulatory levels, as well as the quantities of LILW to be disposed, there are significant differences among the expenses (specific costs) considered. In addition, considering the experiences of other countries, it is reasonable to assume that the estimated specific cost for Croatian LILW repository project up to site license acquisition may amount to 20-25 % of total repository project cost (up to the repository start-up). In such circumstances, the total LILW repository cost in Croatia could be extrapolated to 43,416,000 EUR for 'tunnel' disposal (2,412 EUR per 1 cubic metre of disposed LILW) or 31,016,000 EUR (1,723 EUR per cubic metre of disposed LILW) for shallow ground repository. By comparing specific total costs for similar LILW repositories in other countries, the expected costs for the repository in Croatia lay within world-wide practice in financing operation of such facilities:

▪ Japan (Rokkasho, shallow ground disposal)	8,219 EUR/m ³
▪ Finland (Loviisa, deep geological disposal)	4,971 EUR/m ³
▪ Switzerland (Wellenberg, 'tunnel' disposal)	4,825 EUR/m ³
▪ Finland (Olkiluoto, deep geological disposal)	3,213 EUR/m ³
▪ Sweden (SFR, disposal in submarine rocks)	2,933 EUR/m ³
▪ Germany (Konrad, 'tunnel' disposal)	2,840 EUR/m ³
▪ Belgium (site not specified, shallow ground)	2,562 EUR/m ³
▪ <i>Croatia ('tunnel' disposal, estimated)</i>	2,412 EUR/m³
▪ <i>Croatia (shallow ground, estimated)</i>	1,723 EUR/m³
▪ Hungary (Uveghuta, tunnel disposal)	1,664 EUR/m ³
▪ Spain (El Cabril, shallow ground disposal)	1,294 EUR/m ³
▪ Hungary (Udvari, shallow ground disposal)	1,143 EUR/m ³
▪ France (Centre de l'Aube, shallow ground)	386 EUR/m ³
▪ Czech Republic (Dukovany, shallow ground)	367 EUR/m ³

REFERENCES

- [1] "Low-Level Radioactive Waste Repositories – An Analysis of Costs", Nuclear Energy Agency & Organisation for Economic Co-Operation and Development, Paris, 1999.