Part A

SEVENTH FRAMEWORK PROGRAMME

Theme: Fission-2009-1.1.1

Theme Title: Long-term performance of Engineered Barrier Systems (EBS)

Grant agreement for: Small or medium-scale collaborative focussed research project

Annex I - "Description of Work"

Project acronym: ***PEBS***

Project full title: ***Long-term performance of Engineered Barrier Systems***

Grant agreement no.: ***FP7 249681***

Date of preparation of Annex I: ***Version 3, November 28th, 2011***

Date of approval by the Commission: ***28 November 2011***

Project start date: ***March 1st 2010***

Project duration: ***48 months***

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Part A Structured Information

A.1 Project summary

The main aim of the project PEBS (Long-term Performance of the Engineered Barrier System) is to evaluate the sealing and barrier performance of the EBS with time, through development of a comprehensive approach involving experiments, model development and consideration of the potential impacts on long-term safety functions. The experiments and models cover the full range of conditions from initial emplacement of wastes (high heat generation and EBS resaturation) through to later stage establishment of near steady-state conditions, i.e. full resaturation and thermal equilibrium with the host rock. These aspects will be integrated in a manner that will lead to a more convincing connection between the initial transient state of the EBS and its long-term state that provides the required isolation of the wastes.

The work proposed within the project builds on existing knowledge and experience generated during recent years and supported by ongoing national and EC research programmes. The project pretends to provide a more complete description of the THM and THM-C (thermo-hydromechanical-chemical) evolution of the EBS system, a more quantitative basis for relating the evolutionary behaviour to the safety functions of the system and a further clarification of the significance of residual uncertainties for long-term performance assessment.

The importance of uncertainties arising from potential disagreement between the process models and the laboratory and in situ experiments to be performed within PEBS, and their implications for extrapolation of results will be reviewed, with particular emphasis on possible impacts on safety functions.

In addition to the scientific-tech. aim, the consortium will spread the essential results to the broad scientific community within the EC, China and Japan, use its expertise for public information purposes and promote knowledge and technology transfer through training. WP 5 brings together all activities concerning dissemination and training.

A.2 List of beneficiaries

List of Beneficiaries

Beneficiary Number *	Beneficiary name	Beneficiary short name	Country	Date enter project**	Date exit project**
1	Bundesanstalt für Geowissen-schaften und Rohstoffe	BGR	Germany	1	48
2	Nationale Genossenschaft für die Lagerung radioaktiver Abfälle	NAGRA	Switzerland	1	48
3	Svensk Kärnbränslehantering AB	SKB	Sweden	1	48
4	Gesellschaft für Anlagen- und Reaktorsicherheit mbH	GRS	Germany	1	48
5	Empresa Nacional de Residuos Radioactivos SA	ENRESA	Spain	1	48
6	Asociacion para la Investigacion y el Desarrollo Industrial de los Recursos Naturales	AITEMIN	Spain	1	48
7	Centre Internacional de Mètodes Numèrics en Enginyeria	CIMNE	Spain	1	48
8	University of La Coruna	UDC	Spain	1	48
9	Centro de Investigaciones Energéticas Medioambientales y Tecnológicas	CIEMAT	Spain	1	48
10	Agence Nationale pour la Gestion des Déchets Radioactifs	ANDRA	France	1	48
11	Universidad Autonoma de Madrid	UAM	Spain	1	48
12	Golder Spain	Golder	Spain	11	48
13	Solexperts AG	Solexperts	Switzerland	1	48
14	TK Consult AG	TKC	Switzerland	1	48
15	Clay Technology	Clay Technology	Sweden	1	48
16	Beijing Research Institute for Uranium Geology	BRIUG	China	1	48
17	Japan Atomic Energy Agency	JAEA	Japan	1	48
18	DM Iberia S.A.	DM Iberia	Spain	1	10

* Please use the same beneficiary numbering as that used in the Grant Agreement Preparation Forms
** Normally insert “month 1 (start of project)” and “month n (end of project)”

Part B

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1. Concept and objectives, progress beyond state-of-the-art, S/T methodology and work plan

1.1. Concept and project objectives

1.1.1. General situation

The evolution of the engineered barrier system (EBS) of geological repositories for radioactive waste has been the subject of many national and international research programmes during the last decade (cf. chapter 2.2). The emphasis of the research activities was on the elaboration of a detailed understanding of the complex THM-C processes, which are expected to evolve in the early post closure period in the near field. From the perspective of radiological long-term safety, an in-depth understanding of these coupled processes is of great significance, because the evolution of the EBS during the early post-closure phase may have a non-negligible impact on the radiological safety functions at the time when the canisters breach. Unexpected process Interactions during the resaturation phase (heat pulse, gas generation, non-uniform water uptake from the host rock) could impair the homogeneity of the safety-relevant parameters in the EBS (e.g. swelling pressure, hydraulic conductivity, diffusivity).

In previous EU-supported research programmes such as FEBEX, ESDRED and NFPRO, remarkable advances have been made to broaden the scientific understanding of THM-C coupled processes in the near field around the waste canisters. The experimental data bases were extended on the laboratory and field scale and numerical simulation tools were developed. Less successful, however, was the attempt to use this in-depth process understanding for constraining the conceptual and parametric uncertainties in the context of long-term safety assessment. It was recognised that Performance Assessment (PA)-related uncertainties could not be reduced significantly with the newly developed THM-C codes due to a lack of confidence in their predictive capabilities on time scales which are relevant for PA. To gain confidence in modeling coupled processes in the canister near field a general need was stated for:

- Systematic and traceable validation procedures, which would allow to qualify the predictive capability of the THM-C codes with quantitative performance indicators such as post-test evaluations (e.g. evaluations of blind predictions, dismantling of experiments and post-test analyses).
- Adaptations in the PA methodologies, which would allow the transfer of improved THM-C related process understanding into the corresponding safety function indicators for the EBS

An integrated approach is required to set-up the scientific validation procedures in a context which is relevant for the PA purposes. Thus, validation experiments are to be conducted on the real scale (in-situ experiments, large scale mock-up experiments) to avoid scale effects. Furthermore, the assessed THM-C processes, the experimental conditions and the experimental times should be specified by the needs of PA.

1.1.2. Scope and objectives

The main aim of the project PEBS is to bridge the gap between the improved scientific understanding of THM-C processes and the actual needs of PA to specify EBS related safety function indicators. This comprises the development of systematic validation procedures for THM-C models, allowing for a quantitative evaluation of their predictive capabilities through a traceable prediction-evaluation process. The improved understanding of THM processes feeds in an adapted assessment of long-term safety functions of the EBS through extrapolation of the short-term effects on the long term, including the evolution of their relative impacts and the propagation of uncertainties.

To this end, the detailed S&T objectives of the PEBS are:

- To review recent advances in the current state-of-the-art (methodology, data, knowledge and understanding) affecting the processes in the early evolution of the repository EBS and its treatment in performance assessment
- To discuss how the short-term transients will/may affect the long term performance and the safety functions of the repository
- To evaluate the key thermo-hydro-mechanical and chemical processes and parameters taking place during early evolution of the EBS
- To provide with a reliable good quality experimental HM, THM and THMC data base for the model validation process
- To evaluate the predicted evolution of the EBS using the experimental data as performance indicators and to improve the THM-C models through calibration and further code development
- To use the improved THM-C process models for extrapolation to long-term evolution of the repository EBS taking into account normal and altered scenarios
- To relate the experimental and modeling results and uncertainties to the long-term safety functions of the repository components and to the overall long-term performance of the repository
- To give feedback and guidance for repository design and construction as well as to future R&D

In order to fulfil these S/T objectives in an efficient way, a multi-disciplinary and integrated approach will be applied whereby experimentalists and modellers from various disciplines will be working in an Interactive and coordinated manner. This approach will be ensured by the PEBS project coordinator and implemented by experienced Work Package leaders.

In addition to the above scientific-technical objectives, the PEBS consortium will:

- make the acquired data, knowledge and expertise available and accessible to the broad scientific community within the EU and NAS;
- make the expertise acquired available for public information purposes (including the application of audio-visual tools for the dissemination of information to decision makers, stakeholders and the broader public);
- promote knowledge and technology transfer through workshops and training.

1.1.3. Project concept

The proposed collaborative project PEBS will concentrate on THM-C processes, associated with the evolution of the nearfield around a heat emitting waste canister. The considered buffer materials are granular bentonite and bentonite / sand mixtures, respectively. The evolution of the disposal system is assessed in the early post closure period with emphasis on the thermal evolution, buffer resaturation and the evolution of swelling pressures in the buffer. According to Figure 1 the model validation shall focus on the following periods and parameters:

- The early post closure period (early resaturation time), when the buffer is expected to experience the maximum temperature. In this phase the buffer is largely unsaturated and the thermal evolution of the EBS may be controlled by the effective thermal conductivity of the dry buffer material. The main source of uncertainty arises from possible scale effects in the determination of thermal conductivity (upscaling from laboratory to field scale).
- The resaturation period, when competing processes such as water uptake, thermal impact and the swelling of the buffer will interfere and may lead to unexpected transitory effects (e.g. transients of swelling pressure, water saturation, pore pressure). Confirmation has to be gained, that the transitory effects will not influence the final equilibrated state of the EBS system.

- The pore pressure recovery period, when the EBS system is close to full water saturation and the key THM-parameters tend to reach equilibrium conditions. Statements on the uncertainties with regard to the safety relevant EBS parameters are required (spatial variability of swelling pressure, hydraulic conductivity and porosity in the buffer and in the Excavated Damaged Zone, EDZ).

Both, the resaturation phase and the successive pore pressure recovery period as well as the following hundreds of thousand years which are considered by PA are sometimes addressed as “long-term” behaviour, depending on the perspective of the author. They cannot be observed directly, but have to be accessed by extrapolation in time. In this proposal, two levels of extrapolation are considered:

a) To the end of the resaturation phase. This is of special importance, because it defines the conditions of the buffer during the successive hundreds of thousand years after buffer resaturation and feeds the necessary input to PA. It is the period which is especially interesting in terms of THM behaviour, because it involves temperature and saturation gradients as driving forces for physical and chemical processes.

b) To the end of PA-considered time (usually from 10^5 to 10^6 years). Some THM phenomena such as thermo-osmosis and the high density of adsorbed water may become patent at this time scale. On the other hand, chemical processes such as canister corrosion and chemical Interactions of bentonite with canister corrosion products will occur also during this period of time.

The model validation will be executed in the framework of a prediction-evaluation-improvement process. For this purpose, three large-scale experiments are planned, each of them linked to one of the aforementioned evolutionary periods (Figure 1):

- The early thermal evolution of the EBS will be investigated through a non-isothermal experiment to be conducted in the VE-site of the Mont Terri URL.
- The resaturation phase will be addressed through the continuation of the FEBEX mock-up experiment at CIEMAT’s laboratories in Madrid
- The pressure recovery period will be investigated by continuation of the long-term monitoring phase of the EB experiment at the Mont Terri URL, followed by careful dismantling and post test evaluations.

Blind predictions of the system evolution will be made for each experiment and performance indicators will be defined at the start of the project PEBS. After halftime of the project duration, a model calibration stage will be established to give the modeling groups a chance for improving their model predictions. At the end of the project, the model predictions (blind predictions, calibrated predictions) will be compared with the performance indicators and an overall evaluation of predictions will be conducted.

The calibrated short-term models will be used to elaborate a more quantitative basis for relating the evolutionary behaviour to the safety functions of the system. Thus, the significance of residual uncertainties for long-term performance assessment will be clarified by extrapolation of the short-term model results for a variety of normal and altered EBS evolution scenarios.
Hydraulic transients in bentonite are generally very slow due to its extreme low permeability. Therefore, in order to observe a significant impact of the THM-C processes, longer data series need to be generated and included in the models to allow for a reliable interpretation. This affects in particular medium and large scale experiments (both field and laboratory) where large volumes of bentonite are involved. Since the objective of PEBS is both to perform and to evaluate this type of experiments a project duration of three years was assumed too short too generate the long term data series required and would therefore not fully exploit the financial effort and manpower invested in setting up the new experiments. To optimise this, the length of the project was extended to four years.

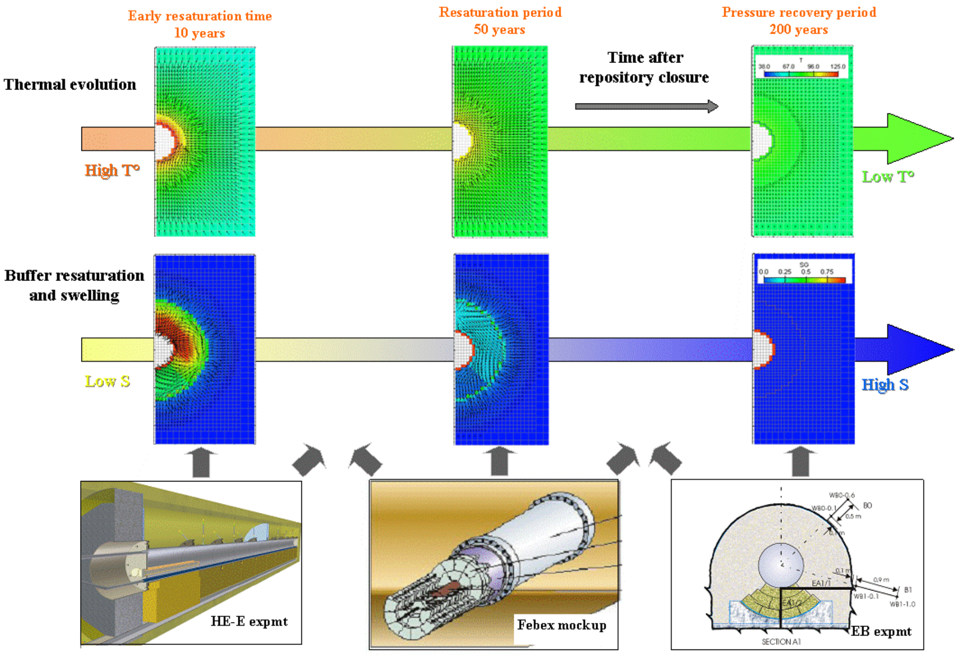

Figure 1: Concept of the validation experiments in the project PEBS.

1.2. Progress beyond the State of the art

Previous and ongoing national and Community-supported research programmes have led to the detailed understanding of the various key thermo-hydro-mechanical and chemical (THM-C) rocesses taking place in the EBS system, including the interfaces within and among EBS components as well as with the host rock. The EC has supported a number of projects studying these key THM and THM-C processes by means of laboratory studies and in situ testing in URLs (i.e. FEBEX, PROTOTYPE, BACCHUS, ECOCLAY and "Mont Terri" EB and HE projects). In the field of PA, the BENIPA project was dedicated to evaluate the performance of bentonite barriers. The main scientific challenge for FP6 consisted in the integration of knowledge on individual near field components and processes and their couplings. Progress in this domain could only be achieved in the NF-PRO project by studying key processes and evolution scenarios for the near field subsystems in an integrated way.

The work proposed within the PEBS project builds on this existing knowledge and experience and proposes to provide a more complete description of the THM and THM-C evolution of the EBS, a more quantitative basis for relating the evolutionary behaviour to the safety functions of the system and a further clarification of the significance of residual uncertainties for long-term performance assessment. The importance of uncertainties arising from potential disagreement between the process models and the laboratory and in situ experiments to be performed within the scope of work of PEBS, and their implications for extrapolation of results will be reviewed, with particular emphasis on possible impacts on safety functions.

1.3. S/T methodology and associated work plan

1.3.1. Overall strategy and general description

PEBS is organized in four RTD Work Packages (WP), the Dissemination Workpackage (also RTD type) and the Project Management Work Package (MGT type), see Figure 2.

The following Figure 2 gives an overview of the 7 PEBS Work Packages and their major tasks

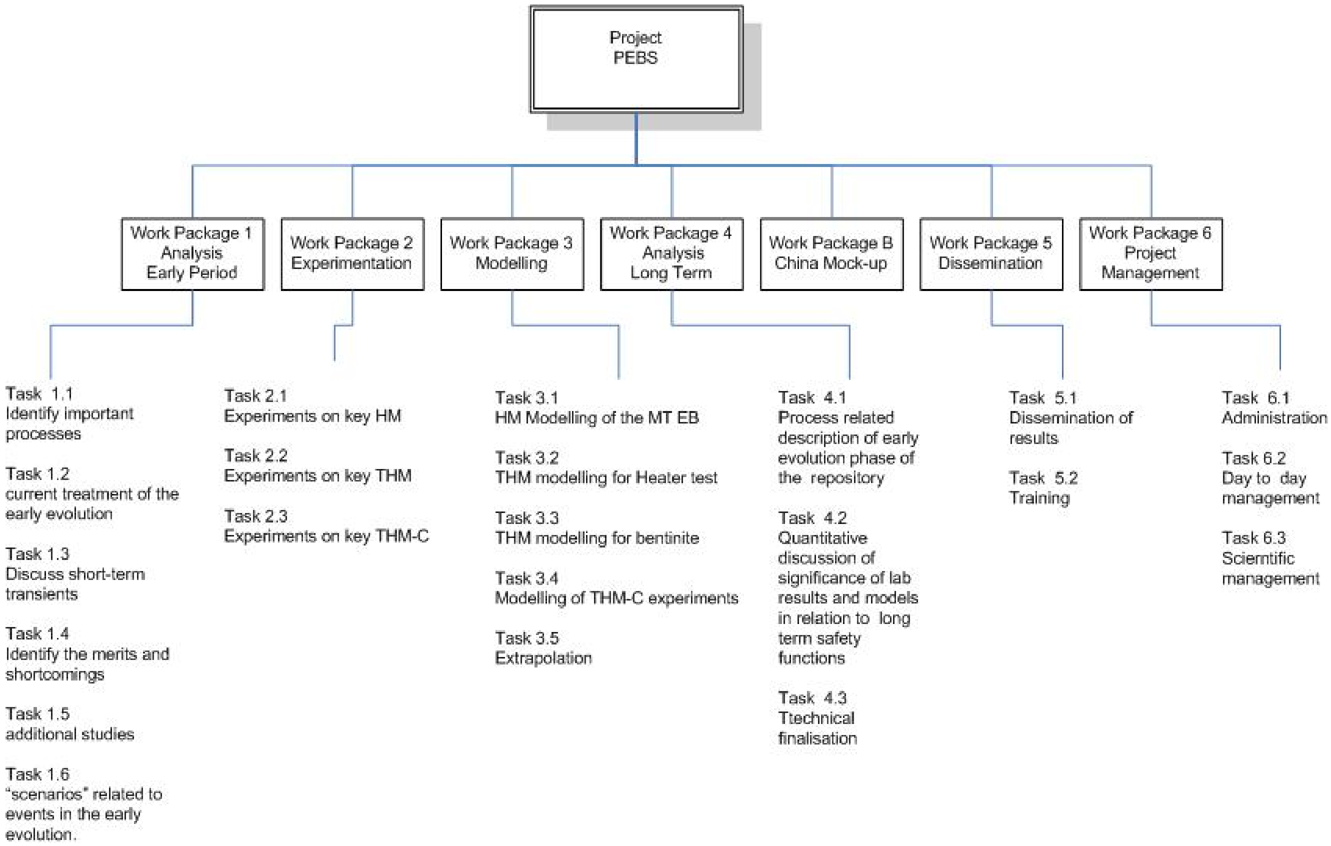

Figure 2: Overview of the Work Packages and its major tasks

WP1 will review recent advances in the current state-of-the-art affecting the processes in the early evolution of the repository EBS and its treatment in performance assessment, in particular the relationship to EBS safety functions. This will clarify the needs for additional laboratory and field experiments targeted at supporting assessments of normal and altered evolution scenarios. WP2 will provide a reliable good quality experimental data bases for HM, THM and THMC processes, including different time and spatial scales, to WP3 and WP4. A technical secretariat especially for co-ordination of WP 2 tasks will be installed. WP3 will make use of the experimental data and the calibrated process models for extrapolation to long-term evolution of the repository EBS taking into account normal and altered scenarios defined in WP1. Finally, WP4 will relate the experimental and modeling results and uncertainties to the long-term safety functions of the repository components and to the overall long-term performance of the repository, giving feedback and guidance for the EBS repository design and construction (Figure 3).

In addition to the scientific-technical aim, the PEBS consortium will spread the essential results to the broad scientific community within and outside the EU. The consortium will use its expertise for public information purposes and promote knowledge and technology transfer through training. Work Package 5 brings together all activities concerning dissemination and training.

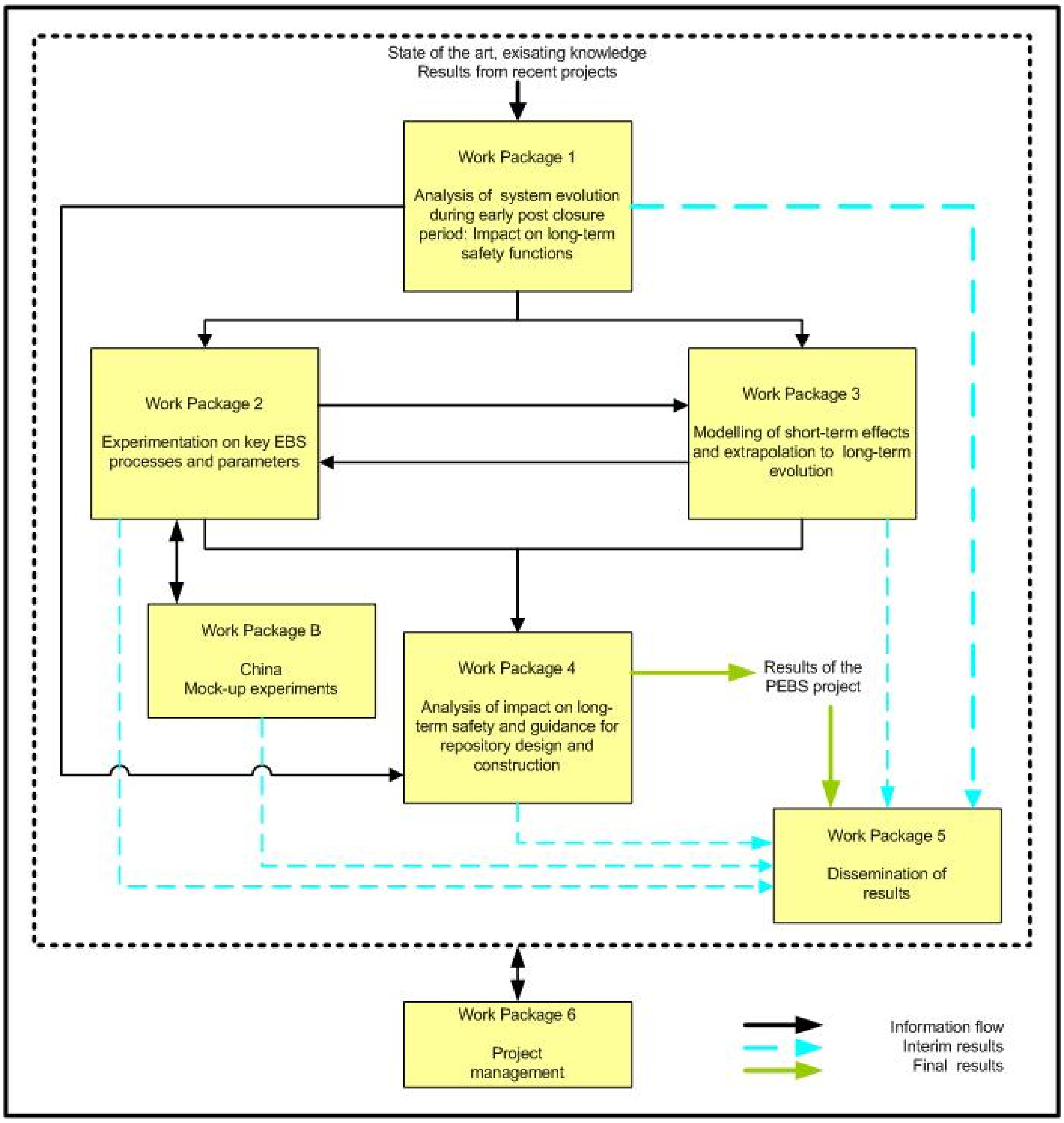

Figure 3: Implementation process of the RTD Work Packages

1.3.1.1. Work Package 1: Analysis of system evolution during early post closure period

Objectives

The early period of repository evolution is characterized by an elevated temperature together with strong thermal and hydraulic gradients (possibly mechanical and chemical as well). The duration of this period is very short in the view of the entire operational timeframe of the repository. However, the processes occurring during this period may have an impact on the performance of the barriers in a longer timescale.

- Identify important processes during the early evolution of the EBS
- Describe the current treatment of the early evolution of the EBS in long-term safety assessments for spent nuclear fuel
- Discuss how the short-term transients will/may affect the long-term performance and the safety functions of the repository.
- Identify the merits and shortcomings of the current treatment
- Discuss the needs for additional studies of these issues and how they can support future assessments – give directions to other WPs
- Define “scenarios” related to events in the early evolution of the EBS.

Conceptual approach

The overall approach will be based on creating a summary of the current treatment of the early post closure period in different safety assessments and identify couplings to long-term performance

State of the art

Basically, the purpose of the entire Work Package is to present the current state of art to serve as background and support for the other Work Packages. A safety assessment of a nuclear waste repository generally rests on a foundation consisting of a reference design, a site description (real or generic), results from R&D, results from earlier assessments and a FEP (Features, Events and Processes) database. Based on this, the evolution of the EBS can be represented in a number of steps:

1. FEP processing (Initial state, internal processes, external factors)
2. Description of the initial state of the EBS, including any deviations from reference design
3. Description and motivation for the handling of the processes in the evolution of the EBS
4. Analysis of a reference evolution
5. Selection and analysis of alternative evolutions (scenarios)
6. Assessment of the importance of the evolution of the EBS in the context of the entire repository

The integration of the steps will give conclusions about the safety of the repository, and may provide feedback concerning the repository design and the need for additional R&D to reduce uncertainties in the assessment.

Implementation of the Work Package

The WP will develop a process-related framework to give a background to the activities in the WPs. The work done in WP1 will be broken down into 6 tasks:

Task 1.1

Identify important processes during the early evolution of the EBS. This task involves a listing of the processes that are considered in description of the evolution of the EBS in safety assessments. This task will also review the outcome of the NF-Pro project. The listing will give input to the expectations from the experiments done in WP2.

Task 1.2

Describe the current treatment of the early evolution of the EBS in long-term safety assessments for HLW and spent nuclear fuel. This task will deal with how the processes described in 1) are treated in the assessments, which types models, assumptions and boundary conditions are used. This task is closely connected with the work in WP3.

Task 1.3

Discuss how the short-term transients will/may affect the long-term performance and the safety functions of the repository. The purpose of this task is to connect the processes to the safety functions in the repository – ie what impact will a process have on the overall performance of the repository. This task will be continued within WP4.

Task 1.4

Identify the merits and shortcomings of the current treatment. This task will make a summary about the uncertainties related to the processes as well as to the treatment of the processes. This includes uncertainties in boundary conditions, data and in the conceptual models.

Task 1.5

Discuss the needs for additional studies inside, outside or after finishing of PEBS of these issues and how they can support future assessments. Based on the results of Task 1.4, lists of issues that will be handled by the PEBS project will be generated. These lists will give guidance to the work in WP2 and WP3.

Task 1.6

Define "scenarios" related to events in the early evolution of the EBS. This task is an integration of the all the previous. The purpose is to define "cases" of EBS evolution that can be treated in WP4

Distribution of work

Work Package leader is SKB. This Work Package will be supported by NAGRA, ENRESA an ANDRA. The work in WP1 will progress during the first 12 months of the PEBS project. After that the assessment activities will be handled in WP4. The management of the scientific tasks is assigned to BGR.

1.3.1.2. Work Package 2: Experimentation on key EBS processes and parameters

General objectives and overview

Evaluation of the key thermo-hydro-mechanical-chemical processes and parameters taking place during the early evolution of the EBS system, as identified in WP1, and then providing with a reliable good quality experimental data base, including different time and spatial scales, as input to the modeling and extrapolation work to be conducted within WP3 and to the analysis of impact on long-term safety to be conducted within WP4.

Conceptual approach

The overall approach is based on performing experiments including different time and spatial scales, according to the needs for additional studies on key processes during the early EBS evolution that will be established through in depth discussions within WP1. WP2 will make use to the extent possible of on going experiments being conducted by the PEBS team (in the laboratory and in situ).

State of the art

The experimental work proposed within the WP2 of the PEBS project builds on this existing knowledge and experience and contributes diverse aspects to the understanding of the short term evolution of the EBS system.

Implementation of the Work Package

The Work Package 2 will be conducted in three separate tasks which focus on different key EBS processes (and their couplings). For all three tasks, different time and spatial scales are envisaged.

Distribution of work

ENRESA is in charge for conducting of this Work Package, with strong contribution of most of the partners, namely: BGR, NAGRA, SKB, GRS, AITEMIN, CIEMAT, ANDRA, UAM, DM Iberia, Solexperts and Golder. The management of the scientific tasks is also assigned to BGR.

Task 2.1 Experimentation on key HM processes and parameters

The evaluation of the key HM processes, namely the resaturation and the swelling of the bentonite buffer, will be performed both at laboratory and at real in-situ scales. The experimental programme includes the continuation of the long-term monitoring and the dismantling of the EB experiment (Mont Terri Rock Laboratory, Switzerland) along with several supporting infiltration tests to be performed in CIEMAT laboratories in Spain with the same bentonite material as in situ.

The EB experiment (October 2000 - November 2003, Contract Nº FIKW-CT-2000-00017) continuous monitoring since the start of the artificial hydration of the bentonite barrier in May 2002 is providing valuable information about the hydro-mechanical evolution of the EBS system, when subjected to a hydration process. Monitoring of the evolution of the barrier in the past 7 years has shown the progressive development of stresses within the clay barrier. There are also data, namely the relative humidity measurements, which suggest that the clay barrier is essentially saturated. However, the fact that stresses are not stabilized suggests that hydration processes are still taking place within the barrier, perhaps at the level of the basic clay units. These processes are not simply modelled by standard THM codes.

The EB experiment (Figure 4) is rather singular because it is a real scale experiment which uses a granular mixture of high density bentonite pellets (GBM) in the clay barrier. The clay barrier is not homogeneous, however, because of the cradle of bentonite blocks which support the dummy canister. It is also an experiment in which a forced hydration system was put in operation in an attempt to saturate the clay barrier in an acceptable time span. These singularities and the observations which suggest that some hydration processes are still active within the barrier are reasons to justify an extension of the life of the experiment and the associated research, before the complete dismantling in 2012.

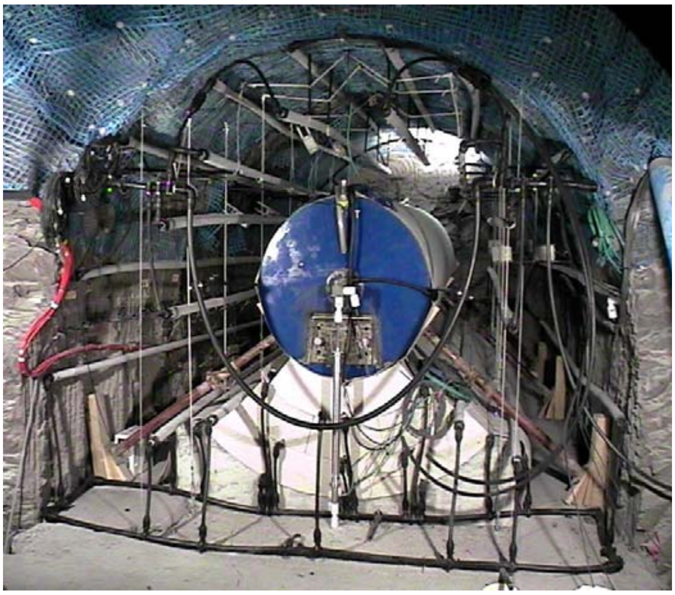

Figure 4: EB experiment emplacement pre-conditions

A controlled dismantling of the EB clay barrier after in depth evaluation of monitoring data will further complete the already gained knowledge in the experiment, and clearly confirm that the use of a GBM is a good option to construct a bentonite barrier of drifts excavated in hard clay formations. Specially important will be to determine the hydraulic conductivity (K) of the GBM actually emplaced (after its saturation "in situ") and its achieved degree of homogeneity, in order to demonstrate that the K value is low enough (and not too heterogeneous), and hence acceptable from the long-term safety point of view.

During the hydration phase between April 2002 and November 2003 changes in seismic parameters gave clear indications for time dependent changes within the first 30 centimeter of the rock mass (EDZ). To a certain extent a reverse behaviour of the rock mass during the dismantling phase is expected. An automated seismic transmission measurement will be performed for one year, starting at the “hot phase” of the dismantling operation. The already installed seismic array consisting of 10 sources and 14 receivers in four boreholes will be reactivated.

To complement the EB in situ experiment, several infiltration tests (about 10) will be performed on the same GBM material to study the kinetics of hydration and swelling development. In particular, the final stages of bentonite saturation will be analysed along with the possible increase of water density as it becomes adsorbed by smectite. The tests proposed consist on the isothermal satu-ration of mixtures of bentonite pellets with water injected at low pressure. The water intake will be measured precisely, as well as the swelling pressure.

Distribution of work for Task 2.1

ENRESA will lead this Work Package. Contributors for this task are BGR, NAGRA, AITEMIN, CIEMAT, ENRESA, ANDRA, SKB, DM Iberia, Golder (takes righths and duties from DM Iberia) and Solexperts

Task 2.2 Experimentation on key THM processes and parameters

The evaluation of the key THM processes will be performed both at laboratory and at real in-situ scales. The experimental programme includes two major tasks:

Subtask 2.2.1 Laboratory experimentation on key THM processes and parameters

The laboratory work included here deals with very different time and spatial scales (from m to cm scale). Four different subtasks are considered:

The FEBEX mock-up

The FEBEX mock-up test has been running during the last eleven years, since 2004 as part of the NF-PRO integrated project co-financed by the European Commission. Heaters are operating at constant power supply (700 W/heater), with the temperature on the surface of the heaters close to 100ºC. The total water volume injected since the beginning of the test to 31/12/2008 was 1093 L, corresponding to an average water content of the bentonite of 22.7%. This means that the overall degree of saturation of the barrier is very high, close to 96.9% if we take the density of water to be 1 g/cm^3, but it is increasing very slowly.

More than 89 % of the total number of sensors remains operative, but this percentage is 93% for temperature, 75% for relative humidity (RH), 65% for fluid pressure, 71% for tangential pressure (PT), 71% for radial pressure (PR) and 82% for axial pressure (PZ).

The database generated has allowed the verification of some hypothesis on the THM processes in the transient phase of the barrier material, mainly in the presence of water vapour. The differences in the behaviour between “hot” and “cold” zones of the buffer indicate major implications of the thermal aspects in the transport processes, either as thermal gradient-driven processes (thermo-hydraulic coupled phenomena), or as temperature-driven processes (chemical ones or Arrhenius type).

Within this subtask, it is proposed the continuation of the FEBEX “mock-up” operational phase in its present state for 4 additional years to allow for THM model calibration related to close to saturation conditions of the buffer within WP3.

Long-term THM tests in cells simulating particular disposal concepts

This subtask will include the performance of laboratory tests in which the conditions of the bentonite in the barrier are simulated with respect to kind and pressure of water and temperature, as well as density and initial water content of the bentonite. Several tests of this kind have been already running during the last years, and its continuation or dismantling (to be decided in WP1) will provide information on the evolution of the barrier at the transient stage. The task could be thus divided in two activities:

(i)Tests already running (see Figure 5)

CIEMAT is carrying out two infiltration tests since 2002, one of them in which FEBEX bentonite is heated at the bottom at 100°C (GT40 test) and the other one performed at isothermal conditions (I40 test). These tests started in the context of FEBEX II Project and went on in the NF-PRO Project. They are providing information on the evolution of relative humidity and temperature inside the bentonite and have been used by several modeling groups to check hypothesis about the processes taking place, in particular those that may delay saturation (threshold hydraulic gradient, thermo-osmosis, microstructural changes). Several options for the continuation of these tests are foreseen: 1) to start heating the isothermal test, what would allow to follow the redistribution of water, 2) to increase the temperature inside the GT test or stop heating, 3) to leave the tests as they are as long as they continue providing information, 4) to dismantle the tests to check the actual conditions inside the bentonite. The decision will be taken with the other participants on the light of the findings of WP1 and the needs of WP3 and WP4.

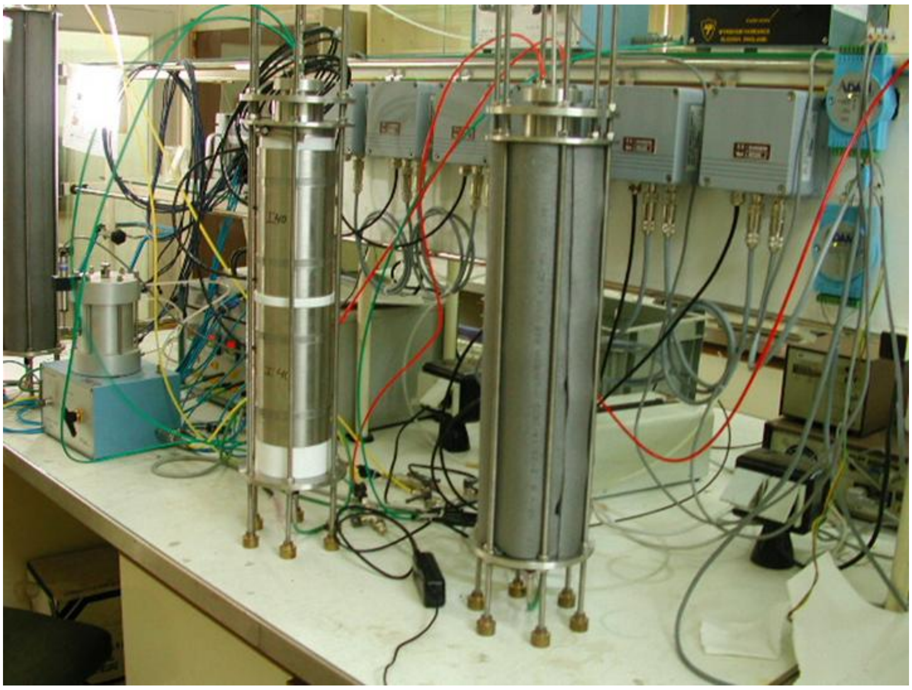

Figure 5: CIEMAT THM cells

(ii) New tests

Two new tests, with other materials (HE-E bentonite/sand mixture) and using realistic heating rates are proposed, in support of the new HE-E heater test to be launched in Mont Terri Rock Laboratory in the framework of PEBS (WP2/T2.2.2). The cells could be modified in order to measure other parameters, like stresses.

Vapour transport in low permeability media

Vapour movement inside the clay has implications on the thermal response of the barrier, since the vapour phase is a way of heat transport; on its hydraulic response, since the vapour generated migrates towards cooler zones, increasing their degree of saturation and consequently decreasing their suction; and on the chemical response, since the convective movement of water in the hot areas implies a redistribution of solutes. However, the spatial extent of the processes associated to vapour transport and their precise effect on the barrier behaviour are not yet well known neither quantified.

Studies on stress-strain behaviour

Mechanical properties of buffer material exposed to increased temperature during and after water saturation are proposed to be studied by laboratory experiments. Buffer material exposed to repository and accelerating conditions involving increased temperature have been investigated in the project LOT at Äspö HRL, Sweden (Figure 6). Stress-strain behaviour in different positions in the LOT parcel and in reference material was determined by unconfined compression tests. Significant lower strain at failure was measured in the material exposed to high temperature

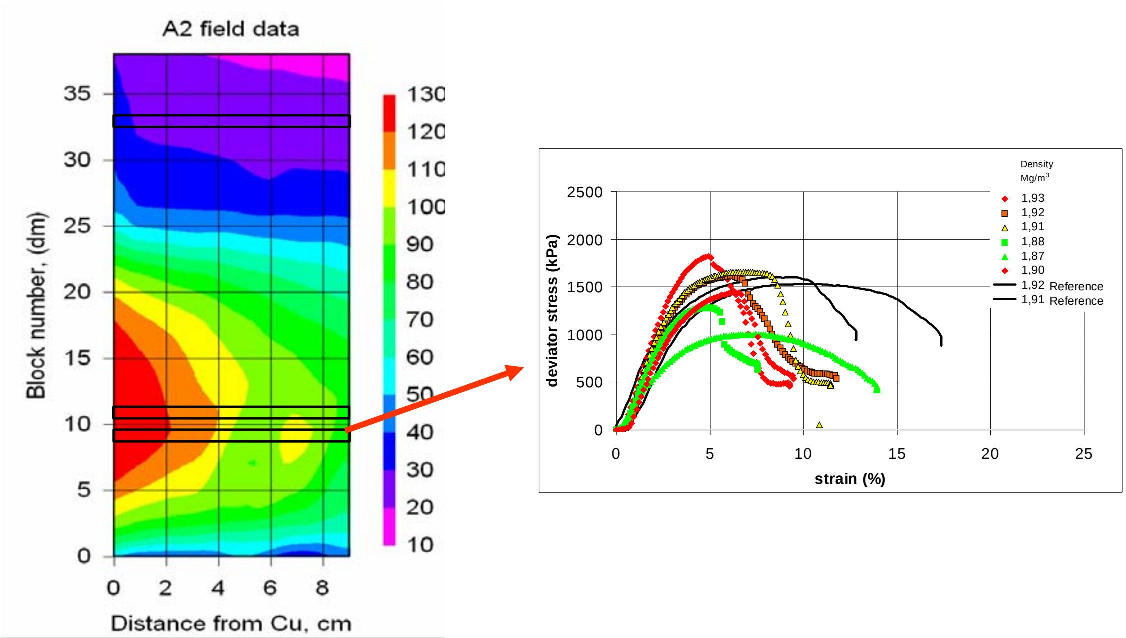

Figure 6: Unconfined compression test. Data from the LOT experiment (Äspö)

Unconfined compression tests are therefore proposed in order to study the mechanical properties more in detail as a function of increased temperature, gradient in temperature or other factors coupled to the exposure of increased temperature.

<u>Subtask 2.2.2 In-situ experimentation on key THM processes and parameters</u>

A new long term experiment elucidating the early non-isothermal resaturation period and its impact on the thermo-hydro-mechanical behaviour is planned. Its objectives are:

- to provide the experimental data base required for the validation of existing thermo-hydraulic models of the early resaturation phase (cf. WP3)
- to provide experimental data bases for model calibration (cf. WP3)
- to upscale thermal conductivity of the partially saturated buffer from laboratory to field scale (pure bentonite and bentonite-sand mixtures)

The experiment HE-E will be performed in the VE tunnel (Mont Terri Rock Laboratory) and is aimed at improving the understanding of the thermal evolution of the near field around a SF/HLW waste container, during the very early phase after emplacement in a 1:2 scale in-situ configuration. Special interest is on the temperature evolution in the buffer and on the thermal impact on the clay rock close to the tunnel (Figure 7).

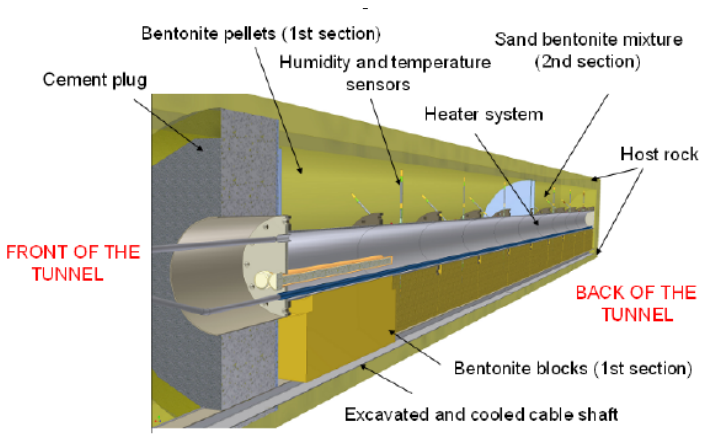

Figure 7 : THM experiment layout in Mont Terri Rock Laboratory

A heater system, capable of representing the temperature curve of the anticipated heat production in the canisters (up to a maximum of 140°C), will, over a period of 3 years gradually lead to and increase in the temperate in the EBS and the surrounding host rock while natural saturation is ongoing. During the experiment the temperature and the water saturation will be monitored through a system of sensors (i) on the canister surface, (ii) in the bentonite and (iii) in the surrounding host rock. A total of 200 sensors in 6 vertical planes will provide the required data density (Figure 8).

With seismic transmission measurements expected changes in the near field of the rock due to the temperature impact will be observed. The existing three 1m long boreholes in the microtunnel which were used for seismic measurements during the Ventilation Experiment will be used for the installation of eight receivers (for example six in the boreholes and two in the GBM) and four source transducers. A daily automated seismic transmission measurement will be performed for one year.

A system of automatic data transmission guarantees optimal data quality and continuity. Within this WP, during the first project year, (i) the experiment will be designed, (ii) its feasibility in terms of providing optimal results within its timeframe tested and (iii) the construction completed. Subsequently 3 years of permanent monitoring will be conducted. During the monitoring analysis of the data will occur. Interaction with WP2 will occur at first when integrating the design calculations from Task 3.2. Then during the monitoring phase, the saturation and temperature data will feed directly into the prediction and evaluation modeling of Task 3.2.

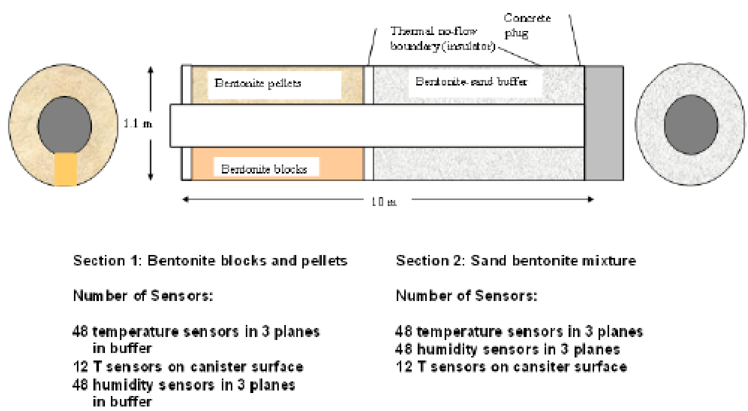

Figure 8: THM experiment layout in Mont Terri Rock Laboratory (Instrumentation)

Two buffer materials will be used in the experiment:

- \- Bentonite pellets will be used in one section of the test as reference material of the Swiss disposal concept in order to gain representative data on buffer evolution.
- \- A sand/bentonite mixture having a higher thermal conductivity will be used in the other section to reach the maximum design temperature in the rock.

Distribution of work for Task 2.2

ENRESA will lead this Work Package. Contributors for this task are AITEMIN NAGRA, CIEMAT, SKB, GRS, BGR, Clay Technology, Golder and Solexperts. BRIUG as a non funding partner will also be involved.

Task 2.3 Experimentation on key THM-C processes and parameters

The evaluation of the key THM-C processes and parameters will be performed at the laboratory. The experimental programme includes two subtasks:

Subtask 2.3.1 THM-C mock-ups

The THM-C mock-ups (GAME tests, Figure 9) simulate the components of the EBS in accordance with the ENRESA's reference concepts (granite and clay). The main differences with the real repository are the smaller scale, the unlimited availability of hydration water–supplied at constant pressure–, and the external steel structure instead of the heterogeneous host rock. The acronym GAME reflects the main aspects under investigation:

- Geochemical: corrosion processes, alkaline plumes, interactions of ground-water with concrete, bentonite and C-steel.
- Advanced: chemical coupling, hydration with representative groundwater and its sampling.
- Mock-up: large scale, TH controlled conditions.
- Experiments: two setups reproduce the expected conditions in the granitic and argillaceous geological repositories after their closure.

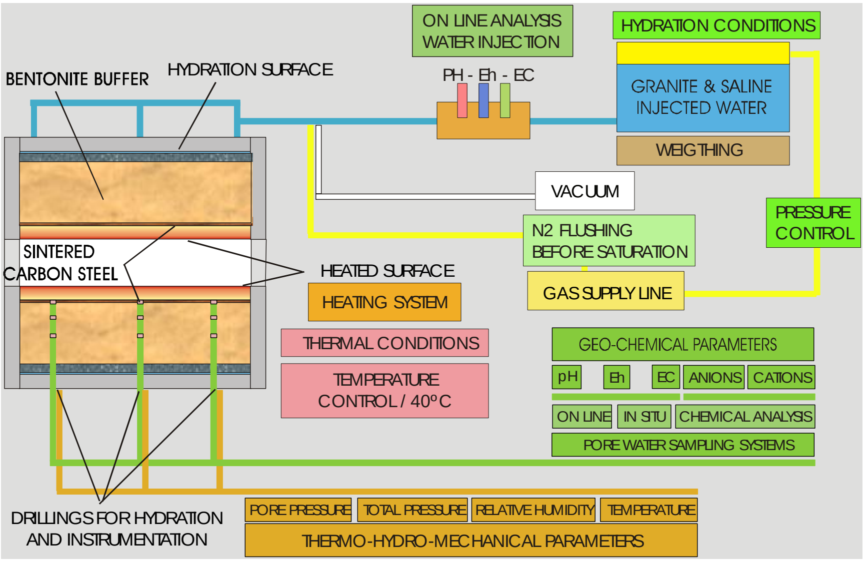

Figure 9: The GAME mock-ups

The tests are intended to accomplish the following objectives:

- Research on the potential changes that may occur in the key parameters of the buffer material as a result of THM and THC processes.
- Monitoring geochemical changes by sampling of pore water, if available, with the minimum possible interference with the system.

The GAME mock-ups started in the framework of the NF-PRO project, but problems at the start of operation forced to stop this phase. Because it was foreseen that they would not be dismantled within the project time frame period, the re-starting of the operational phase after some modifications and feasibility analysis is proposed. The final uptake of post-mortem data would not take place after at least three years of operation.
Thus, the GAMEs will enable the improvement of the knowledge of the THC(M) processes in the EBS and the calibration and validation of the THC(M) numerical models with the post-mortem geochemical information within WP3/T3.4.

The work proposed in this subtask includes the heating-hydration operation of both experiments, sampling and analysis of pore water extracted from test, and management of the data generated.

Subtask 2.3.2 THM and THMC tests aimed at the understanding of key processes taking place at the interfaces

Some of the tests included in this subtask were already started during NF-PRO, and other new tests will be set. They are classified according to the main processes they are intended to analyse.

Study of the corrosion processes at the canister/bentonite interface

This task would be a continuation of WP23 of the NF-PRO Project. The experiments proposed by CIEMAT in the context of NF-PRO integrated project had two main objectives; on the one hand, the study of the corrosion products generated at the canister/bentonite interface under the repository conditions and, on the other, to establish how the corrosion affects the properties of the bentonite. Consequently, the corrosion processes are simulated under representative conditions, and both the study of the corrosion products generated and of the impact on the bentonite properties (mineralogy, geochemistry, porosity, fabric, swelling capacity) are undertaken. Experiments at two scales (bentonite columns of 9 and 2.5 cm height) were performed, with duration from three weeks to 1.5 years, using either corrosion products or steel. The main learnings/conclusions from this research have been:

- Knowledge about the evolution of the corrosion products generated: FeOOH in the post-closure stage, haematite or magnetite during the transient state and ferrous hydroxide and magnetite when bentonite is fully saturated.
- Iron phases precipitate in the cracks and voids of the bentonite compacted blocks.
- Possible movement of iron oxide particles along the bentonite blocks.
- Time and temperature is required for the transformation of montmorillonite into new iron-rich phases. Long-term experiments are necessary.
- Small enrichment of iron in bentonite: formation of iron oxide nanoparticles in iron-rich montmorillonite particles. Cation exchange does not seem to be as important as sorption or precipitation of iron phases.
- Ferrous ions seem to induce a change in the redox behaviour of the clay. The formation of Green Rusts or ferrous hydroxide may be relevant in this process.
- Influence of iron on the bentonite properties: slight decrease on CEC values (sodium and magnesium concentration decrease in the exchange complex), slight decrease on swelling capacity, increase of specific surface and microporosity of the clay due to the precipitation of iron oxide nanoparticles.

To deepen these studies and check the evolution of the processes observed, several experiments are already in course, four in medium cells and three in small cells (Figure 10). They will be dismantled and analysed periodically in order to get information on the evolution over time for up to 4 years. Upon dismantling, geochemical, physico-chemical and mineralogical determinations will be performed along the bentonite columns, and special attention will be given to the interfaces, that will be analysed in collaboration with UAM by means of the following techniques: gas adsorption, µ-Raman, Mösbauer spectroscopy, FTIR, scanning electron microscopy and transmission electron microscopy.

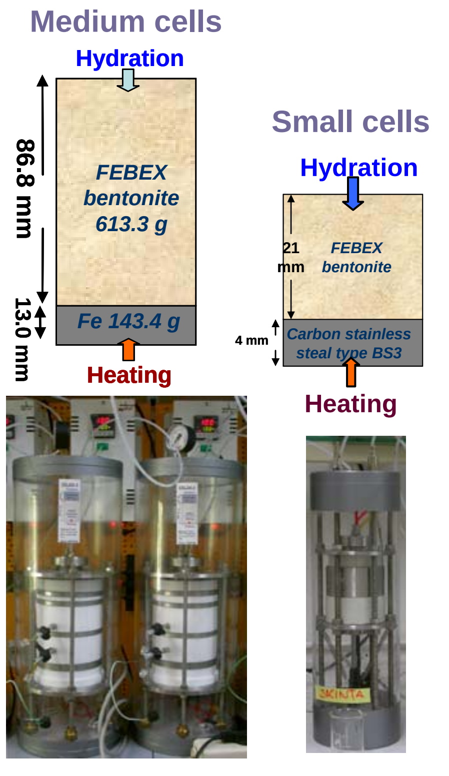

Figure 10: Laboratory tests on corrosion processes at canister/bentonite interface

Study of the processes at the concrete/compacted bentonite interface

This subtask would be a continuation of WP24 of the NF-PRO Project. A series of short and medium-term (0.5, 1 and 1.5 years) experiments at medium scale were run, dismantled and analysed to provide experimental evidences on the physical, chemical and mineralogical changes due to the concrete-compacted bentonite Interaction. Three similar experiments are already in course. Two of them will be dismantled after 3 and 5 years of operation, with the aim of reaching further information on the evolution over time, and another one will be left running during the whole duration of the project.

The expected outcome of these relative long-term Interaction tests is 1) the confirmation of the low impact of the alkaline plume predicted by previous investigations in terms of mineralogical alteration thickness, and 2) the precise establishment and evolution over time of the new formed by-products and how they produce a porosity reduction process affecting diffusive transport. For this purpose, the bentonite columns dismantled will be analysed from a geochemical, physico-chemical and mineralogical point of view. Gas adsorption, µ-Raman, Mösbauer spectroscopy, FTIR, scanning electron microscopy and transmission electron microscopy, among others, will be used. The characterisation and analysis of the interfaces will be performed by UAM. This group has gained its experience on the issue through its participation in ECOCLAY and NF-PRO projects, and will support:

- the preparation and analysis of thin and polished sections from the interface of the 0.5, 1 and 1.5 years experiments, to be studied optically and by SEM/EDX (phases, chemical profiles, altered thickness),
- the study of powders and oriented films of clay by XRD (thermal and chemical treatments) for understanding the crystallochemical and structural modifications of the clay minerals,
- the determination of specific surface and porosity of the altered products and,
- the modeling of the reactive–transport processes observed.

In addition, and in order to aid the characterization of reaction byproducts, microscale diffusion experiments are going to be designed. These experiments will include 0.5-1cm probes in which a $Ca(OH)_2$ disc will be in contact with compacted clay, either connected to a portlandite saturated solution or a typical pH 13.5 OPC cement pore water solution. Zeolites and CSH formation together with porosity changes will be followed by means of diffusion of conservative anions after reaction.

<u>Distribution of work for Task 2.3</u>

ENRESA will lead this Work Package. Contributors for this task are CIEMAT, Golder and UAM (characterization of reaction byproducts, microscale diffusion experiments). BRIUG as a non funding partner will also be involved.

1.3.1.3. Work Package 3: Modeling of short-term effects and extrapolation to long-term evolution

<u>General objectives</u>

The process level modeling work is concentrated in WP3. The overall objectives of this Work Package are

- to perform coupled HM, THM, and THMC analyses to provide a sound basis for the interpretation of the various tests planned in the frame of the PEBS WP2,
- to develop new or improved models as a result of calibration of computation results with the actual measured data, and

- to use the data and improved models for extrapolation to long-term evolution of the repository taking into account the scenarios defined in PEBS WP1 and to investigate model uncertainty and its impact on long-term prediction, thus providing input to PEBS WP4.

Conceptual approach

The Work Package is structured into different tasks with specific objectives.

Task 3.1: HM modeling of the EB experiment will aim at providing a satisfactory scientific representation and a sound basis for interpretation of the EB hydration phase and of the dismantling data. New or improved constitutive laws adjusted with the experimental data will be developed.

Task 3.2: THM modeling of the new HE-E to be performed in the VE microtunnel will focus on the design modeling as well as prediction and interpretation modeling of various teams for validating the constitutive laws employed.

Task 3.3: THM modeling of the long-term FEBEX mock-up test and the long-term THM tests performed in cells in the CIEMAT laboratory will provide a continuing interpretation and an additional extrapolation to the real scale.

Task 3.4: Most of the lab experiments performed within NFPRO on canister corrosion, corrosion-bentonite Interactions and concrete-bentonite Interactions have not been interpreted numerically. Models developed in the frame of NF-PRO and used in performance assessment will be tested with data of these laboratory experiments.

Task 3.5: The data and the improved models will be used for extrapolation to long-term evolution of the repository taking into account the scenarios defined in WP1, and to investigate model uncertainty and its impact on long-term prediction, thus providing input to WP4. This will require a careful assessment of the key long-term processes as well as an evaluation of the resulting uncertainty and its consequences. Coupled analyses of varying degree of complexity, extending to long time scales, will be performed by the different partners. Additionally, existing natural analogues will be evaluated in terms of their meaningfulness for repository long-term evolution.

In accordance with the different repository evolution periods considered in the experiments, the modeling work addresses phenomena relevant for different time scales. Therefore, interpretation and validation modeling performed in the first four tasks will provide information for different time periods in the extrapolation to long-term evolution.

State of the art

The modeling work in the various tasks is starting from different levels of understanding and is improving or validating knowledge in different respects.

Thermal and mechanical behaviour of the backfill materials and the rock are in principle well understood. The THM modeling (Tasks 3.2 and 3.3) aims at validating the current constitutive laws and at reducing the residual uncertainties, especially those deriving from unclear initial conditions and material parameters (Task 3.2). It relies therefore on Task 2.2.

Regarding bentonite resaturation and swelling, however, the existing models are not able to describe the phenomenons observed for instance in the frame of the Mont Terri EB experiment. A density of the interstitial water above 1 g/cm^3, which has to be expected from the results of EB and other experiments, cannot be accounted for up to now. Therefore model development based on the experimental work of Task 2.1 is clearly needed (Task 3.1).

For THM-C modeling, development work is also required. Although THC models are available and have been used in the frame of NF-PRO, respective lab experiments have not been modelled numerically. What is also missing is the coupling between THC and mechanical modeling. This gap will be closed by Task 3.4.

The only possibility to analyse long-term effects in reality is the study of natural analogues. Consequently, there have been various projects on natural analogues, like the BARRA project. While natural analogues can potentially yield useful information, they have to be evaluated carefully in terms of the uncertainties in their evolution. This will be part of Task 3.5, in order to investigate the usefulness of natural analogues for validating long-term extrapolation.

Implementation of the Work Package

The Work Package 3 will be conducted in five tasks which concentrate on modeling of the different experiments and phenomena and on model extrapolation, respectively.

Distribution of work

GRS will lead the work. ENRESA and CIMNE will conduct the work for Task 3.1. Task 3.2 will be handled by NAGRA, GRS, ENRESA, CIMNE and TK Consult. NAGRA, SKB, ENRESA, CIMNE, TK Consult and Clay Technology will be involved in Task 3.3. ENRESA, UDC and JAEA will perform the work for Task 3.4. All modeling institutions (NAGRA, SKB, GRS, ENRESA, CIMNE, UDC, TK Consult, Clay Technology and JAEA) will be involved in Task 3.5. The management of the scientific tasks is assigned to BGR.

Task 3.1

Coupled hydromechanical (HM) analysis of the EB hydration phase will be performed in a 2D configuration incorporating the test protocol and boundary conditions actually used. To take into account the basic features of the barrier material a double structure approach will be used where the potential change of density of the water in the vicinity of the clay particles is incorporated. Both rock and barrier data will be considered. New or improved constitutive laws will be developed as needed according to the comparison with experimental data.

The final state of the barrier will be assessed and interpreted by HM numerical computations using the model calibrated during the performance of the test. The effects of dismantling will be incorporated in the analysis. Modifications to the model will be undertaken if required by the new information available.

The numerical modeling will be performed using CODE_BRIGHT, a powerful computing tool developed for the performance of fully coupled THM analysis in two and three dimensions.

Distribution of work for task 3.1

GRS lead the work package. Contributors for this task are CIMNE and ENRESA.

Task 3.2

Objectives

The new HE-E experiment will subject the engineered barrier and the rock to temperatures higher than in past experiments using realistic heating rates, going beyond previous experience. Also, only natural hydration (i.e. water coming from the rock exclusively) will be used in the tests. Two different EB materials are envisaged (see WP2). The analyses will be performed fully coupled in 2 and 3 dimensions and will comprise the following aspects:

- Scoping calculations for the design of the HE-E
- Development of constitutive models and selection of parameters for the EB materials and the Opalinus clay and predictive modeling of the HE-E
- Interpretative modeling of the HE-E

The modeling strategy is summarized in Figure 11.

The scoping calculations will assure that that the experiment lay-out meets the requirements regarding temperature evolution of buffer materials and rock, and that the monitoring strategy and lay-out is capable of capturing the system behaviour. The prediction/evaluation task consists of

- Blind predictions at the beginning of the experimental phase,
- Calibrated predictions in the mid-term of the monitoring time, and
- Evaluation of the quality of predictions at the end of the monitoring period including a careful assessment of uncertainties in the prediction process.

Both tasks, the experimental design calculation and the prediction/evaluation task, will require close Interactions with WP2. The evaluation will concentrate on the thermal conductivity of the partially saturated media. In addition, the models developed will be refined during the course of the HE-E experiment, and parameters (two-phase flow behaviour, thermal behaviour) will be calibrated once observations become available. The HE-E modeling will be further strengthened by results from the laboratory tests on the thermal behaviour from WP 2.

The scoping calculations will be conducted by CIMNE. Prediction/evaluation modeling will be performed by three modeling teams. CIMNE and GRS will use CODE_BRIGHT, and NAGRA will employ TOUGH2, enabling the comparison of the results of different approaches and modeling teams.

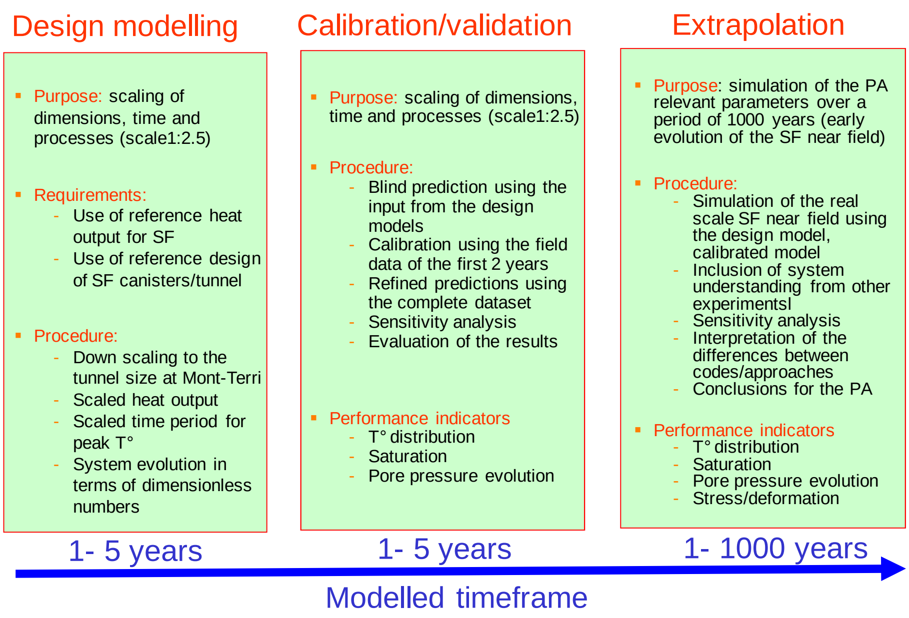

Figure 11: Modeling strategy for the HE-E experiment (design and calibration/validation modeling is part of Task 3.2, extrapolation will be handled in Task 3.5)

Distribution of work

GRS will lead the work package. Contributors for this task are NAGRA, ENRESA, CIMNE, and TK Consult. BRIUG as a non funding partner will also be involved.

Task 3.3

NAGRA will evaluate the applicability of elastoplastic material laws to describe the hydro-mechanical behaviour of buffer materials on a real scale. The performance measures for process validation include transients in pore pressure, swelling pressure, water uptake and saturation as measured in selected target experiments (eg EB, mock-up test, laboratory tests) from WP2 which are most promising in terms of data density and level of system understanding. In this context a contribution of pivotal importance are the porosity and density data, collected from the EB dismantling.

Clay Technology is mainly using the finite element codes ABAQUS and Code Bright, which both are capable of modeling coupled THM processes of both water unsaturated and water saturated behaviour of engineered barriers as well as their Interaction with the host rock and the waste canister. For purely thermal calculations there are also analytical solutions that have been used. Clay Technology will use these tools in WP3 for model verification with different laboratory tests (M3.3-1) and extrapolation to repository scale by modeling large scale in situ tests, with the main focus on the FEBEX (M3.3-2).

CIMNE's and ENRESA's work will focus on analysis of the long-term hydrothermal effects in the FEBEX mock-up test and CIEMAT's long-term THM tests. It will resort to incorporate new processes (microstructure evolution, thermo-osmosis, threshold gradients and others) and approaches to achieve a good representation of the long-term observations. In coordination with WP 3.2, new and enhanced constitutive models for the EB materials will be developed (M3.3-3).

Distribution of work

GRS will lead the work package. Contributors for this task are NAGRA, SKB, ENRESA, CIMNE, TK Consult and Clay Technology. BRIUG as a non funding partner will also be involved.

Task 3.4

Most of the THC modeling work performed in the NFPRO IP was carried out within the context of performance assessment (RTDC 5). On the other hand, most of the lab experiments performed within NFPRO on canister corrosion, corrosion-bentonite Interactions and concrete-bentonite Interactions have not been interpreted numerically. There is a clear need to test the models used in performance assessment analyses with data of recent laboratory experiments. The main objective here is to develop advanced multiple-continua THC(m) models for clay barriers and test them with lab and in situ tests.

UDC will develop advanced multiple-continua models for clay barriers by improving current THC(m) models. Such improvements include:

- Accounting for different types of waters (free, adsorbed and interlayer) in clays and different types of pores (macropores, Interaggregate and intraggregate pores) in multiple-continua models. UDC has already developed such capabilities and has done some testing with lab experiments.
- Incorporating mechanical and geochemical couplings to account for porosity changes caused by swelling phenomena. This leads to fully coupled THMC models. Preliminary results from a coupled THMC model of a heating and hydration experiment on FEBEX bentonite indicate that geochemical results improve when changes in porosity caused by swelling are considered.
- Accounting for time-changes in pressures of reactive gaseous species such as $O_{2(g)}$, $CO_{2(g)}$ and $H_{2(g)}$.

Advanced multiple-continua THC(m) models will be tested with both small- and large-scale tests. Such tests include tests performed within NFPRO that were not modelled (tests will be selected after the first Workshop of the project) and tests to be performed by CIEMAT within PEBS (see WP2) including:

- THMC Mock-up (GAME) tests
- Tests on corrosion processes and Interactions of corrosion products at the canister/bentonite interface
- Tests on processes at the concrete/bentonite interface

Based on the information of key parameters of THM-C processes presented in WP2, JAEA will perform analysis of laboratory and in-situ experiments using their own developed code COUPLYS and show the THM-C processes at the concrete/compacted bentonite interface. Then some key parameters of THM-C process will be clarified through these modeling approaches at the in-situ heterogeneous condition. JAEA will validate their model using experimental results or by comparison to the models of the other PEBS partners.

Distribution of work

GRS will lead this task (efforts calculated in Task 3.2 and 3.5). Contributors for this task are UDC and ENRESA. BRIUG and JAEA as non funding partners will also be involved.

Task 3.5

The objectives of this task are to use the data and improved models from Task 3.1 – Task 3.4 for extrapolation to long-term evolution of the repository taking into account the scenarios defined in PEBS WP1, and to investigate model uncertainty and its impact on long-term prediction, thus providing input to PEBS WP4.

The models developed in the Tasks 3.1 to 3.4 will be applied to the simulation and prediction of the likely long-term evolution of the engineered barrier in the repository. However, this extrapolation to long term will not be a blind extension of the model to different space and time scales but it will require a careful assessment of the key long-term processes as well as an evaluation of the resulting uncertainty and its consequences. Coupled analyses of varying degree of complexity, extending to long time scales, will be performed by the different partners.

For most THM considerations, long-term extrapolation means to extrapolate from the time-scale that can be covered by experiments to the end of the resaturation phase of the buffer in a repository. The time span considered will possibly be several hundred to 1000 years. After this, THM processes will be of minor importance, although processes like thermo-osmosis may play a role.

Chemical processes, on the other hand, may take place at all time scales. Chemical reactions induced by canister corrosion take place during time scales much larger than that of buffer resaturation. It is understood that the gas production by corrosion can also have an effect on THM behaviour, if production rates are so high that not all gas can be transported by dissolution and diffusion in the liquid phase. Since, however, a large project on gas (FORGE) is already funded by the EC, it was decided that gas transport should not be a topic in PEBS.

As a consequence of this consideration, there are two levels of extrapolation in time:

- Extrapolation to the end of the resaturation phase is of special importance, because it defines the conditions of the buffer during the successive hundreds of thousand years after buffer resaturation and feeds the necessary input to PA. It is the period which is especially interesting in terms of THM behaviour, because it involves temperature and saturation gradients as driving forces for physical and chemical processes.

- Extrapolation to the end of PA-considered time (usually from 10^5 to 10^6 years). Some THM phenomena such as thermo-osmosis and the high density of adsorbed water may become patent at this time scale. On the other hand, chemical processes such as canister corrosion and chemical Interactions of bentonite with canister corrosion products will occur also during this period of time.

The use of physically-based models, as opposed to empirical models, allows the straightforward extrapolation in time for long-term evaluation, provided that model assumptions hold over the entire calculation period. A careful analysis will be made to review the validity of model assumptions at different time scales. This is the case for the local equilibrium assumption (LEA) versus a kinetically-controlled reaction. Some chemical reactions must be treated with kinetics at short time scales while they can be modelled with the LEA at large time scales.

The work in Task 3.5 includes:
- Critical assessment of the results of Tasks 3.1 to 3.4 regarding their implications for different time and space scales including long-term conditions
- Identification of the significant processes in the resaturation phase and after resaturation
- Development or modification of the available HM, THM and THM-C formulations to incorporate phenomena and processes deemed to be relevant for long-term predictions
- Performance of coupled numerical analyses for long-term evolution of the engineered barrier system in the repository, with different degrees of abstraction and different focuses according to the different modeling teams. Selection of results useful for long-term safety analysis
- Evaluation of the model uncertainty and its implications for long-term prediction and safety analysis
- Evaluation of natural analogues in terms of their usefulness for the validation of long-term extrapolation. If natural analogues are found which are sufficiently well-defined in the boundary conditions of their evolution, their today's state can be compared to respective modeling results to check long-term modeling capability

UDC as the partner working mainly in chemical modeling will integrate available data for bentonites such as water inflow, temperatures, chemical concentrations, etc. from different scales by working with dimensionless variables. Such data integration will be made in terms of dimensionless variables and will include also data from various large-scale buffer experiments such as the FEBEX mock-up and in situ experiments. Once integration is performed, then the possibility for extrapolation in time also will be performed.

Distribution of work

GRS will lead the work package. Contributors for this task are NAGRA, SKB, ENRESA, CIMNE, UDC, TK Consult and Clay Technology. BRIUG and JAEA as a non funding partner will also be involved.

1.3.1.4. Work Package 4: Analysis of impact on long-term safety and guidance for repository design and construction

Objectives

WP4 must look at all the information developed from various experiments and models in WP 2 and 3 related to the evolution of the EBS and develop a synthesis of what significance the work has for showing how the EBS and near-field rock will behave both during and after the transient period. Of necessity, the evaluation of specific experiments through consideration of the experimental data and the associated modeling tends to focus on the particular experiment being analyzed and not on a complete synthesis of results of other experiments and models. It is the task of WP4 to obtain a fully balanced view of all findings and to relate them to the specific relevant time and spatial domains so that results can be examined in particular with respect to post-transient safety functions (e.g. swelling pressure, hydraulic conductivity, which generally have quantitative required target values) through consideration of such factors as: variations in density of the barrier, evidence for transient vs.

permanent changes to properties such as swelling, changes in mineralogy that may influence swelling, extent of sealing of transient hydraulic pathways etc. The synthesis should permit degree of consistency to be determined for various findings (are they specific only to a particular set of experimental conditions or a particular configuration or can they be considered more generally applicable?) and give feedback to design in terms of guidance for performance limits or modifications to design.

Conceptual approach

The overall approach will be based on developing a synthesis of the understanding of processes that occur during the early evolution stage of the EBS using the results from the experimental work in the project, relative to the foundation for this understanding outlined in WP1.

State of the art

The present approach in disposal system safety assessment regarding the representation of the EBS in long-term safety involves three basic steps. In the first step, the processes that occur during short-term evolution of the EBS are identified based on models and experiments, such that a quantitative and qualitative overview of important processes is developed. The processes in the short-term evolution that are particularly relevant to the long-term safety functions of the barriers are then identified and an evaluation is performed of how significant these are, i.e. do the safety-relevant parameters stay within an acceptable range? Finally, the design of the system may be modified, if there are some concerns about the performance (or the performance margin), or abstracted models for the long-term performance may be modified based on new understanding. Although this is an effective approach, the description of evolution must be based on synthesis of information from many sources, because it is not possible to perform EBS evolution experiments at full-scale over the hundreds of years required to reach the ‘steady-state’ phase of the repository (full saturation, low temperature gradient, etc.) It thus remains difficult to bridge the gap between medium and large-scale EBS experiments that deal with coupled THMC processes and the long-term performance of the bentonite barrier.

Implementation of the Work Package

The experimental studies in this project (but also other related studies outside the project) contribute diverse aspects to the understanding of EBS evolution. It is intended to review these using the framework of WP1 to develop a clearer linkage between experimental and modeling results and safety-relevant characteristics of the EBS.

Distribution of work

Nagra will lead the work with contributions from SKB, ENRESA, ANDRA, BGR and GRS. The management of the scientific tasks is also assigned to BGR.

Task 4.1

The process-related framework for EBS evolution developed in WP1, Task 1.1 will be used as a foundation for the work. This will be updated based on new findings within and outside the project and an evaluation structure for models and status of process understanding as well as a report structure will be developed.

Task 4.2

The findings of the WP2 and WP3 experiments and models will be reviewed in order to develop a more complete qualitative process-related description of the early evolution phase of the repository (the first several hundred years) and the residual uncertainties in the evolution. The results of experiments and models and their significance in relation to long-term safety functions of the buffer, canister and host rock (clay and crystalline) will be discussed in a quantitative fashion, including the importance of residual uncertainties. For the synthesis, other relevant studies (e.g. the in situ FEBEX experiment and SKB studies) besides those in WP 2 and 3 will also be considered. The importance of the transient period with regard to the long-term characteristics particularly relevant to system performance and long-term safety will be discussed (i.e. impacts on buffer swelling pressure, hydraulic conductivity, stress/strain characteristics, maximum temperature reached, heterogeneity of buffer density and variations in swelling pressure etc.). The importance of uncertainties arising from disagreement between models and experiments and their implications for extrapolation of results will be reviewed, with particular emphasis on possible impacts on safety functions. For evaluation of the possible impacts on safety functions, this will be based on insights from existing safety assessment studies (e.g. SR-Can, Opalinus Clay safety case). This task should identify any possible different behaviours of the system that may be implied by the uncertainties or disagreement between models and experiments. In relation to WP1, Tasks 1.4 and 1.6, this will identify possible system evolutions that might differ significantly, as a basis for describing and quantifying different scenarios that might exist. In so doing, it should be possible to evaluate more thoroughly which uncertainties are unimportant, but nonetheless interesting to specialists in relation to limitations in detailed understanding and modeling, and which are significant in relation to performance of the system and require further detailed evaluation in order to provide greater confidence in the safety case.

Task 4.3

Based on the evaluation in Task 4.2, propose an improved and more complete approach to integrating the thermal and resaturation phase of the repository with the long-term steady state phase of repository evolution. In addition, the significant uncertainties will be identified and recommendations will be made for future studies. Finally, the linkage between long-term safety requirements and design requirements of the EBS will be examined.

1.3.1.5. Work Package B China-Mock-up Test on Compacted Bentonite-Buffer

China-Mock-up has been proposed according to a preliminary concept of HLW repository in China since 2009. China-Mock-up to evaluate the key THM-C processes will be performed at the laboratory. The test is intended to evaluate THM-C processes taking place in the compacted bentonite-buffer during the early phase of HLW disposal and to provide a reliable database as input to numerical modeling and further investigations.

The overall approach is based on performing experiments according to the needs for additional studies on key processes during the early EBS evolution. The study will make use to the extent possible of on going experiments being conducted in the laboratory of Beijing Research Institute of Uranium Geology (BRIUG).

China-Mock-up will be constructed with compacted bentonite-blocks in a large steel tank of 900 mm internal diameter and 2200 mm height. An electric heater of 300 mm diameter and 1600 mm length, which is made by the same stainless carbon steel as the substitute of a real HLW container is placed inside the bentonite-buffer. The EBS system will be heated by the heater from ambient temperature to 90°C and then cooled down. The groundwater flow will be simulated by injecting the formation water (taken from the host granite rock in the Beishan site / URL, NW China) around the outer surface of the barrier. It can be expected that complex THM-C processes will occur in the bentonite-buffer, which will be monitored by a number of sensors to be installed at various locations in the buffer. The main parameters to be measured in the EBS include temperature, water inflow, relative humidity (suction), swelling and total pressure, as well as displacement of the heater inside the buffer.

After testing, the China-Mock-up facility will be dismantled and samples will be extracted from the buffer. Possible changes of the bentonite properties will be investigated by determination of geochemical, physico-chemical and mineralogical components of the buffer, and special attention will be given to the interfaces of bentonite/canister.

The China-Mock-up will be numerically modelled to verify the constitutive models and the computer codes to be used, such as FLAC3D, CODE-BRIGHT and Ansys for modeling THM processes; and EQ3/6 and Crunchflow for modeling THC processes. The modeling work includes blind predictions at the beginning of the test, calibrated predictions in the mid-term of the monitoring time, and final simulations at the end of the monitoring period.

The China-Mock-up test will be conducted for 5 years, including test design (6 months), preparation (3 m), construction / installation (6 m), conduction (heating 24 m, cooling 12 m), dismantling and post-test (3 m), evaluation and report (6 m). The modeling work will be performed parallel to the test (see CONDUCTION phase in Fig. 13). A report on the design of the China-Mock-up, a report on the progress of the test will be prepared, a final report on the Mock-test will be provided at the end of the test. Various papers will be produced at different workshops. The China-Mock-up post-mortem analysis report will be prepared in due time because the chinese work has started in summer 2009 (see also Figure 13).

BRIUG is in charge for conducting of this work. The activities related to geological disposal of HLW are supported by the China Atomic Energy Authority (CAEA). The China-Mock-up test is open for the other partners to conduct modeling work. BGR will contribute this work. Also GRS and SCK-CEN will be invited.

This work solely will be implemented by BRIUG as a non funding partner. If other partners will be involved, efforts will not be calculated inside PEBS. This work is not subdivided in Tasks.

1.3.1.6. Work Package 5 Exploitation and Dissemination

Objectives

As outlined in the RTD Work Packages PEBS has an important societal component: Building public confidence in the barrier performance of the near-field of a geological repository for vitrified high level radioactive waste and spent fuel is critical for the future of nuclear power production. Public confidence building in geological disposal depends to a large extent on the ability to clarify that geological disposal is a safe long-term solution for the management of high-level radioactive waste. Finding a broadly accepted solution for the management of radioactive waste is critical for the future of nuclear power production. This is corroborated by data from the EUROBAROMETER[28], which indicates, that a majority of the EU population (69%) supports nuclear energy to make us less dependent on fuel imports such as gas and oil for electricity production within the EU if all waste is managed safely. Current disposal concepts within the EU put strong emphasis on the containment properties of the EBS. Building confidence in the containment function of near-field will therefore contribute to the acceptance of nuclear power as an essential component of the energy mix within the EU.

Dissemination and communication strategy

The following instruments will be used for dissemination strategy:

1. Conferences
   In addition partners of the consortium will present PEBS results at international **conferences** (such as the EURADWASTE),

[28] Third Eurobarometer, EB 271, published in February 2007

2. Events
   Exploitation and dissemination of results on European and global level, what includes **PEBS events** such as a
   a) lab training course (mineralogic lab) will be prepared to spread knowledge widely especially con-cerning both the properties and behaviour of the relevant minerals, their exploration and mineral processing to follow the different needs,
   b) an excursion to a bentonite mine,
   c) a specific 1 day workshop related to training and excursion
   d) two workshops in relation to the end of Work Package 1 and Work Package 4 only for regulatory Authorities to discuss first results and further steps for the ongoing project as well as the specific impacts on licensing and agencies matters and finally a
   e) workshop to present and discuss the PEBS results
3. Website
   The project will create a **website** what will match diverse demand.
4. Newsletter
   A half yearly **newsletter** will be distributed (see also description next page).
5. Publications
   The project will **publish** essential results in international scientific journals for European and global information

Referring instrument no.	Comment
1	The beneficiaries and the non funding partners will give presentations at national and international conferences as part of their dissemination share.
1-5	These above 5 instruments will address results to national, European and global demand of agencies, research, politicians, industry, NGOs and education • Formal base of dissemination and exploitation procedures is the Consortium Agreement. All partners agreed on joint measures. • Development and operations of a website, which includes indications of achievements and crucial results. The website will be structured to follow demand of the stakeholders and the interested public. The website will be published as an English version. • The bentonite training course will be arranged at BGR, Germany. The course will be addressed to scientists and experts of the consortium. Properties of different bentonites are discussed and concerned lab tests will be presented hands on.
2-5	The beneficiaries and the non funding partners will contribute preparation these papers with own smaller articles, figures and photographs as part of their dissemination share.

Implementation of the Work Package

For all essential results, such as indicated in the List of Milestones the partner in charge will be in charge to prepare a short note describing the outcome. These notes will be collected and presented in 18-monthly progress reports and additional information published in the PEBS Website. The half yearly Newsletter will be distributed to partner organisations, ministries, agencies, research organisations, universities, companies and via the website. PEBS experts will forward any requested information to the proposed European Technology Platform for Geological Disposal and will be prepared to participate on joint measures with the EC.

For WS 2 and 4 experts from consortium and the High Level Expert Committee and will be invited; For WS 1 and 3 experts from agencies. The target group of the workshops are:

- 1st Workshop at the end of WP 1(non open workshop): Proposed only for Regulatory Authorities.
- 2nd Workshop (bentonite Workshop): Content will be prepared for Geologists, Mineralogists, mining geologists…..
- 3rd Workshop at the end of WP 4 (non open workshop): Proposed only for Regulatory Authorities (same participants as 1st workshop)
- 4th Workshop (final workshop): Members of the AG. General audience such as: Researchers, agencies, Industry, Universities….

The co-ordinator will participate at the WM-Conference in Phoenix to present results of the PEBS project and to initialise closer and broader information exchange with abroad experts.

To save money and efforts all three workshops will be combined with project meetings.

Task 5.1 Dissemination of the results

Subtask 5.1.1 (Website)

Development of a website, to inform about the scientific and technical content of proposed work and achievements. The website will inform about the partners and will include links to all relevant organisations and other projects (e.g. to SCK-CEN and their KNOWLEDGE DATA BASE developed during the EU Project NF-PRO).

The half yearly newsletter will include a brief review of the achievements, content and date of proposed actions (Training, workshops, excursion), related international projects, results and conferences. The newsletter will be published as a pdf-file. It will include also links, which can be used in a digital version. The newsletter will be prepared for about 1 to 2 pages.

The public deliverables as well as the newsletter will be available online to the public.

Subtask 5.1.2 (Workshops)

The 1st workshop, will be arranged as a closed shop workshop to present and discuss the results of Work Package 1 only to experts of European/abroad Regulatory Authorities. This workshop will follow such objectives as

- Discussion and analysis of Identified important processes (FEPs) during the early evolution of the EBS
- Discussion of the results of the current treatment of the early evolution of the EBS in long-term safety assessments for spent nuclear fuel
- Discuss how the short-term transients will/may affect the long-term performance and the safety functions of the repository.
- Discussion of merits and shortcomings of the current treatment
- Discussion of future assessments related to events in the early evolution of the EBS.

The 2nd workshop will be arranged together with an excursion to a Bavarian bentonite site and will set in relation to a special bentonite training course at BGR bentonite labs in Hannover.

The 3rd workshop (closed shop workshop) will be arranged together with the final workshop at the end of the project. It will be prepared as a closed shop workshop for experts from Regulatory Authorities. Results and draft concepts will be presented. Impacts on licensing will be discussed.

This workshop will be in line with the results of the WP 4 and will reflect also the objectives of the 1st Workshop with such objectives as:

- Discussion the findings i) of the WP2 and WP3 experiments and models, ii) of development of a more complete qualitative process-related description of the early evolution phase of the repository (the first several hundred years) and the residual uncertainties in the evolution, iii) of possible different behaviours of the system that may be implied by the uncertainties or disagreement between models and experiments
- Presentation and discussion of the results of experiments and models and their significance in relation to long-term safety functions of the buffer, canister and host rock (clay and crystalline) in a quantitative fashion, including the importance of residual uncertainties (i)importance of the transient period with regard to the long-term characteristics particularly relevant to system performance and long-term safety; ii) of uncertainties arising from disagree-ment between models and experiments and their implications for extrapolation of results, with particular emphasis on possible impacts on safety functions.
- Presentation of an improved and more complete approach to integrating the thermal and resaturation phase of the repository with the long-term steady state phase of repository evolution.

At the 4th workshop (final workshop) the overall results will be presented and further actions will be discussed.

Subtask 5.1.3 (Presentations)

Presentations of results of the project will be prepared for conferences such as the EURADWASTE or comparable conference to the former TOPSEAL-Conference (this conference will no more be per-formed) and "Clays in Natural & Engineered Barriers for Radioactive Waste Confinement" prepared by ANDRA since 2002.

Distribution of work

BGR will lead this Work Package and will arrange most of the work. The direct involvement of the end-users (notably, the *radioactive Waste Management Agencies/implementing Organisations* (ANDRA, BGR, ENRESA, NAGRA and SKB), *large Nuclear Research Organisations* (GRS, BRIUG, JAEA), *Universities* (UDC and UAM) and *other organisations, including industrial and governmental partners and consultancy companies including SME's* (AITEMIN, CIMNE, CIEMAT, Clay Technology, DM Iberia, TK Consult and Solexperts) guarantees, that the results of PEBS will be used in programmes for raising public participation and awareness at national and industrial level.

External multipliers (associations connected to the consortium, e.g. EuroGeoSurveys[29]) will be invited in addition.

Task 5.2 Training

PEBS will offer a special bentonite training course, which will be completed by an excursion (to a bavarian bentonite mine) and the workshop on bentonites for HRLW disposal.

Objectives of the training course and the excursion

All three subtasks will form measures for complete scientific and technical information for a broader understanding of problems and solutions. The target participants are young professionals as well as scientists working for universities, implementers and regulators entering this research area with e.g geomechanics or mineralogic background. Clay experts of the consortium and members of the High Level Expert Committee (see 2.3.1.6) will be invited to these actions. Additional experts also will be invited to participate but at their own costs.

[29] EuroGeoSurveys is the association of European Geological Surveys. Actually 31 Surveys are associated. Most of the surveys are acting as a division of a ministry or on behalf of a ministry.

Background

Compacted bentonites are currently investigated as geotechnical barrier in high level radioactive waste (HLRW) repositories due to their low permeability, high swelling pressure, and cation adsorption capacity. Bentonite properties vary significantly from one deposit to another and even between different locations of a given deposit. During the training course in the lab both cutting edge and recently implemented methods for bentonite characterisation are presented. The theoretical background as well as training in the lab will cover the actual industrial, environmental and economical demand of globally involved organisations (see also the following publication list). Of special importance for future installations of final repositories will be an optimal specification of the bentonite raw material for the technical application which should cover also economical aspects.

Content of the bentonite training course elements:

- **Lab testing course** State of the art and relevant bentonite lab testing methods for bentonite characterisation are installed at BGR. Theoretical background and practical training will be offered during the 2 day workshop. The course is based on a curriculum developed for recently given courses[30] adapted to the topics of PEBS.
- **Excursion (this is a joint action in line with the 2nd Workshop, see also 5.1.2,)** A prominent exemplary bentonite deposit will be visited (e.g. in Bavaria). Geological heterogeneity and industrial production of bentonites will be presented and discussed.
- **Workshop (2nd Workshop, mentioned under 5.1.2,)** The essential results from lab tests and excursions will be presented in an open workshop. The goal is transfer of knowledge by discussions with experts from industry, universities, agencies and research organisations.

Distribution of work for the training course

The scientific and technical organisation will be performed by Dr. Reiner Dohrmann and Dr. Stephan Kaufhold both from BGR (CVs see paragraph 3.2.1). The VBGU (Verband Geologie, Bergbau und Umwelt, Association for Geology, Mining and Environment) will act as a multiplicator and contact organisation to industry so that the German bentonite industry and associated European mining companies will be involved (EUROMINES members).

Papers published by these both experts, which results and content will be included in the course:

ANDREJKOVICOVA, S., MADEJOVA, J., CZÍMEROVÁ, A., GALKO, I., DOHRMANN, R., KOMADEL, P. 2006. Characterisation of mineralogical and chemical composition of bentonite from Lieskovec, central Slovakia. Geologica Carpathica, 57, 5, 371-378

DOHRMANN, R., KAUFHOLD, S. 2009. THREE NEW, QUICK CEC METHODS FOR DETERMINING THE AMOUNTS OF EXCHANGEABLE CALCIUM CATIONS IN CALCAREOUS CLAYS. CLAYS AND CLAY MINERALS, 57, 3, 251-265

KAUFHOLD, S. 2006. Comparison of methods for the determination of the layer charge density (LCD) of montmorillonites. Applied Clay Science, 34, 14-21

KAUFHOLD, S., DOHRMANN, R. 2008. Detachment of colloids from bentonites in water. Applied Clay Science, 39, 50-59

KAUFHOLD, S., DOHRMANN, R. 2009. STABILITY OF BENTONITES IN SALT SOLUTIONS I SODIUM CHLORIDE. APPLIED CLAY SCIENCE, 45, 171-177

KAUFHOLD, S., STÜHRENBERG, D., DOHRMANN, R. 2009. WATER REDISTRIBUTION BETWEEN BENTONITE AND SALT AT ELEVATED TEMPERATURE. APPLIED CLAY SCIENCE, 46, 245-250

KAUFHOLD, S., POHLMANN-LORZ, M., DOHRMANN, R., NÜESCH, R. 2007. About the possible upgrade of compacted bentonite with respect to iodide retention capacity. Applied Clay Science, 35, 39-46

KLINKENBERG, M., DOHRMANN, R., KAUFHOLD, S.; STANJEK, H. 2006. A new method for the identification of Wyoming bentonites. Appl. Clay Science, 33, 195-206

Plötze, M., Kahr, G., Dohrmann, R., Weber, H. 2007. HYDRO-MECHANICAL, GEOCHEMICAL AND MINERALOGICAL CHARACTERISTICS OF THE BENTONITE BUFFER IN A HEATER EXPERIMENT. THE HE-B PROJECT AT THE MONT TERRI ROCK LABORATORY. PHYSICS AND CHEMISTRY OF THE EARTH, 32, 730–740

[30] Exemplary Clay workshops
First Workshop "Qualitative and Quantitative Analysis of Clays", 5.-8.10.2005, 15 participants, 5 from abroad
Second Workshop "Qualitative and Quantitative Analysis of Clays", 5.-9.3.2007, 16 participants, 7 from abroad

1.3.1.7. Work Package 6: Project Management

1.3.1.7.1. Objectives

The core objective is to match all scientific and administrative goals such as

- proposed scientific results and the proposed quality
- successful dissemination
- keep to the budget
- meet all deadlines
- implementation of all work with deployment of proposed staff

To achieve this goals, the project management has

- to observe the rules
- Consortium management tasks and achievements;
- to solve Problems which have occurred and how they were solved;
- Changes in the consortium, if any;
- Management of project meetings, dates and venues;
- Project planning and status reprting;
- Impact of possible deviations from the planned milestones and deliverables, if any;
- Any changes to the legal status of any of the beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs;
- Development of the Project website, if applicable;
- Use of foreground and dissemination activities (if applicable).

The section should also provide short comments and information on co-ordination activities during the period in question, such as communication between beneficiaries, possible co-operation with other projects/programmes etc.

The management tasks are subdivided as follows (see Figure 12):

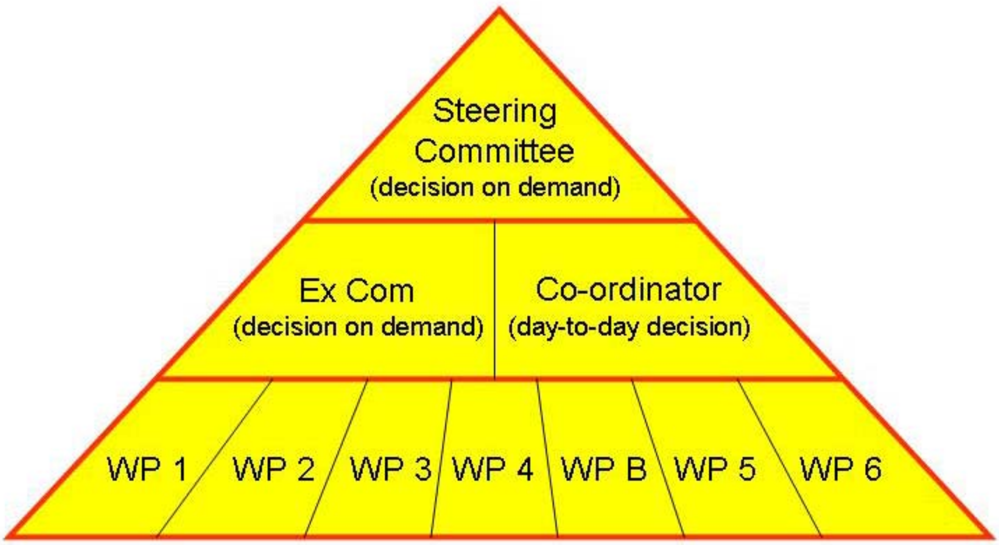

Figure 12 Decisions and hierarchy of the different roles

For PEBS the following levels for co-ordination of work are proposed (see Fig. 12). The detailed content of the different roles are described under Paragraph 2.3.1.6.2 and under Paragraph 3.1:

1. The **Work Package Leader** controls all scientific work inside his work package. He is in charge to implement step by step the proposed results and deliverables.
2. The **Co-ordinator** controls the project at the consortium level. This includes also the implementation and operation of interfaces for a stable, comprehensible and assured information flow between the WPs and the scientific community outside the project. He is in charge for adequate quality control of all processes and the results.
3. For operative management an **Executive Committee, ExCom** will be implemented to answer scientific and technical questions. The Steering Committee will decide if at ExCom level no contend decision can be taken.
4. A **Steering Committee, SC** will be implemented to solve essential overarching problems, to answer complex questions addressed to all partners and for arbitrating.
5. For the review of the final results a **HIGH LEVEL EXPERT COMMITTEE, HLEC** will be installed. The HLEC will be composed of various groups of external experts from i) research, ii) agency and iii) WMO. The results from the workshop no. 1 and no. 3 (closed shop workshops) will be distributed also to the HLEC. Each member of the HLEC will be informed in due time to discuss results and open questions with connecting experts from their own network (structure see Fig 23).

1.3.1.7.2. Role, tasks and responsibilities of the above positions and committees

Task 6.1 Administration

Subtask 6.1.1 Administrative management and reporting

The base for administrative management is the consortium agreement. The administrative management will include the use of already installed SAP-System and the software MS Project (MSP). For efficient distribution of all management data and information (such as minutes, actual schedule, Description of Work, Grant agreement, Consortium Agreement), a web based internal information and communication platform (CP) will be installed. The CP will include information for reading and downloads (open for all members of the project team, the EC scientific officer and the HLEC) and information which can be adapted only by the co-ordinator. Rules will be prepared for up- and downloads.

Reporting includes Periodic and final Reports[31].

a) **PROJECT PERIODIC REPORTs** will be prepared at month 18, 36 and 48. These reports will include a
   - publishable summary of the progress of work and will be submitted within 60 days of the end of each reporting period (including the last reporting period).
   - an overview, including a publishable summary of the progress of work towards the objectives of the project, including achievements and attainment of any milestones and deliverables identified in Annex I. This report will include the differences between work expected to be carried out in accordance with Annex I and that actually carried out,
   - project objectives for the period
   - work progress and achievements during the period
   - deliverables and milestones tables
   - project management
   - an explanation of the use of the resources (personnel)

[31] The detailed requirements for reporting is described in the "guidance notes on project reporting", which can found at the following webaddress: http://cordis.europa.eu/fp7/find-doc_en.html

The beneficiaries will provide a concise overview of the progress of the work in line with the structure of Annex I of the Grant Agreement.

For each RTD work package except project management (WP 6) the following information will be provided by the RTD WP leaders.:

- A summary of progress towards objectives and details for each task;
- Highlight clearly significant results;
- If applicable, explain the reasons for deviations from the initial DoW and their impact on other tasks as well as on available resources and planning;
- If applicable, explain the reasons for failing to achieve critical objectives and/or not being on schedule and explain the impact on other tasks as well as on available resources and planning (the explanations should be coherent with the declaration by the project
- coordinator);
- a statement on the use of resources, in particular highlighting and explaining deviations between actual and planned person-months per work package and per beneficiary in Description of Work
- If applicable, propose corrective actions.

BGR will summarize these reports.

Reporting requirements includes providing during and at the end of the project references and an abstract of all scientific publications. As part of the final project report, the coordinator will submit a full list of publications relating to foreground of the project. All publications shall include the following statement to indicate that said foreground was generated with the assistance of financial support from the Community:

> *The research leading to these results has received funding from the European Atomic Energy Community's Seventh Framework Programme (FP7/2007-2011) under grant agreement n° FP7-249681"* (see Article II.30. of the Grant Agreement).

Contributed and/or invited presentations linked to these scientific publications should also acknowledge support of the Euratom programme and make use of the Euratom FP7 and project logos. Furthermore, such presentations should be documented in the periodic project management reporting.

b) **PROJECT FINAL REPORT** will include these three parts:

- A final publishable summary report covering results, conclusions and socio-economic impact of the project. It will be prepared as a self standing document.
- A plan for use and dissemination of foreground. This document is separate from the publishable report.
- A report covering the wider societal implications of the project, in the form of a questionnaire, including where applicable gender equality actions, ethical issues, efforts to involve other actors and to spread awareness. This document is also separate from the publishable report.

Subtask 6.1.2 Financial Management

BGR will perform the financial management of this project. BGR will follow the EC rules and the used national rules strictly.

a) The **PROJECT PERIODIC REPORT** will include

- an explanation of the use of the resources (finance)
- a Financial Statement from each beneficiary and each third party, if applicable, together with a summary financial report consolidating the claimed Community contribution of all the

beneficiaries (and third parties) in an aggregate form, based on the information provided in Form C by each beneficiary.
- Financial Statements of the beneficiaries will be accompanied by certificates (only BGR and AITEMIN).

b) The **FINAL REPORT ON THE DISTRIBUTION OF THE COMMUNITY FINANCIAL CONTRIBUTION** will be prepared by BGR 30 days after receipt of the final payment

Subtask 6.1.3 Managing of Audits

Partners with EC contribution >375.000 € (in this case BGR and AITEMIN) will have to organise its own audits and have to calculate the financial means in their own budget.

BGR will contract an experienced auditor (from the NBank, Hannover, including certificate of European Court of Auditors) for own PEBS audits. BGR as a Federal Institute will be audited regularly by experts from the German Federal Ministry of Economics and Technology as well as by the German Federal Ministry of Finance.

Subtask 6.1.4 Time Management

For time management BGR will use the already implemented the software MSP. All milestones and deliverables will be scheduled with this system. MSP time tables will be provided by the CP.

Task 6.2 Day to day management

The day to day management actions will take place at the level of the
- **Co-ordination** team at BGR, taking advantage of administrative and scientific resources (see following pages). All contact with the EC for the Project will go through this Co-ordination team. As part of the day to day scientific management the co-ordinator will prepare periodic reports with an overview including a publishable summary of the scientific and technical progress of the work.
- The **RTD Work Package Leader** will ensure and reinforce the co-ordination during the progress of the scientific and technical work (underground laboratory, test facilities, modeling and data processing). Base of the project management are on the one hand the scientific objectives and tasks and on the other hand the staff resources (see following pages) and the financial resources to cover the proposed supply (see paragraph 3.3.2). The Parties are organised as previously mentioned in RTD Work Packages and Tasks according to the extent and complexity of the Proposal. The RTD Work Packages will be guided by the Work Package Leaders that have been appointed by the core members during the preparation phase of the PEBS proposal:
  - SKB Leader Work Package 1
  - ENRESA Leader Work Package 2
  - GRS Leader Work Package 3
  - NAGRA Leader Work Package 4
  - BRIUG Leader of Work Package B
  - BGR Leader Work Package 5 and 6

Task 6.3 Scientific management

a) Management of Scientific Work and progress

The **Co-ordinator** coordinates

RTD type of work (separately calculated in each RTD Work Packages)

- the overall research and technological development activities and the Interactions between the RTD Work Packages

MGT type of work (calculated in the MGT type Work Package)

- maintains the consortium activities (co-ordinators type of work: MGT), what includes
    - maintenance of the consortium agreement,
    - the overall legal, ethical, financial and administrative management including, for each of the beneficiaries, the obtaining of the certificates on the financial statements and on the methodology and costs relating to financial audits and technical reviews,
    - implementation of competitive calls by the consortium for the participation of new beneficiaries, where required by Annex I of this grant agreement,
    - any other management activities foreseen by the annexes, except coordination of research and technological development activities.
- administer the Community financial contribution regarding its allocation between beneficiaries and activities, in accordance with this grant agreement and the decisions taken by the consortium. The coordinator shall ensure that all the appropriate payments are made to the other beneficiaries without unjustified delay;
- keep the records and financial accounts making it possible to determine at any time what portion of the Community financial contribution has been paid to each beneficiary for the purposes of the project;
- inform the Commission of the distribution of the Community financial contribution and the date of transfers to the beneficiaries, when required by this grant agreement or by the Commission;
- review the reports to verify consistency with the project tasks before transmitting them to EC;
- monitor the compliance by beneficiaries with their obligations under this grant agreement.

He will take all necessary actions to implement the decisions of the SC or the ExCom and to provide the partners with the necessary documents, reports and any other proposal regarding communication, knowledge management, workshops, implementation of training activities etc. BGR as Co-ordinator will perform the scientific and overall technical management of the work packages.

The **Work Package Leader** will represent their colleagues working in the respective tasks. The respective progress and possible problems encountered in the Work Package can be discussed under the chairmanship of the Co-ordinator's representative. Remedial actions for the proper conduct of the project if applying have to be decided in due time and the necessary information provided to Work Package Leaders.

The **Steering Committee, SC,** consisting of all Work Package Leaders of the Consortium, is the central committee for discussing and settling technical and administrative project affairs on the basis of technical reports, milestone dates and the budgetary situation. The Steering Committee shall be in charge of the overall direction and major decisions with regard to the Project. Yearly meetings chaired by the Coordinator are foreseen at alternate locations, each third of which is to be held approximately one month before management reports are due to the European Commission. To achieve best value for money, Steering Committee meetings should be scheduled together with technical coordination meetings (or workshops) needed within the Work Packages. Other items such as publications, dissemination of results, intellectual property rights, and legal regulations will also be discussed and decisions taken by the Steering Committee, in line with the application of European Community and National regulations.

The technical and scientific management at the CP-FP level occurs first through the proposed structure of the SC.

- The SC is composed of all partners of the Consortium (not only the WP-leader). It is the central committee for discussing and settling technical and administrative project affairs on the basis of technical reports, milestone dates and the budgetary situation. The SC shall be in charge of the overall direction and major decisions with regard to the Project. Yearly meetings chaired by the Coordinator are foreseen at alternate locations. At the yearly meetings preparation of the 18 monthly management reports will be arranged.

- To achieve best value for money, SC meetings will be as much as possible scheduled together with technical coordination meetings (or workshops) needed within the Work Packages. BGR will prepare for its meetings any financial or technical proposal required or deemed necessary in accordance with the EU Contract,
- review the deliverables or other documents intended to the EC,
- agree on procedures and policies for the management and dissemination of the Knowledge,
- decide upon measures in the framework of controls and audit procedures affecting the Project as a whole and
- fulfil any other function assigned to it by the Consortium Agreement (what includes e.g Intellectual Property Rights - foreground and background, incorporation of new members, control of contacts to other projects, arbitrate between partners, set up and use the rules of liability and responsibility,

The **Executive Committee, ExCom** comprises the Coordinator and the Work Package Leaders. The EC takes all the decisions in everyday Project business, consistent with the overall direction and major Project decisions taken by the Steering Committee. The ExCom directs executive assignments to the Project Management and to the Task Leaders. It receives and acquits the updated Gantt Charts, list of deliverables and associated efforts. The ExCom either meets in conjunction with other project meetings or handles its business by electronic Interaction. The ExCom ensures that there is adequate Interaction between the different Work Packages and defines the needed input/output between them.

The **HLEC** will be installed for yearly advise and the final review at the end of the project. HLEC will give independent information about the quality of the achieved interim results and the essential problems and solutions. HLEC can attend all Workshops. The HLEC should be composed of 4 high level representatives (Prof. Röhlig, Technical University of Clausthal, Germany, Dr. Volkaert, SCK-CEN, Belgium, Mr. Frédéric Bernier, Federaal Agentschap voor Nucleaire Controle, FANC, Belgium, Bo Strömberg, Swedish Radiation Safety Authority, SSM).

b) Quality Management

- **All partners** will follow their own quality management procedures. For the Case of compatibility problems the QM system of BGR will be implemented.
- The **HLEC** will be involved for scientific and technical quality management. They will be invited by the project to attend the Yearly project meetings. they will be asked
  - if the project will follow the state of the art (exemplarly),
  - for advise in the case of unforeseen technical situations
- **BGR will perform the formal quality management** of all work packages.

Efforts on formal quality management will be handled as type MGT. Scientific quality management, above all this includes the contribution of the HLEC, will be handled as type RTD.

c) Management of consortium agreement

Management of IPR, ethic and gender issues.

The efforts (staff months) of Tasks 6.2 and 6.3 are assigned to each RTD work package (WP 1 to 4) and will be managed as type RTD work with the related funding. But a detailed description of all measures in this regard is presented in Work Package 6. Staff months allocated to Task 6.1 are calculated as type MGT work. These efforts are indicated in Work Package 6.

1.3.1.7.3. Distribution of work

Task 6.1 and 6.2 will be managed by the project manager as scientific and technical officer of this project. This both tasks include 8 staff months which are calculated directly under the relevant RTD Work Packages. The management of task 6.3 will be assigned to BGR financial cell. This task includes 18 staff months (6 staff months for Subtask 6.3.4).

BGR will perform Work Package 6. Knowledge of more than 70 EU projects of different FW programmes will be considered (as END in Bruxelles at DG TREN) and various national funded research projects in Germany and Europe. The financial cell of BGR will perform the project on the base of more than 5 years of experience with EU projects. For general questions regarding financial or legal matters BGR will contact EC, the German National Contact Point (Forschungszentrum Karlsruhe) and also the relevant Ministries.

Staff hours for Task 6.1 and Task 6.2 will be calculated with the relevant scientific and technical Work Packages (WP 1 to WP 4). Staff hours for Task 6.3 are calculated for Work Package 6. All financial means for “Subcontracting”, “Travel and subsistence” and “Other specific costs” with relevance to project management are assigned to Work Package 6.

1.3.2. Timing for Work Packages and their components

The conduction of the project indicating essential deliverables and milestones is indicated in Figure 13 and 14. Figure 15 indicates the deliverables.

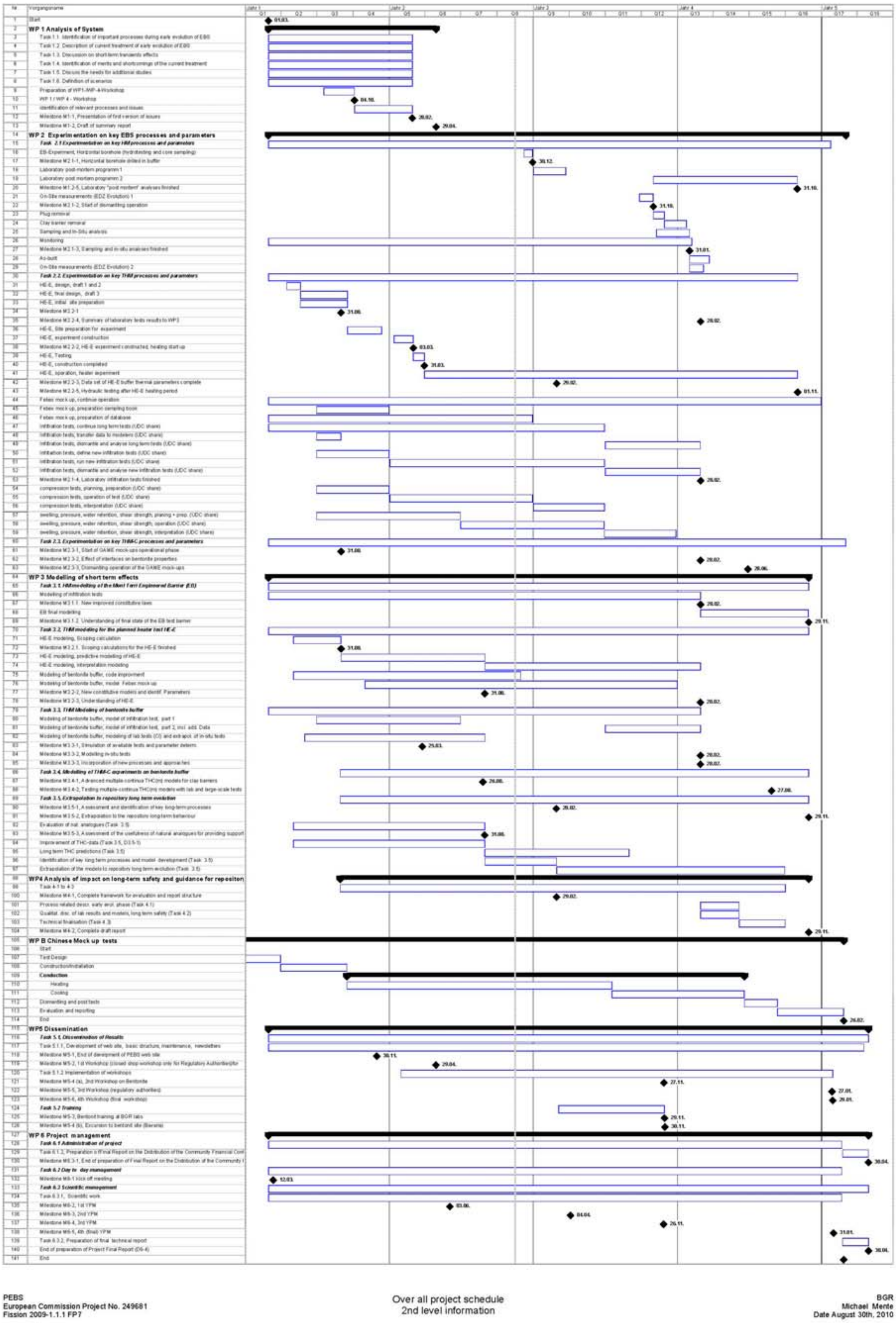

Figure 13: Gantt Diagram of the performance of the project. The schedule indicates essential tasks and Milestones. Deliverables are not included.

1.3.3. Workpackage list

(see Part A, Workplan Tables – Detailed implementation)

1.3.4. Simplified scheduled action plan with some exemplary deliverables

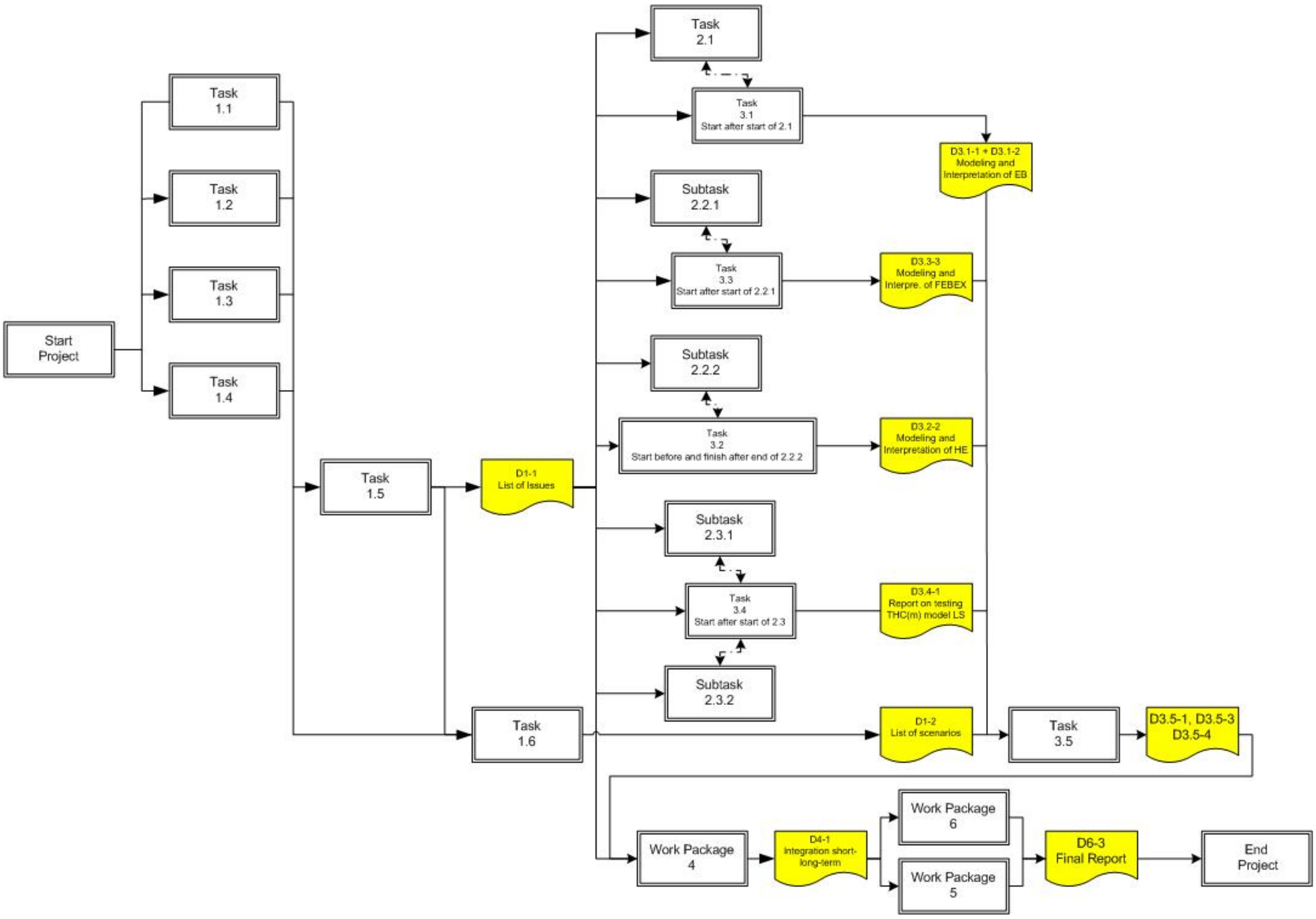

Figure 14 Simplified scheduled action plan with some exemplary deliverables

1.3.5. Deliverables list

(see Part A, Workplan Tables – Detailed implementation)

Del. No.	***Deliverable name***	***WP no.***	***Lead beneficiary***	***Estimated indicative personmonths***	***Nature***	***Dissemi-nation level***	***Deli-very date***
SKB1	Handling of the early evolution of the EBS in SKB safety assessments	WP1	SKB		R	RE	12
NAGRA1	Handling of the early evolution of the EBS in Nagra safety assessments	WP1	NAGRA		R	RE	12
ANDRA1	Handling of the early evolution of the EBS in ANDRA safety assessments	WP1	NAGRA		R	RE	12
ENRESA1	Handling of the early evolution of the EBS in ENRESA safety assessments	WP1	NAGRA		R	RE	12

Figure 15: Internal WP1 Technical Notes and Reports for information transfer (no EC deliverable)

1.3.6. Work Package descriptions

(see Part A, Workplan Tables – Detailed implementation)

1.3.7. Efforts for the full duration of the project[32]

(see Part A, Workplan Tables – Detailed implementation)

1.3.8. List of milestones and planning of reviews

Milestones are control points where decisions are needed with regard to the next stage of the project. For example, a milestone may occur when a major result has been achieved, if its successful attainment is required for the next phase of work. Another example would be a point when the consortium must decide which of several technologies to adopt for further development.

(see Part A, Workplan Tables – Detailed implementation)

2. Implementation

2.1. Management structure and procedures

2.1.1. The project's organisational structure

The execution of the project will follow the implemented project management procedures for

- The Project Co-ordinator will manage the complete project. He takes care of the i) quality of the results, the ii) scheduling, iii) financial matters, iv) all other issues regarding maintenance of the CA, v) scientific and technical documentation, vi) minutes/ Reporting and the vii) management of the communication platform (website for internal and external use). He is in charge for the data and information flow from project to the EC and back.
- For communication yearly project meetings (YPM) will be arranged. At the YPM all questions from day to day business will be discussed. The co-ordinator will prepare minutes which includes an open item list to control completion of actions.
- To solve overarching or legal problems High-level decision-making mechanisms will be installed as management by exception (see Paragraph 3.1.2.).
- The SC will be composed of partner representatives. The HLEC will be invited for the project meetings for reviews and quality management. The SC will be installed to take care of an i) over all quality assurance on a condensed level and ii) for solving crucial problems. The SC meetings will be arranged aside the yearly Project Meetings. The SC together with the ExCom will meet regularly at the project meetings. In case of increasing problems additional meetings can be arranged.
- ENRESA will involve a technical secretariat (taken by DM Iberia) to the WP2 leader, given the scope and variety of the experimental work to be conducted. The technical secretariat together with the WP2 leader will ensure the necessary links to other WPs within PEBS, particularly to WP3 and WP1.
- For general interior communication IT platform will be implemented aside the external website or in combination (as a member site)

32 Please indicate in the table the number of person months over the whole duration for the planned work , for each Work Package, for each activity type by each beneficiary