TECHNICAL BASES FOR THE *INDUSTRIAL SUBCONTRACTING FOR PRODUCTION AND CHARACTERIZATION OF Pb-16Li ALLOY (PRODUCTION TRIAL) IN TBM (EUROfusion – IQS), CONTRACT FINANCED BY THE EUROPEAN COMMISSION UNDER THE PROJECT 101052200 — EUROfusion — EURATOM-2021-ADHOC-IB*

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1. INTRODUCTION

EUROfusion's updated Fusion Research Roadmap aims to acquire the necessary knowledge to start constructing a demonstration fusion power plant (DEMO) five years after ITER is in full-power operation. DEMO will deliver fusion electricity to the grid early in the second half of the century. The Roadmap has been articulated in eight different Missions.

The present grant (Project 101052200) has the goal of implementing the activities described in the Roadmap during Horizon Europe through a joint programme of the members of the EUROfusion Consortium, with the following high-level objectives:

1. Construct and commission ITER
2. Secure the success of future ITER operation via preparation and experiments on present devices
3. Develop the conceptual design of a DEMO fusion power plant
4. Finalise the design and construct a fusion spectrum neutron source (IFMIF-DONES)
5. Advance the stellarator as an alternative approach to fusion power plants
6. Prepare the ITER and DEMO generations of scientists, engineers and operators
7. Promote innovation and European industry competitiveness in fusion technology and beyond.

The ITER success remains an important overarching objective of the programme and much attention is devoted to ensure that ITER operation is properly prepared, and that a new generation of scientists and engineers is thoroughly educated and trained for its exploitation. DEMO is the only step between ITER and a commercial fusion power plant. To achieve the goal of fusion electricity demonstration in the early 2050-ies, the DEMO Conceptual Design has to be completed by 2030 at the latest, to allow the start of the Engineering Design Activities. DEMO cannot be defined and designed by research laboratories alone, but requires the full involvement of industry in all technological and systems aspects of the design. Therefore, specific provisions for the involvement of industry in the Consortium activities are envisaged.

The objective of WP 10 of this project is the development of the Breeding Blanket (BB) System for DEMO, including the Breeding Blanket sectors (BBS) and the associated Tritium Extraction/Removal system.

The specific steps to reach this objective during the Conceptual Design phase are:

- Concept selection studies for Driver and DEMO Test Blanket Selection (2021-2024). The Helium-Cooled Pebble Bed (HCPB) and Water-Cooled Lithium Lead (WCLL) concepts will be further investigated, critical R&D completed and integration aspects clarified in relation to the possible DEMO plant architecture. This will provide a sound basis for the selection of a driver and advanced breeding blanket at G2.
- Validation of the BB system for the CD of DEMO (2025-27).
- Supporting R&D programme to validate the proposed design performance and increase the technical maturity level. This applies to critical technologies such as T-permeation/corrosion barriers, tritium extraction methods, fabrication and qualification of breeder and multiplier materials, and development and validation of alternative lower cost routes of fabrication for structural elements of the BB.

- Support the ITER TBM (Test Blanket Module) programme in preparation of the preliminary (2022) and final (2025) design reviews, as well as the procurement phase for the first TBM (2026-2027). WPBB will carry out the R&D programme jointly for DEMO and TBM in key topics of the ITER TBS (Test Blanket System) development both for the WCLL and HCPB TBM. It will support the breeders and neutron multipliers procurement of the first TBM set.

PbLi is not a standard alloy to be procured on the market, in particular if specific composition constrains are envisaged. Approaching the TBM manufacturing phase it is necessary to identify a reference production technique and one or more manufacturer available, to provide on time the necessary quantities of PbLi alloy with the required content of the 6Li isotope.

The main target of task "*Activities related to the procurement of PbLi for the first TBM*" (BB.TBM.T.02.01.T001) is to define a roadmap to secure the delivery of PbLi for the WCLL-TBS and then for DEMO. A production line for the WCLL-TBS phase should be prepared, with the possibility to update it to follow DEMO needs.

The activity will be developed as follow:

- A preliminary step is the definition of quality control for PbLi production: it is necessary to establish a quality procedure for the PbLi production, including parameters to be checked and reference techniques (each batch should be tested to ensure the quality/standardisation of the production).
- The "nuclear grade" specification should be addressed and defined, considering in particular the Li6 content and the relevant impurities to be specifically controlled to reduce activation issues. A reference production technique, at laboratory scale, will be identified.
- Li6 enrichment aspects shall be addressed, in particular, (i) a suitable chemical compound(s) to be used in the PbLi alloy production, and (ii) its regulatory (dual-use) and legal aspects. The goal should be to make sure that the issue of Li6 enrichment will not be a showstopper for the PbLi procurement and delivery for ITER-TBM and later on for DEMO .
- The first two activities are expected to be completed in 2021, with the production of a set of requirements concerning the control of impurities and the quality assurance of PbLi production.
- A first production trial of PbLi and its characterisation will be carried out and qualified according to the material specifications.
- To ensure quality standard in the production for ITER and DEMO, a return of experience on PbLi manufacturing technique development, qualification and supply is expected.

This task shall allow to progress in solving the issues related to the production of significant batches of lead lithium to be used as breeder material in fusion systems. The final results to be delivered before the PDR meeting, December 2022, shall include an assessment of reference composition, manufacturing technique and quality assurance (nuclear grade), together with a preliminary analysis of regulatory and legal aspects of Li6 enrichment.

2. ACTIVITIES TO BE PERFORMED

Today, fully consolidated lead-lithium eutectic alloy (nuclear grade Pb-15.7(2)^{6}Li) quality assured standards (QAS) are still pending. The generation of the complete QAS is a rich and complex task. The final goal would be to establish a Quality Norm for the future industrial coming production, handling and qualification of (Pb-15.7(2)^{6}Li) for TBMs so the activities should face industrial capabilities urgently.

In this framework, task "Activities related to the procurement of PbLi for the first TBM" (BB.TBM.T.02.01.T001) has been defined in WP10 Breeding Blankets of EUROfusion project (Project 101052200).

The goals of *D005 Production and characterization of Pb-16Li alloy (production trial) in TBM* of BB.TBM.T.02.01.T001 are:

1. Evaluate the Programme amounts of Pb-Li material procurement demands.
2. To deliver a detailed Material Production and Qualification Plan (MPQP).
3. To prepare a production line for the WCLL-TBS phase.
4. To start the management of the material production trials to qualify the material according to the proposed MPQP.

The goal is a net increase of maturity level in view of the Preliminary Design Review (PDR) meeting, at 4Q/2022.

D005 will be executed by CIEMAT (Beneficiary of the Agreement) and IQS (Affiliated Entity of CIEMAT). All the activities related with D005 will be supported by external industrial subcontracting.

The external industrial subcontracting will be managed and supervised in a unique industrial delivery with committed work packages breakdown for:

- WP1: Detailed assessment of material grades volume demands including impurities for WCLL TBMs.
- WP 2: Material grades production and qualification Plan (MPQP).
- WP 3: Scoping production of 6Li and Pb-15.7(2)6Li nuclear grades and selection of 6Li production technique in view of 6LLE TBM procurements.
- WP 4: Design supported on Modelling of a MHD stirrers for Industrial production of LiPb.
- WP 5: Prospecting production trials.

2.1. WP1: Detailed assessment of material grades volume demands including impurities for WCLL TBMs.

The required amounts of diverse forms of PbLi eutectics will be assessed.

Thus, the first scope is to precise the range and volume of the material procurement demand (including technical and programmatic uncertainties) as essential input to range the size of the coming Industrial Procurements for the different types of PbLi eutectic forms (both non-enriched Pb-15.7(2)NLi and enriched grades: Pb-15.7(2)6Li). The 6Li demands should be forcely assessed.

A detailed assessment of the material grades volume demands including impurities for WCLL TBMs has to be performed, based on:

- The present WCLL TBS design specifications (LLE required volumes in the TBM and in the ancillaries).
- The expressed TBM programme phases (and the available operational plans and integration approaches.

2.2. WP 2: Material grades production and qualification Plan (MPQP).

A second part of the subcontracted Industrial activity corresponds to a complete Material Production and Qualification Plan (MPQP) based on 4 packages:

1. Handling Standards:
   QA means to fully set up the Norms and Standards specifying all the handling procedures and protocols and management since alloying elements (Li-forms, Pb) up to final products:
   a. Further checking of the alloying elements (as received) according to suppliers' specifications (impurity levels)
   b. Handling routes and protocols for Li isotopic forms (natural, 6Li)
   c. Handling routes and protocols for Lead quality as alloying element
   d. Sampling procedures to characterize LLE products (both LLE natural and 6Li-enriched, 6LLE)
   e. Pretreatment of alloying elements (Li-forms and Pb) and LLE products pre/post characterization (both DT and NDT)
2. Norms and Standards for constitutive and compositional characteristics:
   The subcontractor should propose their own sampling procedures according to standards to confirm and certify the constitutive and compositional requirements:
   a. The base constitutive properties of the manufactured batches, in terms of the accurate title (precision, to be fixed) and eutectic phase homogeneity (at sub-mm ranges, to be fixed) for the minor alloying element (lithium)
   b. The base compositional properties of the manufactured lots, in terms allowable impurity limits as imposed by specific nuclear uses of the material.
3. Norms and Standards for Material Nuclear Grade testing and qualification:
   Once the material is produced with QA reproducible constitutive and compositional characteristics, the material should be characterized, and this characterization should be standardized. The standardization in this particular case consists in establish:
   a. The set of primary inputs in the material database of LLE as nuclear functional material
   b. The set of reference (QA certified) experimental techniques generating data inputs for the selected primary properties of the material in the database
   c. The type and characteristics of certified equipments (commercial or research) generating such data points entries
4. Functional (nuclear) Material database management QA requirements:
   a. Establish criteria to validate data inputs wit uncertainties of data points in the functional database of the materials

2.3. WP 3: Scoping production of 6Li and Pb-15.7(2)6Li nuclear grades and selection of 6Li production technique in view of 6LLE TBM procurements

The set of potential techniques to produce 6Li in large amounts (e.g.: kgs. For TBM) will be reviewed in terms of efficiency, environmental acceptance, costs and industrial scalability.

Li(6) (and then Pb-15.7(2)6Li) is a dual-use material (e.g. also used for military purposes) having know IAEA (e.g. EURATOM Directives and National Transpositions in EU Countries) safeguards related with its production, management and transport. Well established known protocols will be reviewed in terms of procurement managements and logistics for TBM and DEMO.

The following activities have to be developed in this work package:

- A review of the set of potential techniques to produce 6Li in large amounts. This review will be performed in terms of efficiency, environmental acceptance, costs and industrial scalability.
- A review of Li(6) (and Pb-15.7 6Li) protocols related with its production, management and transport. This review will be performed in terms of procurement managements and logistics for TBM and DEMO.
- A manufacturing or a procurement route for large amounts of 6Li has to be established: where to acquire or how to produce and how to deliver, in the frame of a special regulatory framework.
- A manufacturing route for 6Li has to be proposed. It has to include the conceptual design based on the selected techniques and an experimental Plan to qualify the scalability of the technique as a key point of the 6LLE material Procurement Plan.

2.4. WP 4: Design supported on Modelling of a MHD stirrers for Industrial production of PbLi.

There are four historic basic routes that have been proposed and experienced at laboratory and semi-industrial scales to manufacture PbLi:

- Alloying at a VIM furnace under controlled atmosphere (Ar)
- Alloying by MHD stirrers (controlling atmosphere or not)
- Alloy mixing by forced convection melting
- Powder metallurgy routes (powder cryo-grinding in Ar)

For exploring the second route, it is necessary to propose a design supported on modelling of a MHD stirrer, with an estimated capacity of 100 l h^{-1} for the industrial production of PbLi.

An industrial production line for manufacturing of Pb-15.7(2)NLi for the WCLL-TBM phase will be prepared, with the possibility to update it to follow future DEMO procurement needs. This production line will be based on the MHD stirrers previously designed.

The following activities have to be developed in this workpackage:

- An industrial production line for the WCLL-TBM phase, with the possibility to update it to follow future DEMO needs.

- Design supported on modelling of a MHD stirrer, with an estimated capacity of 100 l h-1 for the industrial production of PbLi.

2.5. WP 5: Prospecting production trials.

In this WP, short-scale demonstration trial batches have to be produced, facing the complete and exhaustive QA tests and using the manufacturing route previously proposed.

Small laboratory scale (1 kg batches) have to be produced alloying by MHD stirrer and qualified according to the proposed MPQP.

3. DUE DATES AND DELIVERABLES

Deliverables corresponding to the different WP will be issued by the subcontractor. These deliverables will include technical reports of the different activities described in the WP and performed by the subcontractor.

The deliverables for the different WP and their due dates are presented in the following table.

WP	Deliverables	Due Date
1	D1 Assessment of material grades volume demands for WCLL TBMs	30.06.2022
2	D2 Material Production and Qualification Plan (MPQP)	30.06.2022
3	D3 Scoping production of 6Li and Pb-15.7(2)6Li nuclear grades and selection of 6Li production technique in view of 6LLE TBM procurements	30.09.2022
4	D4 Design supported on Modelling of a MHD stirrers for Industrial production of PbLi.	30.09.2022
5	D5 Prospecting production trials	30.09.2022

4. SUBCONTRACTING COST

The external industrial subcontracting will be managed and supervised in a unique industrial delivery. The maximum cost of this delivery is 250,000 €.

5. SUBCONTRACTOR CHARACTERISTICS

5.1. General subcontracting criteria

5.1.1. Companies general profiling

The main targets of the activities supported by an external industrial subcontracting are:

- To update the Material Property Data Base (MPDB) for LLE
- To define a roadmap to secure the delivery of LLE for the WCLL-TBS and then for DEMO.

According to that, it seems reasonable to prioritize the scientific and technical capacities of the subcontractors over their economic capacities. Otherwise, a large potential expertise at existing SMEs would be withdrawn.

Non precluding other forms, the ideal profile of a granted qualified bidder would be:

- a Technology-based independent company or,
- a Joint Collaborative Undertaking or Framework Collaboration Contract between a technology-based independent company and R&D laboratory non-statutory-linked and independent from the company.

The bidder commitment with Fusion as a next energy solution should to be appreciated. It seems an added value to the requirement of long-term developments in Fusion and as a way to minimize the industrial risks for LLE procurement.

5.1.2. Form of documentary proofs

For the different blocks of competencies, the proof-of-expertise shall be documented in the form of:

- Published papers,
- Presentations at workshops or technical meetings,
- Dissemination on the Topic (Posters, Talks, seminars, technical reports),
- On-going R&D coded activities (Tasks, …) and officially coded projects,
- Present and past contracts: Procurement or Service contracts in previous tenders.

5.1.3. Transnational-EU private or private-public technological collaboration

Bidders representing private collaborative undertakings or private-public partnerships between entities belonging to different EU countries will be scored favourably.

5.2. Proving competencies on LLE-forms Quality Assurance

LLE has not other uses out of Fusion Technology and the LLE material could be justified to be far from the QA&S (Quality Assurance and Standards) required for a nuclear material in terms of lack of specifications.

Today there exist not ISO or other standards related with handling and qualification of LLE. Just similar norms for similar non-nuclear alloys could be taken as close reference analogues (ISO 3131/- 1, /-5, Light Metals and light alloying metal: methods for processing and treatment).

Along decades, the EU_FP have carried out R&D Technology Programs using diverse sources of LLE materials without the required standardization and quality control of a nuclear material. Some controversial scientific results with huge impact on Breeding Blanket design and fusion reactor safety might be explained in terms of LLE material QA.

Therefore, the QA&S of a new advanced functional material expecting from large-scale industrial procurement is seen to be urgent and compulsory.

Different alloying techniques know today capable to produce LLE alloy are seen to produce different qualities of the material (short-scale Li homogeneity, impurity limits, ...) and the most appropriate to face the established QA requirements should be technically justified and prospectively selected.

The LLE full standardization & QA as nuclear material to be addressed is founded on four main pillars:

- Pilar 1: Alloying elements (Li, Pb) and eutectic ingots handling procedures.
- Pilar 2: Setting and certifying of constitutive and compositional properties of final products.
- Pilar 3: Establishment of LLE-forms characterization standards.
- Pilar 4: QA management of the material functional database.

QA (Pilar 1) means to fully set up the Norms and Standards specifying all the handling procedures and protocols and management since alloying elements (Li-forms, Pb) up to final products.

Before the material characterization, the set of procedures in Pilar 1 includes:

1.1.	- Further checking of the alloying elements (as received) according to suppliers' specifications (impurity levels)
1.2	- Handling routes and protocols for Li isotopic forms (natural, 6Li)
1.3	- Handling routes and protocols for Lead quality as alloying element
1.4	- Sampling procedures to characterize LLE products (both LLE natural and ^{6}Li-enriched, ^{6}LLE)
1.5	- Pretreatment of alloying elements (Li-forms and Pb) and LLE products pre/post characterization (both DT and NDT)

Under general QA principles of minimal modification of products and a universal reproducibility of results, all of these procedures should follow singular or integral Norms and Standards. An example is the set of procedures in the past ISO_3134/- 1, /-5, Light Metals and light alloying metal: methods for processing and treatment, which could serve as close formal reference.

The expertise of the qualified Industrial subcontractor should serve to analyze and propose of such Norms and Standards that should be confirmed (approved) by the contractor (IQS/CIEMAT, e.g., EUROFUSION). Therefore, a documentary proven expertise when facing QA challenges in PILAR 1 should be required and scored in the Tender.

The QA in (Pilar 2) face:

2.1.	- The base constitutive properties of the manufactured batches, in terms of the accurate title (precision, to be fixed) and eutectic phase homogeneity (at sub-mm ranges, to be fixed) for the minor alloying element (lithium)
2.2	- The base compositional properties of the manufactured lots, in terms allowable impurity limits as imposed by specific nuclear uses of the material.

The expertise of an Industrial subcontractor should proof the simultaneous capability to alloy within high-accuracy precision of the Li-title guaranteeing such short-scale (micrometric) homogeneity. Therefore, a documentary proven expertise confronting such alloying issues (2.1.) should be provided and scored in the Tender. The required expertise should unavoidably include one of the potential sets of the confirmed experimental techniques (e.g., AAS, DTA, DC, FA-QMS, …) able to certify Li-title within the required precision and the appropriate metallographic analysis.

The expertise of an Industrial subcontractor should proof its capability to face alloying issues controlling and certifying the level of impurities of LLE products. Therefore, a documentary proven expertise confronting such alloying impurity issues (2.2) should be provided and scored in the Tender. The required expertise should unavoidably confirm experimental techniques certifying impurity contents at the established levels.

Bidders should propose their own sampling procedures according to standards to confirm and certify the constitutive (2.1) and compositional (2.2) requirements.

Other than intrinsic and essential handling, constitutive and compositional certification of manufactured ingots a further (Pilar 3) concerns the characterization standards.

Once the material is produced with QA reproducible constitutive and compositional characteristics, the material should be characterized, and this characterization should be standardized.

The standardization in this particular case consists in establish:

– The set of primary inputs in the material database of LLE as nuclear functional material

- The set of reference (QA certified) experimental techniques generating data inputs for the selected primary properties of the material in the database
- The type and characteristics of certified equipments (commercial or research) generating such data points entries.

Thus, the QA in (PILAR 3) should face:

3.1.	-	The primary material properties in LLE-forms database as fusion functional material
3.2	-	The reference experimental techniques generating data inputs for the LLE material in the database
3.3	-	The set of certified equipments generating such data points entries in the LLE material database

The type and number of the required primary properties of the LLE in its database comes determined by the functional uses of the material… a tritium breeding material with neutronic shielding and neutron multiplying and cooling performances in nuclear fusion components: i.e., the database need is generated by fusion reactor designers.

The database of nuclear functional material is wide and extensive going from:

[1] structural properties (melting point, density, surface tension, ...),
[2] thermo-physical (thermal conductivity, Heat capacities, viscosity, ...),
[3] electric and magnetic properties (electrical conductivity, ... Curie´s point, LLE diamagnetic properties and hysteresis, ...),
[4] physico-chemical as tritium and helium transport,
[5] nuclear properties, etc.

In this case the expertise of the Industrial subcontractor should demonstrate:

1) knowledge of the material as functional material when managing database inputs and material uses and capability to set up checking and quality criteria
2) knowledge and expertise of the set of certified standardized experimental techniques feeding with values the properties in the database
3) a technical capability to establish the set of commercial or R&D equipments supporting QA data.

Pilars 2 and 3 endorse the so-called Full Qualification Plan for the Material (FQPM), e.g., the for LLE-forms characterization standards that keep pending of Industrial Production Routes for a FPQP (Full Production and Qualification Plan).

Some of those properties in the database (e.g., tritium solubility) of the material could be classified as Safety-in-class Properties (SIP). It means that the use of the correct or non-correct values could have nuclear safety impact. In this sense, it can be argued how the database and its management should have also QA and standardization requirements to be faced (Pilar 4).

A QA-managed material database should:

- establish criteria to include, validate or reject data inputs for a given property and
- manage uncertainties of data points.

The QA in (Pilar 4) should face:

4.1.	- Establish criteria to validate data inputs wit uncertainties of data points in the functional database of the materials

In this case the expertise of an Industrial subcontractor should demonstrate (4.1) technical capacity.

5.3. Proving expertise on 6Li market and LLE-forms demands

The consideration of Li(6) as "Defense and Dual-Use Material" entails Nuclear Safeguards and Production, Inventory and Export Controls under EURATOM Treaty frame. This fact adds special logistical and safety difficulties for its industrial use, and this is a regulatory aspect that must be faced by International Projects as ITER.

First part of any material procurement plan to be undertaken by a bidder requires the assessment of the market demands to size production needs.

The reference amount of 6Li to be industrially produced for ITER could be roughly estimated to be in the range of few hundred of kgs. of 6Li (assessment capacity to be demonstrated by Industrial Supplier and agreed with contractor for ITER and DEMO). These values result challenging.

Today Li(6) could be found in the market from a short list of providers offering amounts in the range of tens of grams at high nominal costs (600 €/10 grams). The linear scaling of such nominal costs to TBM demands would represent a significant fraction of TBMs Program budget.

There are currently no known guarantees of industrial supply or known capacity supply capable of providing Li(6) in these quantities.

Qualified bidders should proof knowledge of 6Li market as dual-use material in terms of material availability (in the EU and worldwide) and industrial capabilities to face the expected demands in ITER.

Some of those techniques are naturally scalable to hundred kgs required in an industrial production, other techniques not.

The required industrial expertise for the bidder should proof documental capacity to select in a rationally justified mode the scalable techniques serving for such industrial scale production.

In addition, industrial expertise on 6Li production should be justified in order to propose prospectively a manufacturing route for 6Li, including at minimum the conceptual design based on the selected techniques and an experimental Plan to qualify the scalability of the technique as a key point of the 6LLE material Procurement Plan

In this context, the Industrial subcontractor should proof capability to establish a manufacturing or a procurement route for large amounts of 6Li: where to acquire or how to produce and how to deliver, in the frame of a special regulatory framework.

Assuring the needed amounts of 6Li materials includes several Industrial competencies to be requested to a potential bidder:

5.1.	- Be capable to assess with precision the 6Li demands from the 6LLE material needs (ITER TBM)
5.2	- Be able to proof knowledge on the set of experimental techniques to produce 6Li from natural lithium both at laboratory and at scalable industrial range
5.3	- Be able to demonstrate technical capacity to justify the selection of the most suitable industrial technique to produce large amounts of 6Li in terms of technology availability and nominal costs
5.4	- Proof R&D or Industrial experience on Conceptual Design of devices to produce 6Li at industrial scale.
5.5	- Show proven knowledge on the 6Li Regulatory frame for manufacturing and exports EU and National Regulations, in force (as *INFCIRC/254/Rev.10/Part 2a, 11th May 2017 and amendments*)

Some extra QA isotopic issues should be considered for 6Li as alloying element, e.g. how to certify 6Li, specific impurity limits, etc.

5.4. Proving expertise to generate LLE-forms (LLE, 6LLE) Material Production and Qualification Plan (MPQP)

Li(6) availability is a pre-requisite for 6LLE manufacturing at the required nominal enrichments. All along this decade, LLE-forms should be manufactured for different purposes. Natural LLE will be needed for coming experimental campaign previous to ITER TBM and for the first EM TBM. The enriched forms of LLE (e.g., 6LLE) will be required at the nuclear phases of TBM (-N, -TT, -IN) and future DEMO Breeding Blankets. It is not precluded some direct needs of small amounts 6LLE material for some testing before tritium phases in ITER.

Similar safeguards and Regulations come into force for the enriched 6LLE than for 6Li so they should be also taken into consideration for 6LLE production and transportation.

As for the case of 6Li, the first part of any material procurement plan to be undertaken by a bidder requires the assessment of the market demands to size production needs of LLE and 6LLE.

Once the 6Li availability be assured as an alloying element for 6LLE production, there are four historic basic routes that have been proposed and experienced at laboratory and semi-industrial scales to manufacture LLE:

- Alloying at a VIM furnace under controlled atmosphere (Ar)
- Alloying by MHD stirrers (controlling atmosphere or not)
- Alloy mixing by forced convection melting
- Powder metallurgy routes (powder cryo-grinding in Ar)

The required industrial expertise for the bidder should proof documental knowledge of the different alloying techniques to select in a rationally justified mode the industrial manufacturing route to be confronted to the required QA of the material (Pilars 1-4)

In addition, industrial expertise should be proven as a capacity to select a reliable a manufacturing route and should include proofs of the expertise on the conceptual design of an Industrial Alloying Unit 6LLE. It is assumed as a key step of the 6LLE Material Procurement Plan.

Assuring such step means several Industrial competences to be requested to a potential bidder:

6.1.	- Be capable to assess the scale of the demands for LLE and 6LLE (ITER TBM)
6.2	- Be able to proof knowledge on the LLE manufacturing routes and techniques to justify rationally the most suitable industrial technique to produce LLE-forms
6.3	- Proof R&D or Industrial experience on Conceptual and Engineering Detailed Design of devices to produce LLE at industrial scale.
6.4	- Proof of facing an Industrial Development Plan for LLE-forms manufacturing

5.5. Proving capabilities to manufacture material batches facing QA

The real capabilities of the Industrial bidder to face the future larger 6LLE industrial procurements should be practically proven in the short-term. It may be used as a technological test in order to minimize Program risks related with material procurements.

To do so, the last proof of capabilities should face a short-scale demonstration trials of batches but facing the complete and exhaustive QA tests (Pilars 1-3) using the manufacturing route previously proposed.

Capabilities to demonstrate batch trials production capacity according to the QA should be proven by the Industrial bidder.

The commitment of the bidder to place 6LLE batches should be favorable scored.

To do so, i.e., to assure such demonstration the Industrial bidder should be able to manufacture LLE-forms (6LLE not precluded) trial batches (out of laboratory range) in its selected form (6.4) and to qualify them following procedures and set of QA protocols in Pilars (1-3).

To this purpose, a network of nominated Laboratory and Testing Services should be configured and tentatively proposed. Finally, the industrial trial serves as a practical experience to face and to configure the settings of a scoping goal of integral Standardization for the Material Production and Characterization in the form of an ISO Norm, National Norm, etc.

So, the final set of ideal competencies required for the Industrial bidder would be:

7.1.	- Be capable to manufacture ^{N}LLE trial batches
7.2	- Be capable to manufacture ^{6}LLE trial batches.
7.3	- Be able to qualify them according to procedures and protocols in PILAR (1-3)
7.4	- Proof of experience to configure and manage a network of Laboratory and Testing Services
7.5	- Proof of experience to face undertaking towards ISO Norm, National Norms, etc.

5.6. Summary of subcontractor's competencies and expertise

The subcontractor must demostrate the following competences:

- LLE-forms Quality Assurance:
  - Documentary proven expertise on alloying elements (Li, Pb) and eutectic ingots handling procedure.
  - Capability to alloy within high-accuracy precision of the Li-title guaranteeing short-scale (micrometric) homogeneity.
  - Capability to face alloying issues controlling and certifying the level of impurities of LLE products.
  - Expertise on:
    - Knowledge of the material as functional material when managing database inputs and material uses and capability to set up checking and quality criteria
    - Knowledge and expertise of the set of certified standardized experimental techniques feeding with values the properties in the database
    - Technical capability to establish the set of commercial or R&D equipments supporting QA data.
    - Establishing criteria to validate data inputs wit uncertainties of data points in the functional database of the materials
- 6Li market and LLE-forms demands:
  - Knowledge of 6Li market as dual-use material in terms of material availability (in the EU and worldwide) and industrial capabilities to face the expected demands in ITER.
  - Capability to establish a manufacturing or a procurement route for large amounts of 6Li: where to acquire or how to produce and how to deliver, in the frame of a special regulatory framework.

- LLE-forms (LLE, 6LLE) Material Production and Qualification Plan (MPQP):
  - Knowledge of the different alloying techniques to select in a rationally justified mode the industrial manufacturing route to be confronted to the required QA of the material.
  - Capacity to select a reliable a manufacturing route and should include proofs of the expertise on the conceptual design of an Industrial Alloying Unit 6LLE.
- Manufacturing material batches facing QA:
  - Capabilities to demonstrate batch trials production capacity according to the QA.
  - The commitment of the subcontractor to place 6LLE batches should be favorable scored.
  - The subcontractor should be able to manufacture LLE-forms (6LLE not precluded) trial batches (out of laboratory range) in its selected form and to qualify them following procedures and set of QA protocols.