EUROPEAN COMMISSION
Directorate-General for Research and Innovation

RTD.I – Internal Support Services & Communication
I.3 – Financial Management & Program Support

GRANT AGREEMENT

Project 101165375 — CONNECT-NM

PREAMBLE

This **Agreement** ('the Agreement') is **between** the following parties:

on the one part,

the **European Atomic Energy Community** ('EC-Euratom'), represented by the European Commission ('European Commission' or 'granting authority'),

and

on the other part,

1. 'the coordinator':

CENTRO DE INVESTIGACIONES ENERGETICAS MEDIOAMBIENTALES Y TECNOLOGICAS (CIEMAT), PIC 999614877, established in AVENIDA COMPLUTENSE 40, MADRID 28040, Spain,

and the following other beneficiaries, if they sign their 'accession form' (see Annex 3 and Article 40):

2. **COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (CEA)**, PIC 999992401, established in RUE LEBLANC 25, PARIS 15 75015, France,

3. **HUN-REN ENERGIATUDOMANYI KUTATOKOZPONT (EK)**, PIC 954721919, established in KONKOLY THEGE MIKLOS UT 29-33, Budapest 1121, Hungary,

4. **CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS)**, PIC 999997930, established in RUE MICHEL ANGE 3, PARIS 75794, France,

5. **ALLIANCE EUROPEENNE DE RECHERCHE DANS LE DOMAINE DE L'ENERGIE (EERA)**, PIC 922059885, established in RUE DE NAMUR 72, BRUXELLES 1000, Belgium,

6. **AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE (ENEA)**, PIC 999988521, established in LUNGOTEVERE GRANDE AMMIRAGLIO THAON DI REVEL 76, ROMA 00196, Italy,

7. **EUROPEAN NUCLEAR EDUCATION NETWORK (ENEN)**, PIC 905630704, established in EGMONTSTRAAT 11, BRUSSEL 1000, Belgium,

8. **GESELLSCHAFT FUR ANLAGEN UND REAKTORSICHERHEIT (GRS) gGmbH (GRS)**, PIC 999460162, established in SCHWERTNERGASSE 1, KOLN 50667, Germany,

9. **RUDER BOSKOVIC INSTITUTE (RBI)**, PIC 999875031, established in Bijenicka cesta 54, ZAGREB 10000, Croatia,

10. **JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION (JRC)**, PIC 999992304, established in Rue de la Loi 200, BRUSSELS 1049, Belgium,

11. **INSTITUT JOZEF STEFAN (JSI)**, PIC 999971837, established in Jamova 39, LJUBLJANA 1000, Slovenia,

12. **NATIONAL SCIENCE CENTER KHARKOV INSTITUTE OF PHYSICS AND TECHNOLOGY (NSC KIPT)**, PIC 969818320, established in ACADEMICHNA STREET 1, KHARKIV 61108, Ukraine,

13. **KARLSRUHER INSTITUT FUER TECHNOLOGIE (KIT)**, PIC 990797674, established in KAISERSTRASSE 12, KARLSRUHE 76131, Germany,

14. **NARODOWE CENTRUM BADAN JADROWYCH (NCBJ)**, PIC 999506722, established in ULICA ANDRZEJA SOLTANA 7, OTWOCK 05 400, Poland,

15. **NUCLEAR RESEARCH AND CONSULTANCY GROUP (NRG)**, PIC 999514579, established in WESTERDUINWEG 3, PETTEN 1755 LE, Netherlands,

16. **REGIA AUTONOMA TEHNOLOGII PENTRU ENERGIA NUCLEARA - RATEN (RATEN)**, PIC 949436777, established in STRADA CAMPULUI 1, MIOVENI 115400, Romania,

17. **SUSTAINABLE NUCLEAR ENERGY TECHNOLOGY PLATFORM (SNETP)**, PIC 952482189, established in AVENUE DES ARTS 58, BRUXELLES 1000, Belgium,

18. **STRALSAKERHETSMYNDIGHETEN (SSM)**, PIC 993882080, established in SOLNA STRANDVAG 96, STOCKHOLM 171 16, Sweden,

19. **SLOVENSKA TECHNICKA UNIVERZITA V BRATISLAVE (STUBA)**, PIC 999868823, established in VAZOVOVA 5, BRATISLAVA 81243, Slovakia,

20. **TEKNOLOGIAN TUTKIMUSKESKUS VTT OY (VTT)**, PIC 932760440, established in TEKNIIKANTIE 21, ESPOO 02150, Finland,

Unless otherwise specified, references to ‘beneficiary’ or ‘beneficiaries’ include the coordinator and affiliated entities (if any).

If only one beneficiary signs the grant agreement (‘mono-beneficiary grant’), all provisions referring to the ‘coordinator’ or the ‘beneficiaries’ will be considered — mutatis mutandis — as referring to the beneficiary.

The parties referred to above have agreed to enter into the Agreement.

By signing the Agreement and the accession forms, the beneficiaries accept the grant and agree to implement the action under their own responsibility and in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

The Agreement is composed of:

Preamble

Terms and Conditions (including Data Sheet)

Annex 1 Description of the action[1]

Annex 2 Estimated budget for the action

Annex 2a Additional information on unit costs and contributions (if applicable)

Annex 3 Accession forms (if applicable)[2]

Annex 3a Declaration on joint and several liability of affiliated entities (if applicable)[3]

Annex 4 Model for the financial statements

Annex 5 Specific rules (if applicable)

[1] Template published on Portal Reference Documents.
[2] Template published on Portal Reference Documents.
[3] Template published on Portal Reference Documents.

TERMS AND CONDITIONS

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CHAPTER 1 GENERAL

ARTICLE 1 — SUBJECT OF THE AGREEMENT

This Agreement sets out the rights and obligations and terms and conditions applicable to the grant awarded for the implementation of the action set out in Chapter 2.

ARTICLE 2 — DEFINITIONS

For the purpose of this Agreement, the following definitions apply:

Actions — The project which is being funded in the context of this Agreement.

Grant — The grant awarded in the context of this Agreement.

EU grants — Grants awarded by EU institutions, bodies, offices or agencies (including EU executive agencies, EU regulatory agencies, EDA, joint undertakings, etc.).

Participants — Entities participating in the action as beneficiaries, affiliated entities, associated partners, third parties giving in-kind contributions, subcontractors or recipients of financial support to third parties.

Beneficiaries (BEN) — The signatories of this Agreement (either directly or through an accession form).

Affiliated entities (AE) — Entities affiliated to a beneficiary within the meaning of Article 187 of EU Financial Regulation 2018/1046[4] which participate in the action with similar rights and obligations as the beneficiaries (obligation to implement action tasks and right to charge costs and claim contributions).

Associated partners (AP) — Entities which participate in the action, but without the right to charge costs or claim contributions.

Purchases — Contracts for goods, works or services needed to carry out the action (e.g. equipment, consumables and supplies) but which are not part of the action tasks (see Annex 1).

Subcontracting — Contracts for goods, works or services that are part of the action tasks (see Annex 1).

In-kind contributions — In-kind contributions within the meaning of Article 2(36) of EU Financial

[4] For the definition, see Article 187 Regulation (EU, Euratom) 2018/1046 of the European Parliament and of the Council of 18 July 2018 on the financial rules applicable to the general budget of the Union, amending Regulations (EU) No 1296/2013, (EU) No 1301/2013, (EU) No 1303/2013, (EU) No 1304/2013, (EU) No 1309/2013, (EU) No 1316/2013, (EU) No 223/2014, (EU) No 283/2014, and Decision No 541/2014/EU and repealing Regulation (EU, Euratom) No 966/2012 ('EU Financial Regulation') (OJ L 193, 30.7.2018, p. 1): "**affiliated entities** [are]:
(a) entities that form a sole beneficiary [(i.e. where an entity is formed of several entities that satisfy the criteria for being awarded a grant, including where the entity is specifically established for the purpose of implementing an action to be financed by a grant)];
(b) entities that satisfy the eligibility criteria and that do not fall within one of the situations referred to in Article 136(1) and 141(1) and that have a link with the beneficiary, in particular a legal or capital link, which is neither limited to the action nor established for the sole purpose of its implementation".

Regulation 2018/1046, i.e. non-financial resources made available free of charge by third parties.

Fraud — Fraud within the meaning of Article 3 of EU Directive 2017/1371[5] and Article 1 of the Convention on the protection of the European Communities' financial interests, drawn up by the Council Act of 26 July 1995[6], as well as any other wrongful or criminal deception intended to result in financial or personal gain.

Irregularities — Any type of breach (regulatory or contractual) which could impact the EU financial interests, including irregularities within the meaning of Article 1(2) of EU Regulation 2988/95[7].

Grave professional misconduct — Any type of unacceptable or improper behaviour in exercising one's profession, especially by employees, including grave professional misconduct within the meaning of Article 136(1)(c) of EU Financial Regulation 2018/1046.

Applicable EU, international and national law — Any legal acts or other (binding or non-binding) rules and guidance in the area concerned.

Portal — EU Funding & Tenders Portal; electronic portal and exchange system managed by the European Commission and used by itself and other EU institutions, bodies, offices or agencies for the management of their funding programmes (grants, procurements, prizes, etc.).

CHAPTER 2 ACTION

ARTICLE 3 — ACTION

The grant is awarded for the action **101165375** — **CONNECT-NM** ('action'), as described in Annex 1.

ARTICLE 4 — DURATION AND STARTING DATE

The duration and the starting date of the action are set out in the Data Sheet (see Point 1).

CHAPTER 3 GRANT

ARTICLE 5 — GRANT

5.1 Form of grant

[5] Directive (EU) 2017/1371 of the European Parliament and of the Council of 5 July 2017 on the fight against fraud to the Union's financial interests by means of criminal law (OJ L 198, 28.7.2017, p. 29).

[6] OJ C 316, 27.11.1995, p. 48.

[7] Council Regulation (EC, Euratom) No 2988/95 of 18 December 1995 on the protection of the European Communities financial interests (OJ L 312, 23.12.1995, p. 1).

The grant is an action grant[8] which takes the form of a budget-based mixed actual cost grant (i.e. a grant based on actual costs incurred, but which may also include other forms of funding, such as unit costs or contributions, flat-rate costs or contributions, lump sum costs or contributions or financing not linked to costs).

5.2 Maximum grant amount

The maximum grant amount is set out in the Data Sheet (see Point 3) and in the estimated budget (Annex 2).

5.3 Funding rate

The funding rate for costs is 55% of the action's eligible costs.

Contributions are not subject to any funding rate.

5.4 Estimated budget, budget categories and forms of funding

The estimated budget for the action is set out in Annex 2.

It contains the estimated eligible costs and contributions for the action, broken down by participant and budget category.

Annex 2 also shows the types of costs and contributions (forms of funding)[9] to be used for each budget category.

If unit costs or contributions are used, the details on the calculation will be explained in Annex 2a.

5.5 Budget flexibility

The budget breakdown may be adjusted — without an amendment (see Article 39) — by transfers (between participants and budget categories), as long as this does not imply any substantive or important change to the description of the action in Annex 1.

However:

- changes to the budget category for volunteers (if used) always require an amendment
- changes to budget categories with lump sums costs or contributions (if used; including financing not linked to costs) always require an amendment
- changes to budget categories with higher funding rates or budget ceilings (if used) always require an amendment
- addition of amounts for subcontracts not provided for in Annex 1 either require an amendment or simplified approval in accordance with Article 6.2

[8] For the definition, see Article 180(2)(a) EU Financial Regulation 2018/1046: '**action grant**' means an EU grant to finance "an action intended to help achieve a Union policy objective".

[9] See Article 125 EU Financial Regulation 2018/1046.

- other changes require an amendment or simplified approval, if specifically provided for in Article 6.2

- flexibility caps: not applicable.

ARTICLE 6 — ELIGIBLE AND INELIGIBLE COSTS AND CONTRIBUTIONS

In order to be eligible, costs and contributions must meet the **eligibility** conditions set out in this Article.

6.1 General eligibility conditions

The **general eligibility conditions** are the following:

(a) for actual costs:

(i) they must be actually incurred by the beneficiary

(ii) they must be incurred in the period set out in Article 4 (with the exception of costs relating to the submission of the final periodic report, which may be incurred afterwards; see Article 21)

(iii) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2

(iv) they must be incurred in connection with the action as described in Annex 1 and necessary for its implementation

(v) they must be identifiable and verifiable, in particular recorded in the beneficiary's accounts in accordance with the accounting standards applicable in the country where the beneficiary is established and with the beneficiary's usual cost accounting practices

(vi) they must comply with the applicable national law on taxes, labour and social security and

(vii) they must be reasonable, justified and must comply with the principle of sound financial management, in particular regarding economy and efficiency

(b) for unit costs or contributions (if any):

(i) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2

(ii) the units must:

- be actually used or produced by the beneficiary in the period set out in Article 4 (with the exception of units relating to the submission of the final periodic report, which may be used or produced afterwards; see Article 21)

- be necessary for the implementation of the action and

(iii) the number of units must be identifiable and verifiable, in particular supported by records and documentation (see Article 20)

(c) for flat-rate costs or contributions (if any):

(i) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2

(ii) the costs or contributions to which the flat-rate is applied must:

- be eligible
- relate to the period set out in Article 4 (with the exception of costs or contributions relating to the submission of the final periodic report, which may be incurred afterwards; see Article 21)

(d) for lump sum costs or contributions (if any):

(i) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2

(ii) the work must be properly implemented by the beneficiary in accordance with Annex 1

(iii) the deliverables/outputs must be achieved in the period set out in Article 4 (with the exception of deliverables/outputs relating to the submission of the final periodic report, which may be achieved afterwards; see Article 21)

(e) for unit, flat-rate or lump sum costs or contributions according to usual cost accounting practices (if any):

(i) they must fulfil the general eligibility conditions for the type of cost concerned

(ii) the cost accounting practices must be applied in a consistent manner, based on objective criteria, regardless of the source of funding

(f) for financing not linked to costs (if any): the results must be achieved or the conditions must be fulfilled as described in Annex 1.

In addition, for direct cost categories (e.g. personnel, travel & subsistence, subcontracting and other direct costs) only costs that are directly linked to the action implementation and can therefore be attributed to it directly are eligible. They must not include any indirect costs (i.e. costs that are only indirectly linked to the action, e.g. via cost drivers).

In-kind contributions provided by third parties free of charge may be declared as eligible direct costs by the beneficiaries which use them (under the same conditions as if they were their own, provided that they concern only direct costs and that the third parties and their in-kind contributions are set out in Annex 1 (or approved ex post in the periodic report, if their use does not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants; 'simplified approval procedure').

6.2 Specific eligibility conditions for each budget category

For each budget category, the **specific eligibility conditions** are as follows:

Direct costs

A. Personnel costs

A.1 Costs for employees (or equivalent) are eligible as personnel costs if they fulfil the general eligibility conditions and are related to personnel working for the beneficiary under an employment contract (or equivalent appointing act) and assigned to the action.

They must be limited to salaries (including net payments during parental leave), social security contributions, taxes and other costs linked to the remuneration, if they arise from national law or the employment contract (or equivalent appointing act) and be calculated on the basis of the costs actually incurred, in accordance with the following method:

{daily rate for the person

multiplied by

number of day-equivalents worked on the action (rounded up or down to the nearest half-day)}.

The daily rate must be calculated as:

{annual personnel costs for the person

divided by

215}.

The number of day-equivalents declared for a person must be identifiable and verifiable (see Article 20).

The actual time spent on parental leave by a person assigned to the action may be deducted from the 215 days indicated in the above formula.

The total number of day-equivalents declared in EU grants, for a person for a year, cannot be higher than 215, minus time spent on parental leave (if any).

For personnel which receives supplementary payments for work in projects (project-based remuneration), the personnel costs must be calculated at a rate which:

- corresponds to the actual remuneration costs paid by the beneficiary for the time worked by the person in the action over the reporting period
- does not exceed the remuneration costs paid by the beneficiary for work in similar projects funded by national schemes (‘national projects reference’)
- is defined based on objective criteria allowing to determine the amount to which the person is entitled

and

- reflects the usual practice of the beneficiary to pay consistently bonuses or supplementary payments for work in projects funded by national schemes.

The national projects reference is the remuneration defined in national law, collective labour agreement or written internal rules of the beneficiary applicable to work in projects funded by national schemes.

If there is no such national law, collective labour agreement or written internal rules or if the project-

based remuneration is not based on objective criteria, the national project reference will be the average remuneration of the person in the last full calendar year covered by the reporting period, excluding remuneration paid for work in EU actions.

If the beneficiary uses average personnel costs (unit cost according to usual cost accounting practices), the personnel costs must fulfil the general eligibility conditions for such unit costs and the daily rate must be calculated:

- using the actual personnel costs recorded in the beneficiary's accounts and excluding any costs which are ineligible or already included in other budget categories; the actual personnel costs may be adjusted on the basis of budgeted or estimated elements, if they are relevant for calculating the personnel costs, reasonable and correspond to objective and verifiable information

and

- according to usual cost accounting practices which are applied in a consistent manner, based on objective criteria, regardless of the source of funding.

A.2 and **A.3 Costs for natural persons working under a direct contract** other than an employment contract and costs for **seconded persons by a third party against payment** are also eligible as personnel costs, if they are assigned to the action, fulfil the general eligibility conditions and:

(a) work under conditions similar to those of an employee (in particular regarding the way the work is organised, the tasks that are performed and the premises where they are performed) and

(b) the result of the work belongs to the beneficiary (unless agreed otherwise).

They must be calculated on the basis of a rate which corresponds to the costs actually incurred for the direct contract or secondment and must not be significantly different from those for personnel performing similar tasks under an employment contract with the beneficiary.

A.4 The work of **SME owners** for the action (i.e. owners of beneficiaries that are small and medium-sized enterprises[10] not receiving a salary) or **natural person beneficiaries** (i.e. beneficiaries that are natural persons not receiving a salary) may be declared as personnel costs, if they fulfil the general eligibility conditions and are calculated as unit costs in accordance with the method set out in Annex 2a.

B. Subcontracting costs

Subcontracting costs for the action (including related duties, taxes and charges, such as non-deductible or non-refundable value added tax (VAT)) are eligible, if they are calculated on the basis

[10] For the definition, see Commission Recommendation 2003/361/EC: micro, small or medium-sized enterprise (SME) are enterprises

- engaged in an economic activity, irrespective of their legal form (including, in particular, self- employed persons and family businesses engaged in craft or other activities, and partnerships or associations regularly engaged in an economic activity) and

- employing fewer than 250 persons (expressed in 'annual working units' as defined in Article 5 of the Recommendation) and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million.

of the costs actually incurred, fulfil the general eligibility conditions and are awarded using the beneficiary's usual purchasing practices — provided these ensure subcontracts with best value for money (or if appropriate the lowest price) and that there is no conflict of interests (see Article 12).

Beneficiaries that are 'contracting authorities/entities' within the meaning of the EU Directives on public procurement must also comply with the applicable national law on public procurement.

Subcontracting may cover only a limited part of the action.

The tasks to be subcontracted and the estimated cost for each subcontract must be set out in Annex 1 and the total estimated costs of subcontracting per beneficiary must be set out in Annex 2 (or may be approved ex post in the periodic report, if the use of subcontracting does not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants; 'simplified approval procedure').

C. Purchase costs

Purchase costs for the action (including related duties, taxes and charges, such as non-deductible or non-refundable value added tax (VAT)) are eligible if they fulfil the general eligibility conditions and are bought using the beneficiary's usual purchasing practices — provided these ensure purchases with best value for money (or if appropriate the lowest price) and that there is no conflict of interests (see Article 12).

Beneficiaries that are 'contracting authorities/entities' within the meaning of the EU Directives on public procurement must also comply with the applicable national law on public procurement.

C.1 Travel and subsistence

Purchases for **travel, accommodation** and **subsistence** must be calculated as follows:

- travel: on the basis of the costs actually incurred and in line with the beneficiary's usual practices on travel
- accommodation: on the basis of the costs actually incurred and in line with the beneficiary's usual practices on travel
- subsistence: on the basis of the costs actually incurred and in line with the beneficiary's usual practices on travel .

C.2 Equipment

Purchases of **equipment, infrastructure or other assets** used for the action must be declared as depreciation costs, calculated on the basis of the costs actually incurred and written off in accordance with international accounting standards and the beneficiary's usual accounting practices.

Only the portion of the costs that corresponds to the rate of actual use for the action during the action duration can be taken into account.

Costs for **renting or leasing** equipment, infrastructure or other assets are also eligible, if they do not exceed the depreciation costs of similar equipment, infrastructure or assets and do not include any financing fees.

C.3 Other goods, works and services

Purchases of **other goods, works and services** must be calculated on the basis of the costs actually incurred.

Such goods, works and services include, for instance, consumables and supplies, promotion, dissemination, protection of results, translations, publications, certificates and financial guarantees, if required under the Agreement.

D. Other cost categories

D.1 Financial support to third parties

Costs for providing financial support to third parties (in the form of **grants, prizes** or similar forms of support; if any) are eligible, if and as declared eligible in the call conditions, if they fulfil the general eligibility conditions, are calculated on the basis of the costs actually incurred and the support is implemented in accordance with the conditions set out in Annex 1.

These conditions must ensure objective and transparent selection procedures and include at least the following:

(a) for grants (or similar):

(i) the maximum amount of financial support for each third party ('recipient'); this amount may not exceed the amount set out in the Data Sheet (see Point 3) or otherwise agreed with the granting authority

(ii) the criteria for calculating the exact amount of the financial support

(iii) the different types of activity that qualify for financial support, on the basis of a closed list

(iv) the persons or categories of persons that will be supported and

(v) the criteria and procedures for giving financial support

(b) for prizes (or similar):

(i) the eligibility and award criteria

(ii) the amount of the prize and

(iii) the payment arrangements.

This cost will not be taken into account for the indirect cost flat-rate.

D.2 Internally invoiced goods and services

Costs for internally invoiced goods and services directly used for the action may be declared as unit cost according to usual cost accounting practices, if and as declared eligible in the call conditions, if they fulfil the general eligibility conditions for such unit costs and the amount per unit is calculated:

- using the actual costs for the good or service recorded in the beneficiary's accounts, attributed either by direct measurement or on the basis of cost drivers, and excluding any cost which

are ineligible or already included in other budget categories; the actual costs may be adjusted on the basis of budgeted or estimated elements, if they are relevant for calculating the costs, reasonable and correspond to objective and verifiable information

and

- according to usual cost accounting practices which are applied in a consistent manner, based on objective criteria, regardless of the source of funding.

'Internally invoiced goods and services' means goods or services which are provided within the beneficiary's organisation directly for the action and which the beneficiary values on the basis of its usual cost accounting practices.

This cost will not be taken into account for the indirect cost flat-rate.

D.6 Euratom Cofund staff mobility costs

Euratom Cofund staff mobility costs are eligible, if and as declared eligible in the call conditions, if they fulfil the general eligibility conditions and are calculated as unit cost in accordance with the method set out in Annex 2a.

This cost will not be taken into account for the indirect cost flat-rate.

Indirect costs

E. Indirect costs

Indirect costs will be reimbursed at the flat-rate of 25% of the eligible direct costs (categories A-D, except volunteers costs, subcontracting costs, financial support to third parties and exempted specific cost categories, if any).

Contributions

Not applicable

6.3 Ineligible costs and contributions

The following costs or contributions are **ineligible**:

(a) costs or contributions that do not comply with the conditions set out above (Article 6.1 and 6.2), in particular:

(i) costs related to return on capital and dividends paid by a beneficiary

(ii) debt and debt service charges

(iii) provisions for future losses or debts

(iv) interest owed

(v) currency exchange losses

(vi) bank costs charged by the beneficiary's bank for transfers from the granting authority

(vii) excessive or reckless expenditure

(viii) deductible or refundable VAT (including VAT paid by public bodies acting as public authority)

(ix) costs incurred or contributions for activities implemented during grant agreement suspension (see Article 31)

(x) in-kind contributions by third parties: not applicable

(b) costs or contributions declared under other EU grants (or grants awarded by an EU Member State, non-EU country or other body implementing the EU budget), except for the following cases:

(i) Synergy actions: not applicable

(ii) if the action grant is combined with an operating grant[11] running during the same period and the beneficiary can demonstrate that the operating grant does not cover any (direct or indirect) costs of the action grant

(c) costs or contributions for staff of a national (or regional/local) administration, for activities that are part of the administration's normal activities (i.e. not undertaken only because of the grant)

(d) costs or contributions (especially travel and subsistence) for staff or representatives of EU institutions, bodies or agencies

(e) other :

(i) country restrictions for eligible costs: not applicable

(ii) costs or contributions declared specifically ineligible in the call conditions.

6.4 Consequences of non-compliance

If a beneficiary declares costs or contributions that are ineligible, they will be rejected (see Article 27).

This may also lead to other measures described in Chapter 5.

CHAPTER 4 GRANT IMPLEMENTATION

SECTION 1 CONSORTIUM: BENEFICIARIES, AFFILIATED ENTITIES AND OTHER PARTICIPANTS

ARTICLE 7 — BENEFICIARIES

[11] For the definition, see Article 180(2)(b) of EU Financial Regulation 2018/1046: '**operating grant**' means an EU grant to finance "the functioning of a body which has an objective forming part of and supporting an EU policy".

The beneficiaries, as signatories of the Agreement, are fully responsible towards the granting authority for implementing it and for complying with all its obligations.

They must implement the Agreement to their best abilities, in good faith and in accordance with all the obligations and terms and conditions it sets out.

They must have the appropriate resources to implement the action and implement the action under their own responsibility and in accordance with Article 11. If they rely on affiliated entities or other participants (see Articles 8 and 9), they retain sole responsibility towards the granting authority and the other beneficiaries.

They are jointly responsible for the *technical* implementation of the action. If one of the beneficiaries fails to implement their part of the action, the other beneficiaries must ensure that this part is implemented by someone else (without being entitled to an increase of the maximum grant amount and subject to an amendment; see Article 39). The *financial* responsibility of each beneficiary in case of recoveries is governed by Article 22.

The beneficiaries (and their action) must remain eligible under the EU programme funding the grant for the entire duration of the action. Costs and contributions will be eligible only as long as the beneficiary and the action are eligible.

The **internal roles and responsibilities** of the beneficiaries are divided as follows:

(a) Each beneficiary must:

(i) keep information stored in the Portal Participant Register up to date (see Article 19)

(ii) inform the granting authority (and the other beneficiaries) immediately of any events or circumstances likely to affect significantly or delay the implementation of the action (see Article 19)

(iii) submit to the coordinator in good time:

- the prefinancing guarantees (if required; see Article 23)
- the financial statements and certificates on the financial statements (CFS) (if required; see Articles 21 and 24.2 and Data Sheet, Point 4.3)
- the contribution to the deliverables and technical reports (see Article 21)
- any other documents or information required by the granting authority under the Agreement

(iv) submit via the Portal data and information related to the participation of their affiliated entities.

(b) The coordinator must:

(i) monitor that the action is implemented properly (see Article 11)

(ii) act as the intermediary for all communications between the consortium and the granting authority, unless the Agreement or granting authority specifies otherwise, and in particular:

- submit the prefinancing guarantees to the granting authority (if any)
- request and review any documents or information required and verify their quality and completeness before passing them on to the granting authority
- submit the deliverables and reports to the granting authority
- inform the granting authority about the payments made to the other beneficiaries (report on the distribution of payments; if required, see Articles 22 and 32)

(iii) distribute the payments received from the granting authority to the other beneficiaries without unjustified delay (see Article 22).

The coordinator may not delegate or subcontract the above-mentioned tasks to any other beneficiary or third party (including affiliated entities).

However, coordinators which are public bodies may delegate the tasks set out in Point (b)(ii) last indent and (iii) above to entities with 'authorisation to administer' which they have created or which are controlled by or affiliated to them. In this case, the coordinator retains sole responsibility for the payments and for compliance with the obligations under the Agreement.

Moreover, coordinators which are 'sole beneficiaries'[12] (or similar, such as European research infrastructure consortia (ERICs)) may delegate the tasks set out in Point (b)(i) to (iii) above to one of their members. The coordinator retains sole responsibility for compliance with the obligations under the Agreement.

The beneficiaries must have **internal arrangements** regarding their operation and co-ordination, to ensure that the action is implemented properly.

If required by the granting authority (see Data Sheet, Point 1), these arrangements must be set out in a written **consortium agreement** between the beneficiaries, covering for instance:

- the internal organisation of the consortium
- the management of access to the Portal
- different distribution keys for the payments and financial responsibilities in case of recoveries (if any)
- additional rules on rights and obligations related to background and results (see Article 16)
- settlement of internal disputes
- liability, indemnification and confidentiality arrangements between the beneficiaries.

The internal arrangements must not contain any provision contrary to this Agreement.

ARTICLE 8 — AFFILIATED ENTITIES

[12] For the definition, see Article 187(2) EU Financial Regulation 2018/1046: "Where several entities satisfy the criteria for being awarded a grant and together form one entity, that entity may be treated as the **sole beneficiary**, including where it is specifically established for the purpose of implementing the action financed by the grant."

The following entities which are linked to a beneficiary will participate in the action as 'affiliated entities':

- **UNIVERSIDAD POLITECNICA DE MADRID (UPM)**, PIC 999974844, linked to CENTRO DE INVESTIGACIONES ENERGETICAS MEDIOAMBIENTALES Y TECNOLOGICAS (CIEMAT)

- **ELECTRICITE DE FRANCE (EDF)**, PIC 999926829, linked to COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (CEA)

- **FRAMATOME (FRAMATOME)**, PIC 905291883, linked to COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (CEA)

- **INSTITUT DE RADIOPROTECTION ET DE SURETE NUCLEAIRE (IRSN)**, PIC 999480726, linked to COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (CEA)

- **CENTRALE LILLE INSTITUT (CENTRALE LILLE)**, PIC 999878038, linked to CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS)

- **CENTRUM VYZKUMU REZ SRO (CVR)**, PIC 996153820, linked to ALLIANCE EUROPEENNE DE RECHERCHE DANS LE DOMAINE DE L'ENERGIE (EERA)

- **FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV (Fraunhofer)**, PIC 999984059, linked to ALLIANCE EUROPEENNE DE RECHERCHE DANS LE DOMAINE DE L'ENERGIE (EERA)

- **METAPROJECTS ETS (METAPROJECTS)**, PIC 880385484, linked to AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE (ENEA)

- **NEWCLEO SRL (newcleo)**, PIC 880414390, linked to AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE (ENEA)

- **SINTEC SRL (SINTEC SRL)**, PIC 991688037, linked to AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE (ENEA)

- **ALMA MATER STUDIORUM - UNIVERSITA DI BOLOGNA (UNIBO)**, PIC 999993953, linked to AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE (ENEA)

- **POLITECNICO DI MILANO (POLIMI)**, PIC 999879881, linked to AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE (ENEA)

- **BUNDESANSTALT FUER MATERIALFORSCHUNG UND -PRUEFUNG (BAM)**, PIC 999507692, linked to GESELLSCHAFT FUR ANLAGEN UND REAKTORSICHERHEIT (GRS) gGmbH (GRS)

- **ZAVOD ZA GRADBENISTVO SLOVENIJE (ZAG Ljubljana)**, PIC 999527092, linked to INSTITUT JOZEF STEFAN (JSI)
- **LIMITED LIABILITY COMPANY ENERGORISK (LLC ENERGORISK)**, PIC 936233622, linked to NATIONAL SCIENCE CENTER KHARKOV INSTITUTE OF PHYSICS AND TECHNOLOGY (NSC KIPT)
- **HELMHOLTZ-ZENTRUM DRESDEN-ROSSENDORF EV (HZDR)**, PIC 999470541, linked to KARLSRUHER INSTITUT FUER TECHNOLOGIE (KIT)
- **CHALMERS TEKNISKA HOGSKOLA AB (CHALMERS)**, PIC 999980373, linked to STRALSAKERHETSMYNDIGHETEN (SSM)
- **KUNGLIGA TEKNISKA HOEGSKOLAN (KTH)**, PIC 999990946, linked to STRALSAKERHETSMYNDIGHETEN (SSM)
- **HELSINGIN YLIOPISTO (HY)**, PIC 999994535, linked to TEKNOLOGIAN TUTKIMUSKESKUS VTT OY (VTT)

Affiliated entities can charge costs and contributions to the action under the same conditions as the beneficiaries and must implement the action tasks attributed to them in Annex 1 in accordance with Article 11.

Their costs and contributions will be included in Annex 2 and will be taken into account for the calculation of the grant.

The beneficiaries must ensure that all their obligations under this Agreement also apply to their affiliated entities.

The beneficiaries must ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the affiliated entities.

Breaches by affiliated entities will be handled in the same manner as breaches by beneficiaries. Recovery of undue amounts will be handled through the beneficiaries.

If the granting authority requires joint and several liability of affiliated entities (see Data Sheet, Point 4.4), they must sign the declaration set out in Annex 3a and may be held liable in case of enforced recoveries against their beneficiaries (see Article 22.2 and 22.4).

ARTICLE 9 — OTHER PARTICIPANTS INVOLVED IN THE ACTION

9.1 Associated partners

The following entities which cooperate with a beneficiary will participate in the action as ‘associated partners’:

- **NATIONAL NUCLEAR LABORATORY LIMITED (NNL)**, PIC 999757952
- **MIDDLE EAST TECHNICAL UNIVERSITY (METU)**, PIC 999643492
- **PAUL SCHERRER INSTITUT (PSI)**, PIC 999994923

- **UNITED KINGDOM ATOMIC ENERGY AUTHORITY (CCFE)**, PIC 998811911

Associated partners must implement the action tasks attributed to them in Annex 1 in accordance with Article 11. They may not charge costs or contributions to the action and the costs for their tasks are not eligible.

The tasks must be set out in Annex 1.

The beneficiaries must ensure that their contractual obligations under Articles 11 (proper implementation), 12 (conflict of interests), 13 (confidentiality and security), 14 (ethics), 17.2 (visibility), 18 (specific rules for carrying out action), 19 (information) and 20 (record-keeping) also apply to the associated partners.

The beneficiaries must ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the associated partners.

9.2 Third parties giving in-kind contributions to the action

Other third parties may give in-kind contributions to the action (i.e. personnel, equipment, other goods, works and services, etc. which are free-of-charge) if necessary for the implementation.

Third parties giving in-kind contributions do not implement any action tasks. They may not charge costs or contributions to the action, but the costs for the in-kind contributions are eligible and may be charged by the beneficiaries which use them, under the conditions set out in Article 6. The costs will be included in Annex 2 as part of the beneficiaries' costs.

The third parties and their in-kind contributions should be set out in Annex 1.

The beneficiaries must ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the third parties giving in-kind contributions.

9.3 Subcontractors

Subcontractors may participate in the action, if necessary for the implementation.

Subcontractors must implement their action tasks in accordance with Article 11. The costs for the subcontracted tasks (invoiced price from the subcontractor) are eligible and may be charged by the beneficiaries, under the conditions set out in Article 6. The costs will be included in Annex 2 as part of the beneficiaries' costs.

The beneficiaries must ensure that their contractual obligations under Articles 11 (proper implementation), 12 (conflict of interest), 13 (confidentiality and security), 14 (ethics), 17.2 (visibility), 18 (specific rules for carrying out action), 19 (information) and 20 (record-keeping) also apply to the subcontractors.

The beneficiaries must ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the subcontractors.

9.4 Recipients of financial support to third parties

If the action includes providing financial support to third parties (e.g. grants, prizes or similar forms of

support), the beneficiaries must ensure that their contractual obligations under Articles 12 (conflict of interest), 13 (confidentiality and security), 14 (ethics), 17.2 (visibility), 18 (specific rules for carrying out action), 19 (information) and 20 (record-keeping)also apply to the third parties receiving the support (recipients).

The beneficiaries must also ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the recipients.

ARTICLE 10 — PARTICIPANTS WITH SPECIAL STATUS

10.1 Non-EU participants

Participants which are established in a non-EU country (if any) undertake to comply with their obligations under the Agreement and:

- to respect general principles (including fundamental rights, values and ethical principles, environmental and labour standards, rules on classified information, intellectual property rights, visibility of funding and protection of personal data)

- for the submission of certificates under Article 24: to use qualified external auditors which are independent and comply with comparable standards as those set out in EU Directive 2006/43/EC[13]

- for the controls under Article 25: to allow for checks, reviews, audits and investigations (including on-the-spot checks, visits and inspections) by the bodies mentioned in that Article (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.).

Special rules on dispute settlement apply (see Data Sheet, Point 5).

10.2 Participants which are international organisations

Participants which are international organisations (IOs; if any) undertake to comply with their obligations under the Agreement and:

- to respect general principles (including fundamental rights, values and ethical principles, environmental and labour standards, rules on classified information, intellectual property rights, visibility of funding and protection of personal data)

- for the submission of certificates under Article 24: to use either independent public officers or external auditors which comply with comparable standards as those set out in EU Directive 2006/43/EC

- for the controls under Article 25: to allow for the checks, reviews, audits and investigations by the bodies mentioned in that Article, taking into account the specific agreements concluded by them and the EU (if any).

For such participants, nothing in the Agreement will be interpreted as a waiver of their privileges or immunities, as accorded by their constituent documents or international law.

[13] Directive 2006/43/EC of the European Parliament and of the Council of 17 May 2006 on statutory audits of annual accounts and consolidated accounts or similar national regulations (OJ L 157, 9.6.2006, p. 87).

Special rules on applicable law and dispute settlement apply (see Article 43 and Data Sheet, Point 5).

10.3 Pillar-assessed participants

Pillar-assessed participants (if any) may rely on their own systems, rules and procedures, in so far as they have been positively assessed and do not call into question the decision awarding the grant or breach the principle of equal treatment of applicants or beneficiaries.

'Pillar-assessment' means a review by the European Commission on the systems, rules and procedures which participants use for managing EU grants (in particular internal control system, accounting system, external audits, financing of third parties, rules on recovery and exclusion, information on recipients and protection of personal data; see Article 154 EU Financial Regulation 2018/1046).

Participants with a positive pillar assessment may rely on their own systems, rules and procedures, in particular for:

- record-keeping (Article 20): may be done in accordance with internal standards, rules and procedures
- currency conversion for financial statements (Article 21): may be done in accordance with usual accounting practices
- guarantees (Article 23): for public law bodies, prefinancing guarantees are not needed
- certificates (Article 24):
    - certificates on the financial statements (CFS): may be provided by their regular internal or external auditors and in accordance with their internal financial regulations and procedures
    - certificates on usual accounting practices (CoMUC): are not needed if those practices are covered by an ex-ante assessment

and use the following specific rules, for:

- recoveries (Article 22): in case of financial support to third parties, there will be no recovery if the participant has done everything possible to retrieve the undue amounts from the third party receiving the support (including legal proceedings) and non-recovery is not due to an error or negligence on its part
- checks, reviews, audits and investigations by the EU (Article 25): will be conducted taking into account the rules and procedures specifically agreed between them and the framework agreement (if any)
- impact evaluation (Article 26): will be conducted in accordance with the participant's internal rules and procedures and the framework agreement (if any)
- grant agreement suspension (Article 31): certain costs incurred during grant suspension are eligible (notably, minimum costs necessary for a possible resumption of the action and costs relating to contracts which were entered into before the pre-information letter was received and which could not reasonably be suspended, reallocated or terminated on legal grounds)

- grant agreement termination (Article 32): the final grant amount and final payment will be calculated taking into account also costs relating to contracts due for execution only after termination takes effect, if the contract was entered into before the pre-information letter was received and could not reasonably be terminated on legal grounds

- liability for damages (Article 33.2): the granting authority must be compensated for damage it sustains as a result of the implementation of the action or because the action was not implemented in full compliance with the Agreement only if the damage is due to an infringement of the participant's internal rules and procedures or due to a violation of third parties' rights by the participant or one of its employees or individual for whom the employees are responsible.

Participants whose pillar assessment covers procurement and granting procedures may also do purchases, subcontracting and financial support to third parties (Article 6.2) in accordance with their internal rules and procedures for purchases, subcontracting and financial support.

Participants whose pillar assessment covers data protection rules may rely on their internal standards, rules and procedures for data protection (Article 15).

The participants may however not rely on provisions which would breach the principle of equal treatment of applicants or beneficiaries or call into question the decision awarding the grant, such as in particular:

- eligibility (Article 6)

- consortium roles and set-up (Articles 7-9)

- security and ethics (Articles 13, 14)

- IPR (including background and results, access rights and rights of use), communication, dissemination and visibility (Articles 16 and 17)

- information obligation (Article 19)

- payment, reporting and amendments (Articles 21, 22 and 39)

- rejections, reductions, suspensions and terminations (Articles 27, 28, 29-32)

If the pillar assessment was subject to remedial measures, reliance on the internal systems, rules and procedures is subject to compliance with those remedial measures.

Participants whose assessment has not yet been updated to cover (the new rules on) data protection may rely on their internal systems, rules and procedures, provided that they ensure that personal data is:

- processed lawfully, fairly and in a transparent manner in relation to the data subject

- collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes

- adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed

- accurate and, where necessary, kept up to date

- kept in a form which permits identification of data subjects for no longer than is necessary for the purposes for which the data is processed and

- processed in a manner that ensures appropriate security of the personal data.

Participants must inform the coordinator without delay of any changes to the systems, rules and procedures that were part of the pillar assessment. The coordinator must immediately inform the granting authority.

Pillar-assessed participants that have also concluded a framework agreement with the EU, may moreover — under the same conditions as those above (i.e. not call into question the decision awarding the grant or breach the principle of equal treatment of applicants or beneficiaries) — rely on the provisions set out in that framework agreement.

SECTION 2 RULES FOR CARRYING OUT THE ACTION

ARTICLE 11 — PROPER IMPLEMENTATION OF THE ACTION

11.1 Obligation to properly implement the action

The beneficiaries must implement the action as described in Annex 1 and in compliance with the provisions of the Agreement, the call conditions and all legal obligations under applicable EU, international and national law.

11.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 12 — CONFLICT OF INTERESTS

12.1 Conflict of interests

The beneficiaries must take all measures to prevent any situation where the impartial and objective implementation of the Agreement could be compromised for reasons involving family, emotional life, political or national affinity, economic interest or any other direct or indirect interest (‘conflict of interests’).

They must formally notify the granting authority without delay of any situation constituting or likely to lead to a conflict of interests and immediately take all the necessary steps to rectify this situation.

The granting authority may verify that the measures taken are appropriate and may require additional measures to be taken by a specified deadline.

12.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28) and the grant or the beneficiary may be terminated (see Article 32).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 13 — CONFIDENTIALITY AND SECURITY

13.1 Sensitive information

The parties must keep confidential any data, documents or other material (in any form) that is identified as sensitive in writing ('sensitive information') — during the implementation of the action and for at least until the time-limit set out in the Data Sheet (see Point 6).

If a beneficiary requests, the granting authority may agree to keep such information confidential for a longer period.

Unless otherwise agreed between the parties, they may use sensitive information only to implement the Agreement.

The beneficiaries may disclose sensitive information to their personnel or other participants involved in the action only if they:

(a) need to know it in order to implement the Agreement and

(b) are bound by an obligation of confidentiality.

The granting authority may disclose sensitive information to its staff and to other EU institutions and bodies.

It may moreover disclose sensitive information to third parties, if:

(a) this is necessary to implement the Agreement or safeguard the EU financial interests and

(b) the recipients of the information are bound by an obligation of confidentiality.

The confidentiality obligations no longer apply if:

(a) the disclosing party agrees to release the other party

(b) the information becomes publicly available, without breaching any confidentiality obligation

(c) the disclosure of the sensitive information is required by EU, international or national law.

Specific confidentiality rules (if any) are set out in Annex 5.

13.2 Classified information

The parties must handle classified information in accordance with the applicable EU, international or national law on classified information (in particular, Decision 2015/444[14] and its implementing rules).

Deliverables which contain classified information must be submitted according to special procedures agreed with the granting authority.

[14] Commission Decision 2015/444/EC, Euratom of 13 March 2015 on the security rules for protecting EU classified information (OJ L 72, 17.3.2015, p. 53).

Action tasks involving classified information may be subcontracted only after explicit approval (in writing) from the granting authority.

Classified information may not be disclosed to any third party (including participants involved in the action implementation) without prior explicit written approval from the granting authority.

Specific security rules (if any) are set out in Annex 5.

13.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 14 — ETHICS AND VALUES

14.1 Ethics

The action must be carried out in line with the highest ethical standards and the applicable EU, international and national law on ethical principles.

Specific ethics rules (if any) are set out in Annex 5.

14.2 Values

The beneficiaries must commit to and ensure the respect of basic EU values (such as respect for human dignity, freedom, democracy, equality, the rule of law and human rights, including the rights of minorities).

Specific rules on values (if any) are set out in Annex 5.

14.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 15 — DATA PROTECTION

15.1 Data processing by the granting authority

Any personal data under the Agreement will be processed under the responsibility of the data controller of the granting authority in accordance with and for the purposes set out in the Portal Privacy Statement.

For grants where the granting authority is the European Commission, an EU regulatory or executive agency, joint undertaking or other EU body, the processing will be subject to Regulation 2018/1725[15].

[15] Regulation (EU) 2018/1725 of the European Parliament and of the Council of 23 October 2018 on the protection of natural persons with regard to the processing of personal data by the Union institutions, bodies, offices and agencies

15.2 Data processing by the beneficiaries

The beneficiaries must process personal data under the Agreement in compliance with the applicable EU, international and national law on data protection (in particular, Regulation 2016/679[16]).

They must ensure that personal data is:

- processed lawfully, fairly and in a transparent manner in relation to the data subjects
- collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes
- adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed
- accurate and, where necessary, kept up to date
- kept in a form which permits identification of data subjects for no longer than is necessary for the purposes for which the data is processed and
- processed in a manner that ensures appropriate security of the data.

The beneficiaries may grant their personnel access to personal data only if it is strictly necessary for implementing, managing and monitoring the Agreement. The beneficiaries must ensure that the personnel is under a confidentiality obligation.

The beneficiaries must inform the persons whose data are transferred to the granting authority and provide them with the Portal Privacy Statement.

15.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 16 — INTELLECTUAL PROPERTY RIGHTS (IPR) — BACKGROUND AND RESULTS —ACCESS RIGHTS AND RIGHTS OF USE

16.1 Background and access rights to background

The beneficiaries must give each other and the other participants access to the background identified as needed for implementing the action, subject to any specific rules in Annex 5.

'Background' means any data, know-how or information — whatever its form or nature (tangible or intangible), including any rights such as intellectual property rights — that is:

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and on the free movement of such data, and repealing Regulation (EC) No 45/2001 and Decision No 1247/2002/EC (OJ L 295, 21.11.2018, p. 39).

[16] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC ('GDPR') (OJ L 119, 4.5.2016, p. 1).

(a) held by the beneficiaries before they acceded to the Agreement and

(b) needed to implement the action or exploit the results.

If background is subject to rights of a third party, the beneficiary concerned must ensure that it is able to comply with its obligations under the Agreement.

16.2 Ownership of results

The granting authority does not obtain ownership of the results produced under the action.

'Results' means any tangible or intangible effect of the action, such as data, know-how or information, whatever its form or nature, whether or not it can be protected, as well as any rights attached to it, including intellectual property rights.

16.3 Rights of use of the granting authority on materials, documents and information received for policy, information, communication, dissemination and publicity purposes

The granting authority has the right to use non-sensitive information relating to the action and materials and documents received from the beneficiaries (notably summaries for publication, deliverables, as well as any other material, such as pictures or audio-visual material, in paper or electronic form) for policy, information, communication, dissemination and publicity purposes — during the action or afterwards.

The right to use the beneficiaries' materials, documents and information is granted in the form of a royalty-free, non-exclusive and irrevocable licence, which includes the following rights:

(a) **use for its own purposes** (in particular, making them available to persons working for the granting authority or any other EU service (including institutions, bodies, offices, agencies, etc.) or EU Member State institution or body; copying or reproducing them in whole or in part, in unlimited numbers; and communication through press information services)

(b) **distribution to the public** (in particular, publication as hard copies and in electronic or digital format, publication on the internet, as a downloadable or non-downloadable file, broadcasting by any channel, public display or presentation, communicating through press information services, or inclusion in widely accessible databases or indexes)

(c) **editing or redrafting** (including shortening, summarising, inserting other elements (e.g. meta-data, legends, other graphic, visual, audio or text elements), extracting parts (e.g. audio or video files), dividing into parts, use in a compilation)

(d) **translation**

(e) **storage** in paper, electronic or other form

(f) **archiving**, in line with applicable document-management rules

(g) the right to authorise **third parties** to act on its behalf or sub-license to third parties the modes of use set out in Points (b), (c), (d) and (f), if needed for the information, communication and publicity activity of the granting authority

(h) **processing**, analysing, aggregating the materials, documents and information received and **producing derivative works**.

The rights of use are granted for the whole duration of the industrial or intellectual property rights concerned.

If materials or documents are subject to moral rights or third party rights (including intellectual property rights or rights of natural persons on their image and voice), the beneficiaries must ensure that they comply with their obligations under this Agreement (in particular, by obtaining the necessary licences and authorisations from the rights holders concerned).

Where applicable, the granting authority will insert the following information:

"© – [year] – [name of the copyright owner]. All rights reserved. Licensed to the [name of granting authority] under conditions."

16.4 Specific rules on IPR, results and background

Specific rules regarding intellectual property rights, results and background (if any) are set out in Annex 5.

16.5 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such a breach may also lead to other measures described in Chapter 5.

ARTICLE 17 — COMMUNICATION, DISSEMINATION AND VISIBILITY

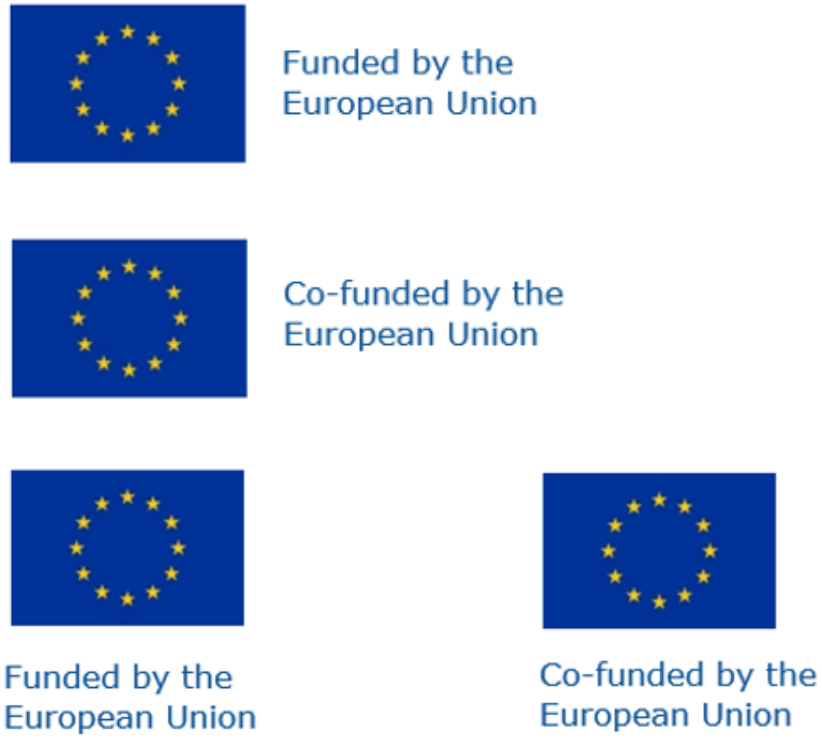
17.1 Communication — Dissemination — Promoting the action

Unless otherwise agreed with the granting authority, the beneficiaries must promote the action and its results by providing targeted information to multiple audiences (including the media and the public), in accordance with Annex 1 and in a strategic, coherent and effective manner.

Before engaging in a communication or dissemination activity expected to have a major media impact, the beneficiaries must inform the granting authority.

17.2 Visibility — European flag and funding statement

Unless otherwise agreed with the granting authority, communication activities of the beneficiaries related to the action (including media relations, conferences, seminars, information material, such as brochures, leaflets, posters, presentations, etc., in electronic form, via traditional or social media, etc.), dissemination activities and any infrastructure, equipment, vehicles, supplies or major result funded by the grant must acknowledge EU support and display the European flag (emblem) and funding statement (translated into local languages, where appropriate):



The emblem must remain distinct and separate and cannot be modified by adding other visual marks, brands or text.

Apart from the emblem, no other visual identity or logo may be used to highlight the EU support.

When displayed in association with other logos (e.g. of beneficiaries or sponsors), the emblem must be displayed at least as prominently and visibly as the other logos.

For the purposes of their obligations under this Article, the beneficiaries may use the emblem without first obtaining approval from the granting authority. This does not, however, give them the right to exclusive use. Moreover, they may not appropriate the emblem or any similar trademark or logo, either by registration or by any other means.

17.3 Quality of information — Disclaimer

Any communication or dissemination activity related to the action must use factually accurate information.

Moreover, it must indicate the following disclaimer (translated into local languages where appropriate):

> "Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or [name of the granting authority]. Neither the European Union nor the granting authority can be held responsible for them."

17.4 Specific communication, dissemination and visibility rules

Specific communication, dissemination and visibility rules (if any) are set out in Annex 5.

17.5 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 18 — SPECIFIC RULES FOR CARRYING OUT THE ACTION

18.1 Specific rules for carrying out the action

Specific rules for implementing the action (if any) are set out in Annex 5.

18.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such a breach may also lead to other measures described in Chapter 5.

SECTION 3 GRANT ADMINISTRATION

ARTICLE 19 — GENERAL INFORMATION OBLIGATIONS

19.1 Information requests

The beneficiaries must provide — during the action or afterwards and in accordance with Article 7 — any information requested in order to verify eligibility of the costs or contributions declared, proper implementation of the action and compliance with the other obligations under the Agreement.

The information provided must be accurate, precise and complete and in the format requested, including electronic format.

19.2 Participant Register data updates

The beneficiaries must keep — at all times, during the action or afterwards — their information stored in the Portal Participant Register up to date, in particular, their name, address, legal representatives, legal form and organisation type.

19.3 Information about events and circumstances which impact the action

The beneficiaries must immediately inform the granting authority (and the other beneficiaries) of any of the following:

(a) **events** which are likely to affect or delay the implementation of the action or affect the EU's financial interests, in particular:

(i) changes in their legal, financial, technical, organisational or ownership situation (including changes linked to one of the exclusion grounds listed in the declaration of honour signed before grant signature)

(ii) linked action information: not applicable

(b) **circumstances** affecting:

(i) the decision to award the grant or

(ii) compliance with requirements under the Agreement.

19.4 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 20 — RECORD-KEEPING

20.1 Keeping records and supporting documents

The beneficiaries must — at least until the time-limit set out in the Data Sheet (see Point 6) — keep records and other supporting documents to prove the proper implementation of the action in line with the accepted standards in the respective field (if any).

In addition, the beneficiaries must — for the same period — keep the following to justify the amounts declared:

(a) for actual costs: adequate records and supporting documents to prove the costs declared (such as contracts, subcontracts, invoices and accounting records); in addition, the beneficiaries' usual accounting and internal control procedures must enable direct reconciliation between the amounts declared, the amounts recorded in their accounts and the amounts stated in the supporting documents

(b) for flat-rate costs and contributions (if any): adequate records and supporting documents to prove the eligibility of the costs or contributions to which the flat-rate is applied

(c) for the following simplified costs and contributions: the beneficiaries do not need to keep specific records on the actual costs incurred, but must keep:

(i) for unit costs and contributions (if any): adequate records and supporting documents to prove the number of units declared

(ii) for lump sum costs and contributions (if any): adequate records and supporting documents to prove proper implementation of the work as described in Annex 1

(iii) for financing not linked to costs (if any): adequate records and supporting documents to prove the achievement of the results or the fulfilment of the conditions as described in Annex 1

(d) for unit, flat-rate and lump sum costs and contributions according to usual cost accounting practices (if any): the beneficiaries must keep any adequate records and supporting documents to prove that their cost accounting practices have been applied in a consistent manner, based on objective criteria, regardless of the source of funding, and that they comply with the eligibility conditions set out in Articles 6.1 and 6.2.

Moreover, the following is needed for specific budget categories:

(e) for personnel costs: time worked for the beneficiary under the action must be supported by declarations signed monthly by the person and their supervisor, unless another reliable time-record system is in place; the granting authority may accept alternative evidence supporting the time worked for the action declared, if it considers that it offers an adequate level of assurance

(f) additional record-keeping rules: not applicable

The records and supporting documents must be made available upon request (see Article 19) or in the context of checks, reviews, audits or investigations (see Article 25).

If there are on-going checks, reviews, audits, investigations, litigation or other pursuits of claims under the Agreement (including the extension of findings; see Article 25), the beneficiaries must keep these records and other supporting documentation until the end of these procedures.

The beneficiaries must keep the original documents. Digital and digitalised documents are considered originals if they are authorised by the applicable national law. The granting authority may accept non-original documents if they offer a comparable level of assurance.

20.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, costs or contributions insufficiently substantiated will be ineligible (see Article 6) and will be rejected (see Article 27), and the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 21 — REPORTING

21.1 Continuous reporting

The beneficiaries must continuously report on the progress of the action (e.g. **deliverables, milestones, outputs/outcomes, critical risks, indicators,** etc; if any), in the Portal Continuous Reporting tool and in accordance with the timing and conditions it sets out (as agreed with the granting authority).

Standardised deliverables (e.g. progress reports not linked to payments, reports on cumulative expenditure, special reports, etc; if any) must be submitted using the templates published on the Portal.

21.2 Periodic reporting: Technical reports and financial statements

In addition, the beneficiaries must provide reports to request payments, in accordance with the schedule and modalities set out in the Data Sheet (see Point 4.2):

- for additional prefinancings (if any): an **additional prefinancing report**
- for interim payments (if any) and the final payment: a **periodic report**.

The prefinancing and periodic reports include a technical and financial part.

The technical part includes an overview of the action implementation. It must be prepared using the template available in the Portal Periodic Reporting tool.

The financial part of the additional prefinancing report includes a statement on the use of the previous prefinancing payment.

The financial part of the periodic report includes:

- the financial statements (individual and consolidated; for all beneficiaries/affiliated entities)
- the explanation on the use of resources (or detailed cost reporting table, if required)
- the certificates on the financial statements (CFS) (if required; see Article 24.2 and Data Sheet, Point 4.3).

The **financial statements** must detail the eligible costs and contributions for each budget category and, for the final payment, also the revenues for the action (see Articles 6 and 22).

All eligible costs and contributions incurred should be declared, even if they exceed the amounts indicated in the estimated budget (see Annex 2). Amounts that are not declared in the individual financial statements will not be taken into account by the granting authority.

By signing the financial statements (directly in the Portal Periodic Reporting tool), the beneficiaries confirm that:

- the information provided is complete, reliable and true
- the costs and contributions declared are eligible (see Article 6)
- the costs and contributions can be substantiated by adequate records and supporting documents (see Article 20) that will be produced upon request (see Article 19) or in the context of checks, reviews, audits and investigations (see Article 25)
- for the final periodic report: all the revenues have been declared (if required; see Article 22).

Beneficiaries will have to submit also the financial statements of their affiliated entities (if any). In case of recoveries (see Article 22), beneficiaries will be held responsible also for the financial statements of their affiliated entities.

21.3 Currency for financial statements and conversion into euros

The financial statements must be drafted in euro.

Beneficiaries with general accounts established in a currency other than the euro must convert the costs recorded in their accounts into euro, at the average of the daily exchange rates published in the C series of the *Official Journal of the European Union* (ECB website), calculated over the corresponding reporting period.

If no daily euro exchange rate is published in the *Official Journal* for the currency in question, they must be converted at the average of the monthly accounting exchange rates published on the European Commission website (InforEuro), calculated over the corresponding reporting period.

Beneficiaries with general accounts in euro must convert costs incurred in another currency into euro according to their usual accounting practices.

21.4 Reporting language

The reporting must be in the language of the Agreement, unless otherwise agreed with the granting authority (see Data Sheet, Point 4.2).

21.5 Consequences of non-compliance

If a report submitted does not comply with this Article, the granting authority may suspend the payment deadline (see Article 29) and apply other measures described in Chapter 5.

If the coordinator breaches its reporting obligations, the granting authority may terminate the grant or the coordinator's participation (see Article 32) or apply other measures described in Chapter 5.

ARTICLE 22 — PAYMENTS AND RECOVERIES — CALCULATION OF AMOUNTS DUE

22.1 Payments and payment arrangements

Payments will be made in accordance with the schedule and modalities set out in the Data Sheet (see Point 4.2).

They will be made in euro to the bank account indicated by the coordinator (see Data Sheet, Point 4.2) and must be distributed without unjustified delay (restrictions may apply to distribution of the initial prefinancing payment; see Data Sheet, Point 4.2).

Payments to this bank account will discharge the granting authority from its payment obligation.

The cost of payment transfers will be borne as follows:

- the granting authority bears the cost of transfers charged by its bank
- the beneficiary bears the cost of transfers charged by its bank
- the party causing a repetition of a transfer bears all costs of the repeated transfer.

Payments by the granting authority will be considered to have been carried out on the date when they are debited to its account.

22.2 Recoveries

Recoveries will be made, if — at beneficiary termination, final payment or afterwards — it turns out that the granting authority has paid too much and needs to recover the amounts undue.

Each beneficiary's financial responsibility in case of recovery is in principle limited to their own debt and undue amounts of their affiliated entities.

In case of enforced recoveries (see Article 22.4), affiliated entities will be held liable for repaying debts of their beneficiaries, if required by the granting authority (see Data Sheet, Point 4.4).

22.3 Amounts due

22.3.1 Prefinancing payments

The aim of the prefinancing is to provide the beneficiaries with a float.

It remains the property of the EU until the final payment.

For **initial prefinancings** (if any), the amount due, schedule and modalities are set out in the Data Sheet (see Point 4.2).

For **additional prefinancings** (if any), the amount due, schedule and modalities are also set out in the Data Sheet (see Point 4.2). However, if the statement on the use of the previous prefinancing payment shows that less than 70% was used, the amount set out in the Data Sheet will be reduced by the difference between the 70% threshold and the amount used.

The contribution to the Mutual Insurance Mechanism will be retained from the prefinancing payments (at the rate and in accordance with the modalities set out in the Data Sheet, see Point 4.2) and transferred to the Mechanism.

Prefinancing payments (or parts of them) may be offset (without the beneficiaries' consent) against amounts owed by a beneficiary to the granting authority — up to the amount due to that beneficiary.

For grants where the granting authority is the European Commission or an EU executive agency, offsetting may also be done against amounts owed to other Commission services or executive agencies.

Payments will not be made if the payment deadline or payments are suspended (see Articles 29 and 30).

22.3.2 Amount due at beneficiary termination — Recovery

In case of beneficiary termination, the granting authority will determine the provisional amount due for the beneficiary concerned. Payments (if any) will be made with the next interim or final payment.

The **amount due** will be calculated in the following step:

Step 1 — Calculation of the total accepted EU contribution

Step 1 — Calculation of the total accepted EU contribution

The granting authority will first calculate the 'accepted EU contribution' for the beneficiary for all reporting periods, by calculating the 'maximum EU contribution to costs' (applying the funding rate to the accepted costs of the beneficiary), taking into account requests for a lower contribution to costs and CFS threshold cappings (if any; see Article 24.5) and adding the contributions (accepted unit, flat-rate or lump sum contributions and financing not linked to costs, if any).

After that, the granting authority will take into account grant reductions (if any). The resulting amount is the 'total accepted EU contribution' for the beneficiary.

The **balance** is then calculated by deducting the payments received (if any; see report on the distribution of payments in Article 32), from the total accepted EU contribution:

{total accepted EU contribution for the beneficiary

minus

{prefinancing and interim payments received (if any)}}.

If the balance is **positive**, the amount will be included in the next interim or final payment to the consortium.

If the balance is **negative**, it will be **recovered** in accordance with the following procedure:

The granting authority will send a **pre-information letter** to the beneficiary concerned:

- formally notifying the intention to recover, the amount due, the amount to be recovered and the reasons why and
- requesting observations within 30 days of receiving notification.

If no observations are submitted (or the granting authority decides to pursue recovery despite the observations it has received), it will confirm the amount to be recovered and ask this amount to be paid to the coordinator (**confirmation letter**).

If payment is not made to the coordinator by the date specified in the confirmation letter, the granting authority may call on the Mutual Insurance Mechanism to intervene, if continuation of the action is guaranteed and the conditions set out in the rules governing the Mechanism are met.

In this case, it will send a **beneficiary recovery letter**, together with a **debit note** with the terms and date for payment.

The debit note for the beneficiary will include the amount calculated for the affiliated entities which also had to end their participation (if any).

If payment is not made by the date specified in the debit note, the granting authority will **enforce recovery** in accordance with Article 22.4.

The amounts will later on also be taken into account for the next interim or final payment.

22.3.3 Interim payments

Interim payments reimburse the eligible costs and contributions claimed for the implementation of the action during the reporting periods (if any).

Interim payments (if any) will be made in accordance with the schedule and modalities set out the Data Sheet (see Point 4.2).

Payment is subject to the approval of the periodic report. Its approval does not imply recognition of compliance, authenticity, completeness or correctness of its content.

The **interim payment** will be calculated by the granting authority in the following steps:

Step 1 — Calculation of the total accepted EU contribution

Step 2 — Limit to the interim payment ceiling

Step 1 — Calculation of the total accepted EU contribution

The granting authority will calculate the 'accepted EU contribution' for the action for the reporting period, by first calculating the 'maximum EU contribution to costs' (applying the funding rate to the accepted costs of each beneficiary), taking into account requests for a lower contribution to costs, and CFS threshold cappings (if any; see Article 24.5) and adding the contributions (accepted unit, flat-rate or lump sum contributions and financing not linked to costs, if any).

After that, the granting authority will take into account grant reductions from beneficiary termination (if any). The resulting amount is the 'total accepted EU contribution'.

Step 2 — Limit to the interim payment ceiling

The resulting amount is then capped to ensure that the total amount of prefinancing and interim payments (if any) does not exceed the interim payment ceiling set out in the Data Sheet (see Point 4.2).

Interim payments (or parts of them) may be offset (without the beneficiaries' consent) against amounts owed by a beneficiary to the granting authority — up to the amount due to that beneficiary.

For grants where the granting authority is the European Commission or an EU executive agency, offsetting may also be done against amounts owed to other Commission services or executive agencies.

Payments will not be made if the payment deadline or payments are suspended (see Articles 29 and 30).

22.3.4 Final payment — Final grant amount — Revenues and Profit — Recovery

The final payment (payment of the balance) reimburses the remaining part of the eligible costs and contributions claimed for the implementation of the action (if any).

The final payment will be made in accordance with the schedule and modalities set out in the Data Sheet (see Point 4.2).

Payment is subject to the approval of the final periodic report. Its approval does not imply recognition of compliance, authenticity, completeness or correctness of its content.

The **final grant amount for the action** will be calculated in the following steps:

Step 1 — Calculation of the total accepted EU contribution

Step 2 — Limit to the maximum grant amount

Step 3 — Reduction due to the no-profit rule

Step 1 — Calculation of the total accepted EU contribution

The granting authority will first calculate the 'accepted EU contribution' for the action for all reporting periods, by calculating the 'maximum EU contribution to costs' (applying the funding rate to the total accepted costs of each beneficiary), taking into account requests for a lower contribution to costs, CFS threshold cappings (if any; see Article 24.5) and adding the contributions (accepted unit, flat-rate or lump sum contributions and financing not linked to costs, if any).

After that, the granting authority will take into account grant reductions (if any). The resulting amount is the 'total accepted EU contribution'.

Step 2 — Limit to the maximum grant amount

If the resulting amount is higher than the maximum grant amount set out in Article 5.2, it will be limited to the latter.

Step 3 — Reduction due to the no-profit rule

If the no-profit rule is provided for in the Data Sheet (see Point 4.2), the grant must not produce a profit (i.e. surplus of the amount obtained following Step 2 plus the action's revenues, over the eligible costs and contributions approved by the granting authority).

'Revenue' is all income generated by the action, during its duration (see Article 4), for beneficiaries that are profit legal entities (— with the exception of income generated by the exploitation of results, which are not considered as revenues).

If there is a profit, it will be deducted in proportion to the final rate of reimbursement of the eligible costs approved by the granting authority (as compared to the amount calculated following Steps 1 and 2 minus the contributions).

The **balance** (final payment) is then calculated by deducting the total amount of prefinancing and interim payments already made (if any), from the final grant amount:

{final grant amount

minus

{prefinancing and interim payments made (if any)}}.

If the balance is **positive**, it will be **paid** to the coordinator.

The amount retained for the Mutual Insurance Mechanism (see above) will be released and **paid** to the coordinator (in accordance with the rules governing the Mechanism).

The final payment (or part of it) may be offset (without the beneficiaries' consent) against amounts owed by a beneficiary to the granting authority — up to the amount due to that beneficiary.

For grants where the granting authority is the European Commission or an EU executive agency, offsetting may also be done against amounts owed to other Commission services or executive agencies.

Payments will not be made if the payment deadline or payments are suspended (see Articles 29 and 30).

If — despite the release of the Mutual Insurance Mechanism contribution — the balance is **negative**, it will be **recovered** in accordance with the following procedure:

The granting authority will send a **pre-information letter** to the coordinator:

- formally notifying the intention to recover, the final grant amount, the amount to be recovered and the reasons why

- requesting a report on the distribution of payments to the beneficiaries within 30 days of receiving notification and

- requesting observations within 30 days of receiving notification.

If no observations are submitted (or the granting authority decides to pursue recovery despite the observations it has received) and the coordinator has submitted the report on the distribution of payments, it will calculate the **share of the debt per beneficiary**, by:

(a) identifying the beneficiaries for which the amount calculated as follows is negative:

{{{total accepted EU contribution for the beneficiary

divided by

total accepted EU contribution for the action}

multiplied by

final grant amount for the action},

minus

{prefinancing and interim payments received by the beneficiary (if any)}}

and

(b) dividing the debt:

{{amount calculated according to point (a) for the beneficiary concerned

divided by

the sum of the amounts calculated according to point (a) for all the beneficiaries identified according to point (a)}

multiplied by

the amount to be recovered}.

and confirm the amount to be recovered from each beneficiary concerned (**confirmation letter**), together with **debit notes** with the terms and date for payment.

The debit notes for beneficiaries will include the amounts calculated for their affiliated entities (if any).

If the coordinator has not submitted the report on the distribution of payments, the granting authority will **recover** the full amount from the coordinator (**confirmation letter** and **debit note** with the terms and date for payment).

If payment is not made by the date specified in the debit note, the granting authority will **enforce recovery** in accordance with Article 22.4.

22.3.5 Audit implementation after final payment — Revised final grant amount — Recovery

If — after the final payment (in particular, after checks, reviews, audits or investigations; see Article 25) — the granting authority rejects costs or contributions (see Article 27) or reduces the grant (see Article 28), it will calculate the **revised final grant amount** for the beneficiary concerned.

The **beneficiary revised final grant amount** will be calculated in the following step:

Step 1 — Calculation of the revised total accepted EU contribution

Step 1 — Calculation of the revised total accepted EU contribution

The granting authority will first calculate the 'revised accepted EU contribution' for the beneficiary, by calculating the 'revised accepted costs' and 'revised accepted contributions'.

After that, it will take into account grant reductions (if any). The resulting 'revised total accepted EU contribution' is the beneficiary revised final grant amount.

If the revised final grant amount is lower than the beneficiary's final grant amount (i.e. its share in the final grant amount for the action), it will be **recovered** in accordance with the following procedure:

The **beneficiary final grant amount** (i.e. share in the final grant amount for the action) is calculated as follows:

{{total accepted EU contribution for the beneficiary

divided by

total accepted EU contribution for the action}

multiplied by

final grant amount for the action}.

The granting authority will send a **pre-information letter** to the beneficiary concerned:

- formally notifying the intention to recover, the amount to be recovered and the reasons why and
- requesting observations within 30 days of receiving notification.

If no observations are submitted (or the granting authority decides to pursue recovery despite the observations it has received), it will confirm the amount to be recovered (**confirmation letter**), together with a **debit note** with the terms and the date for payment.

Recoveries against affiliated entities (if any) will be handled through their beneficiaries.

If payment is not made by the date specified in the debit note, the granting authority will **enforce recovery** in accordance with Article 22.4.

22.4 Enforced recovery

If payment is not made by the date specified in the debit note, the amount due will be recovered:

(a) by offsetting the amount — without the coordinator or beneficiary's consent — against any amounts owed to the coordinator or beneficiary by the granting authority.

In exceptional circumstances, to safeguard the EU financial interests, the amount may be offset before the payment date specified in the debit note.

For grants where the granting authority is the European Commission or an EU executive

agency, debts may also be offset against amounts owed by other Commission services or executive agencies.

(b) financial guarantee(s): not applicable

(c) joint and several liability of beneficiaries: not applicable

(d) by holding affiliated entities jointly and severally liable (if any, see Data Sheet, Point 4.4)

(e) by taking legal action (see Article 43) or, provided that the granting authority is the European Commission or an EU executive agency, by adopting an enforceable decision under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 100(2) of EU Financial Regulation 2018/1046.

If the Mutual Insurance Mechanism was called on by the granting authority to intervene, recovery will be continued in the name of the Mutual Insurance Mechanism. If two debit notes were sent, the second one (in the name of the Mutual Insurance Mechanism) will be considered to replace the first one (in the name of the granting authority). Where the MIM intervened, offsetting, enforceable decisions or any other of the above-mentioned forms of enforced recovery may be used mutatis mutandis.

The amount to be recovered will be increased by **late-payment interest** at the rate set out in Article 22.5, from the day following the payment date in the debit note, up to and including the date the full payment is received.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2015/2366[17] applies.

For grants where the granting authority is an EU executive agency, enforced recovery by offsetting or enforceable decision will be done by the services of the European Commission (see also Article 43).

22.5 Consequences of non-compliance

22.5.1 If the granting authority does not pay within the payment deadlines (see above), the beneficiaries are entitled to **late-payment interest** at the rate applied by the European Central Bank (ECB) for its main refinancing operations in euros ('reference rate'), plus the rate specified in the Data Sheet (Point 4.2). The reference rate is the rate in force on the first day of the month in which the payment deadline expires, as published in the C series of the *Official Journal of the European Union*.

If the late-payment interest is lower than or equal to EUR 200, it will be paid to the coordinator only on request submitted within two months of receiving the late payment.

Late-payment interest is not due if all beneficiaries are EU Member States (including regional and local government authorities or other public bodies acting on behalf of a Member State for the purpose of this Agreement).

[17] Directive (EU) 2015/2366 of the European Parliament and of the Council of 25 November 2015 on payment services in the internal market, amending Directives 2002/65/EC, 2009/110/EC and 2013/36/EU and Regulation (EU) No 1093/2010, and repealing Directive 2007/64/EC (OJ L 337, 23.12.2015, p. 35).

If payments or the payment deadline are suspended (see Articles 29 and 30), payment will not be considered as late.

Late-payment interest covers the period running from the day following the due date for payment (see above), up to and including the date of payment.

Late-payment interest is not considered for the purposes of calculating the final grant amount.

22.5.2 If the coordinator breaches any of its obligations under this Article, the grant may be reduced (see Article 28) and the grant or the coordinator may be terminated (see Article 32).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 23 — GUARANTEES

Not applicable

ARTICLE 24 — CERTIFICATES

24.1 Operational verification report (OVR)

Not applicable

24.2 Certificate on the financial statements (CFS)

If required by the granting authority (see Data Sheet, Point 4.3), the beneficiaries must provide certificates on their financial statements (CFS), in accordance with the schedule, threshold and conditions set out in the Data Sheet.

The coordinator must submit them as part of the periodic report (see Article 21).

The certificates must be drawn up using the template published on the Portal, cover the costs declared on the basis of actual costs and costs according to usual cost accounting practices (if any), and fulfil the following conditions:

(a) be provided by a qualified approved external auditor which is independent and complies with Directive 2006/43/EC[18] (or for public bodies: by a competent independent public officer)

(b) the verification must be carried out according to the highest professional standards to ensure that the financial statements comply with the provisions under the Agreement and that the costs declared are eligible.

The certificates will not affect the granting authority's right to carry out its own checks, reviews or audits, nor preclude the European Court of Auditors (ECA), the European Public Prosecutor's Office (EPPO) or the European Anti-Fraud Office (OLAF) from using their prerogatives for audits and investigations under the Agreement (see Article 25).

If the costs (or a part of them) were already audited by the granting authority, these costs do not need to be covered by the certificate and will not be counted for calculating the threshold (if any).

[18] Directive 2006/43/EC of the European Parliament and of the Council of 17 May 2006 on statutory audits of annual accounts and consolidated accounts or similar national regulations (OJ L 157, 9.6.2006, p. 87).

24.3 Certificate on the compliance of usual cost accounting practices (CoMUC)

Not applicable

24.4 Systems and process audit (SPA)

Beneficiaries which:

- use unit, flat rate or lump sum costs or contributions according to documented (i.e. formally approved and in writing) usual costs accounting practices (if any) or
- have formalised documentation on the systems and processes for calculating their costs and contributions (i.e. formally approved and in writing), have participated in at least 150 actions under Horizon 2020 or the Euratom Research and Training Programme (2014-2018 or 2019-2020) and participate in at least 3 ongoing actions under Horizon Europe or the Euratom Research and Training Programme (2021-2025 or 2026-2027)

may apply to the granting authority for a systems and process audit (SPA).

This audit will be carried out as follows:

Step 1 – Application by the beneficiary.

Step 2 – If the application is accepted, the granting authority will carry out the systems and process audit, complemented by an audit of transactions (on a sample of the beneficiary's Horizon Europe or the Euratom Research and Training Programme financial statements).

Step 3 – The audit result will take the form of a risk assessment classification for the beneficiary: low, medium or high.

Low-risk beneficiaries will benefit from less (or less in-depth) ex-post audits (see Article 25) and a higher threshold for submitting certificates on the financial statements (CFS; see Articles 21 and 24.2 and Data Sheet, Point 4.3).

24.5 Consequences of non-compliance

If a beneficiary does not submit a certificate on the financial statements (CFS) or the certificate is rejected, the accepted EU contribution to costs will be capped to reflect the CFS threshold.

If a beneficiary breaches any of its other obligations under this Article, the granting authority may apply the measures described in Chapter 5.

ARTICLE 25 — CHECKS, REVIEWS, AUDITS AND INVESTIGATIONS — EXTENSION OF FINDINGS

25.1 Granting authority checks, reviews and audits

25.1.1 Internal checks

The granting authority may — during the action or afterwards — check the proper implementation of the action and compliance with the obligations under the Agreement, including assessing costs and contributions, deliverables and reports.

25.1.2 Project reviews

The granting authority may carry out reviews on the proper implementation of the action and compliance with the obligations under the Agreement (general project reviews or specific issues reviews).

Such project reviews may be started during the implementation of the action and until the time-limit set out in the Data Sheet (see Point 6). They will be formally notified to the coordinator or beneficiary concerned and will be considered to start on the date of the notification.

If needed, the granting authority may be assisted by independent, outside experts. If it uses outside experts, the coordinator or beneficiary concerned will be informed and have the right to object on grounds of commercial confidentiality or conflict of interest.

The coordinator or beneficiary concerned must cooperate diligently and provide — within the deadline requested — any information and data in addition to deliverables and reports already submitted (including information on the use of resources). The granting authority may request beneficiaries to provide such information to it directly. Sensitive information and documents will be treated in accordance with Article 13.

The coordinator or beneficiary concerned may be requested to participate in meetings, including with the outside experts.

For **on-the-spot visits**, the beneficiary concerned must allow access to sites and premises (including to the outside experts) and must ensure that information requested is readily available.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

On the basis of the review findings, a **project review report** will be drawn up.

The granting authority will formally notify the project review report to the coordinator or beneficiary concerned, which has 30 days from receiving notification to make observations.

Project reviews (including project review reports) will be in the language of the Agreement, unless otherwise agreed with the granting authority (see Data Sheet, Point 4.2).

25.1.3 Audits

The granting authority may carry out audits on the proper implementation of the action and compliance with the obligations under the Agreement.

Such audits may be started during the implementation of the action and until the time-limit set out in the Data Sheet (see Point 6). They will be formally notified to the beneficiary concerned and will be considered to start on the date of the notification.

The granting authority may use its own audit service, delegate audits to a centralised service or use external audit firms. If it uses an external firm, the beneficiary concerned will be informed and have the right to object on grounds of commercial confidentiality or conflict of interest.

The beneficiary concerned must cooperate diligently and provide — within the deadline requested — any information (including complete accounts, individual salary statements or other personal data)

to verify compliance with the Agreement. Sensitive information and documents will be treated in accordance with Article 13.

For **on-the-spot** visits, the beneficiary concerned must allow access to sites and premises (including for the external audit firm) and must ensure that information requested is readily available.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

On the basis of the audit findings, a **draft audit report** will be drawn up.

The auditors will formally notify the draft audit report to the beneficiary concerned, which has 30 days from receiving notification to make observations (contradictory audit procedure).

The **final audit report** will take into account observations by the beneficiary concerned and will be formally notified to them.

Audits (including audit reports) will be in the language of the Agreement, unless otherwise agreed with the granting authority (see Data Sheet, Point 4.2).

25.2 European Commission checks, reviews and audits in grants of other granting authorities

Where the granting authority is not the European Commission, the latter has the same rights of checks, reviews and audits as the granting authority.

25.3 Access to records for assessing simplified forms of funding

The beneficiaries must give the European Commission access to their statutory records for the periodic assessment of simplified forms of funding which are used in EU programmes.

25.4 OLAF, EPPO and ECA audits and investigations

The following bodies may also carry out checks, reviews, audits and investigations — during the action or afterwards:

- the European Anti-Fraud Office (OLAF) under Regulations No 883/2013[19] and No 2185/96[20]
- the European Public Prosecutor's Office (EPPO) under Regulation 2017/1939
- the European Court of Auditors (ECA) under Article 287 of the Treaty on the Functioning of the EU (TFEU) and Article 257 of EU Financial Regulation 2018/1046.

If requested by these bodies, the beneficiary concerned must provide full, accurate and complete information in the format requested (including complete accounts, individual salary statements or

[19] Regulation (EU, Euratom) No 883/2013 of the European Parliament and of the Council of 11 September 2013 concerning investigations conducted by the European Anti-Fraud Office (OLAF) and repealing Regulation (EC) No 1073/1999 of the European Parliament and of the Council and Council Regulation (Euratom) No 1074/1999 (OJ L 248, 18/09/2013, p. 1).

[20] Council Regulation (Euratom, EC) No 2185/96 of 11 November 1996 concerning on-the-spot checks and inspections carried out by the Commission in order to protect the European Communities' financial interests against fraud and other irregularities (OJ L 292, 15/11/1996, p. 2).

other personal data, including in electronic format) and allow access to sites and premises for on-the-spot visits or inspections — as provided for under these Regulations.

To this end, the beneficiary concerned must keep all relevant information relating to the action, at least until the time-limit set out in the Data Sheet (Point 6) and, in any case, until any ongoing checks, reviews, audits, investigations, litigation or other pursuits of claims have been concluded.

25.5 Consequences of checks, reviews, audits and investigations — Extension of results of reviews, audits or investigations

25.5.1 Consequences of checks, reviews, audits and investigations in this grant

Findings in checks, reviews, audits or investigations carried out in the context of this grant may lead to rejections (see Article 27), grant reduction (see Article 28) or other measures described in Chapter 5.

Rejections or grant reductions after the final payment will lead to a revised final grant amount (see Article 22).

Findings in checks, reviews, audits or investigations during the action implementation may lead to a request for amendment (see Article 39), to change the description of the action set out in Annex 1.

Checks, reviews, audits or investigations that find systemic or recurrent errors, irregularities, fraud or breach of obligations in any EU grant may also lead to consequences in other EU grants awarded under similar conditions (‘extension to other grants’).

Moreover, findings arising from an OLAF or EPPO investigation may lead to criminal prosecution under national law.

25.5.2 Extension from other grants

Results of checks, reviews, audits or investigations in other grants may be extended to this grant, if:

(a) the beneficiary concerned is found, in other EU grants awarded under similar conditions, to have committed systemic or recurrent errors, irregularities, fraud or breach of obligations that have a material impact on this grant and

(b) those findings are formally notified to the beneficiary concerned — together with the list of grants affected by the findings — within the time-limit for audits set out in the Data Sheet (see Point 6).

The granting authority will formally notify the beneficiary concerned of the intention to extend the findings and the list of grants affected.

If the extension concerns **rejections of costs or contributions**: the notification will include:

(a) an invitation to submit observations on the list of grants affected by the findings

(b) the request to submit revised financial statements for all grants affected

(c) the correction rate for extrapolation, established on the basis of the systemic or recurrent errors, to calculate the amounts to be rejected, if the beneficiary concerned:

(i) considers that the submission of revised financial statements is not possible or practicable or

(ii) does not submit revised financial statements.

If the extension concerns **grant reductions**: the notification will include:

(a) an invitation to submit observations on the list of grants affected by the findings and

(b) the **correction rate for extrapolation**, established on the basis of the systemic or recurrent errors and the principle of proportionality.

The beneficiary concerned has **60 days** from receiving notification to submit observations, revised financial statements or to propose a duly substantiated **alternative correction method/rate**.

On the basis of this, the granting authority will analyse the impact and decide on the implementation (i.e. start rejection or grant reduction procedures, either on the basis of the revised financial statements or the announced/alternative method/rate or a mix of those; see Articles 27 and 28).

25.6 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, costs or contributions insufficiently substantiated will be ineligible (see Article 6) and will be rejected (see Article 27), and the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 26 — IMPACT EVALUATIONS

26.1 Impact evaluation

The granting authority may carry out impact evaluations of the action, measured against the objectives and indicators of the EU programme funding the grant.

Such evaluations may be started during implementation of the action and until the time-limit set out in the Data Sheet (see Point 6). They will be formally notified to the coordinator or beneficiaries and will be considered to start on the date of the notification.

If needed, the granting authority may be assisted by independent outside experts.

The coordinator or beneficiaries must provide any information relevant to evaluate the impact of the action, including information in electronic format.

26.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the granting authority may apply the measures described in Chapter 5.

CHAPTER 5 CONSEQUENCES OF NON-COMPLIANCE

SECTION 1 REJECTIONS AND GRANT REDUCTION

ARTICLE 27 — REJECTION OF COSTS AND CONTRIBUTIONS

27.1 Conditions

The granting authority will — at beneficiary termination, interim payment, final payment or afterwards — reject any costs or contributions which are ineligible (see Article 6), in particular following checks, reviews, audits or investigations (see Article 25).

The rejection may also be based on the extension of findings from other grants to this grant (see Article 25).

Ineligible costs or contributions will be rejected.

27.2 Procedure

If the rejection does not lead to a recovery, the granting authority will formally notify the coordinator or beneficiary concerned of the rejection, the amounts and the reasons why. The coordinator or beneficiary concerned may — within 30 days of receiving notification — submit observations if it disagrees with the rejection (payment review procedure).

If the rejection leads to a recovery, the granting authority will follow the contradictory procedure with pre-information letter set out in Article 22.

27.3 Effects

If the granting authority rejects costs or contributions, it will deduct them from the costs or contributions declared and then calculate the amount due (and, if needed, make a recovery; see Article 22).

ARTICLE 28 — GRANT REDUCTION

28.1 Conditions

The granting authority may — at beneficiary termination, final payment or afterwards — reduce the grant for a beneficiary, if:

(a) the beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed:

  (i) substantial errors, irregularities or fraud or

  (ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions, submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.), or

(b) the beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants

awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (see Article 25).

The amount of the reduction will be calculated for each beneficiary concerned and proportionate to the seriousness and the duration of the errors, irregularities or fraud or breach of obligations, by applying an individual reduction rate to their accepted EU contribution.

28.2 Procedure

If the grant reduction does not lead to a recovery, the granting authority will formally notify the coordinator or beneficiary concerned of the reduction, the amount to be reduced and the reasons why. The coordinator or beneficiary concerned may — within 30 days of receiving notification — submit observations if it disagrees with the reduction (payment review procedure).

If the grant reduction leads to a recovery, the granting authority will follow the contradictory procedure with pre-information letter set out in Article 22.

28.3 Effects

If the granting authority reduces the grant, it will deduct the reduction and then calculate the amount due (and, if needed, make a recovery; see Article 22).

SECTION 2 SUSPENSION AND TERMINATION

ARTICLE 29 — PAYMENT DEADLINE SUSPENSION

29.1 Conditions

The granting authority may — at any moment — suspend the payment deadline if a payment cannot be processed because:

(a) the required report (see Article 21) has not been submitted or is not complete or additional information is needed

(b) there are doubts about the amount to be paid (e.g. ongoing audit extension procedure, queries about eligibility, need for a grant reduction, etc.) and additional checks, reviews, audits or investigations are necessary, or

(c) there are other issues affecting the EU financial interests.

29.2 Procedure

The granting authority will formally notify the coordinator of the suspension and the reasons why.

The suspension will **take effect** the day the notification is sent.

If the conditions for suspending the payment deadline are no longer met, the suspension will be **lifted** — and the remaining time to pay (see Data Sheet, Point 4.2) will resume.

If the suspension exceeds two months, the coordinator may request the granting authority to confirm if the suspension will continue.

If the payment deadline has been suspended due to the non-compliance of the report and the revised report is not submitted (or was submitted but is also rejected), the granting authority may also terminate the grant or the participation of the coordinator (see Article 32).

ARTICLE 30 — PAYMENT SUSPENSION

30.1 Conditions

The granting authority may — at any moment — suspend payments, in whole or in part for one or more beneficiaries, if:

(a) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed or is suspected of having committed:

  (i) substantial errors, irregularities or fraud or

  (ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions, submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.), or

(b) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant.

If payments are suspended for one or more beneficiaries, the granting authority will make partial payment(s) for the part(s) not suspended. If suspension concerns the final payment, the payment (or recovery) of the remaining amount after suspension is lifted will be considered to be the payment that closes the action.

30.2 Procedure

Before suspending payments, the granting authority will send a **pre-information letter** to the beneficiary concerned:

- formally notifying the intention to suspend payments and the reasons why and
- requesting observations within 30 days of receiving notification.

If the granting authority does not receive observations or decides to pursue the procedure despite the observations it has received, it will confirm the suspension (**confirmation letter**). Otherwise, it will formally notify that the procedure is discontinued.

At the end of the suspension procedure, the granting authority will also inform the coordinator.

The suspension will **take effect** the day after the confirmation notification is sent.

If the conditions for resuming payments are met, the suspension will be **lifted**. The granting authority will formally notify the beneficiary concerned (and the coordinator) and set the suspension end date.

During the suspension, no prefinancing will be paid to the beneficiaries concerned. For interim payments, the periodic reports for all reporting periods except the last one (see Article 21) must not contain any financial statements from the beneficiary concerned (or its affiliated entities). The coordinator must include them in the next periodic report after the suspension is lifted or — if suspension is not lifted before the end of the action — in the last periodic report.

ARTICLE 31 — GRANT AGREEMENT SUSPENSION

31.1 Consortium-requested GA suspension

31.1.1 Conditions and procedure

The beneficiaries may request the suspension of the grant or any part of it, if exceptional circumstances — in particular *force majeure* (see Article 35) — make implementation impossible or excessively difficult.

The coordinator must submit a request for **amendment** (see Article 39), with:

- the reasons why
- the date the suspension takes effect; this date may be before the date of the submission of the amendment request and
- the expected date of resumption.

The suspension will **take effect** on the day specified in the amendment.

Once circumstances allow for implementation to resume, the coordinator must immediately request another **amendment** of the Agreement to set the suspension end date, the resumption date (one day after suspension end date), extend the duration and make other changes necessary to adapt the action to the new situation (see Article 39) — unless the grant has been terminated (see Article 32). The suspension will be **lifted** with effect from the suspension end date set out in the amendment. This date may be before the date of the submission of the amendment request.

During the suspension, no prefinancing will be paid. Costs incurred or contributions for activities implemented during grant suspension are not eligible (see Article 6.3).

31.2 EU-initiated GA suspension

31.2.1 Conditions

The granting authority may suspend the grant or any part of it, if:

(a) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed or is suspected of having committed:

(i) substantial errors, irregularities or fraud or

(ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions,

submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.), or

(b) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant

(c) other:

(i) linked action issues: not applicable

(ii) the action has lost its scientific or technological relevance, for EIC Accelerator actions: the action has lost its economic relevance, for challenge-based EIC Pathfinder actions and Horizon Europe Missions: the action has lost its relevance as part of the Portfolio for which it has been initially selected

31.2.2 Procedure

Before suspending the grant, the granting authority will send a **pre-information letter** to the coordinator:

- formally notifying the intention to suspend the grant and the reasons why and
- requesting observations within 30 days of receiving notification.

If the granting authority does not receive observations or decides to pursue the procedure despite the observations it has received, it will confirm the suspension (**confirmation letter**). Otherwise, it will formally notify that the procedure is discontinued.

The suspension will **take effect** the day after the confirmation notification is sent (or on a later date specified in the notification).

Once the conditions for resuming implementation of the action are met, the granting authority will formally notify the coordinator a **lifting of suspension letter**, in which it will set the suspension end date and invite the coordinator to request an amendment of the Agreement to set the resumption date (one day after suspension end date), extend the duration and make other changes necessary to adapt the action to the new situation (see Article 39) — unless the grant has been terminated (see Article 32). The suspension will be **lifted** with effect from the suspension end date set out in the lifting of suspension letter. This date may be before the date on which the letter is sent.

During the suspension, no prefinancing will be paid. Costs incurred or contributions for activities implemented during suspension are not eligible (see Article 6.3).

The beneficiaries may not claim damages due to suspension by the granting authority (see Article 33).

Grant suspension does not affect the granting authority's right to terminate the grant or a beneficiary (see Article 32) or reduce the grant (see Article 28).

ARTICLE 32 — GRANT AGREEMENT OR BENEFICIARY TERMINATION

32.1 Consortium-requested GA termination

32.1.1 Conditions and procedure

The beneficiaries may request the termination of the grant.

The coordinator must submit a request for **amendment** (see Article 39), with:

- the reasons why
- the date the consortium ends work on the action ('end of work date') and
- the date the termination takes effect ('termination date'); this date must be after the date of the submission of the amendment request.

The termination will **take effect** on the termination date specified in the amendment.

If no reasons are given or if the granting authority considers the reasons do not justify termination, it may consider the grant terminated improperly.

32.1.2 Effects

The coordinator must — within 60 days from when termination takes effect — submit a **periodic report** (for the open reporting period until termination).

The granting authority will calculate the final grant amount and final payment on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before the end of work date (see Article 22). Costs relating to contracts due for execution only after the end of work are not eligible.

If the granting authority does not receive the report within the deadline, only costs and contributions which are included in an approved periodic report will be taken into account (no costs/contributions if no periodic report was ever approved).

Improper termination may lead to a grant reduction (see Article 28).

After termination, the beneficiaries' obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

32.2 Consortium-requested beneficiary termination

32.2.1 Conditions and procedure

The coordinator may request the termination of the participation of one or more beneficiaries, on request of the beneficiary concerned or on behalf of the other beneficiaries.

The coordinator must submit a request for **amendment** (see Article 39), with:

- the reasons why
- the opinion of the beneficiary concerned (or proof that this opinion has been requested in writing)

- the date the beneficiary ends work on the action ('end of work date')

- the date the termination takes effect ('termination date'); this date must be after the date of the submission of the amendment request.

If the termination concerns the coordinator and is done without its agreement, the amendment request must be submitted by another beneficiary (acting on behalf of the consortium).

The termination will **take effect** on the termination date specified in the amendment.

If no information is given or if the granting authority considers that the reasons do not justify termination, it may consider the beneficiary to have been terminated improperly.

32.2.2 Effects

The coordinator must — within 60 days from when termination takes effect — submit:

(i) a **report on the distribution of payments** to the beneficiary concerned

(ii) a **termination report** from the beneficiary concerned, for the open reporting period until termination, containing an overview of the progress of the work, the financial statement, the explanation on the use of resources, and, if applicable, the certificate on the financial statement (CFS; see Articles 21 and 24.2 and Data Sheet, Point 4.3)

(iii) a second **request for amendment** (see Article 39) with other amendments needed (e.g. reallocation of the tasks and the estimated budget of the terminated beneficiary; addition of a new beneficiary to replace the terminated beneficiary; change of coordinator, etc.).

The granting authority will calculate the amount due to the beneficiary on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before the end of work date (see Article 22). Costs relating to contracts due for execution only after the end of work are not eligible.

The information in the termination report must also be included in the periodic report for the next reporting period (see Article 21).

If the granting authority does not receive the termination report within the deadline, only costs and contributions which are included in an approved periodic report will be taken into account (no costs/ contributions if no periodic report was ever approved).

If the granting authority does not receive the report on the distribution of payments within the deadline, it will consider that:

- the coordinator did not distribute any payment to the beneficiary concerned and that

- the beneficiary concerned must not repay any amount to the coordinator.

If the second request for amendment is accepted by the granting authority, the Agreement is **amended** to introduce the necessary changes (see Article 39).

If the second request for amendment is rejected by the granting authority (because it calls into question the decision awarding the grant or breaches the principle of equal treatment of applicants), the grant may be terminated (see Article 32).

Improper termination may lead to a reduction of the grant (see Article 31) or grant termination (see Article 32).

After termination, the concerned beneficiary's obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

32.3 EU-initiated GA or beneficiary termination

32.3.1 Conditions

The granting authority may terminate the grant or the participation of one or more beneficiaries, if:

(a) one or more beneficiaries do not accede to the Agreement (see Article 40)

(b) a change to the action or the legal, financial, technical, organisational or ownership situation of a beneficiary is likely to substantially affect the implementation of the action or calls into question the decision to award the grant (including changes linked to one of the exclusion grounds listed in the declaration of honour)

(c) following termination of one or more beneficiaries, the necessary changes to the Agreement (and their impact on the action) would call into question the decision awarding the grant or breach the principle of equal treatment of applicants

(d) implementation of the action has become impossible or the changes necessary for its continuation would call into question the decision awarding the grant or breach the principle of equal treatment of applicants

(e) a beneficiary (or person with unlimited liability for its debts) is subject to bankruptcy proceedings or similar (including insolvency, winding-up, administration by a liquidator or court, arrangement with creditors, suspension of business activities, etc.)

(f) a beneficiary (or person with unlimited liability for its debts) is in breach of social security or tax obligations

(g) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has been found guilty of grave professional misconduct

(h) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed fraud, corruption, or is involved in a criminal organisation, money laundering, terrorism-related crimes (including terrorism financing), child labour or human trafficking

(i) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) was created under a different jurisdiction with the intent to circumvent fiscal, social or other legal obligations in the country of origin (or created another entity with this purpose)

(j) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed:

(i) substantial errors, irregularities or fraud or

(ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions, submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.)

(k) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (extension of findings from other grants to this grant; see Article 25)

(l) despite a specific request by the granting authority, a beneficiary does not request — through the coordinator — an amendment to the Agreement to end the participation of one of its affiliated entities or associated partners that is in one of the situations under points (d), (f), (e), (g), (h), (i) or (j) and to reallocate its tasks, or

(m) other:

(i) linked action issues: not applicable

(ii) the action has lost its scientific or technological relevance, for EIC Accelerator actions: the action has lost its economic relevance, for challenge-based EIC Pathfinder actions and Horizon Europe Missions: the action has lost its relevance as part of the Portfolio for which it has been initially selected

32.3.2 Procedure

Before terminating the grant or participation of one or more beneficiaries, the granting authority will send **a pre-information letter** to the coordinator or beneficiary concerned:

- formally notifying the intention to terminate and the reasons why and
- requesting observations within 30 days of receiving notification.

If the granting authority does not receive observations or decides to pursue the procedure despite the observations it has received, it will confirm the termination and the date it will take effect (**confirmation letter**). Otherwise, it will formally notify that the procedure is discontinued.

For beneficiary terminations, the granting authority will — at the end of the procedure — also inform the coordinator.

The termination will **take effect** the day after the confirmation notification is sent (or on a later date specified in the notification; 'termination date').

32.3.3 Effects

(a) for **GA termination**:

The coordinator must — within 60 days from when termination takes effect — submit a **periodic report** (for the last open reporting period until termination).

The granting authority will calculate the final grant amount and final payment on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before termination takes effect (see Article 22). Costs relating to contracts due for execution only after termination are not eligible.

If the grant is terminated for breach of the obligation to submit reports, the coordinator may not submit any report after termination.

If the granting authority does not receive the report within the deadline, only costs and contributions which are included in an approved periodic report will be taken into account (no costs/contributions if no periodic report was ever approved).

Termination does not affect the granting authority's right to reduce the grant (see Article 28) or to impose administrative sanctions (see Article 34).

The beneficiaries may not claim damages due to termination by the granting authority (see Article 33).

After termination, the beneficiaries' obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

(b) for **beneficiary termination**:

The coordinator must — within 60 days from when termination takes effect — submit:

(i) a **report on the distribution of payments** to the beneficiary concerned

(ii) a **termination report** from the beneficiary concerned, for the open reporting period until termination, containing an overview of the progress of the work, the financial statement, the explanation on the use of resources, and, if applicable, the certificate on the financial statement (CFS; see Articles 21 and 24.2 and Data Sheet, Point 4.3)

(iii) a **request for amendment** (see Article 39) with any amendments needed (e.g. reallocation of the tasks and the estimated budget of the terminated beneficiary; addition of a new beneficiary to replace the terminated beneficiary; change of coordinator, etc.).

The granting authority will calculate the amount due to the beneficiary on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before termination takes effect (see Article 22). Costs relating to contracts due for execution only after termination are not eligible.

The information in the termination report must also be included in the periodic report for the next reporting period (see Article 21).

If the granting authority does not receive the termination report within the deadline, only costs and contributions included in an approved periodic report will be taken into account (no costs/contributions if no periodic report was ever approved).

If the granting authority does not receive the report on the distribution of payments within the deadline, it will consider that:

- the coordinator did not distribute any payment to the beneficiary concerned and that
- the beneficiary concerned must not repay any amount to the coordinator.

If the request for amendment is accepted by the granting authority, the Agreement is **amended** to introduce the necessary changes (see Article 39).

If the request for amendment is rejected by the granting authority (because it calls into question the decision awarding the grant or breaches the principle of equal treatment of applicants), the grant may be terminated (see Article 32).

After termination, the concerned beneficiary's obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

SECTION 3 OTHER CONSEQUENCES: DAMAGES AND ADMINISTRATIVE SANCTIONS

ARTICLE 33 — DAMAGES

33.1 Liability of the granting authority

The granting authority cannot be held liable for any damage caused to the beneficiaries or to third parties as a consequence of the implementation of the Agreement, including for gross negligence.

The granting authority cannot be held liable for any damage caused by any of the beneficiaries or other participants involved in the action, as a consequence of the implementation of the Agreement.

33.2 Liability of the beneficiaries

The beneficiaries must compensate the granting authority for any damage it sustains as a result of the implementation of the action or because the action was not implemented in full compliance with the Agreement, provided that it was caused by gross negligence or wilful act.

The liability does not extend to indirect or consequential losses or similar damage (such as loss of profit, loss of revenue or loss of contracts), provided such damage was not caused by wilful act or by a breach of confidentiality.

ARTICLE 34 — ADMINISTRATIVE SANCTIONS AND OTHER MEASURES

Nothing in this Agreement may be construed as preventing the adoption of administrative sanctions (i.e. exclusion from EU award procedures and/or financial penalties) or other public law measures, in addition or as an alternative to the contractual measures provided under this Agreement (see,

for instance, Articles 135 to 145 EU Financial Regulation 2018/1046 and Articles 4 and 7 of Regulation 2988/95[21]).

SECTION 4 FORCE MAJEURE

ARTICLE 35 — FORCE MAJEURE

A party prevented by force majeure from fulfilling its obligations under the Agreement cannot be considered in breach of them.

'Force majeure' means any situation or event that:

- prevents either party from fulfilling their obligations under the Agreement,
- was unforeseeable, exceptional situation and beyond the parties' control,
- was not due to error or negligence on their part (or on the part of other participants involved in the action), and
- proves to be inevitable in spite of exercising all due diligence.

Any situation constituting force majeure must be formally notified to the other party without delay, stating the nature, likely duration and foreseeable effects.

The parties must immediately take all the necessary steps to limit any damage due to force majeure and do their best to resume implementation of the action as soon as possible.

CHAPTER 6 FINAL PROVISIONS

ARTICLE 36 — COMMUNICATION BETWEEN THE PARTIES

36.1 Forms and means of communication — Electronic management

EU grants are managed fully electronically through the EU Funding & Tenders Portal ('Portal').

All communications must be made electronically through the Portal, in accordance with the Portal Terms and Conditions and using the forms and templates provided there (except if explicitly instructed otherwise by the granting authority).

Communications must be made in writing and clearly identify the grant agreement (project number and acronym).

Communications must be made by persons authorised according to the Portal Terms and Conditions. For naming the authorised persons, each beneficiary must have designated — before the signature of this Agreement — a 'legal entity appointed representative (LEAR)'. The role and tasks of the LEAR are stipulated in their appointment letter (see Portal Terms and Conditions).

[21] Council Regulation (EC, Euratom) No 2988/95 of 18 December 1995 on the protection of the European Communities financial interests (OJ L 312, 23.12.1995, p. 1).

If the electronic exchange system is temporarily unavailable, instructions will be given on the Portal.

36.2 Date of communication

The sending date for communications made through the Portal will be the date and time of sending, as indicated by the time logs.

The receiving date for communications made through the Portal will be the date and time the communication is accessed, as indicated by the time logs. Formal notifications that have not been accessed within 10 days after sending, will be considered to have been accessed (see Portal Terms and Conditions).

If a communication is exceptionally made on paper (by e-mail or postal service), general principles apply (i.e. date of sending/receipt). Formal notifications by registered post with proof of delivery will be considered to have been received either on the delivery date registered by the postal service or the deadline for collection at the post office.

If the electronic exchange system is temporarily unavailable, the sending party cannot be considered in breach of its obligation to send a communication within a specified deadline.

36.3 Addresses for communication

The Portal can be accessed via the Europa website.

The address for paper communications to the granting authority (if exceptionally allowed) is the official mailing address indicated on its website.

For beneficiaries, it is the legal address specified in the Portal Participant Register.

ARTICLE 37 — INTERPRETATION OF THE AGREEMENT

The provisions in the Data Sheet take precedence over the rest of the Terms and Conditions of the Agreement.

Annex 5 takes precedence over the Terms and Conditions; the Terms and Conditions take precedence over the Annexes other than Annex 5.

Annex 2 takes precedence over Annex 1.

ARTICLE 38 — CALCULATION OF PERIODS AND DEADLINES

In accordance with Regulation No 1182/71[22], periods expressed in days, months or years are calculated from the moment the triggering event occurs.

The day during which that event occurs is not considered as falling within the period.

'Days' means calendar days, not working days.

ARTICLE 39 — AMENDMENTS

[22] Regulation (EEC, Euratom) No 1182/71 of the Council of 3 June 1971 determining the rules applicable to periods, dates and time-limits (OJ L 124, 8/6/1971, p. 1).

39.1 Conditions

The Agreement may be amended, unless the amendment entails changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

Amendments may be requested by any of the parties.

39.2 Procedure

The party requesting an amendment must submit a request for amendment signed directly in the Portal Amendment tool.

The coordinator submits and receives requests for amendment on behalf of the beneficiaries (see Annex 3). If a change of coordinator is requested without its agreement, the submission must be done by another beneficiary (acting on behalf of the other beneficiaries).

The request for amendment must include:

- the reasons why
- the appropriate supporting documents and
- for a change of coordinator without its agreement: the opinion of the coordinator (or proof that this opinion has been requested in writing).

The granting authority may request additional information.

If the party receiving the request agrees, it must sign the amendment in the tool within 45 days of receiving notification (or any additional information the granting authority has requested). If it does not agree, it must formally notify its disagreement within the same deadline. The deadline may be extended, if necessary for the assessment of the request. If no notification is received within the deadline, the request is considered to have been rejected.

An amendment **enters into force** on the day of the signature of the receiving party.

An amendment **takes effect** on the date of entry into force or other date specified in the amendment.

ARTICLE 40 — ACCESSION AND ADDITION OF NEW BENEFICIARIES

40.1 Accession of the beneficiaries mentioned in the Preamble

The beneficiaries which are not coordinator must accede to the grant by signing the accession form (see Annex 3) directly in the Portal Grant Preparation tool, within 30 days after the entry into force of the Agreement (see Article 44).

They will assume the rights and obligations under the Agreement with effect from the date of its entry into force (see Article 44).

If a beneficiary does not accede to the grant within the above deadline, the coordinator must — within 30 days — request an amendment (see Article 39) to terminate the beneficiary and make any changes

necessary to ensure proper implementation of the action. This does not affect the granting authority's right to terminate the grant (see Article 32).

40.2 Addition of new beneficiaries

In justified cases, the beneficiaries may request the addition of a new beneficiary.

For this purpose, the coordinator must submit a request for amendment in accordance with Article 39. It must include an accession form (see Annex 3) signed by the new beneficiary directly in the Portal Amendment tool.

New beneficiaries will assume the rights and obligations under the Agreement with effect from the date of their accession specified in the accession form (see Annex 3).

Additions are also possible in mono-beneficiary grants.

ARTICLE 41 — TRANSFER OF THE AGREEMENT

In justified cases, the beneficiary of a mono-beneficiary grant may request the transfer of the grant to a new beneficiary, provided that this would not call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

The beneficiary must submit a request for **amendment** (see Article 39), with

- the reasons why
- the accession form (see Annex 3) signed by the new beneficiary directly in the Portal Amendment tool and
- additional supporting documents (if required by the granting authority).

The new beneficiary will assume the rights and obligations under the Agreement with effect from the date of accession specified in the accession form (see Annex 3).

ARTICLE 42 — ASSIGNMENTS OF CLAIMS FOR PAYMENT AGAINST THE GRANTING AUTHORITY

The beneficiaries may not assign any of their claims for payment against the granting authority to any third party, except if expressly approved in writing by the granting authority on the basis of a reasoned, written request by the coordinator (on behalf of the beneficiary concerned).

If the granting authority has not accepted the assignment or if the terms of it are not observed, the assignment will have no effect on it.

In no circumstances will an assignment release the beneficiaries from their obligations towards the granting authority.

ARTICLE 43 — APPLICABLE LAW AND SETTLEMENT OF DISPUTES

43.1 Applicable law

The Agreement is governed by the applicable EU law, supplemented if necessary by the law of Belgium.

Special rules may apply for beneficiaries which are international organisations (if any; see Data Sheet, Point 5).

43.2 Dispute settlement

If a dispute concerns the interpretation, application or validity of the Agreement, the parties must bring action before the EU General Court — or, on appeal, the EU Court of Justice — under Article 272 of the Treaty on the Functioning of the EU (TFEU).

For non-EU beneficiaries (if any), such disputes must be brought before the courts of Brussels, Belgium — unless an international agreement provides for the enforceability of EU court judgements.

For beneficiaries with arbitration as special dispute settlement forum (if any; see Data Sheet, Point 5), the dispute will — in the absence of an amicable settlement — be settled in accordance with the Rules for Arbitration published on the Portal.

If a dispute concerns administrative sanctions, offsetting or an enforceable decision under Article 299 TFEU (see Articles 22 and 34), the beneficiaries must bring action before the General Court — or, on appeal, the Court of Justice — under Article 263 TFEU.

For grants where the granting authority is an EU executive agency (see Preamble), actions against offsetting and enforceable decisions must be brought against the European Commission (not against the granting authority; see also Article 22).

ARTICLE 44 — ENTRY INTO FORCE

The Agreement will enter into force on the day of signature by the granting authority or the coordinator, depending on which is later.

SIGNATURES

For the coordinator

For the granting authority

ANNEX 1

Euratom Research and Training Programme (EURATOM)

Description of the action (DoA)

Part A

Part B

DESCRIPTION OF THE ACTION (PART A)

COVER PAGE

Part A of the Description of the Action (DoA) must be completed directly on the Portal Grant Preparation screens.

PROJECT *Grant Preparation (General Information screen) — Enter the info.*	
Project number:	101165375
Project name:	Coordination of the European Research Community on Nuclear Materials for Energy Innovation
Project acronym:	CONNECT-NM
Call:	HORIZON-EURATOM-2023-NRT-01
Topic:	HORIZON-EURATOM-2023-NRT-01-04
Type of action:	EURATOM-COFUND
Service:	RTD/C/04
Project starting date:	fixed date: 1 October 2024
Project duration:	60 months

TABLE OF CONTENTS

PROJECT SUMMARY

Project summary

Grant Preparation (General Information screen) — Provide an overall description of your project (including context and overall objectives, planned activities and main achievements, and expected results and impacts (on target groups, change procedures, capacities, innovation etc)). This summary should give readers a clear idea of what your project is about.

Use the project summary from your proposal.

CONNECT-NM is a co-funded European Partnership on nuclear materials for all reactor generations that applies modern digital technologies to materials science practices for the acceleration of innovation. It implements plans elaborated in the ORIENT-NM CSA with 5
strategic goals: (1) Nuclear materials (NM) acceleration platforms; (2) NM test-beds for accelerated qualification; (3) Intelligent materials health monitoring; (4) Advanced methodologies for prediction of materials behaviour in operation; (5) NM knowledge organisation system. Accordingly, the work will be organised in 5 research lines: (1) Advanced materials development & manufacturing; (2) Materials & component qualification: testing, standardization & design rules; (3) Non-destructive examination & materials health monitoring; (4) Advanced materials modelling and characterization; (5) Nuclear materials knowledge & data management. Each research line will coordinate call-selected Projects. CONNECT-NM will centralize transversal activities for the benefit of all Projects: e.g. coordination & management; E&T and infrastructure access; communication, dissemination & result exploitation; interaction with stakeholders; data management. Collaboration is foreseen with international organisations and bodies dealing with safety, standardisation, data management, as well as with fusion & non-nuclear energy communities. All activities align with national and European initiatives on nuclear materials, strengthening R&D&I and avoiding fragmentation and duplication, with direct involvement of industry, TSOs and regulatorsas active partners and end-users.

LIST OF PARTICIPANTS

PARTICIPANTS

Grant Preparation (Beneficiaries screen) — Enter the info.

Number	Role	Short name	Legal name	Country	PIC
1	COO	CIEMAT	CENTRO DE INVESTIGACIONES ENERGETICAS MEDIOAMBIENTALES Y TECNOLOGICAS	ES	999614877
1.1	AE	UPM	UNIVERSIDAD POLITECNICA DE MADRID	ES	999974844
2	BEN	CEA	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	FR	999992401
2.1	AE	EDF	ELECTRICITE DE FRANCE	FR	999926829
2.2	AE	FRAMATOME	FRAMATOME	FR	905291883
2.3	AE	IRSN	INSTITUT DE RADIOPROTECTION ET DE SURETE NUCLEAIRE	FR	999480726
3	BEN	EK	HUN-REN ENERGIATUDOMANYI KUTATOKOZPONT	HU	954721919
4	BEN	CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	FR	999997930
4.1	AE	CENTRALE LILLE	CENTRALE LILLE INSTITUT	FR	999878038

PARTICIPANTS

Grant Preparation (Beneficiaries screen) — Enter the info.

Number	Role	Short name	Legal name	Country	PIC
5	BEN	EERA	ALLIANCE EUROPEENNE DE RECHERCHE DANS LE DOMAINE DE L'ENERGIE	BE	922059885
5.1	AE	CVR	CENTRUM VYZKUMU REZ SRO	CZ	996153820
5.2	AE	Fraunhofer	FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV	DE	999984059
6	BEN	ENEA	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE	IT	999988521
6.1	AE	METAPROJECTS	METAPROJECTS ETS	IT	880385484
6.2	AE	newcleo	NEWCLEO SRL	IT	880414390
6.3	AE	SINTEC SRL	SINTEC SRL	IT	991688037
6.4	AE	UNIBO	ALMA MATER STUDIORUM - UNIVERSITA DI BOLOGNA	IT	999993953
6.5	AE	POLIMI	POLITECNICO DI MILANO	IT	999879881
7	BEN	ENEN	EUROPEAN NUCLEAR EDUCATION NETWORK	BE	905630704
8	BEN	GRS	GESELLSCHAFT FUR ANLAGEN UND REAKTORSICHERHEIT (GRS) gGmbH	DE	999460162
8.1	AE	BAM	BUNDESANSTALT FUER MATERIALFORSCHUNG UND -PRUEFUNG	DE	999507692
9	BEN	RBI	RUDER BOSKOVIC INSTITUTE	HR	999875031
10	BEN	JRC	JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION	BE	999992304
11	BEN	JSI	INSTITUT JOZEF STEFAN	SI	999971837
11.1	AE	ZAG Ljubljana	ZAVOD ZA GRADBENISTVO SLOVENIJE	SI	999527092
12	BEN	NSC KIPT	NATIONAL SCIENCE CENTER KHARKOV INSTITUTE OF PHYSICS AND TECHNOLOGY	UA	969818320
12.1	AE	LLC ENERGORISK	LIMITED LIABILITY COMPANY ENERGORISK	UA	936233622
13	BEN	KIT	KARLSRUHER INSTITUT FUER TECHNOLOGIE	DE	990797674
13.1	AE	HZDR	HELMHOLTZ-ZENTRUM DRESDEN-ROSSENDORF EV	DE	999470541
14	BEN	NCBJ	NARODOWE CENTRUM BADAN JADROWYCH	PL	999506722
15	BEN	NRG	NUCLEAR RESEARCH AND CONSULTANCY GROUP	NL	999514579
16	BEN	RATEN	REGIA AUTONOMA TEHNOLOGII PENTRU ENERGIA NUCLEARA - RATEN	RO	949436777
17	BEN	SNETP	SUSTAINABLE NUCLEAR ENERGY TECHNOLOGY PLATFORM	BE	952482189

PARTICIPANTS

Grant Preparation (Beneficiaries screen) — Enter the info.

Number	Role	Short name	Legal name	Country	PIC
18	BEN	SSM	STRALSAKERHETSMYNDIGHETEN	SE	993882080
18.1	AE	CHALMERS	CHALMERS TEKNISKA HOGSKOLA AB	SE	999980373
18.2	AE	KTH	KUNGLIGA TEKNISKA HOEGSKOLAN	SE	999990946
19	BEN	STUBA	SLOVENSKA TECHNICKA UNIVERZITA V BRATISLAVE	SK	999868823
20	BEN	VTT	TEKNOLOGIAN TUTKIMUSKESKUS VTT OY	FI	932760440
20.1	AE	HY	HELSINGIN YLIOPISTO	FI	999994535
21	AP	NNL	NATIONAL NUCLEAR LABORATORY LIMITED	UK	999757952
22	AP	METU	MIDDLE EAST TECHNICAL UNIVERSITY	TR	999643492
23	AP	PSI	PAUL SCHERRER INSTITUT	CH	999994923
24	AP	CCFE	UNITED KINGDOM ATOMIC ENERGY AUTHORITY	UK	998811911

Work package WP1 – Coordination and Daily Management

Work Package Number	WP1	Lead Beneficiary	1 - CIEMAT
Work Package Name	Coordination and Daily Management		
Start Month	1	End Month	60

Objectives

The main objective of this WP is to ensure the Partnership's proficient management, providing an efficient administrative environment and making sure the governance system works smoothly. Project calls, launch and monitoring,including definition of the content of the call, reception of project ideas, brokerage event, reception of actual submission and reviewing process, belong to this WP, with the assistance of all research lines and the EvaCo. Pre-selected projects (PSPs) will also be launched on the first year and monitored. The SAB and the EvaCo will be created and managed. The revision of the materials ID cards and of the strategic research agenda, consideration of aspects of gender dimension and attention to ethics requirements are also parts of this WP. All objectives will be measured by checking that the timing is respected and that the relevant documents are delivered when expected, as well as through a survey.

Description

Task 1.1 – Creation and operation of the Management Support Office (MSO). Lead: CIEMAT; Other Partners: CEA, EERA, EERA/CVR, ENEA, ENEA/Newcleo, ENEA/SINTEC, ENEN, GRS, EERA/Fraunhofer, NCBJ, VTT. M1-M60.
The MSO is composed of employees of Beneficiaries or Affiliated Entities, in number sufficient to cover all the functions that this body is expected to accomplish. They are selected based on their proven competences, in such a way to be overall complementary to each other, and their availability of time to be devoted to the tasks assigned. These employees do not need to be full time dedicated to CONNECT-NM, but shall be enabled by their employers to give priority to the CONNECT-NM tasks over any others.
The MSO is overall responsible for:
• Supporting the Coordinator in the daily management of CONNECT-NM and helping in preparing and implementing the Annual Work Plans (AWPs).
• Supporting the Coordinator and the Executive Board (ExB, see section 3.2.2) in the definition of all the administrative, financial and legal procedures related to the management of CONNECT-NM, described in the Project Quality Handbook (PQH).
• Assisting the Coordinator, the ExB and the EvaCo in the preparation and execution of the Project Calls in all their phases (see section 1.2.6).
• Assisting the Coordinator, the ExB and the Project Leaders in the monitoring of the Project activities and in their financial management, when these are running.
• Providing a Secretary for the ExB and GA meetings.
• Providing logistic support to transversal activities, such as: E&T actions, result exploitation actions, event organisation in general, also in support of the activities of the projects.
• Checking and following all the management procedures, as defined in the PQH.
• Any other action that may be required by the Coordinator to the MSO, in support of CONNECT-NM activities.
In practice, some organisations will be more involved than others in some tasks, as is clarified in the task definition below. A survey will be conducted at the end of each reporting period, to verify the satisfaction of the participants with the way of working of the Partnership.
Related Milestones and Deliverables:
Milestone 1.1.1: Establishment and full operation of the MSO (M1) - CIEMAT
Milestone 1.1.2: First survey of satisfaction (M17) - CIEMAT
Milestone 1.1.3: Second survey of satisfaction (M35) - CIEMAT
Milestone 1.1.4: Third survey of satisfaction (M53) - CIEMAT
Milestone 1.1.5: Final survey of satisfaction (M59) - CIEMAT

Task 1.2 – Administrative and financial management. Lead: CIEMAT; Other Partners: EERA/CVR, EERA, GRS, ENEA/SINTEC. M1-M60.

Subtask 1.2.1 – Project Quality Handbook (CIEMAT + EERA/CVR, EERA, GRS, ENEA/SINTEC). M1-M51. The Coordinator with the help of the MSO shall produce and yearly update a handbook that summarises CONNECT-NM internal structure, procedures inspired to quality management principles and way of functioning.
Related Milestones and Deliverables:

Deliverable 1.2.1.1: First version of the PQH (M4) - CIEMAT
Deliverable 1.2.1.2: Second version revised of the PQH (M15) - CIEMAT
Deliverable 1.2.1.3: Third version revised of the PQH (M27) - CIEMAT
Deliverable 1.2.1.4: Fourth version revised of the PQH (M39) - CIEMAT
Deliverable 1.2.1.5: Fifth version revised of the PQH (M51)- CIEMAT

Subtask 1.2.2 – Management of contractual and financial issues (CIEMAT + ENEA/SINTEC). M1-M60. The Coordinator with the help of the MSO shall monitor the partnership budget, by keeping records of WP and Project financial situation, based on communications from the Beneficiaries and the Project Leaders, eventually producing annual financial reports, as well as the contractual periodic financial report. The MSO shall provide guidance for all consortium members for issues relating to finances and financial reporting. The Coordinator shall be responsible for the timely distribution within the consortium of the funds received from the EC.

Subtask 1.2.3 – Monitoring of the activities of the Partnership (CIEMAT + ENEA/SINTEC). M1-M60. The Coordinator with the help of the MSO and the participation of the ExB (transversal WP leaders and RL leaders, for the latter the work is included in the RLs) shall be monitoring the timely achievement and reporting of milestones and deliverables for the whole partnership. The monitoring and the deliverable and milestone approval workflow will rely on the use of the PMT implemented in the Members Only section of the Partnership's website. While the Coordinator will be the final approver of the Partnership's deliverables and milestones, the RLLs will be the final approvers of the internal deliverables and milestones of the Projects belonging to their respective research lines.

Subtask 1.2.4 – Interaction with the European Commission (CIEMAT). M1-M60. The Coordinator shall be interacting with the EC via the F&T portal or through direct contact with the officer, to ensure fluid communication for any issue that will require this interaction, related with both the fulfilment of contractual duties and the solution of problems faced by the Partnership, including preparation of the contractual scientific & technical progress report (S&TPR) at the end of the reporting period, produced with the input of all WP and RL leaders, as well as the AWP.

Subtask 1.2.5 – Publishable Annual Partnership's Report (PAPREP) (CIEMAT+ CEA, EERA, ENEA, EERA/ Fraunhofer, ENEA/Newcleo, NCBJ, VTT). M1-M60. The Coordinator and the ExB with the support of the MSO shall produce, after the end of each Partnership year, a short report that shall highlight the main steps taken in the implementation of the Partnership and of the Strategic Research Agenda via Projects, mentioning scientific output statistics and any outstanding result. This report will be made public via the website developed in WP3, following the communication and dissemination master plan (see WP3), either as a document or as a webpage.
Related Milestones and Deliverables:
Deliverable 1.2.5.1: First PAPREP (M14) - CIEMAT
Deliverable 1.2.5.2: Second PAPREP (M26) - CIEMAT
Deliverable 1.2.5.3: Third PAPREP (M38) - CIEMAT
Deliverable 1.2.5.4: Fourth PAPREP (M50) - CIEMAT
Deliverable 1.2.5.5: Final PAPREP (M60) - CIEMAT

Subtask 1.2.6 – Annual Work Plan (AWP) (CIEMAT + CEA, EERA, EERA/CVR, ENEA, ENEA/Newcleo, ENEA/ SINTEC GRS, EERA/Fraunhofer, NCBJ, VTT). M1-M48. The Coordinator and the ExB with the support of the MSO shall be responsible for the elaboration of the AWPs. The preparation of these plans shall be based on the annual Research Line Progress Reports (ARLPRs), which are prepared by the Research Line Leaders half way through each Partnership year. Starting from the second Partnership's year, the corresponding opinion expressed by the SAB (see task 1.4) and the IEG (see WP3) will be systematically considered, as well.
Related Milestones and Deliverables:
Deliverable 1.2.6.1: Second AWP (M12) - CIEMAT
Deliverable 1.2.6.2: Third AWP (M24) - CIEMAT
Deliverable 1.2.6.3: Fourth AWP (M36) - CIEMAT
Deliverable 1.2.6.4: Fifth AWP (M48) - CIEMAT

Subtask 1.2.7 – Risk Monitoring (CIEMAT+ CEA, EERA, EERA/CVR, ENEA, ENEA/Newcleo, ENEA/SINTEC GRS, EERA/Fraunhofer, NCBJ, VTT). M1-M60. The Coordinator and the ExB, supported by the MSO, shall monitor and manage the risks incurred by the various WPs, Tasks and Projects within the Partnership, identifying whenever needed relevant mitigation measures, if necessary with the involvement of the General Assembly (see section 3.2.2).

Task 1.3 – Management of the governance of the Partnership. Lead: CIEMAT; Other Partners: CVR, EERA. M1-M60. The Coordinator with the help of the MSO shall make sure that the General Assembly and the Executive Board operate according to the rules set out in the Grant Agreement and in the Consortium Agreement, in particular ensuring that these bodies meet regularly, as well as organising all the practical aspects of these meetings, including announcement,

distribution of the agenda, logistics and the writing and distribution of the minutes. The preparation of the agenda will be led by the elected chair of the General Assembly.
The Coordinator with the help of the MSO shall also be in charge for the technical and logistic organisation of contractual and monitoring meetings at the level of the Partnership: kick-off meeting and plenary meetings (in correspondence of the end of the reporting periods), as well as closing workshop, while making sure the General Assembly and the Executive Board meet according to a calendar to be defined. The MSO shall also support the Project Leaders and the Research Line Leaders for the practical organisation of, respectively, Project and Research Line meetings, according to needs, as well as cross-cutting meetings (across different Research Lines) whenever advisable.
Related Milestones and Deliverables:
Milestone 1.3.1: CONNECT-NM kick-off meeting (M1) - CIEMAT
Milestone 1.3.2: Complete identification of the members of the GA and first GA meeting, with election of GA chair and vice-chair; calendar of GA meetings (M2) - CIEMAT
Milestone 1.3.3: Calendar of ExB ordinary meetings (M3) - CIEMAT
Milestone 1.3.4: First CONNECT-NM plenary meeting (M18) - CIEMAT
Milestone 1.3.5: Second CONNECT-NM plenary meeting (M36) - CIEMAT
Milestone 1.3.6: Third CONNECT-NM plenary meeting (M54) - CIEMAT
Milestone 1.3.7: CONNECT-NM closing workshop (M60) - CIEMAT

Task 1.4 – Creation and management of the Scientific Advisory Board. Lead: CIEMAT; Other Partners: CEA, EERA/CVR. M1-M60.
The Coordinator with the help of the MSO shall make sure that the SAB is created and that the activities of the board are carried out according to plans, in particular:
• Preparation and signature of non-disclosure agreement and Terms of Reference of the SAB (M6);
• Follow up the organisation of the SAB meetings and ensure its correct functioning.
Related Milestones and Deliverables:
Milestone 1.4.1: Creation of the SAB with signature of non-disclosure agreement and approved members and terms of reference (M6) CIEMAT
Deliverable 1.4.1: Approved Rules of Procedure of the SAB (M9) - CIEMAT
Deliverable 1.4.2: First summary of SAB assessments and recommendations (M22) - CIEMAT
Deliverable 1.4.3: Second summary of SAB assessments and recommendations (M34) - CIEMAT
Deliverable 1.4.4 Third summary of SAB assessments and recommendations (M46) - CIEMAT
Deliverable 1.4.5: Final summary of SAB assessments and recommendations (M60) - CIEMAT

Task 1.5 – Organisation of the calls for projects and launch of the selected ones. Lead: CIEMAT; Other Partners: CEA, EERA, EERA/CVR, ENEA, ENEA/Newcleo, ENEA/SINTEC, ENEN, GRS, EERA/Fraunhofer, NCBJ, VTT, SNETP (in-kind). M1-M18 (repeated later if there is a second call).
The Coordinator, assisted by the research line leaders and the MSO shall be in charge for the launch of Project Calls within the Partnership, applying a procedure that shall enable the widest participation possible and require minimum administrative effort on the side of the proposers, ensuring an unbiased and transparent evaluation and selection. The Coordinator with the MSO shall supervise in particular the timeline for the Project Calls, ensuring that the relevant milestones are reached. The procedure is described in detail in section 1.2.3.2 of the DoA.
At the end of the call, a deliverable will be produced providing all the details about the call, including: the ranking list(s) of the project proposals; the reviewers' reports; the list of funded projects and the relevant task agreements.
Related Milestones and Deliverables:
Milestone 1.5.1: Rules for participation, call scope and expected outcome (for each research line) are sent for approval to the general assembly (M2) - CIEMAT
Milestone 1.5.2: Guidelines for Project proposers and approved call text, as well as templates for proposals, are ready (M4) - CIEMAT
Milestone 1.5.3: Publication of the call announcement (M5) - CIEMAT
Milestone 1.5.4: Brokerage event and project ideas' preliminary evaluation (M7) - EERA
Milestone 1.5.5: Creation of EvaCo via subcontracting and preparation of the guidelines for evaluators and reviewers (M9) - ENEN
Milestone 1.5.6: Proposal collection and launch of Project proposal review (M10) – EvaCo (ENEN)
Milestone 1.5.7: Project proposal ranking by the EvaCo and approval of the General Assembly (M14) – EvaCo (ENEN)
Milestone 1.5.8: Project launch after signature of task agreement (M16) - CIEMAT
Deliverable 1.5.1: Report on the Project Call (M18) - CIEMAT
(a similar sequence of milestones and deliverable will apply in case of a second call)

Task 1.6 – Procedure of revision and extension of the materials ID cards and the SRA. Lead: CEA; Other Partners: CIEMAT, ENEA, EERA/Fraunhofer, NCBJ, ENEA/Newcleo, VTT. M1-M60.

A procedure to enable the continuous or periodic update of the materials ID cards that were originally produced in ORIENT-NM will be established. These cards will be made publicly available via the website of CONNECT-NM. Experts will be selected by the ExB, either upon its own initiative, or because the experts proposed themselves. They will modify the ID cards under the supervision of appointed leaders for each family of materials. The new versions will be validated by the ExB. In addition, the ExB will launch a search for experts in the three presently excluded nuclear materials classes, namely polymers, refractory materials and neutron control materials. These experts will be asked to produce relevant ID cards. At the fourth year of the Partnership, a procedure for the revision of the SRA will be launched, which shall involve the ExB, the SAB, the IEG and possibly other experts, particularly the experts in the three above mentioned classes of materials.
Related Milestones and Deliverables:
Deliverable 1.6.1: Revised set of materials ID cards (M42) - CEA
Deliverable 1.6.2: Revised Strategic Research and Innovation Agenda (M60) - CEA

Task 1.7 – Gender Dimension and Ethics Requirements. Lead: CIEMAT; Other Partners: EERA/CVR, ENEA.
Subtask 1.7.1 – Gender Dimension (ENEA). M1-M54. This dimension shall be addressed within this WP for the whole Partnership, including Projects either selected through calls or pre-selected, in two ways:
1) As a standard procedure, close attention has been and will be given to respecting the gender balance in the composition of all Partnership's bodies. This is crucial to make use of all available skills and to break down gender prejudices and stereotypes. The ExB members have been selected to fully respect gender balance and to a large extent this balance is also respected when looking at the group of people in charge for tasks and subtasks within WPs and RL. In order to promote gender balance also at the level of other bodies (e.g. SAB and IEG) and of Project participants, a Gender Coordinator shall be appointed to check the members of the advisory bodies and the participants involved in the research projects, in order to spot cases of gender under-representativeness and invite the group concerned to redress the balance with researchers of different gender, but equivalent experience and CV, so long as possible. As a complement to this task, gender balance will be regularly monitored and a project "Gender Balance" document will be produced, which will analyse the initial and final status of the project in this respect, starting from the data of the project partner organisations.
2) It is often stated that there are no gender dimension issues in nuclear materials science. However, this statement might be the result of a superficial analysis of the overall aspects and features of R&D activities in this field. To address this issue, a Gender Dimension Working Group will be created under the supervision of the Gender Coordinator. The objective of this Working group will be to launch a reflection on this point, e.g. by assessing, from a gender perspective, the risks to workers during ordinary and extraordinary work activities within the research areas, or the features of this work where gender differences may influence the results or, conversely, those that may create discrimination between genders, suggesting in this case possible countermeasures.
Related Milestones and Deliverables:
Milestone 1.7.1.1: Appointment of the Gender Coordinator (M1) - ENEA
Milestone 1.7.1.2: Creation of the gender dimension working group (M6) - ENEA
Deliverable 1.7.1.1: First CONNECT-NM Gender Balance document (M18) - ENEA
Deliverable 1.7.1.2: First set of suggestions of the Gender Coordinator to improve Gender Balance within CONNECT-NM (M24) - ENEA
Deliverable 1.7.1.3: Outcome of the work of the gender dimension working group (M30) - ENEA
Deliverable 1.7.1.4: Second CONNECT-NM Gender Balance document (M36) - ENEA
Deliverable 1.7.1.5: Final set of suggestions of the Gender Coordinator to improve Gender Balance within CONNECT-NM (M42)
Deliverable 1.7.1.6: Final CONNECT-NM Gender Balance document (M54)

Subtask 1.7.2 – Ethics Requirements (CIEMAT+ EERA/CVR). M1-M45. The Coordinator, with the help of the MSO, shall ensure the respect of ethics requirements, throughout the duration of the Partnership. CONNECT-NM shall not deal with research activities that concern any human cells, embryos or tissues, nor will any kind of study be conducted on human beings, both belonging to the consortium and outside it. The Partnership shall not conduct research activities on animals or any other living being, either. Finally, the Partnership shall not handle any special category of personal data. However:
1) Several dissemination events shall be organized within CONNECT-NM and this will require the collection of basic personal data related to the participants (names, contacts, affiliations, occasionally also ID document numbers for access to facilities). The data owners will be informed about the purpose of the data collection, as well as about their rights concerning those data (informed consent). The processing of personal data in CONNECT-NM shall occur in full accordance with the European data protection regulations (GDPR), as well as national requirements. A Data Protection Officer for CONNECT-NM will be appointed and his/her contact information provided. In any case personal data shall be only stored on a project internal, password protected server and deleted when not needed any more for the Partnership's functioning.
2) Projects selected to be funded by the Partnership may include activities carried out by partners located in non-EU

countries: Switzerland, Turkey, Ukraine and United Kingdom. Materials produced in CONNECT-NM may therefore have to be transferred to these countries, or vice versa, e.g. for characterisation purposes. Any activity conducted in those countries on the materials handled within the project will be of the same kind as those conducted in EU countries, i.e. they full comply with EU laws. In no case shall biological or genetic material be the subject of these activities and exchanges. Occasionally, researchers from these countries may travel to EU countries, and vice versa. The activities carried out by EU researchers in those countries will be of the same kind as those carried out in the EU, and vice versa, thus they also fully comply with EU laws, and the workers shall not be exposed to working conditions that do not comply with international and EU laws concerning, i.e. the handling of active materials. Nonetheless, Partnership's Projects involving interaction with these non-EU countries will be asked to provide the relevant ethics self-assessment.
3) Projects selected to be funded by the Partnership may make use of specific artificial intelligence techniques, defined as 'machine-learning' (ML), to assist researchers in the analysis of large or small numbers of materials data. For instance, ML may be used with a view to operating a fast screening of the most suitable materials for given applications based on a large set of properties, or else to establishing correlations between a given dependent variable of importance (e.g. a material property with nuclear safety implications) and complex and interconnected sets of independent variables that characterise the material. These techniques by no means endanger human autonomy and decision-making, as they are only meant to assist researchers to make choices, by providing additional data for the human brain to understand and decide. Nonetheless, Partnership's Projects handling these types of tools will be asked to provide the relevant ethics self-assessment.
The Coordinator, with the help of the MSO, will therefore produce a report that details the measures taken within CONNECT-NM to ensure the respect of all relevant ethics requirements, and/or to provide evidence that this is done. This report will be updated periodically, with information from Projects, to take into account their specificities, which cannot be anticipated before the Projects are selected through calls.
Related Milestones and Deliverables:
Deliverable 1.7.2.1: Ethics Requirements – First issue (M3) - EERA/CVR
Deliverable 1.7.2.2: Ethics Requirements – Second issue (M21) – EERA/CVR
Deliverable 1.7.2.3: Ethics Requirements – Third issue (M45) – EERA/CVR

Work package WP2 – Education, Training, mobility and Access to Infrastructures

Work Package Number	WP2	**Lead Beneficiary**	2 - CEA
Work Package Name	Education, Training, mobility and Access to Infrastructures		
Start Month	1	**End Month**	60

Objectives
The WP is devoted to the organisation and monitoring of education, training and mobility activities, as well as to establish and maintain a framework for the access of the participants to infrastructures, especially large ones, to carry out the activities planned in the Partnership.

Description
Task 2.1 Education and Training. Lead: RATEN; Other partners: CEA, CIEMAT, CEA/EDF, ENEN, GRS, ENEA/POLIMI, STUBA, ENEA/UniBo. M1-M60 This task focuses on the identification of the skills concerning nuclear materials needed for the deployment of the future European nuclear industry and on the organization of E&T events, networks and schemes. An E&T plan defining the rules and procedures for the mobility scheme, the detailed topics and schedule of the schools and workshops and the subjects and preliminary topics for the online training will be issued during the first year of the partnership. Communication on these activities will be performed jointly with WP3. Related Milestones and Deliverables: Deliverable 2.1.1: Education and Training Plan (M4) - CEA Subtask 2.1.1: Mobility scheme (ENEN + CEA, CIEMAT). M1-M60 The mobility scheme will support MSc students, PhD students, post-docs, (early stage) scientists and researchers to participate in conferences, training courses, summer schools, internships, workshops and/or scientific exchange visits, helping them to acquire and develop their competences. This scheme will make use of the network and resources of

ENEN (ENEN++). During the first year, a common working group (EvaCo) will be set-up to evaluate the proposals in this field with ENEN++, at least until May 2025.
Related Milestones and Deliverables:
Deliverable 2.1.1.1: Synthesis of the mobility activities in the nuclear materials field funded by ENEN++ (M23) – ENEN
Deliverable 2.1.1.2: Synthesis of the mobility activities in the nuclear materials field funded by ENEN++ follow-up (M60) – ENEN

Subtask 2.1.2: Summer schools (CEA + CIEMAT, ENEN, GRS, SSM/KTH, ENEA/UniBo, ENEA/Polimi). M1-M53
Summer Schools, exploiting the cooperation with other European initiatives to avoid duplication and for mutual benefit of the projects, will be organized every year. The school portfolio will include courses from already existing initiatives, including project partners, IAEA, OECD-NEA, as well as newly training courses developed in the Partnership. Based on the existing training offers and the identified training needs, a gap analysis will be performed. Once these gaps in the existing landscape are identified, priorities will be defined.
The schools will favour exchanges with senior scientists in the field, and will make students and young scientists aware of the latest advances obtained in the area.
The envisaged activities are as follows:
• 2024, 2026, 2028: European School on Nuclear Materials Science (ESNMS): overview of the methods and techniques used in the nuclear materials domain
• 2025: role of research reactors in development and qualification of nuclear materials. Collaboration with JHR advanced school
The subjects will be confirmed and the organization teams will be chosen during the partnership.
Related Milestones and Deliverables:
Milestone 2.1.2.1: Organization or co-organization of first school (M2) – CEA
Milestone 2.1.2.2: Organization or co-organization of second school (M14) – CEA
Milestone 2.1.2.3: Organization or co-organization of third school (M26) – CEA
Milestone 2.1.2.4: Organization or co-organization of fourth school (M38) – CEA
Milestone 2.1.2.5: Organization or co-organization of fifth school (M50) – CEA
Deliverable 2.1.2.1: Report on the schools organised or co-organised in CONNECT-NM (M53) – CEA

Subtask 2.1.3: Young researcher networking and workshops (RATEN + CEA, ENEN). M1-M58.
A young researcher network will be created early in the partnership to establish links between these future professionals in the various areas of the nuclear materials field. Particular attention will be dedicated to the integration of junior researchers (MSc thesis students, PhD students, post-docs) in the scientific and technical community, since they form the next generation of experts in the field of nuclear materials. A workshop will be organized every year. Each Research Line will propose topics for workshops and the host institutes and lecturers will be chosen according to the theme addressed by each workshop. Young researchers will be involved in the organisation of the workshops (teamed with expert in the field).
Related Milestones and Deliverables:
Milestone 2.1.3.1: Setting up of young researcher network and organization of first workshop (M8) – RATEN
Milestone 2.1.3.2: Organization of second workshop (M20) – RATEN
Milestone 2.1.3.3: Organization of third workshop (M32)– RATEN
Milestone 2.1.3.4: Organization of fourth workshop (M44) – RATEN
Milestone 2.1.3.5: Organization of fifth workshop (M56) – RATEN
Deliverable 2.1.3.1: Report on the young researcher network and workshops (M59) – RATEN

Subtask 2.1.4: Online training (STUBA, CEA, ENEN, ENEA/POLIMI). M1-M44.
Online training, e.g. MOOCs, of interest for the nuclear material field available will be identified and specific online training on subjects not covered will be developed.
Related Milestones and Deliverables:
Deliverable 2.1.4.1: Synthesis of online training available on nuclear materials (M11) – STUBA
Deliverable 2.1.4.2: First online training developed by CONNECT-NM (M26) - POLIMI
Deliverable 2.1.4.3: Second online training developed by CONNECT-NM (M44) - CEA

Task 2.2 Access to Infrastructures. Lead: NRG; Other participants: CEA, CEA/IRSN, CEA/EDF, EERA/CVR. M1-M60.
This task is devoted to identifying opportunities and initiating actions for the access of the participants to infrastructures, especially large ones, to carry out the activities planned in the Partnership. An important aspect will be to inform the partners of the opportunities identified. The activities in Task 2.2 are based partly on the suggested course of action that is described in Deliverable 4.14 of the ORIENT-NM project: Final possible plan for a joint European forum for the coordination of nuclear infrastructure management.
Related Milestones and Deliverables:

Deliverable 2.2.1: Synthesis on European opportunities to facilitate access to infrastructures and obtain funding for nuclear materials experiments (M9) – NRG
Deliverable 2.2.2: Synthesis of links to infrastructures of CONNECT-NM projects (M60) – NRG

Subtask 2.2.1: Access to neutron irradiation facilities (CEA/IRSN + NRG, CEA, CEA/EDF, EERA/CVR). M1-M53.
The focus of this subtask is to identify opportunities of collaborations to fund irradiations and to prepare the legal framework for such collaborations, which should be ready before irradiations can be performed (maybe even designed). Three actions will be included in this subtask:
- Collaboration with FIDES-III OECD/NEA framework. A MoU between the project and the FIDES-III initiative will be prepared. CONNECT-NM will focus in priority on the European aspects of this international collaboration;
- Exchanges with the JHR community to guarantee the consistency of the SRA with the JHR roadmap and identify needs and opportunities for future material irradiations (JHOP2040 CSA);
- Exchanges with ongoing HEU Euratom projects and consortia for future projects, in which irradiation needs are identified, feasibility is investigated, or in which irradiations are being designed or prepared.
Related Milestones and Deliverables:
Deliverable 2.2.1.1: MoU between CONNECT-NM and FIDES-III (M17) – CEA
Deliverable 2.2.1.2: First report on exchanges with FIDES-III (M21) – IRSN
Deliverable 2.2.1.3: Second report on exchanges with FIDES-III (M42) – NRG (to be confirmed via AWPs)
Deliverable 2.2.1.4: Third report on exchanges with FIDES-III (M57)– IRSN (to be confirmed via AWPs)

Subtask 2.2.2: Access to other facilities, in particular ion irradiation facilities and hot labs (CEA/EDF + CEA, NRG, CEA/IRSN, EERA/CVR). M1-M50.
This subtask will include mainly the collaboration with the HEU project OFFERR running under the auspices of the SNETP. A MoU between the projects will be prepared.
- Regular presentations of the status of CONNECT-NM at OFFERR meetings and vice versa;
- Involvement of the CONNECT-NM partners in the OFFERR project. There is a considerable overlap between the participants of CONNECT-NM and OFFERR. Encourage and help facilities of the partners to join the OFFERR infrastructures available to host researchers;
- Contribution to the update of the European User Facility Network (EUFN) catalogue maintained in OFFERR: material research area;
- Technical, research-based cooperation: proposals for projects in CONNECT-NM could be linked to OFFERR proposal for the use of infrastructure.
In addition, other facility networks and open access schemes, e.g. EMIREA (French ion irradiator network), JRC, Czech CIRR scheme (https://www.cicrr.cz/infrastracture) will be identified and liaised with. Information will be given to partners about these opportunities
Related Milestones and Deliverables:
Deliverable 2.2.2.1: MoU between CONNECT-NM and OFFERR (M5) – EDF
Deliverable 2.2.2.2: First report on exchanges with OFFER and contribution of CONNECT-NM to the update of the EUFN catalogue maintained in OFFERR (M14) – EDF
Deliverable 2.2.2.3: Second report on exchanges with OFFER and contribution of CONNECT-NM to the update of the EUFN catalogue maintained in OFFERR (M26) – EDF
Deliverable 2.2.2.4: Report on contribution to OFFERR follow-up (M38) – EDF (to be confirmed via AWPs)
Deliverable 2.2.2.5: Report on access to infrastructures contribution after OFFER (M50) – EDF (to be confirmed via AWPs)
Milestone 2.2.2.1: Presentation of CONNECT-NM at OFFERR meeting (M3) – CEA
Milestone 2.2.2.2: Presentation of CONNECT-NM at OFFERR meeting (M20) – EDF

Work package WP3 – Communication, Dissemination and Result Exploitation

Work Package Number	WP3	**Lead Beneficiary**	5 - EERA
Work Package Name	Communication, Dissemination and Result Exploitation		
Start Month	1	**End Month**	60

Objectives
The overall aim of WP3 is to increase the visibility and support the impact of the CONNECT NM Partnership and its project results. The necessary dissemination and communication activities, including the promotion of open science, will

be planned and undertaken to accomplish this goal. Result exploitation and impact at large will be continually evaluated and boosted through the work of the Innovation and Exploitation Group (IEG). In summary, the objectives of this work package are: (i) To communicate the ongoing work and the results of the project in terms that are readily understandable to stakeholders, not only industry, research and academia, which are already widely represented in CONNECT-NM, but also policymakers; (ii) To promote the dissemination of the project findings through the project website, scientific publications, and presentations at webinars, workshops and conferences; (iii) To foster, under the guidance of experts in innovation and exploitation of results coming from industry and the entrepreneurship world, advice and/or services aimed at enhancing the impact and exploitation potential of projects funded by CONNECT-NM.

Description

Description of work

Task 3.1 – Dissemination, outreach and engagement strategy and plan. Lead EERA, Other Partners: CIEMAT, CEA, ENEA, JRC, SSM, GRS, ENEA/UniBo, GRS/Fraunhofer, NRG, CEA/IRSN, NCBJ, ENEA/Newcleo, ENEN, SNETP-in-kind.

Subtask 3.1.1: Visual identity and communication materials (EERA + CIEMAT; ENEA/MP) M1-M12. To ensure consistent identification of the Partnership, a logo to be used on all project materials will be developed. Templates for deliverables, milestones and presentations will be provided to project participants (by M3), and a flyer and a roll-up will be produced (by M6). According to the evolution of the partnership, it is foreseen that assistance will be provided to make key documents visually attractive for the main stakeholders and in line with the visual identity of the partnership.
Related Milestones and Deliverables:
Deliverable 3.1.1.1: Visual identity material (M3) - EERA
Deliverable 3.1.1.2: Communication materials (M6) - EERA

Subtask 3.1.2: Communication and Dissemination Master Plan (EERA + CIEMAT, JRC, ENEA, SSM, ENEA/UniBo, EERA/Fraunhofer, GRS, NRG, CEA/IRSN, CEA, VTT, NCBJ, ENEA/Newcleo, ENEN, SNETP-in-kind). M1-M60. Several communication measures and targeted audiences associated with CONNECT NM have been identified and quantified throughout the sections 1.1.4 and 2.2. The Communication and Dissemination Master Plan (CDMP) will outline the communication and dissemination activities planned by the CONNECT NM partners for the whole project duration. Produced by M4, this document describes the overall communication strategy for the Partnership and functions as a guide for project partners when speaking or conducting activities about or on behalf of the project. The aim is to include also initiatives of communication and dissemination that incorporate a gender dimension. The CDMP will be updated yearly in an effort to exploit new synergies, dissemination opportunities and interactions that may arise. The CDMP will include:

a) A stakeholder map and network: to enhance the effectiveness of this sub-task, a critical step will be the development of a stakeholder map in which all possible stakeholders, including the ones already identified in section 1.1.4, will be described and categorized according to their potential interest in the partnership, with a view to increasing the opportunities of collaboration and extend the corresponding network.
Consistently with section 1.1.4, the stakeholder map included in the CDMP will be organized according to the following categories:
• International organizations and European associations (CIEMAT + CEA, CEA/IRSN, SNETP)
• Bodies active in the field of standardization (JRC)
• Bodies active in the field of materials data format and management (UniBo)
• Regulators and TSOs (SSM, GRS + CEA/IRSN)
• Fusion and non-nuclear energy (ENEA, EERA/Fraunhofer + CIEMAT)
• Infrastructure managers and initiatives to give access to and coordinate the use of nuclear research facilities (NRG, CEA/IRSN)

b) An engagement plan: Based on this input, an engagement plan will be put together in which, for each stakeholder category, the following will be defined: (i) a plan to effectively communicate the project through various channels, including websites, newsletters and social media with targeted key messages according to their interests; (ii) outreach events, workshops and conferences for the relevant audiences to learn about the project and share insights and experiences from already participating parties. Whenever suitable and beneficial, CONNECT-NM will take part in the organization of already planned third-party events.

c) Key tasks and deliverables per work package: The CDMP will also identify per work package the main tasks and activities that will be carried out, for example, summer schools and mobility schemes (in WP2), targeted workshops (in the RLs), etc., with the purpose of enhancing their promotion as well as the dissemination of their results. For this,

periodic meetings (every three months) will be organized with WP leaders to identify their key tasks and deliverables and to put in place a specific communication and dissemination plan.

Related Milestones and Deliverables:
Deliverable 3.1.2.1: First version of the CDMP (M4) - EERA
Deliverable 3.1.2.2: Second version revised of the CDMP (M14) - EERA
Deliverable 3.1.2.3: Third version revised of the CDMP (M26) - EERA
Deliverable 3.1.2.4: Fourth version revised of the CDMP (M38) - EERA
Deliverable 3.1.2.5: Fifth version revised of the CDMP (M50) - EERA

Subtask 3.1.3: Interaction with external stakeholders (CIEMAT + JRC, EERA, ENEA, SSM, ENEA/UniBo, EERA/ Fraunhofer, GRS, NRG, CEA/IRSN, SNETP-in-kind). M1-M60. Following the identification of key stakeholders in Subtask 3.1.2, the protocols of interaction broadly identified in section 1.1.4 and recalled in section 2.2 will be further defined and applied by the various organizations in charge, depending on the category of the stakeholders (see list above). The activities of implementation of these protocols will be reported in the annual progress report of the work-packages (especially the research lines) involved (see descriptions of WPs 4 to 8).
Importantly, SSM will take the initiative to create and manage a board of representatives of European regulatory bodies (Board of Regulators, BoR) as an advisory body for the Partnership. Biannual meetings (hybrid, virtual or in person) of the BoR will be organized to produce feedback and recommendations for further unfolding the partnership's activities. The work of the BoR is described in more detail in section 2.2.
Similarly, GRS will create and manage a board of representatives from European technical safety organizations (Board of TSOs, BoTSO) serving as an advisory group for the partnership. The BoTSO will mirror most of the features of the BoR. Biannual meetings (hybrid, virtual or in person) of the BoTSO will be organized to produce a concise document of recommendations for the partnership's ongoing and further unfolding activities. Furthermore, final recommendations will be developed, enabling the change of paradigm in nuclear materials research and in the practice of TSOs beyond CONNECT-NM.

Related Milestones and Deliverables:
Milestone 3.1.3.1: Identification of members of the Board of Regulators and Board of TSOs (M12) – SSM, GRS
Milestone 3.1.3.2: Establishment of terms of reference defining the way of working of BoR and BoTSO(M18) – SSM, GRS
Deliverable 3.1.3.1: First Feedback and Recommendations of the BoR and BoTSO (M24) – SSM, GRS
Deliverable 3.1.3.2: Final Feedback and Recommendations of the BoR and BoTSO (M60) – SSM, GRS

Task 3.2 – Design, creation and maintenance of the partnership's website. Lead ENEA/MP; Other Partners: CIEMAT, EERA/CVR, EERA. M1-M60.
A website will be created and managed by ENEA/MP at the beginning of the project in English (M3). Its objective will be threefold: (i) to provide information about the project and the future partnership's calls and outcomes, as well as to disseminate the project deliverables available for public diffusion and other publications produced during the partnership, (ii) to act as a communication channel with the relevant stakeholders, (iii) to support functions and tasks in the context of the coordination and daily management of the Partnership. EERA/CVR will make sure that the website remains up-to-date.
In addition to its informational role, the website will incorporate various interactive features such as survey functionalities, event registrations, database member management, member mailings, and online applications. These features will be aligned with the existing Joint Programme on Nuclear Materials website to ensure continuity and a seamless user experience. EERA and CIEMAT will actively participate to define the evolving features of the website. EERA/CVR shall be in charge to keep the website up-to-date.
Related Milestones and Deliverables:
Milestone 3.2.1: Website operative (M3) – ENEA/MP

Task 3.3 – Dissemination and outreach actions alignment among funded projects. Lead EERA; Other Partners: CIEMAT, EERA/CVR, ENEA/MP, STUBA. M1-M60.

Subtask 3.3.1: Dissemination and outreach guidelines and monitoring (EERA + CIEMAT, ENEN). M13-M60. This subtask will guarantee that the partnership-funded projects will receive support from the consortium partners for their own communication and dissemination activities. For this, as of year 2, a set of guidelines will be put into place with recommendations and best practices, and a series of webinars (in principle, one per year) will be organized to align them in this respect. Moreover, a procedure will be put into place for the financed projects to report back on the activities of communication and dissemination carried out and their results.
Related Milestones and Deliverables:
Deliverable 3.3.1.1: Communication and dissemination best practices handbook (M18)

Subtask 3.3.2: Publications follow-up and open science promotion (STUBA + CIEMAT, EERA/CVR, EERA, ENEA/MP) M1-M60. In this subtask, all CONNECT-NM publications and scientific output in general, including datasets and open software, will be kept track of, for all projects financed by the partnership. An overall list of publications and scientific output will be maintained and made accessible via the website, ensuring that this list is well reflected on appropriate repositories, as well as on the Commission portal whenever relevant, with appropriate links to all of them. In addition, this subtask will take measures to promote open science practices within CONNECT-NM. In particular:

• A procedure will be set in place (by M6) to trace the publications and any scientific output of the participants involved in the Partnership and its Projects. This procedure will be implemented on the website of CONNECT-NM.

• A list of suitable and recommended open-access journals will be prepared and periodically updated.

• Open Science Guidelines (OSG) will be prepared at the beginning of the Partnership (M9) and periodically updated, where the above procedure is described, and any relevant information is provided, together with recommendations to encourage the use of open science practices, particularly in connection with open early sharing and reproducibility of results.

• Accepted articles and preprints shall be shared by timely storing them in suitable open-access repositories, in accordance with the Data Management Plan; posts on social media will be used to promote publications and scientific output in general.

Related Milestones and Deliverables:

Milestone 3.3.2.1: Procedure to monitor scientific output in place (M6) - STUBA

Deliverable 3.3.2.1: First issue of the OSG (M9) - STUBA

Deliverable 3.3.2.2: First revision of the OSG (M36) - STUBA

Deliverable 3.3.2.3: Final revision of the OSG (M48) - STUBA

Task 3.4 – Creation and functioning of the IEG and guidance for boosting innovation. Lead CEA/EDF, ENEA/Newcleo; Other Partners: EERA, EERA/CVR, CIEMAT, SNETP(in-kind). M1-M60.

The Innovation and Exploitation Group (IEG) is composed of commercialization and exploitation experts from various key nuclear industries, such as, in addition to EDF and Newcleo, also Ansaldo Nucleare, ENGIE, or Framatome, together with entrepreneurship representatives, e.g. from startups, and to have contacts with EIC accelerator and other EC innovation and result exploitation boosters. The IEG's primary responsibility will be to offer advice and/or services aimed at enhancing the exploitation potential of projects funded by CONNECT-NM, as well as to report back through its chair and/or vice-chair to the ExB and the GA of CONNECT-NM concerning strategic orientations in order to boost innovation. Within the first year of the partnership, the terms of reference for the IEG will be defined, specifically regarding their role and tasks, the frequency of their meetings, as well as management structure, if applicable. Each IEG member will sign non-disclosure agreements before the group can start its activities. These non-disclosure agreements do not need to be nominative; they may include a whole group at the organization to which the IEG member belongs. Two leading organizations involved in CONNECT-NM, namely EDF and Newcleo, will be in charge of creating the group, defining its way of working and producing over time the relevant deliverables, i.e. the periodic recommendation reports of the IEG. The other group members will act as free-of-charge consultants for identifying innovation and result exploitation paths.

EERA will support, actively monitor and disseminate information about the work of the IEG, particularly providing links with the complimentary support services provided by EU projects and initiatives such as the Horizon Results Booster. By diligently tracking these valuable resources, the IEG and the Partnership's Projects will have the possibility to remain updated on the latest tools, programs, and initiatives that can further amplify the exploitation potential of the partnership's results.

Additionally, starting from the third year of the partnership, EERA, in collaboration with the IEG and interested beneficiaries, will organize a minimum of two webinars per year. These webinars will serve as platforms to share information about exploitation services and address any queries or concerns.

Related Milestones and Deliverables:

Milestone 3.4.1: Creation of the IEG with signature of non-disclosure agreement (M12) - CIEMAT

Deliverable 3.4.1: Approved Rules of Procedures of the IEG (M12) – EDF, ENEA/Newcleo

Deliverable 3.4.2: First recommendation report of the IEG (M20) - EDF, ENEA/Newcleo

Deliverable 3.4.3: Second recommendation report of the IEG (M32) - EDF, ENEA/Newcleo

Deliverable 3.4.4: Third recommendation report of the IEG (M44) - EDF, ENEA/Newcleo

Deliverable 3.4.5: Final recommendation report of the IEG (M56) - EDF, ENEA/Newcleo

Deliverable 3.4.6: Final report on the IEG activities and related initiatives (M60) - EERA

Work package WP4 – Nuclear materials knowledge & data management

Work Package Number	WP4	Lead Beneficiary	14 - NCBJ
Work Package Name	Nuclear materials knowledge & data management		
Start Month	1	End Month	60

Objectives

The overall objective of WP4 is the coordination of the CONNECT-NM activities for the development of a methodology for data management to be adopted by all the research lines that will allow the establishment of a Nuclear Materials Knowledge Organization System (NM-KOS). The aims are the improvement of interoperability between different knowledge domains, the integration between heterogeneous data sources, and the application of the FAIR principles, facilitating the exploration of the knowledge system content by human agents and at the same time to design autonomous digital agents to navigate and harvest the overall content through AI approaches.

Description

Task 4.1 – Preparation of project call(s) on knowledge and data management. Lead: NCBJ; Other Partners: ENEA, ENEA/UniBo, CIEMAT/UPM. M1-M18 (repeated later if there is a second call).
Definition of high level milestones, scope and expectations, also suggesting KPIs, for the preparation of the call for proposals in the first year of the Partnership. Within the framework of the envisioned NM-KOS, it is expected that projects will comprise the following activities :
● Exploration of the nuclear materials domain and the data organisation methodology within a selected RL. Identification of the primary entities and their interrelationships. Cross-cutting cooperation with the domain of experts.
● Translation of the methodology into an ontology model based on the EMMO ontology.
● Linking and integration of the knowledge concepts with actual datasets (expected tight cooperation with the on-going PSP project experts).
The expected results are:
● A preliminary system at least partially encompassing the data of a specified Research Line. The system should provide the capability of data holding and navigation, and should be compliant with the architectonic and methodological prerequisites of NM-KOS.
If there is a second call, the task will be repeated and the content updated.
Related Milestones and Deliverables:
Deliverable 4.1.1: RL1 contribution to call preparation: scope, expectations, expected impact, KPIs, … (M2) - NCBJ

Task 4.2 – Guidance and follow up of projects within the research line. Lead: NCBJ; Other Partners: ENEA, ENEA/UniBo, CIEMAT/UPM. M1-M60.
In this task the projects selected through the call for proposals for this research line will be guided and advised, following up project meetings and organising inter-project meetings, as well as promoting cross-cutting activities with other RLs, as needed. Internal deliverables will be approved and collected in a common workspace. The follow up of the scientific output will be ensured, under the guidance of the Open Science Officer. Work will be reported in the annual Research Line 1 Progress Report (RL1PR), using the provided template. This will include the report of all Projects belonging to the research line.
Related Milestones and Deliverables:
Deliverable 4.2.1: First annual RL1PR (M8) - NCBJ
Deliverable 4.2.2: Second annual RL1PR (M20) - NCBJ
Deliverable 4.2.3: Third annual RL1PR (M32) - NCBJ
Deliverable 4.2.4: Fourth annual RL1PR (M44) - NCBJ
Deliverable 4.2.5: Fifth annual RL1PR (M56) - NCBJ

Task 4.3 – Interaction with internal and external stakeholders of relevance for the research line. Lead: ENEA/UniBo. Other Partners: ENEA, NCBJ, CIEMAT/UPM. M1-M60
This task will be implemented in cooperation with subtasks 3.1.2 and 3.1.3, with which periodic meetings will be held. All relevant stakeholders will be searched and identified. This includes the owners, administrators and project communities involved with relevant (nuclear) materials data and databases, such as ENTENTE, and materials related Horizon Europe projects. Additionally, platforms focused on knowledge and data management like EMMC and EMCC, as well as international organisations, like IAEA, will also be engaged. Data and system users will be identified and engaged to initiate dialogue, gather their specific requirements, and facilitate connections with stakeholders. This engagement aims

to foster collaboration and refine the knowledge system to accurately meet users' needs. Guidelines will be provided for other research lines on internal data management, addressing areas like database structure, documentation, knowledge base mappings, data quality, security, and interaction with this WP. If relevant and feasible, joint workshops with the data & knowledge management communities will be explored.
The work done in this task will be reported in the annual RL1PR.
Related Milestones and Deliverables:
Deliverable 4.3.1: Guidelines for research line internal data management (M12) – ENEA/UniBo

Task 4.4 – Data management plan. Lead: NCBJ. M1-M54.
The Data Management Plan (DMP) for Nuclear Materials Research will encompass a comprehensive approach to handle a wide array of datasets. These will range from experimental results, observational logs, images, texts, to outcomes from advanced numerical models, with data volumes potentially ranging from gigabytes to petabytes. A pivotal component of this plan will be the integration of the Nuclear Materials Knowledge Organization System (NM-KOS) to streamline data organization, accessibility, reusability and interoperability. Central to the plan will be ensuring data findability, with the incorporation of Digital Object Identifiers (DOIs) and deposits into trusted repositories like institutional archives or domain-specific databases. Recognizing the critical nature of nuclear information, the DMP will emphasize rigorous Intellectual Property Rights (IPR) considerations, ensuring that sensitive data will be well-guarded. Timelines for transitioning to open access, where feasible, will be clearly defined. However, the conservative nature of the nuclear sector might limit complete open access. To foster data interoperability, the DMP will lean on widely recognized standards, formats, and domain-specific vocabularies, ensuring seamless collaboration and data exchange. Emphasizing reusability, the DMP will lay out terms for data sharing under licenses like Creative Commons, along with the provision of tools and software for data generation and analysis. A specialized team, dedicated to data management, will be entrusted with the task of preserving data integrity and ensuring its long-term safekeeping. The associated costs, especially considering the security measures for sensitive information, will be integral to the plan.
Related Milestones and Deliverables:
Deliverable 4.4.1: First data management plan (M6)
Deliverable 4.4.2: Revision of data management plan (M30)
Deliverable 4.4.3: Final data management plan (M54)

Task 4.5 – (PSP) Nuclear Materials Knowledge Base (NM-KB) Implementation and Documentation. Lead: ENEA/UniBo; Other Participants: ENEA, NCBJ, CIEMAT/UPM. M1-M12
The primary objective of this pre-selected project is to implement at pilot-scale, and document, the Nuclear Materials Knowledge Base (NM-KB). Emphasizing its foundational nature, the NM-KB is intended to provide a robust base for the comprehensive management and understanding of nuclear materials. The project is divided into two primary goals: (1) Documentation of the NM-KB Architecture and Default Functionality; (2) Pilot-Scale Implementation of NM-KB. Full detail is given in the 1st AWP. Work will be reported in the RL1PR.

Work package WP5 – Advanced materials development and manufacturing

Work Package Number	WP5	**Lead Beneficiary**	6.2 - newcleo
Work Package Name	Advanced materials development and manufacturing		
Start Month	1	**End Month**	60

Objectives
The objectives of this WP are (1) To pave the way to the creation of a potential nuclear MAP in Europe, developing more efficient methodologies which would enable the process of materials discovery and development to become significantly faster and more sustainable; (2) To develop innovative materials solutions to improve the design of structural components, core components, advanced fuel elements (enhanced accident tolerant fuels and enhanced performance fuels), or concrete structures in current or future nuclear reactor technologies; (3) To explore, extend and qualify practical applications of advanced manufacturing processes, including high technology coating processes, to nuclear reactor components design. This will be done through projects, both pre-selected and selected through calls. Projects will have a certain degree of freedom but will have to integrate themselves properly in the future work defined following the pre-selected project on the MAP definition. For example, by addressing one aspect required to improve the efficiency of screening procedures as stated in the methodology section: (a) Application of advanced and fast fabrication methods; (b) Optimized methods to accelerate exposure and subsequent testing; (c) Development of advanced characterization with modern digital techniques.

Description
Task 5.1 – Preparation of project call(s) on advanced materials development and manufacturing. Lead: ENEA/Newcleo; Other Partners: CEA/EDF, KIT/HZDR, KIT, SMM/Chalmers. M1-M18. Definition of high-level milestones, scope, and expectations, also suggesting KPIs, for the preparation of the call for proposals in the first year of the Partnership. It is expected that in this call the activities of this RL will focus on the development of innovative materials solutions for structural and core components, and advanced fuel elements. The classes of materials under scrutiny in this WP are nuclear materials, metallic alloys, concrete, coatings, ceramic and composite materials. Specifically, the investigation on advanced fuels aims at improving the performance and methods of fabrication of nitrides, carbides, MOX, CERMET or CERCER fuel materials. The time-to-market of novel materials is accelerated by employing digital technologies. The expected results are the development of materials and fabrication processes enabling the design and fabrication of new components, that enhance safety in nuclear power reactors. The initial calls are going to be aligned with the activities planned for the first year in Task 5.4. The topics of interest are: • Automatization of advanced manufacturing processes • Discovery of synergies with non-nuclear MAPs • Application of MAP to irradiation and post-irradiation experiments The main outcome of the project is going to be the ìdetailed description of a nuclear MAP module. The results are going to be extended to additional manufacturing processes and materials. If there is a second call, the task will be repeated, and the content updated. Related Milestones and Deliverables: Deliverable 5.1.1: RL2 contribution to call preparation: scope, expectations, expected impact, KPIs. (M2) – ENEA/Newcleo Task 5.2 – Guidance and follow up of projects within the research line. Lead: ENEA/Newcleo; Other Partners: CEA/EDF, KIT/HZDR, KIT, SMM/Chalmers. M1-M60. This task is dedicated to follow up, guide and advise the projects belonging to this research line, organising project meetings and cross-project meetings and encouraging cross-cutting activities with other RLs, as required. The RLL and advisors will monitor the projects through 2 meetings per year (1 physical and 1 remote). They will ensure the connection with fusion projects and non-nuclear applications whenever synergies are applicable. Representatives of other communities could be invited to relevant meetings. RLL and advisors will also ensure, with the help of Project leaders, good connection with other RL, by participating to their respective Project's meetings, whenever relevant, and including their corresponding RL and advisors at relevant RL2 Projects meetings. Specific meetings between RLL, advisors and relevant Project leaders could be implemented to tackle specific interface issues. Interactions with all other RLs are expected in the scope of MAP development. The activities described above are linked with Task 5.4.3, where synergies with existing MAPs in the non-nuclear environment are explored. After collecting and consolidating all projects reports, an annual Research Line 2 Progress Report (RL2PR) will be produced by the Research Line leader (RLL) and advisors, using the provided template, after M6 of each Partnership year. It will detail administrative parts like meetings and issued internal deliverables of projects or other organizational aspects, summarize scientific results obtained in RL projects, mention the forward planning of the projects and comment on impact. Internal deliverables will be approved and collected in a common workspace. The follow up of the scientific output will be ensured, under the guidance of the Open Science Officer. Related Milestones and Deliverables: Deliverable 5.2.1: First annual RL2PR (M8) – ENEA/Newcleo Deliverable 5.2.2: Second annual RL2PR (M20) – ENEA/Newcleo Deliverable 5.2.3: Third annual RL2PR (M32) – ENEA/Newcleo Deliverable 5.2.4: Fourth annual RL2PR (M44) – ENEA/Newcleo Deliverable 5.2.5: Fifth annual RL2PR (M56) – ENEA/Newcleo Task 5.3 – Interaction with internal and external stakeholders of relevance for the research line. Lead: ENEA/Newcleo; Other Partners: CEA/EDF, KIT/HZDR, KIT, SMM/Chalmers. M1-M60. This task will be implemented in coordination with subtasks 3.1.2 and 3.1.3, with which periodic meetings will be held. The national and Euratom projects mentioned in section 1.2.2.1.5, along with other non-nuclear stakeholders, will be contacted to integrate their results into the RL and better conduct projects selected during the open calls. In particular, MAPs under development and applied with some degree of success to other materials, in Europe and elsewhere, will be contacted, along with ML experts and digital development structures. Of importance will be, in this framework, the interaction with the EU-MACE Cost Action. The work done in this task will be reported in the annual RL2PR. Task 5.4 – (PSP) Towards accelerated nuclear materials development – The potential of Nuclear Material Acceleration Platforms and additive manufacturing (MAP-NM). Lead: KIT; Other Partners: EERA/BAM, CEA, SSM/Chalmers, CEA/EDF, KIT/HZDR, ENEA/Newcleo, VTT. M1-M12.

The pre-selected project will be dedicated to: (a) Define a potential nuclear MAP; (b) Evaluate all required modules and self-driving laboratories and their acceleration potential; (c) Identify the acceleration and innovation potential of advanced/additive manufacturing; (d) Describe the interfaces and communication between the modules; (e) Assess existing MAPs outside the nuclear material environment and evaluate possible synergies; (f) Describe in detail the nuclear specific modules (irradiation and PIE) and proposed future potential projects.
The material of focus will be metallic alloys for various applications in the nuclear environment. Full detail is given in the 1st AWP. Work will be reported in the annual RL2PR.

Work package WP6 – Materials and component qualification: testing, standardization and design rules

Work Package Number	WP6	**Lead Beneficiary**	6 - ENEA
Work Package Name	Materials and component qualification: testing, standardization and design rules		
Start Month	1	**End Month**	60

Objectives

The main objective of this work-package is to identify methods to accelerate material qualification. This implies:
1) To evaluate, develop and implement Accelerated Qualification Paths (AQPs) that depend on the class of material, the nuclear system and the level of targeted innovation.
2) To integrate, coordinate and operate test facilities under joint 'Test-Beds' (TBs) to carry out the qualification in a realistic time-frame.
The definition of the AQPs will involve: i) identification of the operational conditions for materials, fuel and components and their safety requirements; ii) compilation of available data in databases; iii) verification of safety functions and generation of data/evidence, iv) synthesis of data/evidence. The AQPs will rely on characterization platforms, the TBs, which will enable exhaustive and repeatable testing according to specific procedures for the intended use. The possibility of using accelerated testing for design will be assessed and the relative standardized protocols or guidelines developed. The TBs will result from coordinated exploitation of present and future European facilities and infrastructures and their rationalized use under a Quality Management System (QMS).

Description

Description of work
Task 6.1 – Preparation of project call(s) on materials and component qualification: testing, standardization and design rules. Lead: ENEA; Other Partners: CEA/Framatome, JRC, NRG, RATEN, JSI/ZAG. M1-M18 (repeated later if there is a second call).
High level milestones, scope and expectations, also suggesting KPIs, will be defined, to enable the preparation of the call for proposals in the first year of the Partnership. It is expected that in this call the activities of this RL will focus on the implementation of AQPs for structural materials, fuel and components. The qualification process will rely on the implementation of TBs involving infrastructures/skills at European level. Expected result is the development an accelerated qualification framework on specific case studies based on (i) accelerated exposure and testing and (ii) support of modelling, data management and design of experiments. If there is a second call, the task will be repeated and the content updated.
Related Milestones and Deliverables:
Deliverable 6.1.1: RL3 contribution to call preparation: scope, expectations, expected impact, KPIs. (M2) - ENEA

Task 6.2 – Guidance and follow up of projects within the research line. Lead: ENEA; Other Partners: CEA/Framatome, JRC, NRG, RATEN, JSI/ZAG. M1-M60.
This task is dedicated to follow up, guide and advise the projects belonging to this research line, organising project meetings and cross-project meetings and encouraging cross-cutting activities with other RLs, as required. The RLL and advisors will monitor the projects through 2 meetings per year (1 physical and 1 remote). Representatives of other communities could be invited to relevant meetings. RLL and advisors will also ensure, with the help of Project leaders, good connection with other RL, by participating to their respective project's meetings, and including their corresponding RL and advisors at relevant RL3 project meetings. Specific meetings between RLL, advisors and relevant project leaders could be implemented to tackle specific interface issues. Interactions with all other RLs are expected in the scope of QP and TB development. A stronger interface with RL1 and RL5 might be needed.

After collecting and consolidating all projects reports, an annual Research Line 3 Progress Report (RL3PR) will be produced by the RLL and advisors, using the provided template, after M6 of each Partnership year. It will detail administrative parts like meetings and issued internal deliverables of projects or other organizational aspects, summarize scientific results obtained in RL projects, mention the forward planning of the projects and comment on impact. Internal deliverables will be approved and collected in a common workspace. The follow up of the scientific output will be ensured, under the guidance of the Open Science Officer.
Related Milestones and Deliverables:
Deliverable 6.2.1: First annual RL3PR (M8) - ENEA
Deliverable 6.2.2: Second annual RL3PR (M20) - ENEA
Deliverable 6.2.3: Third annual RL3PR (M32) - ENEA
Deliverable 6.2.4: Fourth annual RL3PR (M44) - ENEA
Deliverable 6.2.5: Fifth annual RL3PR (M56) - ENEA

Task 6.3 – Interaction with internal and external stakeholders of relevance for the research line. Lead: ENEA; Other Partners: CEA/Framatome, JRC, NRG, RATEN, JSI/ZAG. M1-M60.
This task will be implemented in coordination with subtasks 3.1.2 and 3.1.3, with which periodic meetings will be held. All relevant stakeholders will be identified and contacted. In particular, the institutions involved in the projects and initiatives mentioned in section 1.2.2.2.5 and the International Standard Developing Organizations, in particular the CEN WS064 joint activities, promoted by AFCEN, focused on 'Design and Construction Codes for Gen II, III and IV nuclear facilities', to create synergies and exchange ideas useful for the progresses of the WP/RL. The outcomes of the work-package could be the basis for proposals for the implementation of nuclear construction codes. Actions will be undertaken to strengthen cooperation with the materials research communities involved in fusion technology. Synergies will also be identified with European projects and initiatives on materials for application in high temperatures in hostile environments. Finally synergies will be established and developed with mutual benefit with projects and initiatives on concrete, a material that features heavily in all engineering applications. The work done in this task will be reported in the annual RL3PR.

Task 6.4 – (PSP) Preliminary analysis of the requirements for selected test-beds for nuclear materials. Lead: ENEA; Other Partners: CEA, CEA/Framatome, JRC, NRG, RATEN, JSI/ZAG, CIEMAT, SSM/KTH, CNRS, KIT, EERA/CVR, CEA/NEWCLEO, ENEA/POLIMI. M1-M16.
The pre-selected project will be dedicated to carry out a preliminary analysis of the requirements for selected AQPs and relevant TBs. The state of the art in selected areas relevant for the work in RL3 will be established based on the R&D and pre-normative needs for nuclear materials and components and the present understanding of the materials issues involved. The recommendations and guidelines will also concern the implementation of the QA of the TBs. Full detail is given in the 1st AWP. Work will be reported in the annual RL3PR.

Work package WP7 – Non-destructive examination and materials health monitoring

Work Package Number	WP7	**Lead Beneficiary**	5.2 - Fraunhofer
Work Package Name	Non-destructive examination and materials health monitoring		
Start Month	1	**End Month**	60

Objectives

The main goal of this WP is to develop intelligent materials health monitoring systems to predict material properties over the whole component lifecycle: multi-parameter-based approaches combining different NDT&E techniques to efficiently characterize materials' properties similarly to having different human-senses, using ML algorithms that remove irrelevant or spurious data, best blended in cognitive sensor systems, for advanced digital twin concepts of industrial applicability. The results of this RL will provide knowledge complementary to standard approaches and will help to: (1) Improve knowledge about how nuclear materials behave at high temperature and in conditions of strong degradation (e.g. high irradiation doses, strong corrosive environment), typical of advanced nuclear systems; (2) Develop and improve predictive methodologies for materials behaviour that should be applicable under an increasingly wide range of operational conditions. The ambition of this RL is also to increase sustainability, providing tools that enable test cycles to be reduced and shortened and the number of required tests to be minimized, thus reducing radioactive waste.

Description

Task 7.1 – Preparation of project call(s) on non-destructive examination and materials health monitoring. Lead: EERA/ Fraunhofer; Other Partners: CEA, CER-EK, CEA/EDF. M1-M18.
Definition of high level milestones, scope and expectations, also suggesting KPIs, for the preparation of the call for proposals in the first year of the Partnership. It is expected that in this call the activities of this RL will be limited to the development and optimisation of non-destructive testing and examination (NDT&E) and materials health monitoring techniques for at least a couple of the four pre-selected classes of nuclear materials, for which ID cards have been developed in ORIENT-NM. The expected results are the design and development of examples of intelligent materials health monitoring systems, suitable to be extended for material characterization along the entire material value chain, from material development (under lab conditions) until the end of operation (under operation conditions). If there is a second call, the task will be repeated and the content updated.
Related Milestones and Deliverables:
Deliverable 7.1.1: RL4 contribution to call preparation: scope, expectations, expected impact, KPIs. (M2) – EERA/ Fraunhofer

Task 7.2 – Guidance and follow up of projects within the RL. Lead: EERA/Fraunhofer; Other Partners: CEA, CER-EK, CEA/EDF. M1-M60.
This task is dedicated to follow up, guide and advise the projects belonging to this research line, organising project meetings and cross-project meetings and encouraging cross-cutting activities with other RLs, as required. Internal deliverables will be approved and collected in a common workspace. The follow up of the scientific output will be ensured, under the guidance of the Open Science Officer. Work will be documented in the annual Research Line 4 Progress Report (RL4PR), using the provided template. This will include the report of all projects belonging to the research line (including the pre-selected project).
The RLL and advisors will monitor the projects via two annual meetings (one in person and one remote). Furthermore, the RLL and advisors will guarantee suitable connection with other RL by being present at their respective project meetings, as well as incorporating their equivalent RL and advisors into related RL4 project meetings with the support of Project leaders. Meetings between the RLL, advisors, and relevant project leaders should be arranged to address specific synergies, particularly with RL5, RL6 and RL8.
Upon gathering and consolidating all project reports, RL4 Progress Reports (RL4PR) will be written by the RLL and advisors, using the provided template. The reports will describe the administrative elements of the projects, such as meetings and internal deliverables, as well as other organizational aspects. Additionally, it will provide a summary of the scientific findings obtained in the RL projects, state the forward planning of the projects, and comment on their impact. Internal deliverables will undergo approval and will be collected in a shared workspace. The Open Science Officer will oversee the follow-up of the scientific output.
Related Milestones and Deliverables:
Deliverable 7.2.1: First annual RL4PR (M8) – EERA/Fraunhofer
Deliverable 7.2.2: Second annual RL4PR (M20) – EERA/Fraunhofer
Deliverable 7.2.3: Third annual RL4PR (M32) – EERA/Fraunhofer
Deliverable 7.2.4: Fourth annual RL4PR (M44) – EERA/Fraunhofer
Deliverable 7.2.5: Fifth annual RL4PR (M56) – EERA/Fraunhofer

Task 7.3 – Interaction with internal and external stakeholders of specific relevance for the RL. Lead: EERA/Fraunhofer; Other Partners: CEA, CER-EK, CEA/EDF. M1-M60.
This task will be implemented in coordination with subtask 3.1.3, with which periodic meetings will be held. On-going national research programmes and related projects centred on NDT&E and materials health monitoring will be searched for and identified to establish clusters at national/MS level. Synergies will also be identified with European projects or initiatives dealing with NDT&E for materials operation in challenging conditions (high temperature, corrosive environment). Collaboration with projects funded under Horizon-CL5 can be considered, whenever dedicated to NDT&E for materials and components. In addition, joint activities will be identified with the Technical Area 8 of the SNETP, European Network for Inspection and Qualification (ENIQ), and the transversal JP on Digitalisation for Energy of EERA. Synergies with ongoing European projects such as INNUMAT, DELISA-LTO, and pilot projects of EERA JPNM will also be established. If relevant and feasible, joint workshops with the fusion community will be explored. All activities carried out in this task will be included in the annual RL4PR report.

Task 7.4 –NDT&E along material value chain with respect to three different components and their respective materials and different targeted operation conditions (PSP). Lead: EERA/Fraunhofer; Other Partners: CEA, CER-EK, STUBA, VTT. M1-M12.
In order to reach the goal of this RL, namely the development of intelligent materials health monitoring systems to predict material properties over the whole material/component lifecycle, the PSP will include several activities in support of future projects. A structural matrix will be generated, containing types of NPP materials and components, the operational conditions and related degradation phenomena (in strong collaboration with RL2), and NDT&E applicable at different

segments of the material/component lifecycle, together with their physical principles. Additionally, a thorough analysis of the established guidelines and regulations will be carried out, which may require a review of legal considerations concerning the implementation of NDT&E. Beforehand, attempts will be made to align testing procedures and protocols based on widespread best practices applied across NDT&E laboratories. Full detail is given in the 1st AWP. The work will be reported in the annual RL4PR.

Work package WP8 – Advanced materials modelling and characterization

Work Package Number	WP8	Lead Beneficiary	20 - VTT
Work Package Name	Advanced materials modelling and characterization		
Start Month	1	End Month	60

Objectives

The main objective of this RL is to develop and improve advanced predictive methodologies for nuclear materials behaviour in the areas of structural metals of the primary and secondary circuits, ceramic fuel materials and concrete materials of containments and biological shields. These methodologies are expected to blend physical and data-driven approaches and to become of direct applicability at industrial level, under increasingly wide ranges of operational conditions. This includes advancing multiscale modelling (MSM) approaches by identifying and then resolving gaps in the chaining between scales, as well as improving the efficacy of particular models that currently rely on empirical shortcuts, by combining physics-based and data driven solutions. It also includes identifying and expanding the datasets amenable to machine learning and artificial intelligence. Moreover, the methodologies will help transfer experimental results from different irradiation conditions, e.g. from charged particles to neutrons or fission products. The ultimate ambition of this RL is, through improved modelling and characterization methods, to increase sustainability, by providing tools to reduce specimen size, shorten the test cycles and minimize the number of required tests, so as to decrease the radioactive waste.

Description

Task 8.1 – Preparation of project call(s) on Advanced materials modelling and characterization. Lead: VTT; Other Partners: CEA, IRB, KIPT/Energorisk. M1-M18.
Definition of high level milestones, scope and expectations, also suggesting KPIs, for the preparation of the call for proposals in the first year of the Partnership. The call will enable the identification of case studies that are particularly apt to demonstrate the possibility of improving predictive capabilities, by blending physics-based and data-driven models and/or by linking methods and plan their development. It is expected that the activities of this RL will comprise: 1) advancing particular physics-based models, 2) improving chaining between scales, 3) utilizing data-sets to discover new solutions through the employment of machine learning, and 4) executing particular experiments dedicated to supplying necessary data enabling the aforementioned activities. The expected results are the development or improvement/ extension of physics-based models describing the behaviour of materials under irradiation across scales and of blended physically-based/data-driven models. These should enable the improvement of design and fuel performance codes towards high fidelity and advanced numerical capabilities, in connection and complementarity with projects underway. If there is a second call, the task will be repeated and the content updated.
Related Milestones and Deliverables:
Deliverable 8.1.1: RL5 contribution to call preparation: scope, expectations, expected impact, KPIs. (M2) - VTT

Task 8.2 – Guidance and follow up of projects within the RL. Lead: VTT; Other Partners: CEA, IRB, KIPT/Energorisk. M1-M60.
This task is dedicated to follow up, guide and advise the projects belonging to this research line, organising project meetings and cross-project meetings and encouraging cross-cutting activities with other RLs, as required. Internal deliverables will be approved and collected in a common workspace. The follow up of the scientific output will be ensured, under the guidance of the Open Science Officer. Work will be documented in the annual Research Line 5 Progress Report (RL5PR), using the provided template. This will include the report of all projects belonging to the research line.
Related Milestones and Deliverables:
Deliverable 8.2.1: First annual RL5PR (M8)- VTT
Deliverable 8.2.2: Second annual RL5PR (M20) - VTT

Deliverable 8.2.3: Third annual RL5PR (M32) - VTT
Deliverable 8.2.4: Fourth annual RL5PR (M44) - VTT
Deliverable 7.2.5: Fifth annual RL5PR (M56) - VTT

Task 8.3 – Interaction with internal and external stakeholders of specific relevance for the RL. Lead: VTT; Other Partners: CEA, IRB, KIPT/Energorisk. M1-M60.
This task will be implemented in coordination with subtask 3.1.3, with which periodic meetings will be held. The target of this task is to collect information on available data and on-going activities related to materials modelling and characterisation from project partners to advance the WP8 related activities and avoid duplication of work. Interaction with external stakeholders will be activated in the programme start based on the mapping of the stakeholders (T3.1.2). Interaction will take place via e.g. e-mails, webinars, workshops, meetings and input to newsletters. All activities carried out in this task will be included in the annual RL5PR report.

Task 8.4 – Assessment and demonstration of advanced predictive methodologies (PSP). Lead: VTT; Other Partners: CEA, CIEMAT, CNRS, CNRS/CL, KIPT/Energorisk, VTT/HU, IRB, JSI, SSM/KTH, NCBJ, JRC, NNL. M1-M12.
As evident from the Material ID cards prepared in ORIENT-NM, advanced models are used to differing extents in different material groups. In this PSP a comprehensive technical assessment will be carried out with the objective of identifying specific factors that hinder the full utilization of multiscale models and other advanced models across all the material groups. This assessment will evaluate the extent to which different scales are modelled for each material group, to identify particular gaps for which further developments are required in modelling practice (e.g. data driven), in input data and in characterization methods. An evaluation will also be conducted to identify available data sets, for which ML tools could be employed for data-driven approaches. Finally, by way of proof-of-concept, three different exercises will be carried out with advanced predictive methodologies. All activities will be reported in the annual RL5PR. Full detail is given in the 1st AWP.

Horizon Europe (HORIZON)

Euratom Research and Training Programme (EURATOM)

Description of the action (DoA)

Part B

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LIST OF ABBREVIATIONS

A-BOX	Assertional box
AE	Affiliated Entity
AFCEN	L'Association française pour les règles de conception, de construction et de surveillance en exploitation des matériels des chaudières électro-nucléaires
AM	Additive Manufacturing
AMI2030	Advanced Materials Initiative 2030
AMR	Advanced Modular Reactor
AQP	Accelerated Qualification Paths
AP	Associated Partner
APC	Article Processing Charge
APT	Atom Probe Tomography
ARLPR	Annual Research Line Progress Reports
Arqane	Actions de Réalisation et Qualification en Additif pour le Nucléaire
ASME	American Society of Mechanical Engineers
ATF	Accident Tolerant Fuel
ATF-TS	Testing and Simulation for Advanced Technology and Accident Tolerant Fuels
AWP	Annual Workplan
BEN	Beneficiary
BoR	Board of Regulators
BoTSO	Board of TSOs
CA	Consortium Agreement
CDM	Coordination and Daily Management
CDMP	Communication and Dissemination Master Plan
CEP	Co-funded European Partnership
CONNECT-NM	COORDINATION OF THE EUROPEAN NUCLEAR MATERIALS COMMUNITY FOR ENERGY INNOVATION
CORDEL	Cooperation in reactor design evaluation and licensing
COSIRES	COmputer Simulation of IRradiation Effects in Solids
CP	Crystal Plasticity
CRP	Coordinated Research Projects
CRUD	Create, Read, Update, Delete
CSA	Coordination and Support Action
DD	Dislocation Dynamics
DFT	Density Functional Theory
DIADEM	Dispositifs intégrés pour l'accélération du déploiement de matériaux émergents
DM	Data Management
DMP	Data Management Plan
DMS	Data Management System
DOIs	Digital Object Identifiers
E&T	Education and Training
ECCC	European Creep Collaborative Committee
EERA	European Energy Research Alliance
EERA JPNM	EERA Joint Programme on Nuclear Materials
EMMO	European Materials Modelling Ontology
ENEN	European Nuclear Education Network
ENIQ	European Network for Inspection and Qualification
EPERC	European Pressure Equipment Research Council
ESNII	European Sustainable Nuclear Industry Initiative
EUFN	European User Facility Network
EvaCo	Evaluation Committee
ExB	Executive Board
FAIR	Findability, Accessibility, Interoperability, and Reusability
FIDES-II	2nd Framework for Irradiation Experiments
FR	Fast reactor
GA	General Assembly or Grant Agreement *(depending on context)*
GDPR	European data protection regulations
GIF	Generation IV International Forum
HEA	High Entropy Alloys
HIP	Hot-Isostatic Pressing
HPC	High-Performance Computing
I`M4EU	Innovative Materials for the EU
IAEA	International Atomic Energy Agency
IEG	Innovation and Exploitation Group

IPR	Intellectual Property Rights
JHR	Jules Horowitz Reactor
JP	Joint Programme
JSON-LD	JavaScript Object Notation link data
KDM	Knowledge and Data management
KM	Knowledge Management
LPBF	Laser Powder Bed Fusion
LTO	Long-Term Operation
LWR	Light Water-cooled and moderated Reactor
MA	Minor Actinides
MAP	Materials Acceleration Platforms
MD	Molecular Dynamics
ML	Machine Learning
MOOCs	Massive Open Online Courses
MSO	Management Support Office
MTR	Materials Testing Reactor
NDE	Non-Destructive Examination
NDT&E	non-destructive testing and evaluation
NEA	Nuclear Energy Agency
NEST	Nuclear Education, Skills and Technology
NLP	Natural Language Processing
NM-DMS	Nuclear Materials Data Management System
NM-KB	Nuclear Materials Knowledge Base
NM-KOS	Nuclear Materials Knowledge Organisation System
NPP	nuclear power plant
NuMat	Nuclear Materials Conference
OCES	Ontology Commons EcoSystem
OECD	Organisation for the Economic Cooperation and Development
OFFERR	eurOpean platform For accessing nucleaR R&d facilities
OO	Operational Objectives
ORIENT-NM	Organisation of the European Research Community on Nuclear Materials
OSG	Open Science Guidelines
PAPREP	Publishable Annual Partnership's Report
PAS	Positron Annihilation Spectroscopy
PEPR	programme d'équipement prioritaire de recherché
PHQ	Project Quality Handbook
PIE	Post–Irradiation Examination
PMT	Project Management Tool
PSP	Pre-Selected Project
PWR	Pressurised Water Reactor
QA	Quality Assurance
QP	Qualification Paths
R&D&I	Research, Development and Innovation
RL	Research Line
RLA	Research Line Advisor
RLCT	RL Coordination Team
RLL	Research Line Leader
RLPR	Research Line Progress Report
RLXPR	Research Line X Progress Report
RPV	Reactor Pressure Vessel
SAB	Scientific Advisory Board
SCC	Stress-Corrosion Cracking
SDL	Self-Driving Laboratories
SEM	Scanning Electron Microscopes
SET	Strategic Energy Technology
SHM	Structural Health Monitoring
SMA	Strategic Materials Agenda
SME	Small and Medium-sized Enterprises
SMINS	International Workshop on Structural Materials for Innovative Nuclear Systems
SMoRE II	Accelerator Simulation and Theoretical Modelling of Radiation Effects
SMR	Small and medium size Modular Reactor
SNETP	Sustainable Nuclear Energy Technology Platform
SO	Specific Objective
SQL	Structured query language

SRA	Strategic Research Agenda
T-BOX	Terminological box
TBs	Test-Beds
TEM	Transmission Electron Microscopes
TRL	Technology Readiness Level
TSO	Technical Support Organisation
t-WP	Transversal Work-Packages
WNA	World Nuclear Association
WP	Work-Packages
WPFM	Working Party on Materials Science Issues+A1:D123 in Nuclear Fuels and Structural Materials

1. EXCELLENCE

1.1. Objectives and ambition of the Partnership

1.1.1 Ambition, general objective and vision of CONNECT-NM

The **ambition** of CONNECT-NM is to strengthen safety and sustainability of nuclear energy by promoting innovation in the field of materials for operation under extreme conditions (high temperature and irradiation dose, chemically aggressive environments[1]), to ensure high safety standards in power generation, while accelerating the process of materials development, improvement and qualification, thereby reducing time-to-market. For this purpose the **general objective** of this Partnership is to nurture the coordinated exploitation of national competences, facilities and infrastructures in Europe. European entities with national mandate for research in nuclear materials will join, in pursuance of the common goal of a shift of paradigm in nuclear materials research, from the traditional 'observe and qualify', to the modern 'design and control'. This paradigm change in the field of nuclear materials mirrors the general principle currently targeted in materials science for any application, which reads: 'fit-for-purpose, safe and sustainable by design', in line with the Commission recommendation of 8.12.2022: 'Establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials'. Importantly, in the case of nuclear materials 'safe and sustainable' has a twofold implication, by referring also, and crucially, to the safety and sustainability of the components and systems that are built using fully fit-for-purpose, safe and sustainable materials. The enablers of this paradigm shift are modern digital techniques, such as machine learning (ML), data analytics, high-performance computing, block-chain, robotics, which are at the core of data-driven modelling, high throughput calculations and experiments, and development of digital twins, together with advanced manufacturing techniques and (when available) also lifecycle sustainability assessment tools. In this respect, CONNECT-NM contributes to the current trend towards digitalisation, in the field of materials science (materials informatics).

The **vision** of CONNECT-NM on nuclear energy and materials has been developed in the framework of the **ORIENT-NM** (Organisation of the European Research Community on Nuclear Materials) Coordination and Support Action (CSA), which was partially funded by the Euratom research and training work-programme 2019-2020 (GA 899997) and lasted from October 2020 to March 2023. Significant continuity exists between the coordination group of **ORIENT-NM** and the core group involved in the preparation of the proposal of the present Action. This vision, which is described in the easily downloadable vision paper and strategic research agenda of **ORIENT-NM**, covers:

- **Sustainability**: Nuclear power plants (NPPs) are crucial components, together with renewables, of a resilient and sustainable Energy Union, helping Europe to abate the use of fossil fuels, reduce European geopolitical dependence and become the first climate-neutral continent by 2050. Consistently, projections of the Nuclear Energy Agency (NEA) of the Organisation for the Economic Cooperation and Development (OECD) show that, to achieve net zero by 2050[2], the world nuclear energy capacity should triple by 2050 and many countries, including European ones, are indeed moving forward to expand it. While the proposal of the present Action was under preparation, ministers and industry leaders from over two dozen countries were exploring how to bring new nuclear energy capacity quickly on line, to help governments to achieve their net zero targets (Government-industry conference to chart the nuclear energy path to net zero). Like for all technologies, these efforts need to align with the continuous improvement of the sustainability of nuclear energy. In this context, the European nuclear materials science community, united in CONNECT-NM, is called to provide the tools, knowledge and skills to enable each European country to maintain the desired and needed nuclear capacity and, depending on national policies and priorities, to develop advanced nuclear systems, towards ever increasing sustainability.
- **Innovation**: Research on materials can play a crucial role in enhancing the safety, efficiency, economy and overall sustainability of nuclear energy, in support of: (1) safe and affordable long-term operation (LTO) of current generation (GenII, GenIII) light water-cooled and moderated reactors (LWRs); (2) increasingly safe design, licensing and construction of GenIII+ new builds; (3) deployment of light water small and medium size modular reactors (SMRs) within the next decade; (4) reduction of time and costs for the design, licensing and construction of competitive next generation, more sustainable nuclear reactors, including advanced SMRs (AMRs), within the time horizon of 2040. For example, intelligent online materials health monitoring techniques, coupled with advanced manufacturing, enable the timely detection and replacement of potentially damaged components, thereby increasing safety and safely prolonging the lifetime of the installation. Advanced materials solutions that can withstand higher operating temperatures in contact with harsh radiation and/or chemical environments

[1] These extreme environments are found also in non-nuclear energy applications, e.g., in solar thermal energy, geothermal energy, biomass and hydrogen combustion … That is, the scope of this Partnership goes beyond the boundaries of nuclear energy in a natural way. This is why the name of this Partnership mentions 'energy innovation', and not only 'nuclear energy innovation'.
[2] European Net-Zero Industry Act: Accelerating the transition to climate neutrality

enable the efficiency of the system to be increased and provide higher safety margins in case of deviations from normal functioning. Both achievements have clear and positive economic effects. For this to happen, however, a strong push towards innovation is needed, in order for materials and materials science to effectively produce such impact. Promoting innovation in the field of nuclear materials is the main focus of CONNECT-NM.

- **Acceleration**: The development and qualification of innovative materials solutions in terms of advanced materials and advanced manufacturing processes needs to be accelerated, while also accounting for circularity and sustainability principles. In addition, improving the capability of predicting materials and component behaviour in operation, assisted and verified by continuous monitoring, is crucial in support of safe and effective nuclear plant life management and nuclear component design. Producing this acceleration and achieving these challenging capabilities requires a structured and continued collaboration between academia, research organisations and industrial partners all over Europe. The instrument of a co-funded European partnership (CEP) is especially suitable to build such a structured and continued cooperation, leveraging national capabilities and harmonising national and industrial goals to develop a single European strategy for nuclear materials. A goal-oriented CEP is thus the tool to produce the shift of paradigm in nuclear materials from 'observe and qualify' to 'design and control'.

This vision, projected towards a fast transformational evolution in the field of nuclear materials, is all the more of relevance in connection with the nuclear ecosystem that has been emerging in the last few years, with a blooming of startups in Europe, putting forward a number of new innovative and advanced nuclear reactor concepts. These enterprises are attracting both public and private financing, but most of these concepts will need demonstration. Almost all of them will need either new types of materials or at least new fabrication routes for their components, with increased use of health monitoring systems, as well as in-service inspection with devices coupled to digital twins. Thus, almost all of these enterprises are looking for advanced materials to validate their concept. In this framework, CONNECT-NM can help providing the needed skills and expertise, while creating a connection with infrastructures and standardisation bodies, so as to allow these companies to accelerate their proof of concept, similarly to what is being done outside Europe, for instance in the USA (nuclear innovation alliance programme).

Outside the nuclear field, while **ORIENT-NM** was preparing the grounds for the present proposal, the Advanced Materials 2030 Manifesto was signed by seven institutions ranging from research to industry, and was presented to the European Commission. This Manifesto, independently of **ORIENT-NM**, but consistently with the above vision, underlines the key role that advanced materials play in reaching climate neutrality and sustainability. It triggered the launch of the Advanced Materials Initiative 2030 (AMI2030) and the production of its Roadmap and Strategic Materials Agenda (SMA) for a European partnership dedicated to advanced materials, extended to a broad spectrum of applications (nine 'materials markets', namely: healthcare, construction, energy, transport, home & personal care, packaging, agriculture, textiles, and electronics). These show that, irrespective of the specific application, increasingly complex advanced materials are required at an increasingly faster pace and the major challenges in the design, development, scale up, production and processing of these materials have to be tackled in a cross-cutting way, leveraging game-changing methodologies. For this purpose, 'a radical paradigm shift in materials innovation is needed to drastically accelerate the development and adoption of Advanced Materials. This is now conceivable, supported by appropriate R&I infrastructures, data science and accelerated methodologies that integrate the knowledge of key experts, skills and data from across the Advanced Materials value chain (cit. AMI2030 SMA)'.[3]

Clearly, strong connections exist between the paradigm change promoted in CONNECT-NM and the 'universal' materials research approach put forward in AMI2030. On July 17th, 2023, the Commission proposed new candidate European Partnerships (outside the Euratom framework). One of them is dedicated to Innovative Materials for EU (Innovative Materials for the EU, **IAM4EU**). Such a Partnership would be based on the preparation work made in AMI2030. Importantly, however, AMI2030 does not include nuclear materials in its portfolio! Even though the approaches are cross-cutting and this transversality has to, and will, be exploited, any specificity of nuclear energy can only be addressed within CONNECT-NM: if the nuclear materials research community does not have the opportunity to deal with its own specificities, nobody will do so in its stead. From this viewpoint, CONNECT-NM

[3] The SMA continues as follows: 'An emerging technology which will enable this is the Self-driving Lab; an intelligent experimental platform equipped with different hardware modules that iteratively operate a series of syntheses or physical processes selected and planned by machine-learning algorithms in a closed-loop format, to achieve a predefined objective. […] Similarly, virtual (digital twins) or physical pilot lines, enabled by progress in digitalization, allow the simultaneous development, testing and validation of Advanced Materials and related production and processing technologies. […] Digital technologies that support all segments of the materials lifecycle can also play a key role in accelerating appropriate decision-making, notably by developing and implementing: Block-chain-based data management across the lifecycle of materials and products through the different value chains […]; Digital twins that will facilitate innovation and the design of more sustainable materials , processes and products […]; Data spaces providing extensive, cross-sectorial information to guide development and monitor progress towards sustainability. […] Data based on FAIR principles will significantly accelerate the development of Advanced Materials and processing solutions relevant for Europe's innovation markets'.

profiles itself as the 'nuclear twin' of **IAM4EU**: both would be supporting the future Coordinated Plan on Advanced Materials with Member States, which was announced in the Communication on Critical Raw Materials[4].

1.1.2 Specific and operational objectives of CONNECT-NM

To pursue the general objective introduced in 1.1.1, CONNECT-NM will specifically focus on five Grand Goals, which are achievable to sufficient extent within the next decade, assuming of course that the Partnership's continuity is granted beyond the duration covered by the present proposal. [5]

Therefore, the **specific objectives (SOs),** of CONNECT-NM, i.e., the objectives that are characteristic of this Partnership, are as follows:

- **SO1**: **To reduce drastically the time required to improve, develop, and even discover, new or advanced nuclear materials and elaborate advanced manufacturing processes**. This objective is pursued by developing nuclear-oriented materials acceleration platforms (MAPs) and qualifying advanced manufacturing processes for nuclear applications. MAPs are integrated, highly autonomous systems that combine advanced fabrication, characterisation and modelling methods with modern digital techniques (machine learning, robotic systems, high-performance computing, high throughput calculation and also fabrication …), to achieve materials fitness, safety and sustainability by design. Analogous methodologies are already in use in other technology frameworks (see e.g. section 1.1.4.4). Here they will be applied for the benefit of nuclear energy, for instance including charged particle irradiation in the loop to account for irradiation effects, with the promise of significantly reducing time to market and enhancing innovation. Advanced manufacturing processes are also in use in other technology frameworks, but need here to be fully qualified for the nuclear environment, using approaches that are very similar to those adopted in MAPs.

- **SO2**: **To accelerate the qualification of nuclear materials for safe operation**. This is pursued by developing nuclear materials' test-beds where standardized accelerated qualification paths can be systematically followed. Here test-beds are efficient and integrated networked systems of facilities where advanced and suitably standardised experimental procedures and methodologies are applied for nuclear materials exposure, characterisation and testing, be they destructive, non-destructive or microstructural. The combination of test-beds and accelerated qualification paths, based on a traceability chain that provides access to valid uncertainties, will expectedly reduce qualification time. The creation of a network of organisations will offer the nuclear industry a single-entry reference for any specific nuclear materials qualification need that may emerge. The connection with initiatives coordinating the use of neutron irradiation facilities, as well as with regulators, is an important part of the endeavour of developing nuclear test-beds.

- **SO3**: **To enable safer and more efficient management of the lifetime of nuclear components**. This is pursued by developing methodologies for intelligent material and component health monitoring, through suitable sensors that apply advanced non-destructive examination and testing techniques, combined with machine-learning-based online data analysis for fast diagnostics, with the support of simulation tools, i.e. digital twins of the real components. This way of proceeding will enable the timely identification and even anticipation of potential failures, with clear benefits not only, as is self-evident, for safety, but also for efficiency and economy. The timely detection of problems triggers targeted replacement or repair interventions, reducing costs and increasing the lifetime of large or complex components.

- **SO4**: **To improve the capability of prediction of the behaviour of nuclear materials in operation**. The focus here is on developing advanced and innovative predictive methodologies, by suitably blending physical and data-driven (i.e., machine-learning-based) multiscale models. These will be characterised by strong physical rooting, while also being fast and efficient enough to be of direct application for industrial needs. The development of models of this type is an objective in itself, but it clearly supports all the above SOs (MAPs, test-beds, materials health monitoring …), including support to transfer experimental results achieved under different

[4] COM(2023) 165 final.

[5] These Grand Goals are consistent with, and contribute to, the following research and innovation activities of the Strategic Energy Technology (SET) plan implementation concerning nuclear safety: 1 - Plant safety, risk assessment and severe accidents, integrity assessment of systems, structures and components; 2 - Innovative LWR Generation III design, improved reactor operation and fuel developments; 7 - Innovative materials to improve plant safety and efficiency, and qualification for operation under Gen-IV conditions; 8 - Support the development, licensing, construction and commissioning of high priority Gen-IV demonstrators, and for alternative reactor technologies; and 9 - Cogeneration of heat and electricity. These goals also support the key enabling condition nr. 5: Supporting infrastructures. See SET-plan action nr. 10. Because of its scope and focus, CONNECT-NM will also contribute to Sustainable Development Goals nr. 7 (affordable and clean energy), nr. 9 (industry, innovation and infrastructure), nr. 13 (climate action) and, inherently, nr. 17 (partnerships for the goals).

irradiation conditions. Machine-learning methods need here to address the challenge of the smallness of nuclear materials data, as opposed to big data in other applications.

- **SO5: To create the conditions for nuclear materials data to be correctly collected and stored, so as to be fruitfully analysed, used and exploited**, in support of all of the above SOs. This means to create a single European nuclear materials' knowledge organisation system (NM-KOS). Such a system will be based on the progressive development and use of the relevant ontologies (semantic rules), based on the standards, regulations and procedures that apply specifically for nuclear materials, following at all times FAIR (findability, accessibility, interoperability and reusability), as well as data quality, principles. By being built on solid semantic technology, this NM-KOS will be independent of specific data-formats and data-bases, thereby enabling all available data to be managed within a single platform.

It is important to stress that these SOs will be pursued step-by-step, by developing the corresponding methodology for specific case studies of interest, within dedicated research lines. These research lines will cover all materials science activities of relevance for the general objective of CONNECT-NM. The choice of the case studies will not preclude any nuclear fission system, of current or future generation, with emphasis on the extendibility of the methodology beyond the specific case study. This way of operating will ensure that the results of the research activities of CONNECT-NM will:

- be of immediate use for the chosen system and/or material class, thus they will be applicable and applied, and so their validity verified;
- enable further and faster progress in view of application to other case-studies;
- make the SOs realistic, achievable, and measurable in terms of success when applied to the chosen case studies, while in fact being paradigm-breaking objectives of difficult measurability.

The **ORIENT-NM** CSA identified key nuclear materials issues (materials ID cards), via the involvement of more than 50 nuclear materials European experts. Accordingly, the families of materials covered by the present proposal will be limited to 4, namely: structural materials, including concrete and in-core (mainly metallic) materials; nuclear fuel; and fuel cladding materials (including coated materials). Other families, such as polymers, refractory materials and neutron control materials, although of equal importance, will be considered only after the relevant issues are clearly identified by the corresponding European expert communities. In **ORIENT-NM** these communities were revealed to be currently weak in Europe and to need strengthening. This provides also a criterion to streamline and decide about the use of necessarily limited resources. **Figure 1** schematically summarises these concepts, showing the perimeter of the Partnership.

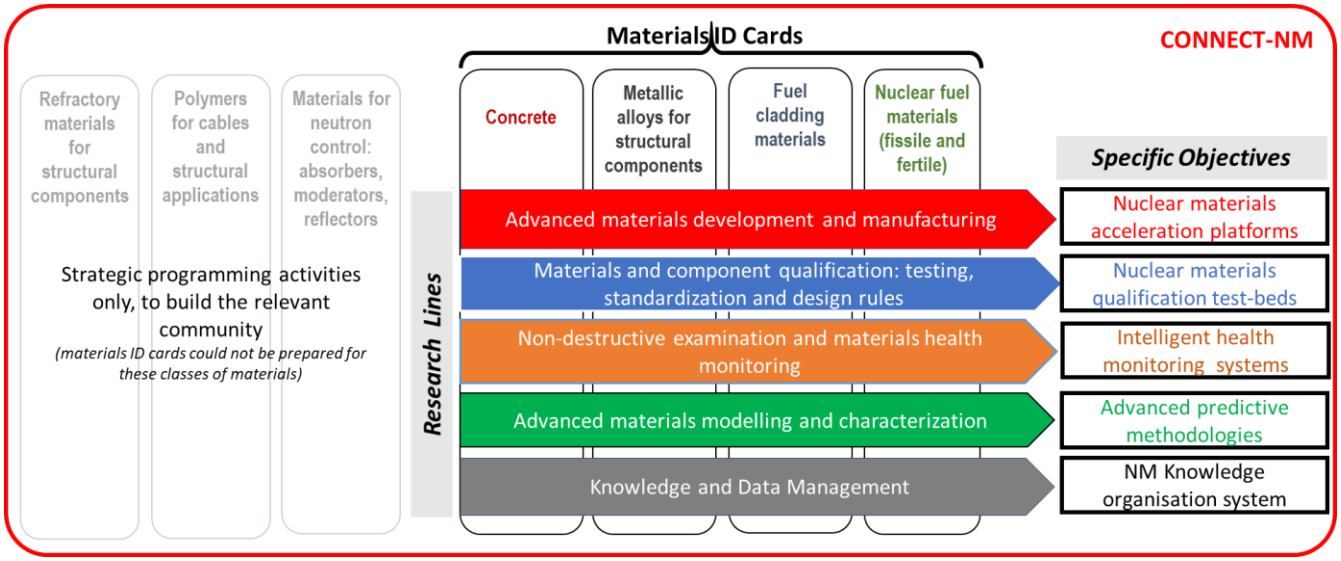

***Figure 1** – Perimeter of CONNECT-NM: materials' families, research lines and specific objectives.*

In support of all and each of the above research lines, i.e. with a view to creating the conditions for the specific objectives to be reached and to broadening their impact, the following **operational objectives (OOs)** are pursued by CONNECT-NM:

- **OO1: Efficiently run the administrative environment and the governance system**, to ensure smooth execution of the targeted research and innovation activities. The governance shall involve EU member states via organisations, called beneficiaries, which receive a national mandate for research in nuclear materials science, together with their affiliated entities. Altogether, beneficiaries and affiliated entities will comprise public and private research organisations, industries and private companies (including SMEs), universities, associations, regulators and technical support organisations (TSOs). The Consortium targets a balanced distribution of responsibilities amongst all these classes of actors.

- **OO2**: **Design and apply an open and transparent procedure for the prioritization of case-studies used for the development of the methodologies within each research line**. Such a procedure shall rely on the matching of top-down general requirements defined within the governance bodies of the partnership and bottom-up formation of open consortia around specific nuclear systems and materials or components.

- **OO3: Ensure the implementation of a monitoring system** to track progress toward objectives, deliverables and milestones, through periodic reporting. The system shall include a self-assessment mechanism, via creation of a Scientific Advisory Board (SAB).

- **OO4: Promote access to the specific infrastructures necessary for nuclear material research activities**, in particular irradiation capabilities, including material research reactors, and hot laboratories, in coordination with existing initiatives. In addition to ensuring access to relevant facilities, a crucial challenge within this objective will be to overcome the limitations in European irradiation capabilities and cover the high costs of neutron irradiations, making use of suitable collaborative frameworks.

- **OO5: Promote high quality and targeted education and training** (E&T) activities in the field of nuclear materials, in coordination with already ongoing initiatives. The selection of these activities will rely on proven needs and will support knowledge preservation and transfer, with a view to preparing a new generation of experts that, from the start of their carrier, will be familiar with the innovative methodologies developed in the framework of CONNECT-NM. Part of this objective is also to make sure that the nuclear materials community can easily access complete and up-to-date information on E&T activities of relevance.

- **OO6: Maximise impact** through the identification of result exploitation paths with the support of an Innovation and Exploitation Group (IEG) and by making use of suitable communication and dissemination tools and practices, with due attention to open science and data management.

1.1.3 Relation to the work-programme

Table 1.1 shows how the activities and features of CONNECT-NM towards the objectives described in 1.1.1 and 1.1.2 match the expected outcomes of the call (HORIZON-EURATOM-2023-NRT-01-04: Co-funded European partnership for research in nuclear materials), contributing to the safe operation of existing and future advanced nuclear installations, including small modular reactors. In this table, each key statement of the call matches the corresponding feature of CONNECT-NM in answer to it. This table, which better clarifies the content of the research lines introduced above, necessarily anticipates information that will be properly described in the remainder of this proposal.

***Table 1.1** – How CONNECT-NM activities and features match the expected outcome from the call*

Nr.	Requirements and expected outcomes from the call	CONNECT-NM match
1	*"This action should contribute significantly to the development of materials for ensuring the highest safety standards and reducing the time-to-market for the various types of materials"*	The ambition of CONNECT-NM is to strengthen safety and sustainability of nuclear energy by promoting innovation in the field of materials for operation under extreme conditions (high temperature and irradiation dose, chemically aggressive environments), to ensure high safety standards in power generation, while accelerating the process of materials development, improvement and qualification, thereby reducing time-to-market. For this purpose the general objective of this Partnership is to nurture the coordinated exploitation of national competences, facilities and infrastructures in Europe. European entities with national mandate for research in nuclear materials will join, in pursuance of the common goal of a shift of paradigm in nuclear materials research, from the traditional 'observe and qualify', to the modern 'design and control'.

Nr.	Requirements and expected outcomes from the call	CONNECT-NM match
2	*"The proposal should also pay due consideration to the criteria for selecting and implementing European partnerships, their monitoring, evaluation, phasing out or renewal as set out in Annex III of the Horizon Europe Regulation"*	The operational objectives address most of these issues: priority selection, implementation, monitoring: (1) Efficiently run the administrative environment and the governance system; (2) Design and apply an open and transparent procedure for the prioritization of case-studies used for the development of the methodologies within each research line; (3) implementation of a monitoring system.
3	*"Proposals should provide for the establishment of an innovation group formed by members that belong to industrial bodies and other relevant institutions, and have expertise in innovation and result exploitation. Its role should be clearly defined. An independent international scientific advisory board established by the partnership would be seen as beneficial for the partnership's activities."*	The monitoring system shall include self-assessment and self-boosting mechanisms, via creation of a Scientific Advisory Board (SAB) and an Innovation and Exploitation Group (IEG). The SAB shall be comprised of internationally recognised experts in the scientific and technical field of materials for nuclear energy. It shall be responsible for giving input to the Partnership concerning operational and strategic issues affecting its scientific and technical orientation. The IEG shall be composed of commercialisation and exploitation experts from various key industry and entrepreneurship representatives. Its primary responsibility will be to offer free-of-charge support advice and/or services aimed at enhancing the exploitation potential of Projects funded by CONNECT NM and possible innovation paths.
4	*"The vision, strategic research agenda and other strategic documents produced by the ORIENT-NM project should form an essential basis for defining the scientific orientation, structure and governance of the partnership on nuclear materials, in full compliance with the rules laid down in the Euratom Research and Training Programme 2021-2025."*	The vision of CONNECT-NM on nuclear energy and materials has been developed in the framework of the **ORIENT-NM** Coordination and Support Action (CSA), which was partially funded by the Euratom research and training work-programme 2019-2020 (GA 899997) and lasted from October 2020 to March 2023. Significant continuity exists between the coordination group of **ORIENT-NM** and the core group involved in the preparation of the proposal of the present Action
5	*"The partnership should be goal-oriented, with well-defined major milestones to enable proper monitoring. Its scope should include all the scientific and technical areas as well as all the horizontal activities related to knowledge management."*	Each specific objective will be pursued step-by-step, by developing the corresponding methodology for specific case studies of interest, within dedicated research lines. These research lines cover all materials science activities of relevance for the general objective of CONNECT-NM. Within each of these research lines, the milestones towards the relevant objective are defined. Knowledge management activities are introduced in two meanings: (1) knowledge organisation systems in connection with data management and (2) education and training initiatives, as part of the operational objectives of CONNECT-NM (OO5).
6	*"Research lines should be proposed with specific projects covering the scientific and technical priorities identified in the strategic research agenda. Projects should cover areas of interest for the relevant national actors and should allow new partners to be included later on whenever relevant. The projects should be defined by technical scope and should not be reserved for just one type of participant."*	The specific objectives will be pursued step-by-step, by developing the corresponding methodology for specific case studies of interest, within dedicated research lines. Projects will address case studies and will be tasks of the various research lines: research lines are thus containers filled with Projects. In this context, one of the operational objectives is to design and apply an open and transparent procedure to prioritise case studies, used for the development of the methodologies within each research line. Such a procedure relies on the matching of top-down general requirements defined within the governance bodies of the partnership and bottom-up formation of open consortia round specific nuclear systems and materials/components. This procedure will take the form of a call for Project proposals, open to all actors: public research organisation, private companies, universities, SMEs … Public brokerage events will make sure that not only the beneficiaries of the partnership and their affiliated entities, but also new third parties, as well as associated partners from outside the EU, can contribute to Projects. The Projects will address case-studies for the development of the methodologies of the research lines, freely selected by multi-participant-type consortia, without preclusion for any nuclear fission system, although

Nr.	Requirements and expected outcomes from the call	CONNECT-NM match
		materials will belong only to the four selected categories (concrete, in-core structural materials, fuel, fuel cladding).
7	*"The partnership should cover all relevant activities: common research and strategic studies, the sharing of facilities, knowledge management, mobility and training of researchers, in collaboration and complementarity with existing initiatives dedicated to coordinating and managing the use of existing nuclear materials research infrastructures."*	Besides the activities within the research lines, which align with the **ORIENT-NM** strategic research agenda, CONNECT-NM has, among others, the following operational objectives. First, to promote high quality and targeted E&T activities in the field of nuclear materials, including training through research and mobility between European organisations, in coordination with existing initiatives (OO5), in particular the ENEN association and the **ENEN++** project, in support of knowledge preservation and transfer. Second, to enable and promote easier access to nuclear infrastructures (OO4). Access to neutron irradiation infrastructures within suitable collaborative frameworks will be a crucial aspect, addressed by interacting with existing European and international initiatives dedicated to coordinating and managing their use (e.g. **OFFERR** and **FIDES-II**). This will optimise and rationalise their exploitation, avoiding repetition and duplication of efforts. In addition, test-beds are expected to be exactly the result of integration of facilities and infrastructures located in different European laboratories, thus consolidating the rational exploitation of research facilities at European level. CONNECT-NM will therefore effectively promote the coordinated exploitation of experimental facilities and infrastructures in Europe, including training and mobility.
8	*"Consolidate, at European level, the exploitation of unique relevant experimental facilities and infrastructures aimed at rationalising their use and avoiding the unnecessary repetition and duplication of costly experiments."*	
9	*"To maximise knowledge management and especially the impact on smaller and less advanced national programmes, a set of horizontal activities on knowledge transfer and on education and training have to be designed and implemented within the partnership. The partnership should be open to international R&D cooperation, with the managers expected to represent it in areas of competence in international events and forums."*	One of the operational objectives (OO5) is to promote high quality and targeted E&T activities in the field of nuclear materials, in support of knowledge preservation and for the preparation of a new generation of experts. These, from the start of their carrier, will be familiar with the innovative methodologies developed in the framework of CONNECT-NM and will address the future needs of the nuclear community and industry. These E&T activities will be organised transversally to all research lines, based on documented needs, i.e. after identification of the type and level of training that is required, including industrial interests. In addition, these activities will be harmonised with similar ones organised at national, European or international level (e.g. IAEA, NEA, …),, to optimise costs and avoid duplications.
10	*"Improve the quality of modern education methods and the training of scientists and nuclear industry specialists in connection with nuclear materials."*	
11	*"Boost knowledge about the durability of the main structural materials used in the nuclear island, such as low alloy, austenitic and ferritic-martensitic steels, as well as other metallic alloys and materials for fuel elements and fuel. This helps ensure that existing and future nuclear plants are operated safely in the long term."*	Knowledge about the durability of metallic structural and cladding materials, as well as fuel, will be boosted in all research lines, especially in 'Materials and component qualification; testing, standardization and design rules', as well as in 'Advanced materials modelling and characterization' and 'Non-destructive examination and materials health monitoring'.
12	*"Improve knowledge about advanced nuclear fuels with optimised performance for different reactor cores, increased safety and lower spent fuel long-term toxicity."*	Advanced and/or accident-tolerant fuels and fuel cladding materials, including coated materials, for application in current and future technology reactors, are part of the partnership's portfolio in all research lines, especially 'Advanced materials development and manufacturing' and 'Materials and component qualification; testing, standardization and design rules'. Another research line is dedicated to developing the 'Nuclear materials knowledge organisation system', which is required to guarantee integrated access to nuclear materials data, responding to FAIR principles, dealing also with data quality aspects.
13	*"Develop and qualify materials and materials solutions (e.g. coatings) for core applications, advanced fuel elements, including enhanced accident tolerant fuels and/or enhanced performance fuels."*	
14	*"Improve knowledge about advanced nuclear fuels with optimised performance for different reactor*	

Nr.	Requirements and expected outcomes from the call	CONNECT-NM match
	cores, increased safety and lower spent fuel long-term toxicity. Determine quality assured data like nuclear cross sections with low uncertainties."	
15	*"Improve knowledge about the degradation of secondary structural materials such as concrete or polymers that are subjected to degrading conditions typical for nuclear installations."*	Concrete is explicitly included in the portfolio. Polymers will enter at a later stage, when the corresponding (and strengthened) research community has identified the relevant issues and synthesised them in materials ID cards.
16	*"Improve knowledge about how nuclear materials behave at high temperatures and in conditions of strong degradation (e.g. high irradiation doses, strong corrosive environment), typical in advanced nuclear systems."*	High temperature, high (as much as reasonably achievable) irradiation and corrosive environments will be part of the case studies selected, e.g., in 'Materials and component qualification; testing, standardization and design rules', as well as in 'Advanced materials modelling and characterization' and 'Non-destructive examination and materials health monitoring', thereby improving knowledge on materials behaviour in these conditions, which correspond to extreme operating conditions that may be common to other systems than nuclear.
17	*"Develop methodologies for identifying innovative materials solutions that are applicable to both nuclear fission and fusion domains."*	A whole research line ('Advanced materials development and manufacturing') addresses the development of nuclear MAPs and advanced manufacturing processes. MAPs are integrated, highly autonomous systems that combine advanced characterisation and modelling with modern digital techniques, to achieve materials fitness, safety and sustainability by design. Nuclear MAPs are *de facto* tools that are suitable to perform a fast screen amongst materials that are potentially resistant to selected extreme conditions for any application. A nuclear MAP is therefore thought to be eventually of use not only for fission, but also for fusion applications, and in general for any applications where materials are exposed to harsh conditions. For this reason, also Member States and Associated Countries that do not use nuclear power to generate electricity can find an interest in participating in the Partnership
18	*"The scope of a partnership on nuclear materials should cover the research interests of all Member States and Associated Countries dealing with nuclear materials research and not be limited to nuclear power generating countries."*	
19	*"Improve research collaboration on materials of common interest with other domains beyond nuclear; this is needed to improve the efficiency of other energy generating technologies (e.g. increased working temperatures of electricity generating turbines) or advanced ones (e.g. concentrated solar power)."*	The methodologies developed in CONNECT-NM are of general applicability in materials science, indeed a similar approach is of application in a very wide range of cases, different from nuclear energy. The specificity of CONNECT-NM is to focus on materials for harsh operating conditions (high temperature and irradiation dose, chemically aggressive environments), which are of wider application than just nuclear energy. In this context, the AMI2030 initiative, which is not under the umbrella of Euratom, represents a promising counterpart for collaboration, even without cash-flow, e.g., by launching parallel projects or setting up schemes for frequent interaction.
20	*"Further develop and optimise modern non-destructive examination techniques needed for the accurate health monitoring of relevant structures during operation, including online and automated strategies."*	A whole research line ('Non-destructive examination and materials health monitoring') pursues precisely this goal: intelligent material and component health monitoring implies the development of the key technologies that enable the application of advanced monitoring methods through non-destructive examination and testing. These, coupled with suitable diagnostics and simulation tools, including advanced predictive methodologies, enable the widespread implementation of digital twins for optimised component and plant life management and increased safety
21	*"Develop and improve predictive methodologies for materials behaviour that should be applicable under an increasingly wide range of operational conditions and help transfer experimental results achieved*	A whole research line ('Advanced materials modelling and characterization') pursues this goal, amongst others: advanced predictive methodologies should suitably blend physical and data-driven (i.e. machine-learning-based) multiscale models, to achieve superior capability

Nr.	Requirements and expected outcomes from the call	CONNECT-NM match
	under different irradiation conditions (for example ion irradiation vs neutron irradiation).”	of prediction of materials behaviour in operation. They are characterised by strong physical rooting, while being also fast and efficient enough to be of direct application for industrial needs. Models of this type are of course also strongly supporting the development of test-beds, MAPs and materials health monitoring schemes, including support to transfer experimental results achieved under different irradiation condition.
22	*“Better understand the transferability of experimental results achieved by different irradiation techniques (for example ion irradiation vs neutron irradiation).”*	
23	*“Develop enhanced standardised experimental techniques necessary to streamline experimental approaches for irradiated materials based on a traceability chain that provides access to valid uncertainties, producing nuclear materials databases that respond to FAIR principles.”*	A whole research line (‘Materials and component qualification; testing, standardization and design rules’) is dedicated to developing standardised qualification paths to be applied in suitable test-beds, i.e., experimental procedures and methodologies for nuclear materials exposure, characterisation and testing, be they destructive, non-destructive or microstructural. These methodologies, based on a traceability chain that provides access to valid uncertainties, provide accelerated paths to qualification. Another research line is dedicated to developing a ‘Nuclear materials knowledge organisation system’, which is required to guarantee integrated storage of and access to (improved) nuclear materials data, responding to FAIR principles, as a basis for design and fuel performance codes. Advanced predictive methodologies developed in ‘Advanced materials modelling and characterization’ also support the improvement of design and fuel performance code.
24	*“Improve nuclear data/reference data, design codes and standards relevant for nuclear materials and fuel performance codes, developed in close agreement with standardisation bodies and in interaction with nuclear regulators and their technical support organisations.”*	
25	*“Improve the transfer of knowledge within the respective research community to European industry and nuclear regulators.”*	Several industries and TSOs are directly involved in the management and strategy making of the Partnership. In addition, part of the communication, dissemination and result exploitation activities target interactions with a wide spectrum of stakeholders. These include certainly industry, which is also involved in CONNECT-NM through participation in WP management and the Innovation and Exploitation Group, as well as regulators and TSOs, via the creation for each of them of a Board that interacts with the Partnership and provides advice, directly involving regulators and TSOs as beneficiaries of CONNECT-NM.

1.1.4 Links and collaboration opportunities

ORIENT-NM thoroughly addressed the issue of establishing links and collaboration opportunities for CONNECT-NM, via dialogue with the concerned stakeholders. They included:

1. International organisations and European associations;
2. Bodies active in connection with standardisation and design codes, materials data format and management and computer science, as well as TSOs and regulators;
3. Fusion energy, specifically EUROfusion (also a Partnership);
4. Other non-nuclear energy technologies and non-Euratom work programme;
5. Frameworks for access to infrastructures, especially irradiation facilities.

These links, described in this section, are very important to make optimal use of the limited financial resources that are allocated to CONNECT-NM, so as to boost the possibilities and thus the impact of the Partnership. In addition, the links with past, present and future Euratom projects are also briefly presented below.

1.1.4.1 International organisations and European associations

a) International Atomic Energy Agency (IAEA), especially the three sections dedicated to LTO, materials for advanced reactor systems and fuel.

Two main channels of interaction have been identified between CONNECT-NM and the IAEA, subject to IAEA’s established mechanisms, rules and regulations, namely:

(1) Coordinated Research Projects (CRP): several on-going CRPs address topics that are of potential interest for CONNECT-NM and are open to creating synergy and interaction with its Projects. In the longer term,

Partnership's Projects may be the motivation for the launch of parallel, or complementary, IAEA CRPs, on subjects of common interest. For instance, the following on-going CRPs are of relevance for CONNECT-NM:

- SMoRE-II (Accelerator Simulation and Theoretical Modelling of Radiation Effects), started 2016;
- Fuel Materials for Fast Reactor, started 2019;
- ATF-TS (Testing and Simulation for Advanced Technology and Accident Tolerant Fuels), started 2020;
- Standardization of Subsized Specimens for Post-Irradiation Examination and Advanced Characterization of Fuel and Structural Materials for Small Modular Reactor and Advanced Reactor Applications, approved, to be started.

(2) Joint organisation of workshops and training courses, e.g. in collaboration with the International Centre for Theoretical Physics in Trieste.

b) Nuclear Energy Agency (NEA) of the Organization for the Economic Cooperation and Development (OECD): Both NEA and CONNECT-NM recognised mutual interaction as beneficial, so as to join efforts devoted to nuclear materials related research. The NEA is a key partner that provides a bridge between the work done within the EU and similar undertakings worldwide. In particular, when standard methods and approaches are to be developed, cooperation with the NEA will provide a broader community of practices. Links with appropriate NEA representatives have been identified and CONNECT-NM representatives are involved in a number of NEA working parties, working group and expert groups, relevant to material science research, e.g. the Working Party on Materials Science Issues in Nuclear Fuels and Structural Materials (WPFM) and the Working Group on Fuel Safety (WGFS). Through these links, NEA task forces may contribute to CONNECT-NM activities and NEA Joint Projects might nucleate from the CONNECT-NM framework. Two already running international Joint Projects are of significant importance: (1) The 2nd Framework for Irradiation Experiments (**FIDES-II**), which promotes international fuels and materials irradiation campaigns; (2) Nuclear Education, Skills and Technology (**NEST**) framework[6]. Not all the NEA member states contribute to these projects, whose membership changes from a project to another, and results are generally only accessible to contributing countries, during an embargo period that is specific to each project. However, the EU participates to some of these efforts through the JRC and, when this is not the case, information exchanges could be organized between the projects' management boards and Partnership's representatives.

c) Generation IV International Forum (GIF): The GIF has established System Steering Committees (SSCs) to implement the R&D for each Generation IV Reactor Concept, with participation from GIF members interested in contributing to collaborative R&D. The collaboration between CONNECT-NM and the GIF may take place through the SSCs: its chair and co-chair may participate, upon invitation, in CONNECT-NM meetings, favouring mutual alignment and reinforcing synergies among the R&I Partnership's programme and the GIF. EURATOM representatives in GIF involved in CONNECT-NM, as well as JRC, may act as contact points, proposing jointly organised dedicated meetings, workshops and seminars, according to needs and opportunities.

d) European associations: Following the example and precedent of the Horizon Europe co-funded European partnership PIANOFORTE, CONNECT-NM includes as beneficiaries three major European associations with strong and deep nuclear energy and materials involvement, namely: SNETP (Sustainable Nuclear Energy Technology Platform), EERA (European Energy Research Alliance) and ENEN (European Nuclear Education Network). These are all international non-profit associations under Belgian law, which pursue networking and scientific goals:

SNETP is the recognised ETIP (European Technology and Innovation Platform) for nuclear energy, in connection with the European Union's SET Plan: it supports and promotes the safe, reliable and efficient operation of Generation II, III and IV civil nuclear systems. SNETP's international membership includes industrial actors, research and development organisations, academia, technical and safety organisations, SMEs, as well as non-governmental bodies. SNETP is engaged to provide in-kind a number of services for related projects, for instance: (1) contribute to dissemination and communication; (2) facilitate researcher's mobility and training; (3) promote harmonisation and cross-cutting issues; (4) ensure dialogue with sectorial stakeholders, Member States, other associations or international organisations.

EERA is the largest low-carbon energy research community in Europe and a key player in the SET Plan. It brings together 250 organisations from 30 European countries that believe in a fair, environmentally

[6] Three additional Joint Projects of interest are:
- **TAF-ID-3**, Thermodynamic of Advanced Fuels – International Database, Phase 3.
- **TCOFF-2**, Thermodynamic Characterisation of Fuel Debris and Fission Products Based on Scenario Analysis of Severe Accident Progression, Phase 2 (closed), EC-JRC Karlsruhe is a member of the project.
- **SMILE**, Studsvik Materials Integrity Life Extension.

sustainable and competitive climate-neutral society, to be built carrying out a pervasive transformative process of the energy system. EERA therefore promotes a holistic and systemic view to address the multidisciplinary nature of the clean energy transition. It pursues the mission of catalysing European energy research for a climate-neutral society by 2050 and coordinates its activities through 18 Joint Programmes (JP) that provide world-leading scientific expertise on three pillars: low-carbon technologies, materials, and systems' topics. One of these JPs (EERA JPNM) is entirely dedicated to nuclear materials and, together with SNETP, is the cradle in which the present Action was born.

The direct involvement of SNETP and EERA is the most efficient way to make sure that the participation in CONNECT-NM's Projects and activities can be the widest possible, reaching down to all potential contributors, throughout Europe and even beyond, and involving all classes of actors, by making use of the wide network of experts that these associations provide. It will also boost the impact of the Partnership, since particularly SNETP offers a strong link with industrials, TSOs and, partly, regulators, as well.

The mission of **ENEN**, in turn, is the preservation and further development of expertise in the nuclear fields by higher E&T. ENEN is equipped with all tools, in particular an established mobility scheme, and contacts to facilitate the organisation and guarantee the success of E&T initiatives. The inclusion of ENEN as beneficiary is therefore crucial to pursue at least two of the operational objectives of CONNECT-NM: improvement of educational methodologies adapted to nuclear materials scientists and promotion of mobility. It will also guarantee that the most complete and up-to-date information about education and training activities in Europe and beyond will be accessible to the whole community of nuclear materials.

Finally, in **ORIENT-NM** also established contacts with NuclearEurope, the voice of the European nuclear industry in energy policy discussions with EU institutions and other key stakeholders. NuclearEurope may act as a springboard and amplifier towards its members and beyond for any communication action undertaken by CONNECT-NM, be it in the form of newsletters, factsheets, or flyers.

1.1.4.2 Bodies active in connection with standardisation and design codes, materials knowledge and data management, as well as TSOs and regulators

a) AFCEN (L'Association française pour les règles de conception, de construction et de surveillance en exploitation des matériels des chaudières électro-nucléaires) is an international association that produces nuclear design codes offering accurate and practical rules for the design, construction and in-service inspection of components, for use in industrial or experimental nuclear facilities. There is an obvious mutual benefit to establish a close collaboration between CONNECT-NM and AFCEN. The designer needs and priorities, defined by AFCEN, provide a roadmap for pre-normative research to be conducted within the Partnership, particularly in the research line 'Materials and component qualification; testing, standardization and design rules'. Members of AFCEN are expected to become involved in the advisory bodies of CONNECT-NM.

b) ECCC (European Creep Collaborative Committee) coordinates Europe-wide development of material data for high temperature applications, in particular creep, with focus on power generation. ECCC is independently governed, although with close links to the European industry, through Joint Industrial Projects that carry out the main R&D activities of interest for the group. The executive committee of ECCC has expressed a strong interest for collaboration with connect-NM on nuclear materials. ECCC provides a link to industrial partners, non-nuclear power generation stakeholders and standardisation bodies. The possibility of a bi-lateral agreement covering commonalities between CONNECT-NM and the ECCC Joint Industrial Programme will be explored (specific legal aspects pending to be analysed).

c) EPERC (European Pressure Equipment Research Council) is a no-profit international association that coordinates, develops and promotes the common technical interests and strategies of European scale through pre-normative research and standardisation work. EPERC organizes conferences, seminars and workshops in the field of pressure equipment and pressure plant, with the collaboration of relevant stakeholders worldwide. EPERC expressed great interest in collaborating with CONNECT-NM, with special emphasis on reviewing and updating the design codes (e.g. in relation to EN 13445), based on pre-normative research. EPERC sees its main role in disseminating research results and industry experience for pressure vessel equipment.

d) CORDEL (Cooperation in reactor design evaluation and licensing) is part of the World Nuclear Association (WNA). It focuses on promoting the international standardisation of nuclear reactor designs and the harmonisation of regulatory requirements, as well as industrial codes and standards, in order to decrease the efforts and modifications needed for a reactor designs deployed in several countries. A representative of CORDEL expressed a clear interest for direct involvement in the CONNECT-NM SAB or IEG.

e) ETSON (European Technical Safety Organisation Network) is the network of 12 national TSOs in Europe. It contributes to the harmonisation of nuclear safety practices within Europe and beyond and carries out joint

research programmes on nuclear safety. A large number of materials-connected areas exist, where nuclear safety is the primary challenge. ETSON will likely interact with CONNECT-NM through national members.

f) EMMC (European Materials Modelling Council) coordinates activities for different stakeholders including modellers, materials data scientists, software owners, translators and manufacturers in Europe with the overall objective to support the integration of materials modelling and digitalisation for more agile and sustainable product development. EMMC's activities and expertise are therefore at the core of the paradigm shift in nuclear materials science that CONNECT-NM pursues. Currently, one representative of EMMC (from UniBo), with expertise in nuclear energy and materials, is directly involved in the research line 'Nuclear materials knowledge organisation system', thereby ensuring that the methodology that is put forward in the EMMC will be applied to nuclear materials, while acting as link with that community. Important EMMC projects, which CONNECT-NM will be drawing on, are:

- **OntoCommons**: Ontology-driven data documentation for Industry Commons (2020-2023). A H2020 CSA dedicated to the standardisation of data documentation across all domains related to materials and manufacturing.
- **OntoTrans**: Ontology-based system for more competitive manufacturing processes (2020-2024). A H2020 project addressing the needs of the materials manufacturing industry to enable access to the relevant information and data and use materials modelling more effectively.
- **OpenModel**: Integrated Open Access Materials Modelling Innovation Platform for Europe (2021-2025). A Horizon Europe project developing an open-access materials modelling platform that aims to provide a comprehensive solutions for Europe's materials modelling needs.

g) EMCC (European Materials Characterization Council) supports the establishment of a community of European stakeholders in the process of developing and improving materials characterisation tools, gathering needs and requirements of this community to a common forum. As part of this activity, a platform for materials open research data is under development. EMCC has strong links with EMMC, which is directly represented in CONNECT-NM via involvement of EMMC members, thus links with EMCC will be established through EMMC.

1.1.4.3 Fusion energy, specifically EUROfusion

The aims of the EUROfusion programme are outlined in the 'Roadmap to the Realisation of fusion Energy', which includes as a mission the research on innovative materials and materials solutions. Three Eurofusion Work Packages are mainly concerned:

- WPMAT (materials), with 7 sub-projects: (1) Engineering Design Data and Integration, to develop DEMO specific design rules for the selected materials; (2) Advanced reduced activation ferritic-martensitic Steels; (3) High Heat Flux Materials for plasma facing components; (4) Functional (optical, dielectric) Materials; (5) Neutron irradiation campaigns; (6) ITER Test Blanket Module characterization programme, dedicated to Eurofer97; (7) Materials Technology (large scale production, welding, coatings);
- WPBB (Breeding Blanket), which deals with research on functional materials like tritium breeders, neutron multipliers, and anti-corrosion/anti-permeation coatings for application to the DEMO reactor, as well as some work on the compatibility of Eurofer97 with breeder and water as coolant;
- WPPRD (Prospective R&D), where work on oxide dispersion strengthened steels and advanced high heat flux materials is being performed.

In fusion the approach remains largely based on the 'observe and qualify' paradigm and no clear move towards a paradigm shift is currently pursued, thus the methodologies developed in CONNECT-NM can benefit fusion as much as fission. It is fairly straightforward to identify fusion-related case-studies that could be of interest for fission applications, too: they can be found in the relevant ORIENT-NM deliverables. Interaction with the fusion materials community will therefore be ensured, by appointing a CONNECT-NM liaison with EUROfusion, specifically with WPMAT, WPBB and WPPRD, to further identify commonalities. In addition, mutual invitation to meetings of the two Partnerships will be considered.

1.1.4.4 Other non-nuclear energy technologies and non-Euratom work programme

EERA is the most suitable framework for collaboration between nuclear and non-nuclear energy technologies. From EERA, common initiatives between CONNECT-NM and other, non-Euratom funded projects of relevance are launched, leveraging the long-standing collaboration between EERA JPs. In particular, the EERA JPNM has been long collaborating and organising joint activities with the JP AMPEA (Advanced Materials and Processes in Energy Materials), the JP DfE (Digitalization for Energy), and others. Recently, the jointly prepared EU-Mace (European Materials Acceleration Center for Energy, 2023-2027) Cost Action (nr. CA22123) has been officially approved and

launched. This initiative intends to become an ecosystem for accelerated materials development at the user end, gathering researchers and stakeholders with state-of-the-art digital and material competences, combined with the market/social pull. In this framework, which is consistent with the specific objectives of CONNECT-NM, commonly funded initiatives, particularly related to dissemination, communication and possibly result exploitation, as well as with E&T, can be easily devised. More generally, within EERA it will be easy to interact and find synergies with other energy technologies where materials exposure to extreme conditions is an issue, especially solar thermal energy, biomass and geothermal energy, fuel cells and hydrogen.

Also through EERA, significant contacts have been taken with the already mentioned (*section 1.1.1*) AMI2030 initiative, culminating with the final EM4I (Energy Materials for Innovation) workshop, held in March 2023 in the framework of **ORIENT-NM**. It is now known (*section 1.1.1*) that the Commission proposed new candidate European Partnerships (outside Euratom) and one of them is planned to be dedicated to Innovative Materials for EU (IAM4EU). Such a Partnership would be based on the preparation work made in AMI2030. If this Partnership is launched, several avenues of collaboration with CONNECT-NM will open. While cash-flow can be excluded, through the contacts that already exist between the CONNECT-NM and the AMI2030 communities it is expected that synergies can be developed through parallel and complementary activities, with mutual benefit.

On the other hand, while the **IAM4EU** partnership may become an important reference for collaboration with CONNECT-NM, a pioneering project has been **BIG-MAP** (The Battery Interface Genome – Materials Acceleration Platform, 2020-2023). This project, part of the large-scale and long-term European research initiative BATTERY 2030+, pursues a radical paradigm shift in battery innovation, which will lead to a dramatic speed-up in the battery discovery and innovation time, possibly reaching a 5-10 fold increase relative to the current rate of discovery within the next 5-10 years. **BIG-MAP** relies on the development of a unique R&D infrastructure and accelerated methodology that unites and integrates insights from leading experts, competences and data across the entire battery (discovery) value chain with machine learning, high performance computing, large-scale and high-throughput characterization, as well as autonomous synthesis robotics. **BIG-MAP** is therefore a good example to be looked at to focus CONNECT-NM R&D&I activities, especially towards the development or discovery of advanced materials, but also in connection with data harvesting and managing.

1.1.4.5 Frameworks for the access to infrastructures, especially irradiation facilities

OFFERR: eurOpean platform For accessing nucleaR R&d facilities (2022-2026). OFFERR is a Euratom funded CSA that supports the SNETP Association in setting up a system for R&D experts, to facilitate access to key nuclear research infrastructures all over Europe. Once identified, access to the available infrastructures will be financially supported through a system of proposal acceptance. This, and its likely successor, is therefore an important framework for collaboration with CONNECT-NM, in order to obtain access to nuclear materials research infrastructures, in a spirit of optimization of the use of resources.

FIDES-II: 2nd Framework for Irradiation Experiments. This OECD-NEA Joint Project (see above) was launched in 2021 and provides a framework for the coordination of the use of irradiation facilities, to ensure adequate service to the interests of the worldwide nuclear community. Specifically, FIDES-II connects a global network of research facilities to perform high-priority experiments, based on an internal procedure of project approval. The funds come from the involved OECD Member States, according to the rules of NEA Joint Projects. Its extension (FIDES-III), which will start in 2024, is therefore another very important framework for collaboration with CONNECT-NM, to enable the access to neutron irradiation facilities, again in a spirit of optimization of the use of the resources.

Jules Horowitz Reactor (JHR) consortium and working groups: The JHR Material Test Reactor is currently under construction at the CEA Cadarache site. Once commissioned (after 2030), this unique experimental irradiation tool will provide the means needed to test the behaviour of materials and fuels under irradiation, in order to support current and future nuclear reactors. This facility is funded by an international consortium of 15 members, comprised of national research centres (from Europe and not only), as well as industries. Each member of the consortium, which includes Euratom, holds access rights to perform irradiation experiments in the reactor. In addition to a governing board, working groups have been formed to agree on a number of priority experiments to be performed. While waiting for the start of the JHR, these groups have been launching joint projects and looking for opportunities to perform them in available facilities, for example through FIDES-II. In the future, when JHR is operative, this consortium will be able to perform irradiation experiments. In particular, the **JHOP2040** (Jules Horowitz Operation Plan 2040) CSA, now ended, produced a roadmap for the use of the Euratom access rights to JHR. The JHR consortium is therefore also an important framework for collaboration with CONNECT-NM, with a view to designing consensual irradiation campaigns in Europe.

1.1.4.6 Links with past, current and future Euratom projects

The past Euratom projects (ended in 2015 and after) shown in **Table 1.1a** constitute the starting point and the background for the paradigm shift promoted in CONNECT-NM. The research that will be conducted in the framework of the Partnership will benefit from the basis provided by the results achieved in them.

***Table 1.1a** – Past EURATOM projects on which CONNECT-NM will build. ADS, accelerator-driven system; FR: fast reactors; GFR: gas-cooled FR; LFR: lead-cooled FR; LWR: light water reactor; SFR: sodium-cooled FR.*

Acronym	Full Name	Period	Class of materials	Reactor systems	Highlights
FAIRFUELS	FAbrication, Irradiation and Reprocessing of FUELS and targets for transmutation	2009-2016	Fuels	FR, ADS	Dedicated minor actinide fuels were fabricated and irradiated in a comprehensive irradiation programme. In parallel, Post Irradiation Examination (PIE) of previously irradiated fuels and targets and modelling of the fuel behaviour were performed to provide in-depth information on their irradiation behaviour.
MATTER	MATerials TEsting and Rules	2011-2015	Structural materials, cladding, coatings	LFR, ADS, FR	Focused on ferritic-martensitic steels' data to be extended in the design code RCC-MRx: microstructural testing, negligible creep, creep-fatigue, weld factors fatigue; thermal ageing, environmental effect of lead and eutectic lead-bismuth for fracture, tensile and corrosion.
ASGARD	Investigation recyclability and manufacture of CERMET, CERCER, oxides, carbide and nitride fuels	2012-2016	Fuels	FR	This project investigated and evaluated different nuclear fuels for use in mainly fast reactors. As a result Mg based CERCER fuels were dropped from follow up projects. New recycling strategies as well as manufacturing methods were developed.
PELGRIMM	PELlets versus GRanulates: Irradiation, Manufacturing & Modelling	2012-2017	Fuels	SFR	This project addressed minor actinide (MA) bearing oxide fuel homogeneous and heterogeneous recycling for GenIV SFR Systems. Progress was made in fabrication, irradiation and qualification of two MA-bearing fuels forms (pellet and spherepac), including PIE, modelling and simulation of fuel behaviour and performance under irradiation, from normal to off-normal operating conditions.
NUGENIA+	Preparing NUGENIA for Horizon 2020	2013-2016	Structural and fuels	LWR	Launched a large number of small projects addressing a wide spectrum of issues of relevance for the various technical areas of the platform: ancestor of a partnership like CONNECT-NM.
MatISSE	Materials' Innovations for a Safe and Sustainable nuclear in Europe	2013-2017	Structural materials, cladding	FR, ADS	Covered the then key priorities identified in the EERA JPNM: pre-normative research in support of GenIV systems, Oxide Dispersed Strengthened steels, refractory composites for high temperature applications, improvement of predictive capabilities.
CEBAMA	Cement-based materials, properties, evolution, barrier functions	2015-2019	Concrete	-	This project improved the knowledge base for the Safety Case via safety impact of microstructural and porosity changes of cementitious materials and cement degradation, creation of long-term models, development of modelling expertise and methodologies and) upscaling modelling in time and space.
SOTERIA	Safe long term operation of light water reactors based on improved understanding of radiation effects in nuclear structural material	2015-2019	Structural materials	LWR	Flux and fluence effects on reactor pressure vessel (RPV) steels and internals in pressurised water reactors; assess residual lifetime of RPV taking into account metallurgical heterogeneities; assess effect of the chemical and radiation environment on cracking in internals; develop modelling integrated on single platform for reassessment of structural components during NPPs lifetime.
INCEFA+	INcreasing Safety in NPPs by Covering	2015-2020	Structural materials	LWR	Development of new guidelines for the assessment of environmental fatigue damage susceptibility in NPP components, to ensure safe operation.

	gaps in Environmental Fatigue Assessment				
ATLASPlus	Advanced Structural Integrity Assessment Tools for Safe Long Term Operation	2017-2021	Structural materials	LWR	Innovative quantitative methodologies to transfer laboratory material properties to structural integrity assessment; enhanced treatment of weld residual stresses under LTO; advanced simulation tools based on fracture mechanics; improved engineering methods to assess components under LTO; integrated probabilistic assessment methods.
GEMMA	GEnIV Materials Maturity	2017-2021	Structural materials, cladding, coatings	LFR, ADS, GFR, SFR	Focused on austenitic steels for GENIV applications: 316L(N) welded joints, with special emphasis on environmental effect as basis for design rules in RCC-MRx: large amount of data on corrosion in Pb and PbBi, exploration of alumina forming alloys, modelling; evaluation of residual stresses
NOMAD	NDE System for the inspection of operation-induced material degradation	2017-2021	Structural materials	LWR	Development, demonstration and validation of a non-destructive evaluation tool for the local and volumetric characterisation of the embrittlement in operational reactor pressure vessels.
M4F	Multiscale Modelling For Fusion and Fission materials	2017-2021	Structural materials	FR, fusion	Multiscale modelling applied to understanding microstructural causes of hardening and embrittlement in ferritic-martensitic steels, both under neutron and ion irradiation, and to provide insight into plastic flow localization to develop models enabling the modification of the design rules for this class of steels.
ADVISE	Advanced Inspection of Complex Structures	2017-2022	Structural materials	LWR	Advance the ultrasonic inspection of complex structured materials, for which conventional ultrasonic techniques suffer from severe performance limitations due to the micro and/or macro-structure, relying on a multi-pronged strategy.
INSPYRE	Investigations Supporting MOX Fuel Licensing in ESNII Prototype Reactors	2017-2022	Fuels	FR	Use separate effect investigations to physically model basic phenomena occurring in fuel; characterize key irradiated fuel samples to fill knowledge gaps; combine basic and technological research to enhance and extend reliability of traditional empirical laws; implement the new models and data obtained in the fuel performance codes.
MEACTOS	Mitigating EAC Through Optimization of Surface Condition	2017-2022	Structural materials	LWR	Improve the safety and reliability of NPP by improving the resistance of critical locations, including welds, to environmentally assisted cracking, through the application of optimized surface machining and improved surface treatments.

Concerning ongoing projects, those in **Table 1.1b** are especially important for CONNECT-NM, so suitable links will be established with them, on a case-by-case basis, most likely through mutual invitations and joint dissemination and also E&T activities, while follow-ups of those that will end before the start of the Partnership may end up being proposed in CONNECT-NM:

Table 1.1b *– Ongoing EURATOM projects of interest for CONNECT-NM. ADS, accelerator-driven system; FR: fast reactors; LFR: lead-cooled fast reactor; LWR: light water reactor; MSR: molten salt-cooled reactor; WWER: water-water energy reactor.*

Acronym	Full Name	Period	Class of materials	Reactor systems	Highlights
IL TROVATORE	Innovative cladding materials for advanced accident-tolerant energy systems	2017-2023	Cladding materials	LWR	Explored the use of highly innovative materials, to identify amongst them the best candidate accident tolerant fuel cladding materials, for use in light water reactors, validating them in an industrially-relevant environment, i.e. under neutron irradiation in PWR-like water. Its activities are of high interest for the research lines 'Advanced materials development and manufacturing' and 'Materials and component qualification: testing, standardization and design rules'.

ACES	Towards improved assessment of safety performance for Long-Term Operation of Nuclear Civil Engineering Structures	2020-2024	Concrete	LWR	ACES is advancing in the assessment of safety performance for long-term operation of NPPs. Experimental and modelling techniques are used to study related deterioration and ageing mechanisms. The project focuses on the physical understanding of degradation processes, such as radiation effects, internal swelling reactions and liner corrosion. The findings will help improve the safety and operational designs of next-generation NPPs, as well.
DELISA-LTO	DEscription of the extended LIfetime and its influence on the SAfety operation and construction materials performance – Long Term Operation with no compromises in the safety	2020-2024	Structural materials	WWER	This project focuses on WWER to determine the most affected and threatened components concerning Long-Term Operation (LTO). The aim is to describe the effect of LTO on the material properties and develop simulation tools to predict degradation, targeting thermal ageing and swelling. It is another modelling-oriented project that also includes activities related to non-destructive examination.
ENTENTE	European Database for Multiscale Modelling of Radiation Damage	2020-2024	Structural materials	LWR	This project designs a European database for radiation embrittlement experimental and modelling data, where data produced in previous EU-funded projects and within ENTENTE will be collected, cured and stored. Thus this project is starting to address issues of data formatting and data quality that will be at the core of CONNECT-NM, particularly in the research line dedicated to 'Knowledge and data management'.
FRACTESUS	Fracture mechanics testing of irradiated RPV steels by means of sub-sized specimens	2020-2024	Structural materials	LWR, FR	This project, relevant for both Gen III+ LTO and future nuclear systems, addresses the issue of limited availability of neutron-irradiated materials by developing small specimen testing techniques in order to make better use of the available material. In particular, it proposes to reuse tested Charpy specimens for fracture mechanics testing using miniature Compact Tension specimens to analyse RPV embrittlement.
NUCOBAM	Nuclear Components based on Additive Manufacturing	2020-2024	Structural materials	LWR	This project develops a methodology to qualify components produced via additive manufacturing that comply with nuclear codes & standards. Its results are of interest for the research lines 'Advanced materials development and manufacturing' and 'Materials and component qualification: testing, standardization and design rules', where the activities might be further extended.
PATRICIA	Partitioning And Transmuter Research Initiative in a Collaborative Innovation Action	2020-2024	Fuels	FR, ADS	The objective of the Domain 2 of PATRICIA aims at improving Fuel Performance codes, which are key simulation for the design and qualification of fuel elements, especially for Americium-bearing fuels.
PUMMA	Plutonium Management for More Agility	2020-2024	Fuels	FR	To address the future needs of nuclear industry, PUMMA project investigates various options for plutonium management in Generation-IV systems and assesses their impact on the full fuel cycle, taking into account safety and performance, focusing on fuel with high Pu contents (45%).
STRUMAT-LTO	STRUctural MATerials research for safe Long Term Operation of LWR NPPs	2020-2024	Structural materials	LWR	This project addresses still open gaps concerning the understanding of the origin of the embrittlement of reactor pressure vessel steels, especially at high dose, by studying a set of irradiated high-Ni materials. It is a modelling-oriented data providing project that also includes activities related to non-destructive examination.
HARMONISE	Towards harmonisation in licensing of future	2022-2025	Structural materials	LWR, FR	The objective here is to achieve harmonisation and standardisation of methodologies, codes and standards, as well as in the assessment of nuclear reactor components, including needs for next generation NPPs, where the role

	nuclear power technologies in Europe				of digital technologies and probabilistic frameworks is of particular interest.
FREDMANS	Fuel Recycle and Experimentally Demonstrated Manufacturing of Advanced Nuclear Solutions for Safety	2022-2026	Fuels	FR	This project aims at proving that advanced fuels, in particular nitride fuels, are a viable option for industrial use that can enhance the safety, sustainability and economics of nuclear power operation, as well as of the recycling of spent fuel.
INNUMAT	Innovative Structural Materials for Fission and Fusion	2022-2026	Structural materials	FR, fusion	This project develops and qualifies innovative structural materials for fission LFR and MSR, as well as for fusion DEMO. Materials included are high entropy alloys and alumina forming austenitic steels (prospective structural materials for Gen IV and SMRs), as well as weld overlay and coated 15-15Ti for LFR. Because of its wide spectrum of activities and the focus on innovative materials, this project represents a precursor of CONNECT-NM, at least concerning metallic structural and cladding materials.
iWeld	AI-supported ultrasonic weld inspection will overcome the obstacle of thick weld joints	2022-2026	Structural materials	LWR	The objective is to develop ultrasound-based advanced inspection tools specifically dedicated to welds, using machine learning methods to be trained on a large number of internal material structures. Thus this project, like INNUMAT, anticipates some of the objectives of CONNECT-NM.
MIMOSA	MultI-recycling strategies of LWR SNF focusing on MOlten SAlt technology	2022-2026	Fuels and structural materials	MSR	This project intends to develop a multi-recycling strategy for LWR spent fuels based on MSRs and existing European infrastructures and then compare it with other strategies. To speed up the deployment of MSRs, the project also addresses key aspects of their technical feasibility and performance.
OPERA-HPC	OPEn HPC theRmomechanical tools for the development of eAtf fuel	2022-2027	Fuels	FR	The objective of this project is to develop open tools using High Performance Computing enabling a full 3D high-fidelity thermo-mechanical simulation of the fuel element including the material microstructure. This will contribute to the design of so-called fuel element digital twins.

Concerning projects that, if approved, are expected to be starting together with CONNECT-NM, of special importance are materials related projects approved in answer to the following sections (if any), with which suitable collaboration arrangement will have to be set up: 'HORIZON-EURATOM-2023-NRT-01-01: Safety of operating nuclear power plants and research reactors'; 'HORIZON-EURATOM-2023-NRT-01-02: Safety of light water small modular reactors (LW-SMRs)', 'HORIZON-EURATOM-2023-NRT-01-03: Safety of advanced and innovative nuclear designs', and 'HORIZON-EURATOM-2023-NRT-01-05: Partitioning and transmutation of minor actinides, towards industrial applications' sections.

1.1.5 Overall and forward planning and possible exit strategy

Presently, a 'standard' duration of 5 years is foreseen for CONNECT-NM, as this duration enables sound planning of activities, commensurately with the resources that have been allocated to the Partnership. Considering that the Project call and selection will likely take somewhat more than one year, Projects will be able to run for as close to 4 years as possible, which is a reasonable duration for R&D&I projects. Shorter project durations would not be commensurate with the ambitions of CONNECT-NM. Realistically, however, the specific objectives of CONNECT-NM can be reached to a satisfactory extent over a timeframe of about a decade, thus it is necessary to devise already now the possible steps to be taken beyond the proposed 5 years of Partnership.

Importantly, in order not to have to wait until the end of the second year of the Partnership to be able to report some R&D&I results, pre-selected projects of limited duration and with limited budget are consensually included directly in the present proposal. This is done in accordance with, and in application of, the indication provided in the Euratom Research and Training work programme 2023-2025: 'This action aims at establishing a partnership that implements research based on proposed research lines and/or through calls for proposals'.

Because of the limited financial allocation for the planned 5 years, the opportunity of a second project call will be linked with the potential increase of the Partnership's budget, announced in the Euratom work programme 2023-

2025, as follows: 'Subject to adoption by the Council of a regulation establishing the Euratom Research and Training Programme 2026-2027 and adoption of the Euratom Work Programme 2026-2027, the Commission envisages providing the partnership with top-up funding, which will be determined later.' Without sufficient top-up funding it is not reasonable to foresee a second call. In addition, to create the best conditions for this second call, it may be necessary to agree on a possible prolongation of the Partnership, to enable the Projects selected in this second round to run for sufficient time, see **Figure 2**. It is important to emphasise that, with the exception of the cost of the organisation of the call itself, virtually all of the top-up funding can be used for R&D&I projects, given that all the management, coordination and support activities, ranging from E&T, mobility and access to infrastructures, to dissemination, communication and result exploitation, are already covered by the provisions expected for the present proposal. Therefore, such a top-up funding would provide a significant further boost towards the specific objectives of the Partnership. If, however, the top up funding was not sufficient to fully support a second call, then the available resources could be best used to add new tasks to running projects, also by considering an appropriate extension. In the absence of top-up funding, in contrast, a reasonable exit strategy will need to be adopted. Since CONNECT-NM was born in the framework of the EERA-JPNM and SNETP, and these platforms have a long standing experience of internal collaboration, using local institutional funding, such a strategy can only be based on the willingness to keep working together in this framework, although with significantly reduced ambitions. Use will be made as much as possible of funding opportunities, both at national and European level. However, these opportunities will not be coordinated between themselves to the same extent as a Partnership can do.

Irrespective of the future scenario, the following two final actions will be taken within the Partnership:

- A revision of the strategic research agenda will be launched towards the end of the planned 5-year duration of the Partnership, in full alignment with relevant documents issued by the involved platforms (SNETP and EERA), which will be implemented for a possible third call, either in the framework of an extended and then renewed CEP, or within a different framework.
- A reflection will be made on how CONNECT-NM can be stabilised as an entity, within the framework given by EERA and SNETP, also independently of its status of co-funded European partnership.
- If continuity is granted, based on the outcome of the task dedicated to exploring frameworks for irradiation campaigns, another action will be added, namely: design, prepare and possibly perform one or several irradiation campaigns.

These actions will be entrusted to suitable task forces and partially funded by the Partnership, as sorts of internal CSAs, included in the corresponding annual workplans.

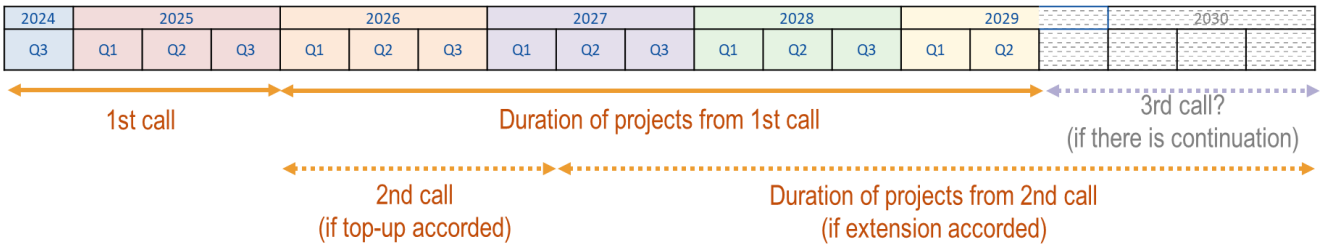

***Figure 2** – Possible evolutions of CONNECT-NM and possible relevant calls for Projects.*

1.2 Methodology

1.2.1 Fundamental concepts in modern materials science

Here we describe the fundamental concepts, assumptions and tools or methods, based on which the work will be organized and performed in CONNECT-NM, in order to achieve the Partnership's objectives, both specific and operational. Concerning the SOs, many of these concepts and assumptions are independent of the technology of final application. Modern materials research follows indeed two guiding principles:

a. *Materials should be designed from the start in view of not only their final application, but also maximisation of sustainability, in terms of: (1) replacement of critical raw materials with less critical ones in their chemical composition; (2) full consideration of their possibility of second use after their first life.*

b. *The processes of materials discovery and development need to become significantly faster and more sustainable than now; manufacturing processes also need to become more sustainable and better controlled; the whole material/component lifecycle, from fabrication to recycling or re-use through operation needs to be monitored to ensure functionality and made more sustainable.*

The tools that enable these goals to be achieved, again irrespective of the technology of application, are:

- High throughput fabrication and characterization (the latter mainly via fast non-destructive examination and testing techniques), as well as calculation (mainly of *ab initio* type), to gather a large amount of data on the properties of several materials under several conditions. This should possibly be fully automated through robotics.
- Advanced manufacturing, in particular additive manufacturing or other advanced methods that enable in principle full or at least significant control on materials composition and architecture, with minimal waste.
- Data-driven modelling, based on the use of machine learning to analyse data, classify them in multi-dimensional phase spaces, find correlations between properties and use these correlations to provide a feedback and iteratively identify the best candidate materials for the final application. Also advanced physical models based on computer simulation, thus with the use of high performance computing, can be a crucial tool, especially if blended with data-driven models.
- Digital twins, i.e. virtual representations of real systems, namely materials and components, linked by continual data and information flows throughout their life cycle (production, transportation, behaviour in operation, second life). Digital twins may make use of all kinds of models: empirical, semi-empirical, physical, and of course data-driven. To fully act as virtual replicas of the material/component they refer to, their predictions are continuously verified and adapted through sensors that make use of non-destructive examination techniques connected to the real material/component.
- Lifecycle sustainability assessment tools that provide criteria to identify the best research paths from the point of view of overall sustainability, taking into account all aspects, from raw materials to the manufacturing process and the decommissioning phase.

Items 1, 2 and 3 are combined, conceptually and physically, in materials acceleration platforms, or self-driving autonomous materials laboratories, which feature closed loop synthesis and characterization using robots. Item 5 can be potentially an input to a MAP. Digital twins are conceptually connected with monitoring the health of materials and improving life cycle management, but the concept can be in fact extrapolated to help throughout all steps of materials discovery, design and development. It is easy to see the connection between these general concepts, assumptions and tools, and most of the SOs and related research lines described in *section 1.1.2*.

The full exploitation of data-driven approaches requires that data be not only collected, but especially connected through fast networks that adopt, in order to appropriately search and classify new data, suitable semantic technologies (ontologies). These are controlled vocabularies that enable the machine to identify what a human expression corresponds to and thus to look in the right place for relevant data, as well as to logically connect additional data, so as to extend the network. Techniques based on ontologies make it possible to think of virtual discovery centres that are physically delocalized, but functionally connected through appropriate data-exchanging networks. This is the fundamental concept behind the development of a knowledge organisation system.

However, the application of the above concepts and assumptions, with the support of the listed tools, is especially challenging in the case of materials for harsh operating conditions and, particularly, for nuclear applications, where irradiation is a very specific and complex type of operational environment and regulation is especially strict. Thus CONNECT-NM is launched having clearly in mind the following caveats:

1. Importance of a fast-track to materials qualification for nuclear applications

   MAPs are sophisticated and fast screening methods that propose especially promising possibilities for a given application. Later these possibilities need to be further tested and qualified in a more standard way, to verify their actual suitability for the expected purposes. In order for the selected material to be eventually usable to fabricate specific components, this material has to be introduced in approved design codes (or treated in fuel performance codes), following the instructions and recommendations from regulators, because in the nuclear field the qualification of materials has a strong connection with safety. Thus, accelerated nuclear materials' discovery is of little help without any qualification fast track, which is why such a research line, which does not necessarily have a parallel for non-nuclear applications, has been included in CONNECT-NM.

2. Big versus small data and data-driven versus physical modelling

   If the expected purposes require exposure to harsh environment for long times, as is the case for nuclear materials, a truly useful MAP should include the capability of predicting long term materials performance from rapid measurements, carried out on the as-received material, or on materials exposed to conditions that are not representative of those that are actually expected. Currently, this capability is, more often than not, unavailable

and represents a major challenge. Data-driven models can be of great help in this framework, but suffer from two limitations. First, modelling based on machine learning implicitly calls for a series of conditions that data should comply with. Namely, data need to be of sufficiently high quality, fully consistent with each other, and, especially, abundant. In the nuclear field, however, because of the difficulty of getting data under irradiation, it is not so frequent that data are abundant. Moreover, without established practices for microstructural characterisation, many valuable data that connect also with physical models are not necessarily consistent with each other, if they are coming from different laboratories. Under these conditions, the application of conventional data-driven techniques may become questionable. Data-driven techniques need to be made reliable also with a limited number of data. 'Few-shot learning' is a field that clearly needs to be further developed for nuclear materials applications. These approaches rely on the appropriate use of few high, and many low, fidelity data, and in general call for the coupling of physical and data-driven models. Physical input is also essential because extrapolation capabilities cannot be guaranteed by purely data-driven models. Thus, blending data-driven and physical models, to avoid the 'black-box' danger and thus the dubious extrapolation capability that is implicit in purely data-driven methods, is crucial for nuclear materials, which is why a dedicated research line has been included in CONNECT-NM.

The above considerations provide the rationale for the research lines that have been foreseen for CONNECT-NM, each of them oriented to reach one of the specific objectives of the Partnership. In what follows, the approach to be followed towards these objectives, also in the light of the above caveats, is described in detail for each research line, analysing the state-of-the-art, explaining how progress beyond the state of the art will be pursued, stressing interdisciplinary aspects and relating the overall methodology with national and international research, whenever possible.

1.2.2 Methodology to reach CONNECT-NM specific objectives (SO)

1.2.2.1 Advanced materials development and manufacturing

1.2.2.1.1 State of the art

Currently, no material of industrial production can sustain the target GenIV operating conditions for a sufficiently long time to provide the safety, reliability and availability that is required of crucial components to ensure economical/commercial viability of these systems. Thus, the availability of a large palette of materials providing superior resistance to irradiation and corrosion in a wide enough temperature window is essential to make GenIV reactors a reality and nuclear energy production fully sustainable.

Concerning current generation reactors, lifetime extension can be (and indeed has been) granted with current materials technology, while light water-cooled or high-temperature gas-cooled SMRs can be designed by making use of known and proven materials. However, innovative materials solutions pave the way towards either increased safety and efficiency, or cost reduction without compromising safety and efficiency. An example is the reduction of failure incidents of bolts and fuel assembly springs by employing advanced material solutions with superior resistance to stress-corrosion cracking (SCC). In this framework, advanced manufacturing techniques and processes are essential to secure and improve component supply chains for timely, efficient, and targeted repair or replacement of components.

More in general, to harvest the full sustainability and decarbonization potential of nuclear energy, aspects of circularity and life cycle assessment need to be addressed, as well. These aspects include closer attention to the supply of raw minerals, the optimization of component lifetime by appropriate maintenance and replacement via monitoring of materials and components health in operation, and the recyclability or (if possible) reusability of materials, thus anticipating decommissioning issues.

Qualification programmes (*section 1.2.2.2*) provide a major constraint in the deployment of new materials and technologies. Each time a new material solution is proposed for a nuclear reactor, a long and costly process of full qualification and codification is required. Thus, as exemplified by the projects discussed below, qualification steps can currently be taken only for a reduced number of promising materials, which have emerged from a selection based on previous screening. This screening in turn is currently doable in practice only for very few candidates, generally selected based on existing knowledge. The screening is performed in the same way as the qualification of materials, i.e. by exposure and testing (the "observe and qualify" paradigm). However, for screening the goal is not to fully define the design rules for licensing and construction, it is rather to give a first assessment of the behaviour of the few candidates to identify the most suitable one(s), on which to focus attention. Thus, a typically small set of properties of interest is selected to be measured, after exposure to a reduced set of representative and, especially, affordable conditions. However, even these small sets may currently correspond to significant work and cost, particularly when neutron irradiation is involved. There remains a certain probability that all materials in this small set (sometimes a set of only a couple of materials) must be discarded at some point, because of some inacceptable behaviour under conditions of relevance for the target system. This happened for instance when the ferritic-

martensitic T91 steel was abandoned for use in heavy liquid metal-cooled systems, because of the observation of liquid metal embrittlement, after several years had been dedicated to its qualification for this use. Clearly, this is a risky and inefficient way of screening, which eventually may lead to using a non-optimal material solution, simply because it is the one for which, after several years of work, there are sufficient data for codification and therefore design of the component. The lengthy qualification process and the costly screening of new material solutions combined with the hurdle of licensing make nuclear industry often overly conservative and incremental, i.e. there must be generally very strong reasons before changing to a different type of material solution.

One strong reason to introduce innovative nuclear materials is given by the need to efficiently replace and repair in current NPPs obsolescent components, the provider of which is often not anymore on the market, as well as by the advantage of weld-free components, removing limitations in terms of component shapes. This is enabled by advanced manufacturing techniques, such as additive manufacturing (AM) or hot-isostatic pressing (HIP), which are being actively introduced as very promising for application in the nuclear industry. AM offers flexible solutions for replacement and repair, while suffering from no shape limitation; HIP may bring solution to material and processing issues with forging or casting in the nuclear field.

Main drivers to move towards these techniques are:

(i) The ability to produce directly parts close to the right shape, significantly reducing machining time and the quantity of raw materials that is required to produce them;
(ii) Reduced lead times, as these manufacturing methods can often deliver components in weeks or months, as opposed to conventional manufacturing methods (forging, casting, extrusion, etc.) which can often take years;
(iii) Flexible production of limited quantities of unique shapes and reduced minimal quantities for the production to be profitable: components can be produced essentially on demand in the required quantity, eliminating the need for warehousing of parts or alternative supply chains;
(iv) Overall reduced costs, because of all the previous points.

Importantly, apart from direct industrial application, additive manufacturing offers an opportunity for acceleration of materials development, by providing a fast and efficient fabrication route for sets of materials of the same kind, with different composition nuances or different architectures for fast materials screening. However, the safe and controlled application of advanced technologies such as AM and HIP in the nuclear environment require increased understanding of how they work and full process qualification, before they can be readily applied to new build construction or component replacement, abiding regulations.

Despite the importance of these topics, only relatively few recent Euratom projects have been/are dedicated to the optimization of either materials or their fabrication route. Moreover, the number of material candidates addressed is generally limited, due to both time and budget constraints. The projects of interest are (*see also section 1.1.4.6*):

- **IL TROVATORE**, which proposes innovative material solutions for fuel cladding of pressurised water reactors (PWRs), using ceramics such as SiC/SiC composites and MAX-phases and considering coatings, and tests them in order to identify a really ‘accident tolerant fuel’ (ATF).
- **INNUMAT**, which is dedicated to developing and qualifying innovative structural and cladding materials for advanced reactors, namely molten salt and liquid metal-cooled reactors, as well as fusion reactors. The number of candidate materials is not negligible, but still limited to a few, due to time and budget constraints. Of importance is the effort dedicated to high entropy alloys (HEA), as it partially introduces a modern way of operating, as described in the next section. This project also includes irradiation experiments (ions for a first screening, and later neutrons), and the development of tests on small specimens, to palliate for the small quantity of material available.
- **FREDMANS** develops concepts for both alternative fuels and recycling of spent fuel, focusing on nitride fuels.
- **NUCOBAM** addresses the nuclear requirements of the AM technology, dedicating effort to the qualification of the Laser Powder Bed Fusion (LPBF) fabrication process for nuclear applications. The project is PWR oriented and addresses two main applications (fuel grid and valves) and one material (316L stainless steel). Budget reasons prevented Inco 718 from being studied as a potential second material candidate. Despite efforts, however, significant work is still needed to bring AM practices to full maturity for nuclear applications.
- The (non-Euratom) European project **EnDurCrete** focuses of the improvement of the environment footprint for civil engineering structures because clinker-based concrete is not a good material solution in terms of CO_2 emission. The difficulty of controlling different ageing pathologies of the current concretes leads to high cost of civil works maintenance in comparison with metallic parts. In literature, some alternative concretes without or with a very little clinker and possibly combined with self-healing agents should be qualified in an accelerated approach in order to prepare the construction of future nuclear power plants.
- Finally, the French national project **DEMOCRITE** investigates the application of HIP for the fabrication of primary piping elbows.

1.2.2.1.2 Progress beyond the state of the art

Timely availability of innovative materials and material solutions is the prerequisite for boosting innovation in the nuclear field. While this also requires accelerated and integrated material qualification paths (*section 1.2.2.2*), equally important is the accelerated development of materials and materials solutions tailored to the specifications of the envisaged application, following the 'design and control' paradigm. These applications include core applications and advanced fuel elements, including enhanced accident tolerant and/or enhanced performance fuels. Improving and accelerating the development and qualification of materials needs the development of new performing methodologies and strategies for the efficient identification of innovative materials solutions. Efficient and affordable screening procedures become even more important when, additionally to improved intrinsic engineering properties (e.g. resistance to high temperature, corrosion or irradiation), lifecycle improvement for increased sustainability have to be considered, i.e. the number of variables to be included in the process of development and selection of materials solutions increases.

A way to achieve accelerated materials development through systematic screening is the creation of so called material acceleration platforms, in which, with the help of robotic systems, the methodology of combinatorial manufacturing and high-performance characterization of materials, supported by machine learning methods, are incorporated in an integrated and automated way, thereby becoming autonomous materials discovery systems. The most challenging aspects of a nuclear MAP is the evaluation of the performance of materials under irradiation, as well as the prediction of its long-term behaviour. Irradiation with charged particles (ions, protons, electrons), which is regularly used today to emulate neutron-irradiation induced damage for reasons of better accessibility, cost and time efficiency, as well as simplified materials handling when compared to neutrons, provides a reasonably fast and efficient method to assess irradiation tolerance in the framework of a MAP. However, the acceleration potential is brought by the need of methodology development to overcome limits in materials characterization related to the small penetration depths of ions and requires better understanding of ion-neutron transferability (see also *section 1.2.2.4*). The European project **M4F** provided some insight into selected aspects of ion-neutron transferability; however, further work is needed.

Finally, the exploitation of AM and HIP, both as a flexible means for component fabrication as well as an integrated part of a MAP, requires establishing a rational basis for the selection of the appropriate fabrication technique and parameters to reproducibly obtain optimum materials and component properties, transitioning from a 'trial-and-error' to a 'design and control' approach. This is especially important in nuclear applications, because the strict safety requirements do not allow departures from full reproducibility of the result of the fabrication process. The work towards this aim may profit from the incorporation of the concept of MAPs for the optimization of fabrication processes (i.e. fast, preferably non-destructive characterization methods, together with machine learning methods), as it relies on screening through a wide range of parameters.

The present research line will be dedicated to pursuing the above, cutting-edge research and development targets, so far never pursued in the nuclear field.

1.2.2.1.3 Overall methodology for advancing towards the stated RL objectives

The development of a nuclear MAP is a remarkable scientific challenge, which requires developing the ability of assessing properties of structural significance in a routine and fast manner, as well as of extrapolating the long-term behaviour of the material from a range of initial features. Addressing this challenge requires the application of methodologies that belong also to other research lines, for instance the development of reliable predictive methodologies (to anticipate long term behaviour from initial properties) and of suitable and properly calibrated non-destructive examination methods (to perform fast measurements of properties that otherwise would take significant time to be assessed). However, in this case they should be focused on developing materials screening capabilities. Therefore, in the initial part of the project, also 'traditional' material testing techniques must be integrated with digital technologies to achieve the following results:

- Application of fast fabrication and post-fabrication treatment methods (advanced manufacturing) to produce larger quantities of specimens for the investigation of materials.
- Optimization of testing procedures to monitor materials properties and performance during fabrication.
- Employment of advanced characterization procedures to collect data through the use of small specimens and non-destructive examination techniques.
- Development of *ad hoc* predictive methodologies of the long term behaviour of materials.

These activities are also connected with the direct use of advanced manufacturing for the replacement/repair of components in NPPs. Subsequently, the project must focus on the development of a MAP for materials to be used in the nuclear industry. In practice, a nuclear MAP can take a significant amount of time and resources to be developed and faces multiple challenges in various fields. One possible strategy consists in proceeding incrementally, starting from MAPs developed for non-nuclear applications, where processes such as corrosion or

high temperature mechanical degradation are important, complementing this with a specific screening on radiation effects. The following steps should be followed:

- Identification and description of the modules required for a nuclear MAP and their acceleration potential.
- Identification of synergies with existing MAPs in the non-nuclear environment. There is potential for mutual enrichment and enforcement of nuclear and non-nuclear activities towards the establishment of MAPs. MAPs are developed and applied with some degree of success in the case of functional materials, also in Europe (**BIG MAP** project, see *section 1.1.4.4*), and for carbon nanotubes. Interaction with the **EU-MACE** Cost Action (*section 1.1.4.4*) may also be useful here.
- Explore in detail the synergies and acceleration potential of advanced manufacturing as a MAP module, but also for component development. A MAP for structural materials may face the challenge of manufacturing a sufficient amount of reasonable-sized specimen representative of an industrial route. Advanced manufacturing technologies coupled with a thermo-mechanical simulation system appear as a promising solution.
- Detailed description of a nuclear specific module on irradiation and post–irradiation examination (PIE). Irradiation with charged particles (ions, protons, electrons) is suitable to provide a reasonably fast and efficient method to assess irradiation tolerance in the framework of a MAP. However, methods to overcome limits towards applicable PIE methods and to handle issues of ion-neutron transferability need to be further developed.
- Identification and development of the most suitable materials informatics tools for data collection, storage, analysis, including relevant ontologies (*section 1.2.2.5*).

The activities in this research line, in addition, cannot be exclusively focused on the practical development of the MAP modules, at the risk of producing very little scientific data useful for the progress of nuclear materials. On the other hand, they cannot fully adopt current methodology and be disconnected from the MAP development activity, either, at the risk of never achieving its practical implementation. Therefore, activities will also include production of scientific data on innovative nuclear materials, to be integrated in the framework of MAP development, for example, by addressing one aspect required to improve the efficiency of screening procedures.

MAPs development should also not be tailored to serve a single reactor technology, if this research line is expected to be relevant for the most important needs of European industrials. The number of industrial actors who can benefit from a project, the importance of its problematic to nuclear industry, or even the technology readiness level (TRL) of the solutions provided, will be considered in the evaluation of project proposals. Activities showing the highest level of synergies between nuclear technologies, possibly including fusion or even non-nuclear technologies, will be favoured.

1.2.2.1.4 Inter-disciplinary aspects of the approach used, connections with other applications

The above methodologies and enabling tools certainly apply to a wide range of materials, of which nuclear materials are a subset, as well as a wide range of applications; and they require the integration of several disciplines. Thus, there is clearly ground for collaboration between nuclear and non-nuclear energy applications as to materials acceleration platform development. In fact, the strategy designed above starts from non-nuclear to move towards nuclear applications. MAPs are built up from modules and self-driving laboratories (SDLs) addressing all the steps required for material development and qualification across various fields of work. Among these are material design, material manufacturing, mechanical property evaluation, testing in environment and, in the case of nuclear materials, testing under irradiation. Modelling, machine learning, automation, and defining standards are cross cutting issues for all modules and SDLs. Thus by definition MAPs are an inherently inter-disciplinary approach.

1.2.2.1.5 Alignment with national or international research and innovation activities

The research effort in the nuclear materials area is resource-intensive and extremely costly. Only a fully integrated research program that makes use of the assets of laboratories and industries all over Europe can be able to properly handle R&D&I in this domain. Several European countries support nuclear materials research as part of their national research programs. To avoid duplication and improve complementarity, the consolidation of the R&D&I efforts in Europe in the nuclear materials domain is needed to gather the necessary dedicated resources and pursue a common research agenda. In Europe, many projects face the issue of characterization of a wide variety of grades or parameters. CONNECT-NM will strive to align and possibly collaborate with these initiatives. Some examples are given here:

French **DIADEM** (*Dispositifs intégrés pour l'accélération du déploiement de matériaux émergents*) programme (*programme d'équipement prioritaire de recherché, PEPR*): **DIADEM** aims at accelerating the conception and the deployment of innovative materials, more sustainable and with better properties, using the power of artificial

intelligence, thus essentially to produce MAPs and related technologies. It has a budget of 85 M€ for 8 years (until 2030).

French **Arqane** (*Actions de Réalisation et Qualification en Additif pour le Nucléaire*): **Arqane** is a French project led by EDF with the objective of demonstrating and validating the industrial maturity of additive manufacturing for the nuclear industry, in the specific case of two complementary processes: LPBF and arc-wire/laser-wire.

German-Canadian Materials Acceleration Centre: born in the framework of Mission Innovation, this centre merges the research communities of Germany and Canada on the topic of harnessing advanced machine learning to accelerate the discovery, design, device integration, and demonstration of materials for sustainable energy technologies. Its mission is to support the growth of MAPs, by assisting in aligning approaches and directions; promote common methods, standards, and collaborative actions; and establish a new regimen for the training of scientists and engineers who will lead future developments at the interface of materials science, energy technology and information science. CONNECT-NM will benefit from direct collaboration with this Centre.

These initiatives, along with Euratom projects mentioned in *section 1.1.4.6*, will be contacted to take them into account in order to better prepare and select projects proposed in the calls, as well as, possibly, to integrate their results into the RL. Other stakeholders of great importance for the RL, such as machine learning platforms, digital development structures, and current non-nuclear MAP projects should also be identified and contacted. The MAP 'mapping' performed in the framework of **EU-MACE** (*section 1.1.4.4*), as well as within the WPFM of the NEA/OECD, will be useful for this purpose.

1.2.2.2 Materials and component qualification: testing, standardization and design rules

1.2.2.2.1 State of the art

Currently, the time for the qualification[7] and codification of a new material for nuclear applications is at least 20 years. In order to exploit the full potentiality of nuclear energy in connection with the energy transition (Green Deal objectives), qualification time needs to be reduced drastically (ideal target: from 20 to 5 years). This can be achieved by working on accelerated qualification paths (AQPs).

The evaluation and implementation of AQPs for the various materials and nuclear systems is one of the first steps to get to qualification in a realistic time-frame. In this context, a strategic vision and a roadmap for nuclear materials has been already developed in the framework of **ORIENT-NM**. The experts of the Technical Advisory Group (TAG) identified the classes of materials that need continued R&D and qualification for different nuclear systems, namely: i) structural metallic materials, ii) cladding materials, iii) fuel and iv) concrete.

To date, QPs are based on the 'observe and qualify' approach, i.e. by conducting primarily standardized tests of representative material batches in a sequential way. Data are processed into engineering properties and design rules that are eventually included in materials design codes or fuel performance codes. The main bottleneck in this approach is the time required for long duration qualification tests (e.g. creep, corrosion tests, microstructure evolution). In addition, the high cost and/or complexity of tests, the limited availability of facilities (irradiation, radiological labs, hot cells, etc.) and the lack of test standards usually lead to further delays. Another concern is extrapolation of data to operational conditions.

In most cases, materials characterization applies methodologies established in the regulations. However, standardized methodologies and procedures are missing for some applications, e.g. for corrosion and mechanical testing in non-conventional coolants, where the control of the chemistry of the coolant is relevant. R&D should therefore be devoted to pre-normative research, for the development of testing protocols and guidelines, in support of AQPs.

In the case of components in contact with aggressive fluids, a way to reduce the time to market of innovative nuclear systems and their licensing consists in adopting protective coatings/diffusion layers to face the corrosion issues. Coatings are considered for lead-cooled fast reactors and molten salt-cooled systems to protect cladding and structural materials from corrosion. They are envisaged for application to ATF cladding in LWRs, as well. Their use may represent an advantage, because of the possibility of using as substrate materials that are already codified in standards for nuclear application. However, except for the reactor pressure vessel of PWRs, for which weld-overlay cladding is a standard practice, the use of coatings and diffusion layers is not present in nuclear codes and standards.

[7] IAEA definiton: 'A qualification programme shall be implemented to verify that items important to safety at a nuclear power plant are capable of performing their intended functions when necessary, and in the prevailing environmental conditions, throughout their design life, with due account taken of plant conditions during maintenance and testing.'

The introduction of coatings therefore requires an intensive qualification programme to implement design rules, as well as component and system qualification, industrial manufacturing and quality inspection procedures.

In the specific case of fuel testing, emphasis is on extending material property tests, on a targeted matrix and application, with varying physical-chemical parameters (composition, stoichiometry, etc.), while including the evolution of these properties as functions of burn up/irradiation history. Recent examples include thermal conductivity and melting point tests in the **PUMMA** and **PATRICIA** projects (*section 1.1.4.6*) on oxides for fast reactor systems, or the mechanical (creep) tests in the **INSPYRE** and **Opera HPC** projects, as well as atomic transport behaviour (actinides, fuel gases, etc.) studies in **INSPYRE** (*section 1.1.4.6*). Although facilities equipped to perform tests on irradiated fuels are scarce, some projects attempted to align tests between labs and their reporting (e.g. **PUMMA, ESNII+**), to provide comparable data sets, thus facilitating fuel performance code development and validation.

Concerning concrete, this material performs a variety of safety-related functions, such as transferring loads to the ground, providing lateral stability and structural stiffness, radiation shielding and resistance to loads occurring in emergency or accident conditions. Due to the push in the concrete industry to lower its environmental footprint, new types of cementitious binders are being developed. At the same time, the operational boundary conditions are changing as new NPP systems are introduced. This fact, combined with the fact that concrete is made of locally available materials and is often cast and cured on-site, increases the risk of insufficient long-term performance. Moreover many concrete elements in NPPs are not accessible and thus the monitoring and repair are limited. To ensure the longevity of concrete in nuclear applications, especially as new types of concrete make their way to the market, a clear and robust qualification programme is required.

Finally, irradiation testing under representative conditions is a mandatory and crucial part of nuclear materials qualification, but presents several criticalities. First, the facilities devoted to structural materials and fuel irradiation are few and high-costly in the operation and maintenance. Moreover it is hard to obtain alignment of capabilities between testing laboratories, in particular for irradiated fuels. Besides the high radiotoxicity, fuels can have additional requirements, e.g. to atmospheric conditions, depending on the chemistry. Handling highly radioactive material affects the post irradiation examination and subsequent testing requires test setups in sufficiently shielded (hot cells) environments and reduction of sample volume is often needed to allow operations in a less shielded environment. The characterization sites are few and not necessarily close to the irradiation sites. Transportation of both irradiated steel and fuel samples is a major concern: the lack of harmonization and different regulations approaches in each country cause major difficulties, especially across borders. The characterization capabilities and sample preparation and storage are key to this research, as well as the ability to transport materials to and from the characterization facilities. Progress in this field has a strong need to align and unite efforts at European level. The availability of service-aged material mined from commercial reactors could provide, in this context, a strong support to enhance the knowledge base and partially supply for the scarcity of neutron irradiation facilities in Europe and worldwide.

1.2.2.2.2 Progress beyond the state of the art

The R&D associated with materials qualification is, as discussed, very time/resource expensive. Therefore, a drastic change in the methodology is needed. The development of AQPs is, accordingly, one of the main objectives of this research line. An acceleration of the time for qualification requires a reduction in the long-lasting tests and reduced need for experimental data that are difficult to obtain (e.g. neutron irradiation tests). For this purpose, the conventional 'observe and qualify' approach should be overcome by fully integrating modelling capabilities, data management and associated data-driven approaches, to achieve a paradigm shift towards 'design and control'. In addition to reducing the amount of testing, new accelerated tests, including separate effect model validation, need to be developed. The qualification 'philosophy' may also be revised for some applications, e.g. by considering qualification of components rather than material portions, especially from additive manufacturing or different approaches for components where safety relies on coatings. This approach will be non-sequential and address different time and length scales.

Once AQPs are identified, they need to be properly carried out. Here one needs to face the limitation of experimental facilities in Europe to support qualification. It is therefore necessary that the potentiality of existing test facilities distributed in Europe is optimized, the skills/competencies interconnected and facilities made available to receive and test fuels and materials, through coordinated networks. We refer to such networks as Test-Beds (TBs), i.e. integrated platforms that enable exhaustive and repeatable testing to be carried out on materials, in accordance with specific procedures for the intended use. The infrastructures of the TB are not necessarily located at a defined site or laboratory and can be the result of coordinated characterization work by different specialized laboratories, using different techniques. TBs should ideally include various experimental testing and characterization facilities for materials, including irradiation, and be coupled to advanced modelling and data management approaches. The implementation of TBs from the coordination of the existing and future infrastructures/skills will be a step forward to the harmonization of the European research in nuclear materials and the alignment on the qualification paths will allow effective resource allocation, avoiding redundant or conflicting activities within different teams, inefficiencies, and missed opportunities. Moreover, TBs will work as 'hubs' for the development of standards and common practices, for a variety of experimental techniques. The alignment of the characterization processes under a common and

structured methodology will further contribute to the acceleration of materials development and qualification, by enabling the research community to do timely adjustments and optimally orient the use of resources. It is important to emphasise that, besides limited coordination efforts to maximize complementarities and skill interconnections in the framework of specific EURATOM projects, or by the EERA JPNM and SNETP initiatives, the implementation of stable organizational and legal structures as TBs for nuclear materials have never been put in place so far at European level. This will be a major objective of this research line.

The implementation of TBs will greatly benefit from sufficient understanding of the key parameters of importance and the capability to produce representative conditions and reliable samples for the investigations. For instance, materials performance in innovative coolants involves processes whose physico-chemical mechanisms are not completely understood, which hinders proper pre-normative work and standardization. Correct understanding of physical mechanisms and availability of models (*section 1.2.2.4*) is thus expected to enable the adoption of AQPs (e.g. for the long term behaviour at high temperature of mechanical properties, corrosion resistance, microstructure stability). On the other hand, AQPs need the acceptance of the European nuclear regulatory bodies and their technical support organizations. For this reason, too, they need robust bases. Correct data harvesting and management is equally crucial, while in some cases the adoption of non-destructive testing and examination may be an asset. Thus, the work of this research line will be strongly connected with all other research lines of CONNECT NM.

Finally, the standardization of the use of small specimen test techniques is a necessary step in several contexts, starting from the development of neutron resistant materials and fuels, due to the limited space for irradiation in the reactor cores and the lack of irradiation facilities. Small specimen test techniques are also required for the accelerated development of innovative alloys, through rapid prototyping to get meaningful data from small batches of material in the kg range. The development of additively manufactured components will benefit from the standardization of miniaturized tensile specimen tests, as well. The design flexibility that AM offers comes indeed with design and production issues. Complex geometries and thickness variations cause locally big differences in the microstructure, resulting in inhomogeneities in the physical properties. So, the assessment of the actual mechanical properties of additive manufactured materials requires testing on small samples that need to be extracted from the real component. For all these reasons, small specimen testing standardization will also be part of this research line. In connection with small or miniaturised specimens, a rational use of ion irradiation can be a tool to shorten the qualification path, by combining neutron and ion irradiation data with modelling and the use of database. The lack of reactors for irradiation makes this a likely obligatory choice.

1.2.2.2.3 Overall methodology for advancing towards the stated RL objectives

The evaluation, development and implementation of AQPs and the establishment of TBs need to be done step-wise. Nevertheless, a common framework should be established for both processes. For the AQPs this involves the basic principles starting with the collection of available data (state-of-the-art), the production of new experimental data and the gradual integration of modelling and digitalization in the selection of the methodology to accelerate the qualification process. The work is expected to be carried out with special applications in mind as case-studies (i.e. specific nuclear system and/or material). The cases to be selected will be based on the priorities and urgencies to support deployment. A close involvement of reactor designers and stakeholders, as well as regulators as much as possible, or at least TSOs, is crucial. This research line will take advantage of the developments in the others, as well, but exclusively targeting it for qualification.

The development and definition of AQPs for a given case-study will follow various partially iterative steps:

- Establish boundary conditions for identified classes of materials & fuel in dedicated nuclear systems and applications to have a target on qualification requirements (use of **ORIENT-NM** materials identity cards);
- Establish safety requirements for components and materials & fuel in the specific nuclear systems and applications;
- Collect available data (material/fuel properties), available material (e.g. treated, aged, irradiated) and creation of databases; here, too, the material identity cards of **ORIENT-NM** are a starting point;
- Identification of data gaps and which tests are missing;
- Revision of the facilities available in Europe and discussion on the needs for construction of other facilities to accomplish the full AQPs.

These activities can be addressed by a large number of partners, so also entities that have not so much experience on AQP and standardization for qualification could gain skills/expertise to be exploited in the framework of the Partnership, aligning the capabilities of the partners. Working groups for material classes should be created, with breakdowns to nuclear systems, where applicable, and lists of main contacts per member state (for each material class). Finally, interaction, discussion and collaboration with regulatory bodies and stakeholders will be fundamental

to revise the available information and add the new methodology, discussing the requirements and R&D needs to achieve the AQPs.

The establishment of TBs will be an incremental process, starting from pilot experiences with limited targets, than progressively moving towards higher levels of integration and flexibility. Suitable case studies must be selected, around which small groups of laboratories will start developing a joint way of working, sharing facilities and infrastructures and competencies in a defined network and establishing common protocols of operation. This operation will benefit from the experience gained over the years and from the synergies established at European level with the activities carried out in the frame of EERA-JPNM and SNETP collaborative initiatives and in the projects funded by EURATOM. The combination of the collective results and their implementation in suitable models, building databases of properties, will be the high added value of the characterization TBs in the CONNECT NM program.

The creation of the TBs will be assessed through the following:

- Identification of the needs for experimental tests for the qualification of specific nuclear systems or materials, mapping the existing facilities and identifying the missing ones. This is to be done together with AQPs activities and with the activities related to creating a scheme to access infrastructures (see *section 1.2.3.4*), to create the TB networks.
- Guidelines/protocols for best-practice of testing and pre-normative research on testing standardization: these are considered as pillars and projects devoted to these aspects will be a priority above all in order to align the results of the tests and guarantee high quality and reliability and reproducibility of the data inside the TB network. Collaboration with CEN-WS064 is an asset. Round robin tests to assess the quality of the protocols are advised.
- Investigation of methods for accelerated testing should be assessed in dedicated projects or tasks to accomplish the goal of AQPs, together with definition of guidelines/protocols for the testing. Collaboration with CEN-WS064 is an asset. Round robin tests to assess the quality of the protocols are advised.
- Integrating the support of modelling in the design of experimental approaches used in the qualification methodology is advised.
- Implementation and use of a unique data format in order to merge all the data in a common database is a cornerstone. Harmonized guidelines based on lessons learned when different laboratories apply the same physical principles of a method, using different ways of processing signals and data are crucial.
- Sharing of information and data through dedicated networks is important. Data collection in dedicated shared-points and/or database creation will be necessary for the consultation between the partners of the TBs. This will be largely responsibility of the research line dedicated to ‘Knowledge and Data Management’, but use of the outcome needs to be foreseen in the construction of TBs, in interaction with the relevant RL.

The technological challenge of creating nuclear TBs is significant, but it also has important legal, as well as political and managerial dimensions, which must be adequately addressed. In addition, progress is needed in the harmonization and stabilization of transport regulations of irradiated materials, especially nuclear fuels, between the various Member States, in order to avoid long delays in nuclear materials research projects.

1.2.2.2.4 Inter-disciplinary aspects of the approach used, connections with other applications

A reliable testing network for materials for innovative reactors and fuel cycle technologies, both existing and under development, will lead to benefits for all parties, including fusion and non-nuclear low-carbon energy technologies where operating conditions are extreme. One of the key pillars for reaching net-zero emissions is producing energy more efficiently by increasing the operational temperature. However, high-temperature degrades materials, being the cause of failures in several industrial sectors like aeronautics, chemical and petrochemical, electricity generation from fossil fuels or renewable sources, as well as the automobile industry. Biomass combustion gases, supercritical CO_2 and molten salts in Brayton cycle thermal solar plants with energy storage, temperatures higher than 2000°C for space and hypersonic planes, and molten sand and ashes are just a few examples of the extremely harsh and/or complex environments present in these applications. Establishing of good practices, guidelines and protocols and possibly standards for materials testing, manufacturing and operation in hostile environments is thus a general cross-cutting problem, which concerns many energy technologies.

The standardization of the use of small specimen test techniques is also a key point for the development and qualification of neutron resistant materials, both in fission and fusion context. Small specimen test techniques with standard protocols are equally important to accelerate the development and characterization/qualification of new experimental materials/alloys, thanks to the possibility of obtaining meaningful data from small amount of prototyping batches (in the kg range). Finally, as stated above, the development of standards for additive manufacturing (AM) will benefit from the standardization of miniaturized tensile specimen tests, as well.

Protective coatings are widely used in technology and their use is foreseen to protect structural materials in the hottest regions of Gen IV reactors and for ATF cladding. Their introduction in nuclear will largely benefit from the work done in other technological/industrial contexts. Similarly to AM characterization, coating qualification may require testing on real components, so characterization and development of protocols standards for coated component qualification, as well as standards for manufacturing, is essential. In turn, the developments and the characterizations performed in CONNECT-NM will further enhance their development in other industrial sectors.

Concrete structures feature heavily in all civil engineering applications for load-bearing elements. Of special interest in connection with nuclear applications are dams in hydropower plants, cooling towers in coal power plants, tunnels and marine structures such as jetties, submarine pipelines and windfarm floating platforms. The transferrable knowledge comprises the assessment of the behaviour and the modelling of the performance of, e.g., penetration of aggressive ions, phase changes due to environmental factors, spalling in fire and fracture mechanics. Developments in the fields of self-healing, high-performance and fibre-reinforced concrete, as well as in additive manufacturing, are expected to have a bearing on the use of concrete in nuclear applications.

The TBs and the Partnership, finally, will contribute to build a seed for collaboration on materials beyond the nuclear sector, and act as a starting point for an all-encompassing initiative on materials, as is put forward, e.g., in the Advanced Materials 2030 Manifesto.

1.2.2.2.5 Alignment with national or international research and innovation activities

Several initiatives related to nuclear materials qualification have been undertaken during the last decade under the EURATOM umbrella (*section 1.1.4.6*), as well as under the aegis of European and International Institutions such as IAEA and NEA (*section 1.1.4.1* and projects mentioned there).

Among the EURATOM ones: **MATTER**, **GEMMA**, and **INNUMAT** for structural and cladding materials; **FAIRFUELS**, **PELGRIMM**, **INSPYRE**, **PATRICIA**, **PUMMA**, **FREDMANS** and **OPERA-HPC** for fuel; **MIMOSA** for both (molten salt oriented); and **ACES** for concrete. The sheer number of projects reveals that there exists a somewhat coordinated effort only for oxide fuels, also defined through EERA-JPNM pilot projects. Small specimen testing standards are currently being addressed in the framework of **FRACTESUS**. Concerning concrete, outside Euratom, **Table 1.2** lists some relevant initiatives:

***Table 1.2** – National and international initiatives concerning concrete, related to the research line dedicated to 'Materials and component qualification: testing, standardization and design rules'.*

SMARTINCS	H2020 SMARTINCS - Marie Skłodowska-Curie Actions	Thermal and mechanical behaviours of geopolymer concrete at elevated temperatures	2019-ongoing
TemGPC	H2020 EXCELLENT SCIENCE - Marie Skłodowska-Curie Actions	Self-healing, multifunctional, advanced repair technologies in cementitious systems	2019-ongoing
ReSHEALience	H2020 GRANT AGREEMENT Nº 760824	Rethinking coastal defence and green-energy service infrastructures through enhanced-durability high-performance fiber reinforced cement-based materials	2018-2022
LORCENIS	H 2020 GRANT AGREEMENT Nº 685445	Long lasting reinforced concrete for energy infrastructure under severe operating conditions	2016-2020
SHDS	H2020 EXCELLENT SCIENCE - Marie Skłodowska-Curie Actions	Seismic-resistant highly deformable structures	2015-2017

Additionally, the following three activities are related to accelerated tests and codification/standardization (*section 1.1.4.2*):

- CEN-WS064 'Design and Construction Coded for Gen II,III and IV nuclear facilities' Phase 1-3 (2011 – 2022), Phase 4 (2023-ongoing). Proposal of Code Evolution RCC-MRx and associated R&D activities and standards.
- Generation IV International Forum Working Group "Advanced Manufacturing and Materials Engineering" (AMME from 2018). Accelerated qualification methods for advanced manufacturing.
- European Creep Collaborative Community. Develops best practices and data sheets for creep deformation and life assessment for different industrial sectors.

Importantly, although all above-mentioned initiatives align with CONNECT-NM, none established a common and shared way of working, under suitable quality assurance, to produce consistent and lab-independent data. The nuclear materials TBs in CONNECT-NM will be thus a great boost, provided that there is willingness to integrate facilities, infrastructures and assets spread all over Europe under a single umbrella of coordinated, flexible and advanced exploitation. **OFFERR**, or its successor, may be a convenient framework to support the creation of nuclear TBs.

1.2.2.3 Non-destructive examination and materials health monitoring

1.2.2.3.1 State of the art

Nuclear materials in operation are exposed to high temperatures and high irradiation levels. Fast reactors also use non-aqueous coolants, for which the full compatibility of materials still needs to be demonstrated. Monitoring the subsequent degradation is crucial in order to safely manage component lifetime. An especially effective way to do this is using qualified non-destructive testing and evaluation (NDT&E). However, in the nuclear energy sector NDT&E has been considered until recently only to detect macroscopic defects (e.g. cracks) in components, during periodical inspections, thus not fully benefitting of the potential of these techniques. The capability of NDT&E to characterize metallic materials properties and their progressive change at a macroscopic level has been therefore the focus of several EURATOM projects funded under H2020 and Horizon Europe (*section 1.1.4.6*):

- The H2020 funded **ADVISE** project addressed the ultrasonic inspection of complex structured materials, specifically corrosion resistant alloys such as austenitic welds and cast austenitic steels, for which conventional ultrasonic techniques suffer from severe performance limitations due to the microstructure. **ADVISE** developed microstructural characterization techniques for these materials, as well as imaging techniques to account for the microstructure and enhance signal-to-noise ratio and defect characterization.
- Building upon the foundations laid by **ADVISE**, **iWeld** aims to progress towards implementing imaging and characterisation methods *in situ* and broadening their application scope beyond the nuclear energy sector. The project will deliver a reliable technique for heterogeneous weld inspection, by improving the understanding of the effect of the microstructure and its associated uncertainty on ultrasonic imaging, and by accounting for the uncertainty of the microstructure in imaging complemented by inversion algorithms.
- The **NOMAD** project aimed at creating a synergetic combination of physically different NDE methods (ultrasonic, electrical and electromagnetic) as a hybrid tool for the characterization of the neutron-irradiation induced embrittlement in surveillance specimens and cladded large blocks of RPV steels, accounting for local heterogeneities. Individual NDT&E features generated by means of micromagnetic and piezo-ultrasonic techniques have shown systematic dependency on degradation. The combination of this complementary information on material degradation enabled fully non-destructive materials characterization across many material properties. Using state-of-the-art regression analysis algorithms, it was possible to estimate the DBTT of surveillance specimens with 20 °C accuracy. Moreover, micromagnetic methods were identified as suitable to characterize neutron-irradiation induced embrittlement in cladded specimens.
- The suitability of the ultrasound scattering technique for the characterization of embrittlement in miniaturized specimens is currently being addressed within the **STRUMAT-LTO** project.
- The on-going **DELISA-LTO** project addresses the implementation of non-destructive eddy current monitoring and/or testing, including validation of this approach on the thermal aging and swelling of material from real plants, with well-described operational history, supported by simulation and modelling.

Most NDT&E activities have thus concerned metallic materials, including fuel element materials. Regarding concrete, over the years this material can be affected by various pathologies, due to chemical reactions. These phenomena can lead to the degradation of the mechanical properties and in particular the capacity of concrete to guarantee the confinement of radioactive materials. The appearance of damage and its seriousness depend on numerous parameters related to the chemical composition and the history of environmental conditions. The detection of these pathologies at an early stage with current NDT&E techniques remains a challenge. In contrast, significant research has been performed on NDT&E for polymers used in cables (**TEAMCables**, **El Peacetolero** …). This is not reviewed here, though, as these materials are not the primary focus of this Partnership, at least not in its first phases.

1.2.2.3.2 Progress beyond the state of the art

Despite past and still on-going effort in the field of NDT&E, these techniques are too often designed as an afterthought, rather than being an integral part of the design and manufacture of materials and components. So, lessons learnt in the area of NDT&E clearly point to the need of three paradigm changes:

- Materials and components need to be easily characterised by means of NDT&E. Inspection-oriented material and

component design has to be considered from the beginning of the lifecycle, to enable replacement of components or retrofitting.

- The concept of Structural Health Monitoring (SHM), based on permanently installed sensors, has demonstrated its added value in aerospace, oil and gas industries, and civil engineering. The expected benefits of SHM as a complement to traditional NDT&E techniques for nuclear applications are clear: easier and safer operation, reduction in inspection time and cost. In addition, the possibility of more frequent measurements and even continuous monitoring opens the way to predictive maintenance.
- Combining ageing models with physics-based and data-driven models, based on machine learning, thereby creating digital twins for materials and structural components, to be updated via sensor measurements, will enable enhanced diagnostics and prognostics.

In setting the design of components, lifetime assumptions are currently made concerning actual material composition, microstructural state, mechanical properties and their degradation during service: defect location, defect density, defect size, operational factors such as number and magnitude of temperature and/or pressure cycles, as well as neutron flux (fluence rate and dose rate). The evaluation of these parameters by continuous inspections, as targeted in CONNECT-NM, shall enable a more correct estimation of the operational lifetime of NPPs. Continuous in-service inspection for existing and future NPPs is a powerful tool in support of high level safety and reliable operation. NDT&E can in fact contribute to all stages of the product lifecycle, starting with the development of materials and products, but covering also their maintenance, their repair, and finally their recycling where feasible. In this context, future NDT&E needs to include also sensors suitable to capture production-related microstructural patterns and to merge them in the sense of an individual fingerprint, a so-called ‘product DNA’, deposited in ‘digital product files’.

Consistently, this research line shall define, develop and optimize multi-parameter approaches for the non-destructive characterization of the material degradation in materials and components for NPPs, enabling the capture of (macro- and microscopic) material properties (material DNA) right from the start of its development, until its end-of-life. The development of robust technologies capable of determining in-service material performance will depend on model accuracy and data reliability. Hence, there is a need for collecting experimental reliable key data captured under realistic operation conditions. Non-destructive methods for materials characterization of components during operation can then be very helpful to assess *in situ* the actual material degradation of components and provide such key data. (The *in situ* evaluation of the health condition of components can be in fact performed only by means of NDT&E). In the long-term, this will facilitate material optimisation based on its response to operation-relevant conditions, inspection-oriented design of materials and components, as well as predictive maintenance technologies, by providing reliable key experimental data collected non-destructively in all stages of the entire product life cycle.

1.2.2.3.3 Overall methodology for advancing towards the stated RL objective

The main goal of this research line is to define activities focused on the development and optimisation of innovative non-destructive examination techniques needed for the accurate health monitoring and prediction of NPP relevant materials and components applicable along their circular value chain in line with the paradigm shift from ‘observe and qualify’ to ‘design and control’. The idea is not to replace, but to complement, inspection methods or procedures that are currently applied, since NDT&E techniques are suitable to collect key data in all stages of the product life cycle, ensuring that changes of material properties at different scales and under different conditions (during manufacturing, processing and operation) are captured. More than one measuring technique should be used (hybrid approaches), to increase accuracy and reliability when describing the changes of the material properties against disturbing influences, such as material variations and surface conditions. These hybrid approaches also present the advantage of yielding information at different volume scales, some NDT&E techniques being surface-oriented, while others volumetric. Hybrid approaches can also determine material properties at local level.

Accordingly, the main starting activities of the research line will be:

1. The coordination and initiation of European research activities in order to harmonise NDT&E relevant knowledge, data and tools across Europe. This will include:
    - Identifying all past and on-going European research activities on this topic to review the state of the art, including national activities;
    - Mapping experimental NDT&E facilities involved in NPP related R&D activities throughout Europe;
    - Encouraging knowledge and research infrastructure sharing;
    - Establishing links with other international activities;
    - Identifying research gaps and needs.
2. The development and optimization of innovative methods, based on cognitive auto-adaptive sensor technologies, with focus on the understanding of the physical mechanisms that determine the response of the material under

given conditions.

3. Building intelligent devices to collect reliable experimental key data during laboratory materials characterisation until industrial inspection of in-service components at all stages of the component lifecycle for nuclear applications, moving from TRL 3 to TRL 7.
4. The implementation of innovative machine learning algorithms, allowing generated data to be handled and analysed.
5. NDT&E data storage and management in sovereign data infrastructures allowing traceability, reusability, interoperability and exchange while maintaining confidentiality and safety (section 1.2.2.5).

In the longer term, the objective will be to integrate NDT&E already in the design and production of materials and components for future NPPs, additionally to in-service inspection or monitoring, i.e. to implement the paradigm changes listed above. This will link with the following activities:

- In connection with inspection-oriented material and component design from the development phase, accounting also for component replacement:
  - Update the design codes for high temperature applications in the case of GenIV systems (task belonging to the 'Materials and component qualification' research line);
  - Include the fact of enabling/facilitating NDT&E as a variable for the design of complex materials and components (e.g. in MAPs, section 1.2.2.1).
- In connection with materials data generation at all stages of the product lifecycle and their integration in digital twin files:
  - Combination of different test and screening procedures for material properties;
  - Back-training of models at inspection to material properties and their changes over the entire product lifecycle, i.e. to the history of the changes of materials properties, to identify the possible origins of defects, thanks to the significant amount of *a priori* knowledge that becomes in this way available before each inspection measurement;
  - Creation of synthetic training data-sets for machine learning.
- For efficient SHM:
  - Develop sensors that focus on the deviations from the above collected *a priori* information and measure it directly: this is an example of 'cognitive' sensors, which are able to decide by themselves (using machine learning) which data to store. Applying this concept, significant reduction of irrelevant data is achieved, which aids the further analysis and processing of a now reduced data set; i.e. multi-parametric approaches to select relevant data are used, instead of 'blind' big data analysis;
  - Development of monitoring technologies robust to harsh conditions (radiation, temperature …);
  - During the maintenance and monitoring processes in NPPs, gather data by different sensors at continuous time intervals;
  - Data fusion and interrelation of data generated by different NDT&E methods

Advanced data fusion and machine learning-driven decision-making techniques can then be leveraged to enable the system to not only monitor the state of individual structures, but also infer about their interdependencies and, thus, the evolution of the system as a whole.

It is important to emphasise that, due to their physical principles, most NDT&E methods for materials characterization do not provide direct quantitative information about the material properties. Non-destructive methods are in general based on interactions of external fields or waves with the material microstructure at different scales and at depths from the surface. Therefore, NDT&E techniques often do not deliver direct information about the microstructure, e.g. radiation defect density or size. However, the propagation of these external fields or waves and the subsequent effects and signals measured by means of NDE probes does depend on the material microstructure. To deduce quantitative information, training with reference methods is generally needed, i.e. careful calibration on different relevant materials, at different degradation levels, as realistically as possible, is required. Correlations between mechanical, microstructural and NDT&E parameters, including quantification of reliability and uncertainty, are to be analysed and documented with respect to initial (non-degraded, non-irradiated) microstructure, material variability and other influencing factors. The advantage is that, after training, the non-destructive prediction of the materials properties of other specimens/components of the same material becomes possible. In order to reach the goal of this RL, therefore, a matrix needs to be created, including: relevant materials, targeted degradation conditions, geometry of the samples to be investigated. For this step to be taken, strong collaboration with other research lines is needed. Multiple NDT&E methods shall be applied to multiple scales of samples in different degradation condition. The results

shall be compared and combined across different methods, samples and degradation parameters, in order to define hybrid approaches and finally demonstrate them. This ensures the transfer of results across these sample scales and to interpret the results independently of the geometry. Moreover, algorithms shall be developed for the fusion of data obtained by different NDT&E techniques on different sample scales at different stages of the product life cycle, allowing backtracking of material properties. Additionally, machine learning algorithms shall be implemented to enable cognitive sensors to decide which information is significant and useful and which not. This selection can then provide key data for the optimisation of the material manufacturing, processing or ageing models.

1.2.2.3.4 Inter-disciplinary aspects of the approach used, connections with other applications.

This research line will gather expertise on NDT&E and machine learning in Europe, applied to the field of nuclear energy, for different material classes. Moreover it will merge complementary knowledge, expertise and capabilities dedicated to common goals: material science (degradation phenomena of structural materials, concrete and fuels), physics and engineering (techniques of non-destructive testing and evaluation), data science (data handling, data processing, data extension, data fusion) and nuclear engineering (inspection concept in NPPs). In addition, since tests performed non-destructively do not generally determine directly the material properties, in order to quantify the material properties non-destructively, measured parameters/features must be first correlated to the material properties of interest, which are customarily measured destructively. It means that non-destructive materials characterization needs a preliminary teaching/calibration process, which calls for a strong cooperation between physicists, engineers and material scientists.

Furthermore, the necessary competences form a mosaic of different TRL-related expertise:

- Academic and research partners to identify and resolve challenges connected with special knowledge in developing suitable procedures for non-destructive data collection, processing and evaluation, as well as in application of machine learning techniques for data processing/augmentation and model building, including all aspects connected with the technical robustness of machine-learning-based models.
- Engineering and industrial partners to define concepts which suit with requirements of field application and to advice and guide on requirements of the in-service inspections concerning the development of a test concept and the project outcome.

Finally, NDE&T techniques are also key for the development of MAPs (*section 1.2.2.1*), while also contributing to the understanding of microstructural evolution in materials in operation (*section 1.2.2.4*), thus creating a cross-cutting channel through research lines. In general, this research line shall easily connect with the whole digitalization trend in the nuclear (and not only) industry field, bridging the gap between materials microstructure, properties, processing parameters, modelling activities focused on aspects of in-service material degradation on one side, and in-service inspection and condition monitoring of NPP components, on the other. The topic of the non-destructive evaluation techniques has thus a strong cross-sectorial character.

1.2.2.3.5 Alignment with national or international research and innovation activities

Table 1.2a non-exhaustively comprises national and international initiatives related to this research line.

***Table 1.2a** – National and international initiatives related to the research line dedicated to 'Non-destructive examination and materials health monitoring'.*

Activity/Funding	Know-how to be applied in CONNECT-NM
NOMAD/H2020-EURATOM	Devices for NDT&E measurements on irradiated surveillance and cladded RPV material; Know-how concerning algorithms of ML for modelling DBTT
El Peacetolero/ H2020-EURATOM	Know-how concerning a unique data format for heterogeneous datasets and data extension procedures
STRUMAT-LTO/ H2020-EURATOM	Know-how concerning NDT&E on miniaturised specimens of irradiated materials
German national funding programme	Stressless2: Know-how concerning NDT&E measurements on parts of large metallic components BetoNPP: Know-how concerning NDT&E measurements on concrete Safety4NPP: Know-how concerning NDT&E measurements

SMILE/OECD-NEA	Know-how concerning NDT&E on parts of large components
SNETP-TA4 and TA8	Know-how exchange concerning characterization of embrittlement; Know-how exchange concerning validation of non-standardized NDT&E methods and ML-based model(s)
EERA–tJP Digitali-sation for Energy	Know-how exchange concerning application of ML algorithms
EERA-JPNM	iEDDY pilot project: Know-how concerning application of NDT&E for fuel cladding material

1.2.2.4 Advanced materials modelling and characterization

1.2.2.4.1 State of the art

Materials' modelling has undergone significant advancements in recent years, revolutionizing the understanding and utilization of different materials. This multidisciplinary field blends physics, chemistry, and computational science to simulate and predict the properties and behaviour of materials at various scales and in different conditions. In this framework, modern digital techniques at the basis of data-driven modelling are establishing important links with modelling-oriented experimental testing and data, as well as physical model development. Several techniques and methods have been and are being applied for materials modelling. In what follows, a short overview on the current materials modelling approaches is given. Experimental characterization is here considered as an essential part of modelling, by providing real data both to develop and improve the models. The list is not exhaustive and other suitable methods can be employed throughout the programme.

1. Advanced physical modelling: Advanced physical modelling through numerical simulation and modern materials examination methods are at the heart of the 'design and control' paradigm. This is made possible thanks to the vast increase in computational power experienced over the last decades, combined with ever greater power of techniques for microstructural and micromechanical characterization of materials, which enable in-depth observation and testing at all scales. This approach is expected to become increasingly robust, initially only underpinning, then gradually improving and even replacing the traditional empirical approaches that are still used, e.g. in fuel performance codes or in dose-damage correlations for LWR pressure vessels.
   In atomic scale simulations, quantum mechanics-based approaches, such as density functional theory (DFT), have become increasingly powerful in predicting electronic structure-related properties. Formation, migration and binding energies, as well as other defect properties, e.g. related with their elastic field, can be accurately calculated. Via DFT-based phase diagram predictions, materials modelling enabled the precise prediction of phase stability, alloy compositions, and phase transformations under various conditions, aiding in the development of novel materials with tailored properties. Molecular dynamics (MD) simulations with interatomic potentials or DFT allow the exploration of material behaviour at finite temperatures. This has applications in understanding thermal-physical/chemical or mechanical properties, as well as diffusion mechanisms. Advanced MD techniques now account for complex factors like dislocations, grain boundaries and crystal defects. Next, mesoscale techniques like kinetic Monte Carlo simulations and phase-field methods can be used to model microstructural evolution. These methods help predict the development of populations of radiation defects, grain growth, phase separation, and other mesoscale phenomena. The availability of increasingly powerful supercomputers and cloud-based resources has accelerated materials modelling via high-performance computing (HPC), enabling the simulation of ever larger and more complex systems, with increasing fidelity. All these physical models, however, require suitable data for calibration and validation, from model-oriented experiments (*point 3 below*).
2. Data-driven models: The main current limitation of physical computational models is that they still have difficulties to consider, at all scales, the effects of the complexity of materials chemistry and related mechanisms of degradation, even more when the interaction with the environment (e.g. coolants) must be accounted for. This difficulty is likely to require significant time and effort to be overcome. An alternative path has therefore recently started to be intensively pursued, utilizing modern digital techniques such as machine learning — also used for the analysis of data obtained from materials health monitoring (*section 1.2.2.3*) — to extract relevant materials features from large amounts of data, i.e. (big) data-driven modelling. These techniques make the best of the available data by identifying complex correlations between the parameters that define the materials or components, the exposure conditions, and the final properties of interest. This is achieved by providing a large number of examples, on which the method is trained. These sophisticated algorithms often prove to be very powerful. The specific example in the nuclear materials field where a ML-based approach is being applied with some degree of success concerns correlations for RPV steel embrittlement versus neutron fluence and other variables. The knowledge of materials´ behaviour in operation will then be improved by these models that underpin

empirical performance correlations, extending them reliably to unexplored operational regimes.

3. Model-oriented experiments; Model-oriented experiments are crucial in order to develop suitably calibrated and validated physical models. In these experiments, materials are exposed to external factors, as for screening or qualification purposes, but the objective here is to better understand mechanisms, by separating variables and effects, rather than to measure engineering properties. In experiments of this type, key variables, such as temperature and irradiation dose or dose rate, are accurately controlled and varied over sufficiently wide ranges. For this purpose, specific exposure facilities are needed, especially for irradiation, and the use of charged particles can be a valuable and affordable tool. Subsequent microstructure and microchemistry characterization are essential parts of model-oriented experiments. The combined use of various advanced characterization techniques is essential, because each of them provides complementary pieces of information, which are all indispensable in order to actually take advantage of the added value of model-oriented experiments. Suitable mechanical characterization is equally important, including micromechanical experiments from specimens at single grain scale, often the only possibility in the case of specimens irradiated with charged particles, due to the limited penetration of the latter. Moreover, mechanical tests addressing uni- vs. multi-axial load, cyclic load, relaxation, load sequence, non-proportional loading, etc., in correlation with the observed microstructure, can be of interest, depending on material type, and on the purpose of the models to be developed. These experiments are invariably delicate to perform and may be longer than, and almost as costly as, those performed for qualification. They provide, however, a higher level of fundamental physical understanding, as opposed to the collection of engineering data for the production of correlations that is typical of traditional qualification procedures. Thus, they strongly contribute to the paradigm shift towards 'design and control'. An advantage, with respect to qualification experiments, is that, in this case, it may not be strictly necessary to irradiate under conditions that are fully representative of operation, so long as models can reproduce them. This opens the way to performing so-called 'piggy-back' irradiation experiments, i.e. experiments in which space left free by other experiments is used to irradiate materials for modelling purposes, instead of filling the volume with dummy materials.
4. Digital twins: Even though digitalisation of the nuclear industry is still in an early stage, digital twins are starting to be used also for materials development, as well as monitoring. The objective of using digital twins include e.g. improving safety, providing support for selection process, reducing the costs and enhancing the lifetime of nuclear components. Digital twins are based on the idea of accessing actual operating data, to continuously improve its capability of tracing the evolution over time of materials and components. Digital twins are therefore the final device where physics-based and data-driven models blend, as the simulation of processes based on the numerical resolution of fundamental equations is corrected based on empirical data and applying machine learning algorithms.

Important work on nuclear materials modelling has been done in previous Euratom projects and/or is underway in current ones (*section 1.1.4.6*). Concerning structural materials for fission and fusion, the **M4F** project integrated several experimental and computational materials science tools to understand and model the complex phenomena of radiation defects formation and their effects on the macroscopic behaviour of ferritic/martensitic steels. The on-going **INNUMAT** project develops innovative materials for nuclear applications by developing a comprehensive modelling approach for the design of alloys, including their radiation tolerance. The project performs advanced characterization to support the modelling activities. Modern modelling techniques have improved the understanding and performance of nuclear fuel materials, too, e.g. in the **INSPYRE** project and in the on-going **PuMMA** and **PATRICIA** projects. The latter two will advance the state of the art on the understanding of mixed oxide fuels, enhancing the atomistic and thermodynamic modelling for the evaluation of thermal properties.

Fuel cladding materials modelling has also made significant advancements over the last decade, improving our understanding of their behaviour under irradiation and reducing the gap between atomistic and macroscopic scale, while enabling a more comprehensive understanding of their mechanical, thermal and irradiation properties. For instance, in the **GEMMA** project modelling has been applied with a view to enhancing the swelling resistance of austenitic steels, through composition tuning. MD and kinetic Monte Carlo simulations have been used to study the effects of ionizing radiation on fuel cladding materials at the atomic scale, including prediction of defect formation, diffusion, and recovery processes. In the EU project **IL TROVATORE**, innovative fuel cladding material concepts were demonstrated to improve the safety of reactors and a wide range of modelling activities were conducted to capture the multiscale evolution of damage in ATF clads/joints.

Concerning concrete, the EU project **CEBAMA** targeted the implementation of geological disposal by improving the knowledge base for the Safety Case for European repository concepts. The project studied a variety of important cement-based materials, linking experimental work with modelling activities. The focus was mainly on physical and chemical processes that could lead to changes in transport properties both in cementitious systems and at their interfaces with clays or compacted bentonite.

Materials' modelling, especially on metallic materials, has thus evolved into a dynamic and indispensable field, setting the basis for a 'designed and controlled' development of innovative materials with enhanced properties and

performance, across diverse industrial sectors. The on-going integration of advanced computational methods, machine learning, and experimental validation promises exciting opportunities for breakthroughs in materials science and engineering. Despite the remarkable progress, however, challenges still remain, such as accurately modelling real materials compositions under complex extreme conditions, and incorporating quantum or at least chemical effects in larger-scale simulations. Especially with nuclear materials, where safety is an essential aspect, future directions in the materials modelling should involve increased integration with experimental techniques, and a focus on multi-scale and multi-physics simulations, the possibilities of which should be boosted by taking advantage of modern machine learning approaches. The methods that have been developed so far for metallic materials should be extended to non-metallic ones, like ceramic nuclear fuel and concrete.

State-of-the-art materials characterisation methods, techniques and capabilities are also essential to produce reliable modelling results and simulations. For instance, *in situ* testing in scanning electron microscopes (SEM) and transmission electron microscopes (TEM) can produce data critical to crystal plasticity (CP) and dislocation dynamics (DD) methods, respectively, in specialized experiments, as was demonstrated in the **M4F** project for metals and is being done in the **Opera HPC** project for fuels. In turn, several experimental techniques require models to be correctly interpreted. Positron annihilation spectroscopy (PAS) is a good example, because it is sensitive to the density of electronic states depending on the type of defects and chemical species where positrons annihilate, and these are quantities that can be calculated by DFT. Other examples are TEM image simulation and simulations of the processes occurring when applying atom probe tomography (APT), especially with a view to properly analysing the raw data.

1.2.2.4.2 Progress beyond the state of the art

The ‘design and control’ approach is based on the assumption that our predictive capability is sufficiently enhanced to enable the physical description of the evolution in time of both the microstructure and the microchemistry of materials exposed to irradiation and/or high temperature and/or coolants. The output of these models acts then as input to meso- and macroscopic length scale models, in a multiscale modelling framework and spirit, thereby enabling prediction of the changes experienced by the materials properties in operation. Since the modelling tools are generally computationally costly to run and often use parallel software, HPC can be a crucial asset. The bottleneck of physics-based model development is, however, the correct identification and parameterisation of all important physical mechanisms. On the other hand, one of the main problems with data-driven modelling procedures is that they are too often blind: in super-vised learning the ML approach produces a sort of ‘black box’ transfer function between input and output, in principle devoid of any physics, even though sometimes this procedure does manage to improve our physical understanding. The more data are available, the higher are the chances that this procedure provides probative results, although it remains risky and unwarranted to rely on extrapolations. In general, a trial-and-error approach is used to identify the best performing ML and relevant training method.

To give an example, in the case of RPV steels plenty of data are available from surveillance and materials testing reactor (MTR) experiments, thus a purely ML-based approach is especially promising. This situation, however, is not necessarily common in the nuclear materials field. More often than not, only limited data are available for pre-normative research and for modelling, from exposure to a variety of environments and irradiation conditions, due to the high cost and therefore relative scarcity of relevant irradiation experiments. Thus, a completely blind approach based on ‘big data’ analysis techniques is of hardly any use in the case of nuclear materials, for which data are in fact generally rather ‘scarce’ than ‘big’. ML methods that are able to find logic in scarce sets of data (sometimes denoted as ‘few-shot learning’) do exist. Their principle is that, whenever high fidelity data are missing, pseudo-examples based on lower fidelity data are used as complement, with appropriate weight. Their application relies on the availability of various ways to obtain data and reaches its highest efficiency when input is received from both experimental high-quality data and data of different fidelity level, e.g. from models.

It has been shown in some cases that the inclusion of microstructural data from advanced characterization in the set of input variables greatly improves the predictive capabilities of ML algorithms, because of the added physical content that this involves. Therefore, in the field of nuclear materials and components, the integration of data-driven and physical modelling (blending models), especially exploiting ‘few-shot learning’, combined with advanced microstructural examination, is likely to be the most promising path to take a step further in support of materials development, qualification and monitoring.

Bringing this objective to practice builds on the fact that Europe has a long, well-rooted and established history of projects dedicated to predicting the behaviour of nuclear materials in operation, especially under irradiation. These projects have produced tools, skills, and expertise especially in the multiscale modelling field. These tools, skills and expertise need to be exploited at their best by blending them with emerging data-driven approaches, taking into account the specificities of nuclear materials issues. Among them, the most burning one is the almost chronic lack of sufficient data for model validation/calibration, as well as for qualification. While this can be partially offset by suitably integrated dedicated test-beds, or by ‘piggy-back’ irradiation experiments, blending models are expected to enable complex problems, for which purely physics-based modelling tools are still lacking, to be addressed more effectively, so as to become usable for assessments also at industrial level.

In practice, this progress focuses on the industrial applicability for design and safety purposes, through fast and efficient advanced predictive methodologies obtained by blending the 'traditional' physical multiscale models with more recent data-driven approaches. This research line shall profit, therefore, from all opportunities offered by modern digital techniques: in addition to machine learning, also block-chain, 3D visualization, data analytics, high-performance computing, and possibly robotics, among others.

1.2.2.4.3 Overall methodology for advancing towards the stated RL objective

This research line intends to enhance knowledge on the main structural and fuel materials of nuclear systems, by developing and utilizing, in a combined way, advanced characterization and modelling methods, the latter including physical and data-driven approaches.

Exposing materials to real conditions costs time and resources and requires infrastructures, even though the process can be accelerated by creating test-beds (*section 1.2.2.2*). Moreover, in practice, the conditions that can be explored correspond to simulations or approximations of real ones, and data can never cover all ranges. Exposure times or doses comparable with the lifetime of the reactors are only rarely accessible, or they may be accessible at higher dose rates using MTRs, as is customarily done to evaluate RPV steel embrittlement. The combinations of effects, and their synergy, are also difficult to simulate in a laboratory. Finally, until the system is operated, no feedback can be obtained through materials health monitoring. Extrapolation of data is therefore unavoidable, but purely empirical extrapolations have limited reliability. Relying only on the observation of the materials performance under a variety of conditions, unavoidably limited to relatively few data (as is the main ingredient in their qualification and licensing), corresponds to the 'observe and qualify' paradigm.

In order to shift to the 'design and control' paradigm and accelerate materials development (*section 1.2.d.1*) and qualification (*section 1.2.2.2*), as well as in support of intelligent monitoring (*section 1.2.2.3*) with digital twins, it is of crucial importance to understand correctly and model all ageing and/or degradation mechanisms that may be active during the required lifetime of components and materials. With this goal in mind, this RL pursues the development of physical models coupled to advanced microstructural characterization to achieve high-level understanding and predictive capability, in combination with suitable data-driven modelling approaches. This is executed in close collaboration with the adjacent RLs pursuing the elaboration of design rules, assessment, and test procedures, for both operating and off-normal conditions, for all the materials of interest.

During the **ORIENT-NM** project, the following modelling needs were identified in the materials identity cards for the four main materials groups that are in the focus in CONNECT-NM:

- For metallic materials, in particular austenitic stainless steels and nickel-based alloys, accurate multiscale modelling for long-term structural performance with respect to degradation and cracking (swelling, irradiation assisted stress corrosion cracking, fatigue …) has been identified as of high importance. This is applicable also for GenIV steels, which may be exposed to liquid metal embrittlement, too, together with improvements in creep and creep-fatigue modelling. The large number of variables involved in these processes calls for an approach where machine learning is used in support of physical models, in order to manage the complexity of the problem, especially in terms of chemistry and contact with fluids. On ferritic/martensitic steels, up-to-date modelling to simulate mechanical properties, particularly low temperature radiation-induced embrittlement and creep and creep-fatigue behaviour at high temperature are considered important. Here, too, suitable integration of physics-based and data-driven models has to be envisaged, because of the complexity of the processes involved. Finally, reliably predicting RPV steel embrittlement in current reactors, in connection with LTO, remains a dominant niche in the overall landscape of modelling the change of mechanical behaviour versus dose, dose-rate, temperature, and composition.
- As per fuel cladding materials, experimental & modelling scientific bases are needed in support of pre-normative research to establish new design rules and reliable mechanical test methods for the various accident tolerant fuel cladding solutions that are currently considered, ranging from chromium-coated zirconium to ferritic/martensitic steel clad and even SiC/SiC composites, in order of decreasing TRL. The main issue with these components is their inherent exposure to very high doses, which are currently difficult to simulate with available physics-based modelling tools. This circumstance, therefore, also calls for integration with data-driven techniques, although the high-dose implies limited data, thus clearly suggesting the need for few-shot learning approaches.
- Further progress is needed in the understanding and modelling of the elementary mechanisms governing the evolution of fuel properties in reactor, especially in transient conditions, including accidental ones. The main properties that have a significant impact on operational and safety issues are the thermal properties and margin to melt; the atom transport properties (self-diffusion and behaviour of fission gases and helium); the microstructure evolution, including fuel fragmentation, relocation and dispersal; the evolution of mechanical properties with temperature and irradiation with emphasis on creep and fracture; finally the thermochemistry of irradiated fuel and the chemical interaction with the cladding.

- For concrete, the materials identity cards indicate, for the various degradation mechanisms, their consequences and the R&D efforts made and needed. For temperature effects on delayed deformation and damage, efficient and well-validated empirical models for finite element computations exist. These models, however, need calibration on laboratory and monitoring data, or else on predictions of the behaviour of concrete from more fundamental models which do exist, but are also insufficiently validated. For accidental phases and particular operational situations involving exposure of concrete to relatively high temperatures, experimental data is lacking and the modelling is even less mature. The development of micromechanical models for prediction of concrete properties (drying, shrinkage, creep and damage) from concrete mix proportions at moderate temperature is also needed, to overcome the lack of data on real containment buildings, to be used for phenomenological model calibration. Structural modelling of concrete requires the development of modelling approaches for damage of massive structures at early age for getting initial stress state and initial crack, damage of structure in accidental situations. Also needed is modelling of corrosion, irradiation, microbial activity and reactive transport processes in concrete, as well as multiscale modelling approaches for void and defects in steel-concrete structures.

Irrespective of the class of materials, one specific issue that needs to be addressed with suitable models concerns the capability of correctly assessing up to what extent charged particles can be used in irradiation experiments to reproduce the effects of neutron irradiation in structural and cladding materials, as well as concrete, and of fission fragment production in the specific case of fuel. The final goal should be to develop a tool that enables a transfer function to be built to deduce neutron/fission product effects from charged particle effects. Here, too, the suitable blending of physical and data-driven approaches is expected to be of help.

In all cases, including the particularly complex one of concrete, it is crucial to establish a clear causal link between macroscopic changes and meso- or microstructural evolution. The causal link, however, may be the result of a large number of variables. Here is where ML techniques may help. As a pre-requisite to any activity in this research line, it is important to identify those case-studies where a path to integrate physical and data-driven modelling can be clearly made out. In other cases, the need may be more for improved physical understanding or correct calculations of physical properties and parameters, than a problem of resorting to machine learning.

1.2.2.4.4 Inter-disciplinary aspects of the approach used, connections with other applications

Advanced modelling and characterisation of nuclear materials support crucially the overall safety, efficiency, economy and sustainability of nuclear systems. The work of this research line is therefore targeted to contribute to safe long-term operation of the current nuclear power fleet, but also to develop materials for future reactors, including SMRs, having reduced design time and costs. Moreover, materials with superior radiation, thermal gradient and corrosion resistance are essential both for next generation nuclear reactors and fusion.

The approaches used in this research line are in fact common to, and useful for, all previous research lines, and imply strong interaction with the research line on knowledge and data management. Physical models based on a multiscale modelling approach, and data-driven models, are in fact ubiquitous and are needed at all levels, to support and accelerate materials discovery, qualification, and monitoring. Thus, projects in this research line will need to align with projects in other research lines, to provide the predictive capabilities that are needed there. Finally, these approaches are much more general than just for nuclear materials, even though radiation effects are a very specific feature of nuclear applications that has to be addressed in this framework, as in no other field efforts will be made to address it. As mentioned, complex advanced materials are increasingly required at a faster pace for many applications to extreme conditions. To enhance the design, development and scale up of these materials, advanced characterisation and modelling need to be applied and developed further. Due to the climate crisis, all energy sectors require innovation in the field of advanced materials, but this requirement goes beyond to other sectors, such as transportation and mobility, production technologies and heavy industry. Throughout the programme, active dissemination of results and networking with other industries can advance the deployment of new methods and materials outside the programme's nuclear energy scope.

1.2.2.4.5 Alignment with national or international research and innovation activities

The NEA WPFM (*section 1.1.4.1*) addresses materials science aspects of nuclear fuel, cladding and structural materials, including support to the development and selection of innovative and advanced materials solutions. The WPFM works on the development and evaluation of experimental methods and data assessment and preservation, together with the advancement of multi-scale modelling and simulation, to progress validated predictive methodologies for assessment and/or design purposes.

The SNETP, and in particular its European Sustainable Nuclear Industry Initiative (ESNII) has stated several materials related challenges in pursuing R&D on GENIV systems and has on-going activities on materials development and qualification, as a cross-cutting topic among its three pillars. The on-going **ENTENTE** project is strongly aligned with CONNECT-NM, being dedicated to research on radiation damage of reactor pressure vessel (RPV) steels in nuclear plants, with the goal to design a European database for radiation embrittlement experimental

and modelling data. Also, new experiments and models are being established and process-structure-properties-performance workflows developed, based on machine learning tools, to make robust use of new and existing data using data-driven modelling techniques and data informatics. The project **ACES**, in turn, targets advances in the assessment of safety performance to secure the safe and long-term operation of nuclear power plants reliant on safety-critical concrete infrastructure. It follows a multidisciplinary approach, utilizing state of the art experimental and modelling techniques and material characterization at different scales, focusing on the physical understanding of the degradation processes and physical phenomena.

The EERA JPNM has also recently launched a number of self-funded (i.e. financed with the institutional funds of the organisations involved) pilot projects, many of which have strong modelling components, ranging from those dedicated to the ion-neutron irradiation transferability, to mechanical test specimen reduction.

In Finland, the **SAFIR2022** and **KYT2022** programmes (2019-2022) have been supporting research in support of nuclear energy safety, and the work continues in the **SAFER2028** (2023-2028) scientific programme. About 20 different projects within the programme involve aspects of materials science, characterization and modelling across structural materials, nuclear fuel and concrete. In France, the **DIADEM** programme has strong modelling connections, as well, particularly in terms of blending traditional multi-scale and modern data-driven approaches.

1.2.2.5 Knowledge and Data Management

1.2.2.5.1 State of the art

Nuclear material science is a highly multidisciplinary field that encompasses a wide range of scientific and engineering disciplines, covering a multitude of aspects. Central to each of these aspects, particularly for the activities described above, is the heavy reliance on data, their quality, and the degree of organization and interoperability of the data across different subdomains. As a result, a substantial volume of diverse and rich data, spanning various data types and metadata, needs to be collected and utilized (categories in *section 1.2.6*). Yet, nuclear materials data are currently significantly dispersed and the scarce repositories are not connected.

Effective Data Management (DM) procedures, designed to augment communication among scientists, engineers, stakeholders, and other relevant parties, are therefore sorely needed in the field of nuclear materials. In the realm of material science in general, DM is an essential element that intersects with its numerous facets, forming a framework that fosters efficient and transparent data exchange. This exchange requires interoperability between data, i.e. enabling data sources to share and integrate data, based on a common model. Importantly, efficient DM practices, once implemented, hold the potential to optimize data utilization, which is particularly important considering the significant financial investments typically involved in their production. In recent years, DM has not only integrated itself within mainstream research processes across all fields, but also catalysed improved scientific outcomes, enabling the application of modern modelling techniques, while facilitating more traditional qualification approaches, where development was often hindered by data scarcity, limited access, or lack of common metadata standards.

Effective DM can be currently realized through the use of ontology technologies, ontology-based metadata and corresponding database systems. Ontologies represent a formal encapsulation of knowledge that provides definitions and descriptions of the concepts and relationships specific to a domain. They must be built in close collaboration with domain experts, to ensure precision and comprehensiveness within the targeted domain. By carefully constructing an ontology that accurately represents the domain and through adhering to it, following the best practices established in the field, one can guarantee the integrity and quality of the collected data and metadata. Inherent in this model is the principle that the complexity of the domain directly influences the complexity of the ontology. Notably, there has been considerable progress in the development of ontologies and ontology-based database systems. In the field of material science, this is exemplified by projects such as **ENTENTE**, **OntoTrans** and **OntoCommons** (*sections 1.1.4.2 and 1.2.2.5.4*), and relevant scientific publications. Critical to these developmental efforts is the widely established necessity for compliance with the FAIR (Findability, Accessibility, Interoperability, and Reusability) principles, which provide a *de facto* standard. By following them, an effective, robust and dynamic DM is currently achievable. The introduction of ontology-based systems has recently brought about improvements across all FAIR aspects leading, in particular, to the development of best practices and the improved culture of DM within specific domains. Specific improvements have been seen in data findability and interoperability, mainly through the establishment of clearly defined concepts, relationships, and vocabularies within ontologies. Additionally, increased accessibility has been facilitated through the creation of systems built upon these ontologies. However, the population of accessible repositories, i.e. to load data to databases, remains a challenge. Progress could be achieved in this respect by fostering the systems' wider adoption, through suitable incentives for data uploading, and a focus on comprehensive and user-friendly documentation development. The latter has a potential to lower the entry threshold, making ontology-based systems more accessible not only to experts, but also to end-users.

Ontologies have by now established themselves in various hierarchical levels: top-level, middle-level, and domain-level. Incorporating top-level ontologies is critical for creating a framework that integrates the other levels. This is

especially relevant in dynamically evolving domains like materials science, where new techniques continually emerge. Using top-level ontologies can facilitate a federation of interoperable databases, reducing data fragmentation and preventing silos. This approach offers multiple benefits: it bridges the disciplinary gap between different domain-level ontologies and helps achieve Industry 5.0 standards, by narrowing the gap between human input and digital tools. It also enhances cross-disciplinary understanding and improves compatibility of domain-specific systems. Importantly, it enhances interoperability between standards, vocabularies, data, and software tools, while allowing more effective data documentation. Despite these advantages, ontology developers often hesitate to use top-level ontologies, due to the overhead involved. This is further magnified by the fact that terms and approaches in top-level ontologies are not well-understood outside specialized fields, i.e. domain-level ontologies remain more accessible. The landscape of top-level ontologies is also fragmented, with conflicting commitments across different communities, which causes the emergence of so-called data silos. Another challenge is the competence bottleneck in formal knowledge representation, as few individuals possess the multidisciplinary skills required for ontology development. The broader adoption of top-level ontologies to achieve intra- and cross-domain interoperability, was the subject of the **OntoCommons** project, aiming at creating a unified ontology framework.

Specifically in the nuclear field, a complementary approach was proposed by the IAEA, which has taken the initiative to assist Member States by publishing guidelines on implementing semantic technologies in nuclear knowledge management (KM). In its documentation it highlights how the use of Semantic Web standards is crucial in establishing a framework of interconnected data sources, facilitating interoperability at both the data and system levels. These standards, known as 'linked data', signify a shift from hierarchical structures to network-based organization of data and knowledge. This becomes especially important in scenarios where data is dispersed among different content providers or stakeholders, as is the case in the field of nuclear materials, requiring standardized data exchange for effective management of distributed knowledge. The IAEA works cover topics such as semantic information technologies, World Wide Web standards focused on interoperability, creation of knowledge bases based on distributed knowledge and the development of knowledge-driven applications. The IAEA's efforts in promoting semantic technologies emphasize their significance in improving KM within the nuclear domain.

1.2.2.5.2 Progress beyond the state of the art

Recently, there have been significant advances in nuclear materials modelling and experimentation. This progress has enabled rapid data generation and the proposal of new materials. Along with these changes, there has been considerable improvement in the fields of ontologies, terminology, classification, and data documentation. Notably, initiatives like EMMO (European Materials Modelling Ontology) have emerged. Led by EMMC, EMMO's goal was to create a standardized language and framework for materials modelling across Europe. This initiative has been further built upon by projects such as **ENTENTE**. However, despite these advances, a core issue persists: the challenge of insufficient data interoperability and integration. This problem hinders optimal data use, often resulting in the creation of ontological silos that constrain knowledge representation.

The envisioned Nuclear Materials Knowledge Organization System (NM-KOS) aims to tackle these complexities by using semantic technologies and adhering to a standardized knowledge model. This approach ensures data coherence and integrity, while also improving operational efficiency and delivering long-term cost savings. Specifically, a 2-layered design will permit efficient data integration, particularly through linking knowledge with data, enabling the mapping, interconnection, indexing, and access of real-time information from various sources, revealing potentially overlooked relationships. Additionally, the presented design (*see 1.2.2.5.3*) will enable the use of ML techniques, aiding this system to automate high-throughput experiments, extracting properties from literature through natural language processing and data-mining databases. ML might help resolve complex property dependencies, assisting scientific breakthroughs. In this context, the development of ‘explainable artificial intelligence’ and a robust human-machine interface is crucial for further progress. Emphasizing the importance of a digital ecosystem in today's materials and manufacturing landscape, the system will help create connections between stakeholders such as manufacturers, suppliers, and consumers, while promoting the formation of virtual organizations, integrating different facets of nuclear material science, and unlocking the possibility of digital transformation. On top of that, the system will also offer tools for safeguarding sensitive data, curating, analysing, and exploiting data through a user-friendly interface. This aligns with the FAIR principles, contributing significantly to the data management culture.

The KM-DM system's success, consistent with the FAIR principles, depends on interdisciplinary collaboration, essential for optimizing the efficiency of scientific endeavours. Particularly in the domain of nuclear materials, this collaboration establishes a foundation for the advancement of the next generation nuclear systems and the refinement of the current systems. The role of the Partnership is here essential, involving academia, research entities, and industrial stakeholders. The proposed solutions offer multiple benefits across all Partnership’s research domains. They improve data accuracy, consistency, and management. Set protocols and metadata, boost data sharing and simplify analysis. Considering the potential of KM-DM, integration with state-of-the-art technologies, such as semantic technologies, expands the adoption of data-centric strategies and cross-disciplinary methods. This change will lead to a modern approach in materials science based on the 'design and control paradigm'. This encompasses

autonomous material discovery and cutting-edge manufacturing (*section 1.2.2.1*), ML-driven data models (*1.2.2.4*), and cognitive sensors (*1.2.2.3*). Collectively, these innovations will assist materials acceleration platforms and self-reliant materials labs with integrated synthesis and characterization processes (*section 1.2.2.1*).

1.2.2.5.3 Overall methodology for advancing towards the stated RL objective

The NM-KOS methodology will be based on well-established semantic technologies and industry ready software solutions. It will be designed as a two-layered system:

1 Nuclear Materials Data Management System (NM-DMS), i.e. one or more databases aimed to store the actual data (e.g. mechanical properties, microstructural features …), generated by the project activities or imported from external pre-existing sources;

2 Nuclear Materials Knowledge Base (NM-KB), specifically a graph database (a.k.a. triplestore) that will store: (a) the abstract knowledge (i.e. the ontology); (b) the information about domain entities (e.g. device, material sample, testing procedure, modeling workflow …); (c) the metadata needed to describe them (e.g. name, titles, unique identifiers …); and (d) the mapping between KB entities and actual DMS data or other external data sources.

This two-layered approach enables a convenient separation between the data level (DMS) and the semantic level (KB), making the second an incremental addition to the first, reducing the dependencies and enhancing the usability of the overall system. In fact, the NM-KOS will allow users to focus on the NM-DMS only when dealing with their data storage activities and requirements, leaving the KB as a powerful semantic-based tool for data exploration and querying. The NM-DMS will make use of database technologies, the mapping of which has been already implemented by most of the graph database software vendors, in order to enable direct access to data from the NM-KB query system. Existing datasets not included in the NM-DMS can be mapped by the NM-KB, by providing the metadata for the identification of e.g. the data owner, provider, Uniform Resource Identifier, license, and access conditions (see DOME 4.0 data marketplace metadata list for datasets).

The NM-KOS architecture is depicted in **Figure 3**, showing the interactions between the NM-KB, the integrated databases (NM-DMS), and other external, potentially heterogeneous, databases. The hierarchical framework, incorporating the directional cues of arrows, illustrates the adaptive nature of the approach, aimed at establishing a comprehensive superstructure that facilitates access to diverse data types. This will allow the implementation of the data federation approach, with NM-KB as the unique query end point for all NM-DMS databases, by means of the SPARQL[8] language and protocol for querying and accessing different data sources.

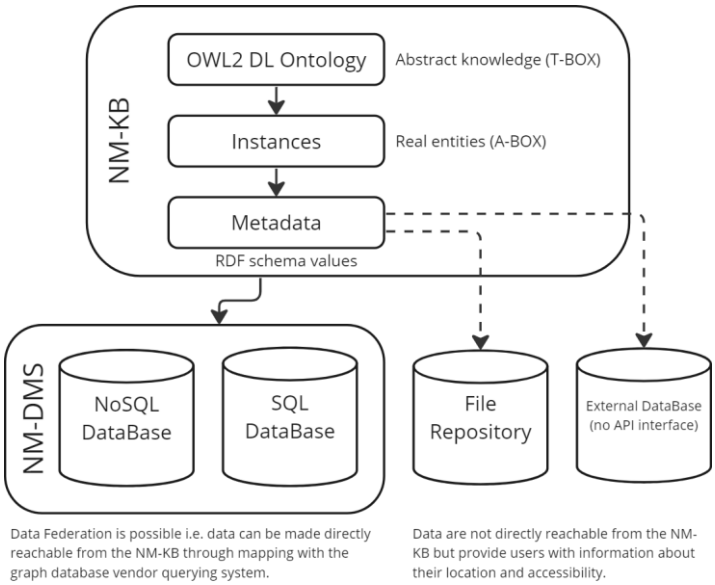

Figure 3 *- Diagram for the two-layer NM-KOS. SQL stands for structured query language.*

[8] SPARQL is an acronym for “SPARQL Protocol and RDF Query Language”, https://www.w3.org/TR/sparql11-query/

Given the NM-KB and NM-DMS connected structure, the proposed approach to data documentation for a specific CONNECT-NM application case can be summarised by the following steps.

1. Application ontology development, creating the T-BOX (terminological box) for the application related concepts (if not already available), including the datasets structures with a description of each single data entry.
2. Populating the NM-KB with the A-BOX (assertional box) entries for every occurrence of the application (e.g. testing, measurement, sample) including related metadata. This can be easily implemented creating a JavaScript Object Notation link data (JSON-LD) schema for each application, already mapped with the ontology concepts.
3. Populating the NM-DMS with the data content, following the specific requirements of the graph database software for mapping with the NM-KB. Using a No-SQL database (e.g. MongoDB) this can be done using a JSON-LD file containing the data.

Data Management System

The foundation of this infrastructure primarily consists of available or newly created separate databases (DBs). The growing amount of data associated with the expanding range of these databases requires the incorporation of various dissimilar resources with significantly distinct formats and meanings into operational procedures. The central concept behind the upcoming infrastructure revolves around creating a unified space that amalgamates data with diverse structures initially housed within separate autonomous databases (database federation).

The objective is to go towards the greatest extent possible, avoiding explicit favouritism towards any specific nuclear system or material class. The main goal of this undertaking is to establish a uniform method for engaging with present and forthcoming data in their native formats, both from beneficiary, affiliated and third parties involved.

The NM-DMS shall consist of several databases (SQL or NoSQL) storing actual data. The choice between SQL (Structured Query Language) databases and NoSQL (Not Only SQL) databases depends on the requirements of the applications running on top of the NM-KOS. Namely, it will depend on:

1. Data model: In SQL databases, data is organized in rows and columns, using structured tables with predefined schemas. NoSQL databases are more flexible in terms of structure, offering several data models, such as key-value, column, document-based or graph databases. NoSQL databases do not have schemas or have flexible schemas, enabling changing the data structure.
2. Scalability: SQL databases are not very scalable, except if they are distributed, but this makes their use and maintenance more complex. NoSQL databases provide horizontal scalability, that is, they are able to manage more data by adding more servers, without making their use or maintenance more complex.
3. Consistency: SQL databases offer strong consistency, providing ACID (Atomicity, Consistency, Isolation, Durability) characteristics, making this choice suitable when data integrity is needed. On the other hand, NoSQL databases provide weaker consistency models, such as eventual consistency.
4. Ease of use: SQL databases are based on the declarative SQL query language, which is user-friendly and enables the use of basic CRUD (Create, Read, Update, Delete) operations.

An effort towards unified database types, at least for databases that are still to be developed or under development, will be attempted.

The databases included in the NM-DMS should be based on technologies that are compatible with the existing graph database vendors virtualization interfaces. Data virtualization is a technique that gives direct access to other databases (e.g. relational databases) with SPARQL queries, eliminating the need to replicate data. The implementation exposes a virtual SPARQL endpoint, which translates the queries to SQL, using declarative mapping.

Knowledge Base

The NM-KB will contain three different types of information:

- The domain and application ontologies: these are based on the EMMO and expressing the abstract knowledge (T-BOX) about the nuclear materials domain, using the OWL2 DL language, i.e. a dialect of the Web Ontology Language for the Semantic Web, which allows the expression of formalised knowledge. It represents concepts about, e.g. materials and processes' classes (e.g. composite, irradiation), relations like those between a physical quantity and the material (e.g. hardness is a property of solids) or measurements and devices. It also provides constraints about relation domains and range, to grant consistency of the knowledge base content.
- The instances (or individuals), i.e. the knowledge about the existence of a specific resource, representing the actual occurrence of a particular concept (A-BOX), such as, e.g., a specific sample coming from a material batch and its measured physical quantities, or the process of neutron irradiation involving a radiation source and a target material.

- The data providing: (a) information to interpret the resource ontological nature (e.g. definitions, comments …) or to relate it to a specific real world object (e.g. location, ID …), usually called metadata; or (b) actual data that are related to the resource (e.g. time of acquisition, physical quantity …).

An industry-ready commercial graph database software (e.g. GraphDB, Stardog) can be used for the implementation of the NM-KB. These are well-known and widely used architectural solutions for knowledge management, with built-in interfaces for data federation through virtualisation, allowing the user to retrieve the actual data from the querying system, provided by the graph database interface, seamlessly integrating local and remote data. It is important to underline that actual data are not stored in the NM-KB, but in the federated external databases

Practical implementation

The initial step will be the development of flexible data formats and the expansion of the ontologies to accurately describe all data of interest within the Partnership. This will be implemented as local database/data-management systems in each RL. This critical initial step will enable easier data integration and interoperability at later stages, supporting all data-centric activities and ensuring compatibility with current data sources. The use of established solutions, such as the extendable **ENTENTE** database, will make this process more efficient. The subsequent step will be the creation of the KM system. This will hold information about domain entities and metadata, integrating local RL relevant databases into it through mappings. Different levels of integration can be achieved at this stage.

The approach is fundamentally two-layered, separating raw data from abstract ontology-based metadata. This allows future seamless integration of additional databases and enables the implementation of additional features of use for data-driven modelling, automatic data processing and retrieval, sensitive data protection and support for versioning. In the initial stages, a temporary data gathering solution is planned to ensure no valuable data is lost during the transition to the full-scale database. At this stage, promoting effective DM practices across the Partnership is crucial.

The implementation timeline involves launching a pilot version of the KM system as a pre-selected project, followed by one call on DM development and KM integration, and one call on establishing an interdisciplinary (cross-RL) workflow leveraging NM-KOS. The subsequent steps will tackle specific challenges, such as integrating external databases and developing new metadata standards for novel experimental and modeling techniques. Overall, this methodology aims to create a robust and adaptable data ecosystem that can support a wide range of research pursuits, while adhering to the FAIR principles.

1.2.2.5.4 Inter-disciplinary aspects of the approach used, connections with other applications

KM/DM's efforts intersect multiple areas, underpinning all other scientific pursuits of the Partnership and significantly contributing to its broader goals, ultimately helping to enhance the safety of Nuclear Power Plants. The objective of KM/DM is to construct an efficient system for data and knowledge organization and lifecycle management, which involves establishing core principles, formats, standards, and ontologies, and implementing them within an architecture that separates the knowledge and the data layers. The improvement in KM/DM not only benefits individual subdomains, but also aids in synchronizing efforts across them. In this sense, KM/DM bridges the gap between different subdomains, offering a common framework in the form of a centralized platform, unifying and aggregating data, and routing to various specialized databases built around their corresponding ontologies and taxonomies. By facilitating effective communication within the Partnership regarding data circulation and quality, it maximizes the Partnership's interdisciplinary character, aligning it with FAIR principles.

By leveraging insights collected during the above activities, this research line will develop a modular ontology to cover research directions pursued within the other research lines of the Partnership. This includes creating new metadata standards and formats to capture in full depth data collected in the procedure of materials and components qualification, in particular in creating TBs for nuclear materials (*section 1.2.2.2*), and materials health monitoring systems based on NDT&E (*section 1.2.2.3*). Similarly, new formats will support advanced modelling that blends physics with data-driven models and characterization (*section 1.2.1.4*), which will thus benefit from the database features. The overall idea is that ontologies help to be more accurate in the data documentation, especially in providing metadata that help to connect given data to other domains.

The NM-KOS will improve for all RL data storage and access, which are cornerstones for advancing scientific progress, especially in today's rapidly evolving scientific landscape, where cross-disciplinary collaborations are indispensable. Such collaborations may involve integrating experimental data with model data, merging physical and data-driven machine learning models for predicting materials behaviour, or implementing digital twins for optimized component and plant management. Additional applications include combining advanced characterization techniques with digital technologies to yield better outcomes. The NM-KOS will catalyse, streamline and orchestrate these collaborative efforts, providing an engineering framework for the seamless implementation of workflows and pipelines. This, in turn, will accelerate the digitization process in the specialized field of nuclear materials, aligning it with the broader shift towards a 'design and control' paradigm. The common infrastructure established by the NM-

KOS will enable effective knowledge sharing and introduce digital workflows to ensure transparency and reproducibility, efficiently using instrumentation and expertise developed across various projects.

1.2.2.5.5 Alignment with national or international research and innovation activities

Efforts in this research line will benefit from the experience gathered during the **ENTENTE** project, which was focused on developing a unique database to store results of characterisation techniques and models on radiation damage of RPV steels. The **ENTENTE** database incorporates general data, as well as data on full microstructural characterization, and associates them with mechanical properties and modelling data. Using an incremental approach, and leveraging efforts of multidisciplinary teams (material scientists, engineers, developers), the project enabled the stepwise construction of a modular database, gradually broadening its scope to include additional techniques at subsequent stages of the development, in particular through defining new effective data formats (for microstructural, mechanical and modelling data), as well as suitable interfaces for interoperability. This was made possible by leveraging ontology technologies, enabling the database to be viewed via a universally agreed conceptualization of the domain of interest through ontology-based Data Access.

The second initiative conceptually underpinning the efforts of this research line are **EMMC & EMCC**. With their agile methodology for data and knowledge management, **EMMC & EMCC** provide a robust framework to be incorporated in the NM-KOS, with distinct advantages: flexibility, extendibility, and capability to facilitate seamless data exchange. These attributes are critical to enhance efficiency in a complex research ecosystem characterized by diverse research topics. The EMMC & EMCC initiatives integrate various aspects of materials development, including data- and physics-based modelling, characterisation and pre/post-processing. This integration enables digitisation across the entire value chain and requires the incorporation of data and knowledge repositories that adhere to FAIR principles and are rooted in strong interoperability foundations, including ontologies and enabling tools/platforms such as digital marketplaces and open simulation platforms.

Important EMMC initiatives are the **Ontotrans**, **Ontocommons**, **OpenModel** projects (*section 1.1.4.2*):

Ontotrans provides an ontology-based Open Translation Environment. Its artificial intelligence approach enables end users to represent in a standard ontological form their manufacturing process challenges and to connect them with relevant information sources and materials modelling solutions, capable of supporting optimal materials and process design, thereby demonstrating high robustness.

OntoCommons lays the foundation for interoperable, harmonized and standardized data documentation through ontologies, facilitating data sharing and pushing data-driven innovation, to bring out a truly Digital Single Market and new business models for European industry, exploit the opportunities of digitalisation and address sustainability challenges, by developing the Ontology Commons EcoSystem (OCES) - a set of ontologies and tools that follows specific standardization rules.

OpenModel – Integrated Open Access Materials Modelling Innovation Platform for Europe. OpenModel aims to design, create, provide and maintain a sustainable integrated open platform for innovation which delivers predictable, validated, and traceable simulation workflows integrating seamlessly third-party physics-based models, solvers, post-processors and databases.

Moreover, as mentioned in section 1.2.2.5.1, the IAEA has undertaken initiatives in the realm of knowledge representation. For example, the Fast Reactor Knowledge Portal is designed to counteract the on-going loss of information regarding Fast Reactors (FR) by collecting, safeguarding, and granting access to available data and knowledge concerning FRs. This platform facilitates various aspects of knowledge management, such as sharing, development, search, discovery, collaboration, and communication pertaining to FR-related information.

Similarly, the Idaho National Laboratory has developed the DIAMOND Ontology, while the Nuclear Regulatory Commission has established the Nuclear Reactor Engineering Ontology. The DIAMOND Ontology serves as a model for applications and processes within, and associated with, NPPs. The Nuclear Reactor Engineering Ontology systematically organizes and cross-references established terminology glossaries and stakeholder lists into machine-readable terminological resources, enhancing their utility for computational purposes.

Finally, the NEA activities within WPFM concentrate on innovating experimental approaches, safeguarding data, and refining multi-scale simulations to foster predictive methods for design and assessment. The WPFM orchestrates specialized groups, bridging sophisticated modelling with practical applications, and encourages interdisciplinary initiatives

All the above initiatives may offer invaluable resources for constructing a Knowledge Management System for Nuclear Materials within CONNECT-NM. By drawing insights from these existing frameworks, we can significantly streamline the knowledge acquisition process, facilitating a more comprehensive and nuanced understanding of nuclear materials and their associated processes.

1.2.3 Methodology to reach CONNECT-NM operational objectives (OO)

In this section we describe how the operational objectives will be pursued in CONNECT-NM. The procedures described here have taken in some cases inspiration from the practices applied in two already running CEPs, namely **EUROfusion** and **PIANOFORTE**.

1.2.3.1 Efficiently run the administrative environment and the governance system

The main idea at the basis of the management of the Partnership is that the Projects in the research lines should be exclusively dedicated to R&D&I, and they can do so because coordination and administration, decision-making, access to infrastructures, mobility, education & training, communication, dissemination, result exploitation, open science, data management and gender dimension, are all centralised at Partnership's level, at the service of the Projects. This way of proceeding, with *lato sensu* 'management' activities that are cross-cutting through research lines ('transversal activities'), will simplify the work of project leaders and researchers involved in the Projects, allowing them to focus on the work they know best, while enabling a significant optimisation of the use of resources.

A management support office (MSO) will be created to aid in their daily tasks the coordinator, the governance bodies, the Projects and the persons in charge for the various centralised activities. The detailed functions of the MSO are described in section 3, specifically in the description of WP1 (*section 3.1.3.1*), and its role in the overall structure is clarified in section 3.2.2.

Quality assurance (QA) criteria will be applied as much as possible to define clear and objective procedures for the management of the Partnership in all its aspects, inspired by the norm ISO-21500:2012 (guidance on project management). The QA of policies and processes will be partly defined by the rules set out in the Consortium Agreement, especially concerning the governance structure. Partly, however, these procedures will be developed in the course of the Partnership, to ensure clarity, transparency, simplicity and efficiency in all aspects of its management. These procedures will be collected in a single document, the project quality handbook (PHQ), which will be produced at the beginning of the Partnership and updated periodically, and which all Partnership's participants will be able to consult at any time. This document will describe among others the roles and responsibilities of coordinator and MSO, governance bodies, advisory bodies, work-package and task leaders, project leaders, persons in charge for deliverables, etc. This document will include protocols for project launch, implementation and follow up (e.g. guidelines to issue deliverables, milestones, minutes of meetings ...) to project leaders, as well as protocols for dissemination and open science, including relevant needed approvals, among others. An important part of the QA of a Partnership concerns the control of costs, in line with the project budget, at the end of each year and of each reporting period. There is indeed a need to clearly identify, via suitable procedures, the costs of each project separately from the cost of the 'functioning' of the Partnership, eventually matching a single overall cost report, taking into account the application of different reimbursement rates depending on the type of activity and partner. Finally, the PQH will include processes of control and evaluation to detect possible deviations and intervene with corrective measures or adaptation of the structure and processes. Following QA principles, a survey of the satisfaction of the participants with the way of working of the Partnership will be conducted.

1.2.3.2 Open and transparent procedure for the prioritization of case-studies

It is important to emphasise that the launch of project calls is NOT, in itself, an objective of CONNECT-NM. However, project calls have been identified as the most transparent and balanced way to define priorities, matching top-down general requirements (defined within the governance bodies of the Partnership, after considering the opinion of the advisory bodies), to bottom-up formation of open consortia around specific case-studies (nuclear systems and materials or components). A transparent, but drastic, prioritization procedure is essential in a situation where, clearly, the allocated resources are totally insufficient to cover the whole spectrum of research activities that could *a priori* fall within the scope of the Partnership.

The organisation of Projects calls will proceed according to the following steps[9]:

[9] This procedure is original and largely based on the experience accumulated over the years within SNETP, specifically in NUGENIA, and within the EERA JPNM, for the preparation and selection of project proposals. It is a procedure that applies similar principles of transparency and openness, as in PIANOFORTE, but also significant simplifications, as in EUROfusion.

1. Preparation of the call scope and expected outcome for each research line, by the involved research line team and endorsed by the governance bodies. General Project proposal eligibility criteria and boundary conditions will also be identified, consistently with the eligibility rules generally applied by the EC; for instance:

- The Project shall be clearly aligned with the RL objectives as described in the proposal and in the SRA written in **ORIENT-NM**;
- The Project should concern one of the four families of materials considered in the CONNECT-NM partnership;
- The Project consortium shall be comprised of a minimum of two independent legal entities from two different EU Member States or Euratom Associated Countries; in addition, the Project may include legal entities from non-associated third countries, that do not receive any financial support from the EU grant;
- Participants may come from a beneficiary, an affiliated entity, a third party or an associated partner, but the leader should be a beneficiary or an affiliated entity;
- The inclusion of at least one end-user (industry, TSO, regulator …) in the Project consortium will be considered as a bonus;
- …

Indications will be provided about the expected budget, based on the decision of the governing bodies (*section 3.2.2*). For example, the General Assembly may decide to allocate a maximum reimbursement per project.

2. Preparation of the proposal submission procedure and system, the guidelines for Project proposers and the final call text, including suitable templates for the proposal and the financial commitment: the submission system and the guidelines will be written and structured to enable smooth submission of the proposal; in addition, the MSO and the research line leaders will be available to assist proposers at any stage of the submission procedure.

3. Publication of the call announcement(s): the call will be advertised through a series of communication channels that include: the CONNECT-NM website, the Funding and Tenders portal and the beneficiaries' websites, especially the associations, providing clear information about submission opening and closing dates; the call will remain open for at least two monts.

4. The submission will proceed in two steps, as follows:

First stage: Project ideas and brokerage event. In this phase the proposers will be asked to describe briefly the core of the project proposals' ideas, including objectives, methodology, expected results and impact, as well as the core group of proposers and a tentative assessment of the expected costs, also advising on possible external experts as reviewers. At this stage, the consistency of the project ideas with the call content and with predefined general eligibility criteria, including national eligibility checks, will be assessed by the Executive Board (*section 3.2.2*) and non-binding advices of proposal merging, modification, or withdrawal will be given. Next, a brokerage event will be organised, in which these ideas are presented by the proposers to a wide audience. This brokerage event will be advertised through all available communication means, especially through associations, to ensure the widest participation possible, well beyond the till then established Partnership's consortium. The goal of this event is to enable the inclusion in the project proposal consortia of the widest spectrum of organisations which can potentially provide valuable contributions, such as new affiliated entities, candidate third parties and associated partners, within the available budget.

Second stage: project proposal submission and subsequent evaluation. The proposals, now described in full detail, especially in terms of subtask breakdown (projects will formally be tasks within the work-packages associated with the research lines) and financial aspects, according to a template, will be submitted using a dedicated procedure, to be implemented in the CONNECT-NM website. Projects may include cross-cutting aspects through different research lines. However, each project proposal shall be assigned to one and only one research line, upon explicit request of the proposers, because the project shall be stated to contribute mainly to the corresponding specific objective. An evaluation committee (EvaCo) will be formed, comprised of selected experts belonging to the advisory bodies, as well as *ad hoc* designated impartial experts, to assist the Executive Board for the project ranking. External EvaCo members will be remunerated for their work via subcontracting. The EvaCo will distribute the eligible project proposals to external and independent reviewers for their evaluation. These reviewers may have been suggested by the proposers, but will be in any case selected by the EvaCo, based on their international renown as experts in the relevant field, making sure no conflict of interest may be generated, e.g. by choosing the reviewers from outside Europe or from clearly independent and impartial frameworks, with the request of signing a non-disclosure agreement and a no-conflict-of-interest declaration. These reviewers will be asked to provide scores to each proposal, according to a set of pre-established criteria, which will largely follow the EC standards in terms of evaluation of excellence, impact and implementation, as well as emphasising adherence to the project call terms. Note that the EvaCo will also be in charge to evaluate and rank mobility action applications.

5. Ranking and selection of the proposals: The EvaCo will be in charge to establish the ranking of projects for their funding by the Partnership, strictly based on respect of the eligibility criteria, the terms of the call and the scores assigned by at least three independent external reviewing experts. Each member of the EvaCo will act as independent expert observer for the reviewing process of a number of project proposals, eventually producing a report for each of them; these reports will be part of the corresponding Partnership annual report. The input of the members of the EvaCo for the ranking of the project proposals shall be organised in such a way that any potential conflict of interest is avoided. In particular, a member of the EvaCo shall not participate in any decision in which a situation or circumstance of personal and/or professional nature can compromise his or her ability to decide in the best interest of CONNECT-NM, based on a list of potential conflicts that each EvaCo member will provide and sign before participating in the ranking (no-conflict-of-interest declaration). In case of strongly diverging opinions expressed by the reviewers on the same project, or upon decision of the EvaCo, meetings with reviewers, or hearings of the projects proposers, will be set up, to consensually smoothen divergences or clarify doubts about the project proposal content. The ranking will be made both in absolute terms and per research line; the ranking will be part of the relevant Partnership annual report. Based on the ranking proposed by the EvaCo, it will be the General Assembly of the Partnership (*section 3.2.2*), representing all Beneficiaries, to have the ultimate decision about how many projects can be funded. If proposals have identical scores, those from participating EU Member States and Associated Countries with still available funding can be given precedence. In order to optimise the distribution of funds and maximise the number of selected projects, modifications in either the subtask breakdown or the requested budget of the given selected projects might be negotiated with their proposers. If deemed suitable, a lower reimbursement rate than the standard one may be proposed, in order to enable that a lower-in-rank project may be launched. In addition, it is in the right of the proposing consortia to decide to pursue with their own means projects that have not been granted financial support by the Partnership. They will in any case be enabled to count on the opportunities and support offered by the Partnership to Projects in terms of transversal activities, i.e. dissemination, communication, result exploitation, access to infrastructure and mobility opportunities, etc.

6. Publication of the information about the outcome of the open call; the leaders of the projects that have been accepted will also be notified about the following steps to be taken.

7. Project launch and reporting: For each of the selected projects, a task agreement will be signed between the coordinator and the project leader, on behalf of all project partners. This task agreement will be based on the project proposal and will summarise the subtask breakdown, establishing internal milestones and deliverables, as well as addressing all financial and ethical aspects.[10] This document will be kept as simple and concise as reasonably possible. The project leader will be responsible to organise a project kick-off meeting as official start of the Project, as well as any other project meeting, online or in-person, under the supervision of the corresponding research line leader. The project leader will also be responsible for providing the MSO with the annual project financial report, following an established template, as well as to provide the research line leader with all the scientific and technical information that is needed to report about the project in the annual Research Line Progress Report (RLPR). The Project will need to include in the budget sufficient provisions to cover the expenses related to mandatorily open access publications. The project leaders can always count on the assistance of the MSO, via research line leaders, for any aspect related to project coordination (e.g. support for meeting organisation or report preparation), communication and dissemination actions, mobility requests, etc.

1.2.3.3 Monitoring system and self-assessment mechanism

The monitoring of the activities of the Partnership and its Projects, particularly the QA-based approval workflow of deliverables and milestones, will benefit from the use of an established Project Management Tool (PMT) implemented in the Members Only section of the Partnership's website, inherited from the EERA JPNM website, where it has been long used. Work-package leaders will be responsible for the monitoring of the activities of each work-package towards the coordinator, while the project leaders will be responsible for the monitoring of their projects towards their research line leader. For monitoring purposes, all of them shall rely on the assistance of the MSO to use the PMT and the approval workflow. In-person Partnership plenary meetings will be organised in concomitance with the end of the reporting periods, as the occasion to meet, exchange information, report, and monitor results. The contractual Periodic Activity Reports at the end of each reporting period will be the milestones for thorough monitoring of the activities of the Partnership.

The activities of the Partnership and its Projects will be periodically assessed by a Scientific Advisory Board (SAB). This SAB will be comprised of internationally recognised experts in the scientific and technical field of materials for

[10] The adoption of this procedure, i.e. signature of a task agreement, corresponds to the practice used in EUROfusion.

nuclear energy, both internal and external to the Partnership, to be selected from varying work backgrounds: research, industry, and academia. Members from renowned research centres such as CEA and SCK CEN, as well as LANL in the US, and also industry (Jacobs) and a TSO (IRSN), have already been identified. Other members will be searched for from extra-European research organisations, as well as, possibly, from the NEA. As advisory body, the SAB shall be responsible for giving input to the governance bodies concerning operational and strategic issues affecting the scientific and technical orientation of the Partnership. In particular, it will be in charge of overseeing the implementation of the Strategic Research Agenda. Some SAB members may also be involved in the evaluation of Project calls, by being selected as EvaCo members, after signing a declaration of no-conflict of interest. The SAB shall provide yearly assessments of the activities of CONNECT-NM in the previous year, having access to all deliverables and/or reports, after signature of a non-disclosure agreement. It will also provide yearly recommendations, to be taken into account for the following Annual Work Plan, being also charged with overseeing in due time the revision of the SRA.

1.2.3.4 Access to infrastructures

The advancement of innovative reactor concepts towards the stage of demonstration and deployment invokes the development and assessment of new materials that need to be able to cope with the challenging operating conditions in these reactors. An essential step is the generation and acquisition of experimental data for modelling and qualification purposes, by exposing candidate reactor materials to conditions that mimic those of future reactors in operation. This includes amongst others the fabrication of samples and objects to be irradiated, the execution of irradiation experiments in MTRs and the characterization of the irradiated materials in hot laboratories.

Therefore, the verification of the availability of these specific infrastructures and the knowledge of future development plans is required to ensure the feasibility of future material research activities.

In particular, over the past decades the number of European MTRs, many of them built in the late 1950s and 1960s, has steadily decreased, due to ageing often in combination with the lack of (financial) appreciation of the benefits of nuclear research. Even with the prospect of new facilities coming available in the 2030s and beyond, access to these MTRs remains a delicate issue. In addition, the costs of irradiation experiments, especially when the availability of irradiation time is getting limited, are extremely high.

A joint European forum focused on the coordination of nuclear infrastructure management, as first step towards optimised and harmonised use of nuclear infrastructures (not only MTRs) would therefore be a great asset to facilitate future progress in the domain of nuclear materials.

In **ORIENT-NM**, existing initiatives of this type were identified and first contacts were established with two of them: the **OFFERR** European Project (eurOpean platForm For accEssing nucleaR R&d facilities) and the NEA Second Framework for Irradiation Experiments (FIDES-II):

OFFERR. As an outcome of the first call of the Horizon Europe Euratom framework (WP2021-2022), the **OFFERR** proposal, prepared under the auspices of the SNETP, started in September 2022. The objectives of the **OFFERR** project include the establishment of a sustainable network gathering state-of-the-art nuclear research infrastructures all over Europe, including MTRs and material research facilities. **OFFERR** launches calls for proposals to receive financial support for transnational access to key nuclear research infrastructures. The calls will be open to project proposals within all disciplines and topics of research, in line with the strategic research and innovation agenda of SNETP; so, not only materials infrastructure, but including them, as well. **OFFERR** is thus partially answering the need to coordinate access to key nuclear materials infrastructures.

The management of **OFFERR** acknowledges the benefits and added value of interaction with CONNECT-NM. A close collaboration is therefore planned between the Partnership and the **OFFERR** project, especially concerning the MTRs and the facilities participating in the materials research area, to facilitate their use.

Ways of interaction with **OFFERR** could include

- Regular presentations of the status of CONNECT-NM at **OFFERR** meetings and vice versa.
- Involvement of the CONNECT-NM partners in the **OFFERR** project[11], encouraging and helping facilities of the partners to join the **OFFERR** list of infrastructures available to host researchers.
- Contribution to the update of the material research area of the European User Facility Network (EUFN) catalogue maintained in **OFFERR**.
- Technical, research-based cooperation: proposals for projects in CONNECT-NM could be linked to **OFFERR** proposals for the use of infrastructure.

[11] There is a considerable overlap between the participants of CONNECT-NM and OFFERR.

A Memorandum of Understanding (MoU) detailing the modes of interaction between the projects will be prepared at the beginning of CONNECT-NM. This MoU is expected to be extended to any possible successor of **OFFERR**. Other facility networks and open access schemes, e.g. EMIREA (French ion irradiator network), JRC, and the CICCR Czech scheme, have been also identified to liaise with. Information will be given to partners about these opportunities.

FIDES-II and FIDES-III. The link between NEA and CONNECT-NM is discussed in section 1.1.4.1. In **ORIENT-NM** contacts have been taken with **FIDES-II**, i.e. the current framework for irradiation. **FIDES-II** ended in March 2024 and will continue as **FIDES-III**, so this is the new framework for collaboration. The involvement of CONNECT-NM participants in **FIDES-III** will enable the identification of European needs and capabilities and of irradiations of common interest for both **FIDES-III** and CONNECT-NM. The possibility of hosting in **FIDES-III** an irradiation campaign designed in, or in collaboration with, CONNECT-NM will be explored. The legal and financial boundaries of this collaboration, however, need to be studied. A MoU detailing the modes of interaction between the Partnership and the **FIDES-III** framework will be prepared as a task of CONNECT-NM.

In addition, contacts have been made with the Jules Horowitz Reactor community (*see section 1.1.4.5*), which is currently working on prioritizing joint irradiation plans at European level. This community also interacted with NEA and **FIDES-II** (**FIDES-III** in the future), and may be involved in the endeavour of creating the correct framework of collaboration and identifying the content of the campaign. Interaction will also continue to guarantee the consistency of the future revision of the SRA of the Partnership with the JHR roadmap, identifying needs and opportunities for future material irradiations, as started in the **JHOP2040** CSA.

1.2.3.5 Education and training

To facilitate competence building related to nuclear materials, comprehensive E&T activities will be organised based on proven needs of the nuclear materials research community and industry. These activities will support knowledge preservation and prepare a new generation of experts that, from the start of their carrier, will be familiar with the innovative methodologies developed in the framework of CONNECT-NM.

E&T activities will be organised on subjects for which a clear and commonly agreed upon need is identified in the research lines pursued by the Partnership, consistently with top-down guidelines. These subjects will inherently require multidisciplinary profiles that may not be currently available. In particular, emphasis will be given to match materials science knowledge with expertise in the use and development of digital techniques, as well as with the skills that are required to promote innovation. To bridge the identified gaps, new activities will be developed based on state-of-the-art information in the field.

The E&T activities will combine the scientific expertise of the scientists involved in the research lines pursued by CONNECT-NM and the didactic expertise of the staff involved in the management of the E&T, to ensure efficiency and effectiveness. Modern information sharing techniques, such as peer teaching, blended teaching and project based teaching, will be applied. The involvement of the members of the SAB and the IEG will also be fostered.

Furthermore, to inform all stakeholders of the E&T activities, a dedicated and user-friendly webpage will be developed and embedded in the CONNECT-NM website, jointly with the communication and dissemination activities of the Partnership. This webpage, in addition to being used for the organization and announcement of the E&T activities, will provide suitable links to pages that provide information of interest in connection with the research lines of the Partnership. The ENEN website will also be used to advertise the E&T activities.

The E&T activities will rely on four main pillars

i. Promotion of mobility. In this way, CONNECT-NM aims at developing and transferring competences (i.e. knowledge, skills and attitudes) via pathways other than the traditional academic approach (i.e. classroom or online learning and practical exercise sessions). The mobility scheme will support MSc students, PhD students, post-docs, (early stage) scientists and researchers to participate in conferences, training courses, summer schools, internships, workshops and/or scientific exchange visits, helping them to acquire and develop their competences. This scheme will make use of the network and resources of ENEN (**ENEN++**), so that scientists can be brought together into an effective exchange of experience, best practices and results. Furthermore, the mobility programme will support access to dedicated infrastructures (e.g. experimental facilities, laboratories) associated with nuclear materials science, using the facilitated access to the infrastructure permitted by the Partnership and its association with the **OFFER** project.

ii. Training schools and massive open online courses (MOOCs). A portfolio of basic and specialized training courses will be established. One of the tasks of CONNECT-NM will consist in identifying relevant and complementary initiatives, coordinating and complementing them as best as possible. This portfolio will include courses from already existing initiatives, including project partners, IAEA, OECD-NEA, as well as training courses newly developed in the Partnership. The main aim of developing new training courses will be to bridge gaps between the current training offer and the identified needs of the partners and stakeholders in the field of nuclear materials. Based on the existing training offers and the identified training needs, a gap analysis will be performed. Once

these gaps in the existing landscape are identified, priorities will be defined and training materials will be developed according to these priorities. The training offer will be made available through an easily accessible database, on the CONNECT-NM and also the ENEN websites.

iii. Workshops for young researchers, with particular attention for the integration of junior researchers (MSc thesis students, PhD students, post-docs) in the scientific and technical community, since they form the next generation of experts in the field of nuclear materials. It is important to create a dialogue between the established scientific and technical community within the CONNECT-NM and the student community. The involvement of ENEN in the Partnership will be key to implement this dialogue successfully, since it provides a platform for competence building and networking.

iv. Training through research, which will be embedded in the technical projects of CONNECT-NM.

In order to optimise the use of resources, whenever possible E&T initiatives will be organised in collaboration with other entities, ranging from international organisations (IAEA, NEA, …) and European associations (including those involved in the Partnership: SNETP, EERA and, especially, ENEN), to bodies of various type (e.g. related to standardization or TSOs), fusion and/or non-nuclear energy, specific infrastructures (e.g. Jules Horowitz Reactor community), and other on-going Euratom projects. The organization of workshops and online training will also enable the industry and TSO community to be updated with the latest findings in the nuclear materials field.

1.2.3.6 Impact maximisation

Impact maximisation is addressed in section 2.2.

1.2.4 Gender dimension

As a standard procedure, close attention has been and will be given in CONNECT-NM to respecting the gender balance in the composition of all Partnership's bodies. This is crucial to make use of all available skills and to dissipate gender prejudices and stereotypes. The members of the Executive Board (*section 3.2.2*) have been selected to fully respect gender balance and to a large extent this balance is also respected in the group of people in charge for tasks and subtasks within work-packages and research lines. In order to promote gender balance also at the level of other bodies (e.g. SAB and IEG) and of Project participants at large, a Gender Coordinator shall be appointed to check the members of the advisory bodies and the participants involved in the research projects, in order to spot cases of gender under-representativeness and invite the group concerned to redress the balance by opening opportunities to researchers of different gender, but equivalent experience and CV, so long as possible.

However, considering the gender dimension in research does not mean to merely pay attention to gender balance. Science, technology, engineering and mathematics research topics often appear to be gender-neutral. In particular, it is often stated that there are no gender dimension issues in nuclear materials science. However, this statement might be the result of a superficial analysis of the overall aspects and features of R&D activities in this field. Questions should be asked to identify aspects that may not be as gender-neutral as expected at first sight, such as: Who decides on the research agenda? Whose interests and needs are served with the research? Who will mainly be the users of the knowledge that is to be produced? Who can benefit and in what way from the research? To address this issue, within CONNECT-NM a Gender Dimension Working Group will be created under the supervision of the Gender Coordinator, with the objective of launching a reflection on this point. In addition to the above questions, this group may assess, from a gender perspective, issues such as the risks to workers during ordinary and extraordinary work activities within the research areas, or the features of this work where gender differences may influence the results or, conversely, those that may create discrimination between genders, suggesting in each case possible countermeasures.

In addition, the gender dimension will be mainstreamed in educational provisions and outreach activities linked to the Partnership, for instance by including dissemination actions on research subjects that are dealt with in a gender perspective. An example can be R&D promotion videos in which female researchers appear, possibly talking in the mother tongue of the researcher, whose audience will be (very young) students, from the country of the female presenting researcher. Another example could be E&T actions dedicated to high school / first year university students, to make the subject matter of CONNECT-NM and the latest scientific discoveries known, which are to be administered mainly by female researchers, possibly in the language of the recipients. In general, the idea is to privilege female and minority gender speakers over male speakers in dissemination and E&T activities. The aim is to break down prejudices related to women's ability to apply themselves to scientific and mathematical subjects and to make it possible to imagine a future for all students as researchers in the field of the Partnership.

1.2.5 Open science

Fully aware of how crucial it is to embrace Open Science to improve reproducibility and transparency, CONNECT-NM will take a suitable approach towards more collaborative science. A dedicated task shall deal with promoting

Open Science within the Partnership's research activities, for which an Open Science Officer will be appointed. Guidelines about Open Science practices will be prepared at the outset of the Partnership and periodically updated, in order to inform all researchers involved about their contractual obligations in this sense, as well as to encourage them to put in place recommended practices, particularly in connection with open early sharing and reproducibility of results (Open Science Guidelines, OSG). Immediate open access will be provided to all peer-reviewed scientific publications through the Zenodo repository, or equivalent. In particular, 'gold' open access, where the publications become immediately openly available online, will be ensured via provisions for dissemination, to cover the article processing charge (APC). Open access options will be recommended, to make the best use of the financial resources reserved for publications. For example, consideration will be given to the possibility of publishing in open access journals with low or free APC, or exploiting institutional agreements to cover publishing costs, so that open access fees are paid by the institution or the country's library organization. In this respect, a thorough investigation of potential target scientific journals will be performed to identify scientific publication venues, not necessarily 'gold' open access, but allowing the accepted version of the manuscript to be uploaded for free and without embargo onto the Zenodo repository, or equivalent, licensed under CC BY or equivalent. This list will be added to the OSG and periodically updated. A copy of accepted manuscripts will also be stored in a dedicated open repository on the CONNECT-NM website and in general pre-prints will be shared in a suitable platform, including Zenodo, or equivalent, whenever possible. Each publication will be promoted through social media posts to further increase the accessibility to research outputs. Participation in open peer-review and other open science practices will be encouraged, whenever possible and in line with both the opinion of the partners and the policy of the target journal. Openly accessible datasets, codes, etc., will also be stored in the Zenodo repository, or equivalent, respecting the principle "as open as possible, as closed as necessary", in accordance with the procedure defined in the Data Management Plan (*next section, 1.2.6*), in particular those datasets that are related to already deposited peer-reviewed articles.

1.2.6 Data management

Knowledge and Data Management (KDM) are central to the approach pursued in CONNECT-NM, with a whole dedicated research line (*section 1.2.2.5*). Such a research line has the objective of establishing a Nuclear Materials Knowledge Organisation System to enhance interoperability between knowledge domains, integrating heterogeneous data sources and in full application of FAIR principles. This will facilitate the exploration of knowledge systems' content by both human and autonomous digital agents. Interoperability is thus specifically addressed as part of the R&D&I pursued in CONNECT-NM: a critical part of the corresponding research line will be establishing the standards and definitions relating to the vocabulary of data to facilitate interoperability.

Concerning types, in the realm of nuclear materials research, diverse categories of data and research outputs are produced, encompassing:

1. Experimental Data: A broad spectrum of measurements will be performed within CONNECT-NM, ranging from irradiation tests and material degradation studies to stress tests, corrosion rates, material property measurements, radiation dosages, and stress-strain data.
2. Observational Data: The monitoring of reactor fleets, prototypes, and real-world materials under operating conditions yields observational data. This could involve data obtained from surveillance, monitoring sensors, and continuous monitoring, generating time-series data.
3. Images: The visualization of materials at microscopic scales is facilitated by images like micrographs, high-resolution scans, and tomographic data. These images enable in-depth material characterization, including insights into microscopic structures and radiation damage.
4. Text: A variety of contents such as research papers, descriptive findings, research articles, protocols, and qualification pathways will be produced witin the Partnership. This textual information forms the metadata and descriptions that provide context and understanding to the data.
5. Numerical Data: The outcomes of computational models, both physics-based and data-driven, produce numerical datasets. These datasets contribute quantified insights into the behaviour of materials under various conditions.

The sizes of these data-sets cover a wide range, depending on factors such as research complexity and data resolution. For experimental and numerical data, due to the intricate nature of materials behaviour, the datasets could span from gigabytes to even petabytes, especially in case of high-resolution images and complex simulations.

To ensure findability of CONNECT-NM data/research outputs, Digital Object Identifiers (DOIs) shall be used for research articles (*see also previous section, 1.2.5*), codes and datasets. Institutional repositories and public archives like arXiv for preprints and Zenodo for actual articles and datasets, as well as domain-specific repositories, EU-level databases, and industry-approved databases, will be used.

Concerning accessibility, notwithstanding a strong engagement to Open Science (*previous section, 1.2.5*), it is essential to be aware of the fact that, due to the sensitive nature of nuclear applications and the strong industrial involvement in CONNECT-NM, intellectual property rights (IPR) could be a concern and be particularly stringent in some cases. Thus not all data may be openly accessible. However, whenever possible open access to data will be given at the shortest delay. Access to restricted data (e.g. in-service inspections and continuous monitoring data) will be based on specific provisions among verified researchers for replication and verification purposes.

Reusability of data/research outputs will be based on licenses: Creative Commons for publicly accessible data, likely custom licenses for restricted or proprietary data. Tools/Software/Models used for data generation and analysis shall be documented and, if possible, made publicly available. Proprietary tools and software or models may be made available under restrictive licenses for academic purposes. Machine learning models for data analysis could be made available for reuse in similar contexts. Open-source platforms may be usable for less sensitive tasks, but proprietary software may be necessary for highly specialized tasks.

Finally, a dedicated data management team shall be responsible for maintaining data integrity, conducting quality assurance, and ensuring long-term storage. Costs may be significant, though, given the need for secure, long-term storage, especially if the data includes sensitive or classified information.

The practical implementation of DM within CONNECT-NM will be based on the adoption of a data management plan (DMP), which will be produced in its first version early in the Partnership and later revised.

2 IMPACT

2.1 Project's pathways towards impact

2.1.1 Unique contribution towards the impacts expected from the call

Table 2.1 illustrates the pathways enabled by the results pursued in CONNECT-NM towards each of the impacts that the Commission expects from this action.

Table 2.1 *– How CONNECT-NM results will make a difference towards the expected impacts from the call.*

Nr.	Expected impacts from the call	CONNECT-NM contribution
1	*"Structured consolidation of the European research community on nuclear materials"*	CONNECT-NM is the result of a more than 10 year-long process of progressive consolidation and self-organisation of the European research community on nuclear materials within two platforms: the EERA-JPNM and SNETP, particularly the NUGENIA pillar. Thus to some extent CONNECT-NM has already had this impact before the preparation of this proposal. The actual launch of CONNECT-NM will further and greatly strengthen this consolidation, by providing stable financial support to a structure that is *de facto* already in place, including research lines and internal projects, thereby increasing the ambition of this community to the level required to have a real impact on nuclear energy safety and sustainability.
2	*"Contribute to maintaining the high level of safety of nuclear installations for current and future fleets, in full compliance with relevant European regulations."*	The impact on safety and sustainability of the specific objective of each research line of CONNECT-NM is specifically illustrated in **Table 2.1e**.
3	*"Develop scientific knowledge and technological expertise applicable to the nuclear materials domain, including the coordinated use of infrastructures for materials qualification with sustainable quality assurance, and the production of reliable nuclear databases that meet FAIR principles."*	CONNECT-NM is built upon the idea of producing knowledge and expertise in the technological field of nuclear materials, putting modern materials science practices in the forefront, through its research lines. CONNECT-NM will necessarily need, and therefore develop, schemes to access major nuclear infrastructures, especially neutron irradiation facilities, thereby consolidating collaboration with existing initiatives that are already, *in parte* or *in toto*, dedicated to this, such as **FIDES-II/III** and **OFFERR** (or its successor), as well as the JHR community. In parallel, the test-beds that are pursued as specific objective of one of the research lines will effectively be the result of the integration of infrastructures and facilities that are located in various European laboratories into a single delocalised entity: their correct operation, in application of standardized and accelerated qualification paths, necessarily requires quality assurance practices to be followed. Finally, a whole research line is dedicated to creating a nuclear materials knowledge organisation system, which is at the fundament of the integration of databases, in application of FAIR principles.
4	*"Improved interaction of the nuclear materials research community with European nuclear regulatory bodies and their technical support organisations."*	CONNECT-NM will foster the creation of a Board of Regulators and a Board of TSOs, with which information will be exchanged on the paradigm shift that is pursued within the Partnership and on the safety-related requirements that regulators and TSOs see in connection with it. In addition, TSOs will be directly involved in the projects, to take care directly of safety aspects in the various research lines.
5	*"Improved exchange of knowledge across the respective research communities, including for example fusion and non-nuclear energy generating technologies"*	Very strong and solid strategies have been prepared in **ORIENT-NM** and will be implemented in CONNECT-NM in order to maintain a link and strengthen cooperation with the materials research communities involved in fusion and in non-nuclear energy technologies. These are based on the establishment of a scheme of continuous interaction and exchange of information, particularly with **EUROfusion**. In the case of non-nuclear applications, if the **IAM4EU** Partnership is eventually launched, the possibility of running parallel and complementary projects, between which collaboration can be set up, has been seriously considered and discussed.

Nr.	Expected impacts from the call	CONNECT-NM contribution
6	*"Improved quality of education and training of nuclear materials specialists, achieved in a coordinated manner across the EU in collaboration with existing nuclear education networks."*	The E&T strategy pursued in CONNECT-NM strives to identify the actual E&T needs and coordinate at European level all relevant initiatives. The objective is to produce a generation of young nuclear materials scientists that are experts in the innovative methodologies that are adopted and developed in the Partnership. The major nuclear energy education network, i.e. ENEN, is directly involved in the Partnership, thus full coordination of actions is ensured.

More general impacts that are expected from the research carried on in CONNECT-NM, with some economic and societal implication, are:

- Provide a drive towards innovation and technological advancement, fostering the development of new materials solutions and manufacturing processes, of use also beyond nuclear application (materials operating in harsh environments), which align with sustainability goals, thereby benefitting a wider spectrum of stakeholders than just nuclear industries or regulators.

- Promote a culture of continuous improvement and change of paradigm in materials science, supporting the growth of sustainable practices within the nuclear industry.

- Enhance overall efficiency and productivity, both on the research and on the industrial side, creating job opportunities for new and young experts, partly formed within the Partnership itself, thus indirectly contributing to economic growth in the framework of the energy transition.

- Support the long-term sustainability of nuclear energy by prioritizing safety and reliable operations, thus enabling its widespread use, overcoming current reluctance in several countries, thereby contributing to greenhouse gas emission reduction.

2.1.2 Unique contribution of the research lines towards the expected impacts: scale and significance

The following sections better detail the unique contribution towards impact of each research line, including scale and significance.

2.1.2.1 Advanced materials development and manufacturing

Innovative materials with better initial properties and performance in terms of resistance to degradation enable safer design of installations, with increased lifetime of components. This leads to a better use of resources and minimized environmental impact, by improving the availability of installations, which makes them not only more sustainable, but also more economic. In addition, advanced manufacturing techniques and processes, such as additive manufacturing and hot isostatic pressing, offer new freedom of design. This can help to further increase the performance of components, and thus installations efficiency and sustainability. Moreover, these techniques may reduce by up to 50% the use of raw material in the manufacturing phase. They can also improve materials recyclability, or enable on-site repair or fast replacement of components, which could reduce negative economic effects of conservative safety decisions, while improving the circularity of nuclear energy.

By focusing on these two axes, this research line will impact significantly on safety and sustainability improvement of nuclear industry on the long term, as summarised below in **Table 2.1e**. In particular, activities on advanced materials development and manufacturing are specifically expected to:

- Boost knowledge about promising known materials with low TRL and bring them to the level of near-qualified materials solutions.
- Enable the discovery of new innovative materials solutions to improve the design of structural components, core components, advanced fuel elements (enhanced accident tolerant fuels and enhanced performance fuels), or concrete structures, for different nuclear technologies and systems, with as many synergies as possible with non-nuclear applications.

Activities on advanced manufacturing processes in the scope of this research line are, in addition, expected to:

- Boost process parameters optimization and the qualification of advanced manufacturing techniques for relevant materials already used in nuclear technologies.

- Build materials design strategies based on tailoring the specific process parameters of advanced manufacturing techniques to develop new materials.
- Explore and extend the practical applications of advanced manufacturing processes to nuclear reactor components design, in view of identifying technologies with the highest interest.
- Extend the use of advanced technology coating processes to protect nuclear materials, by boosting the knowledge on these techniques and bring them to near-qualified materials solutions.

Finally, as a pre-requisite for the research line, the eventual construction of fully autonomous nuclear MAPs, designed to accelerate the above expected outcomes, will make it possible to:

- Develop screening methodologies to extend the range of materials, conditions and/or manufacturing process parameters which can be investigated.
- Find optimized materials solutions more efficiently and speed up their development, accelerating the safety strangthening of nuclear industry, and increasing its sustainability.
- Identify innovative materials solutions that are applicable to several nuclear fission technologies and to fusion, as well as building synergies with other industries.
- Minimize the quantity of materials used, as well as the time and costs of innovative materials development.

Table 2.1a highlights some expected impacts that are especially connected with this research line.

***Table 2.1a** – Expected impacts from the research line dedicated to 'Advanced materials development and manufacturing'.*

Nr.	Expected impacts from the call	Research line contribution
1	*"Structured consolidation of the European research community on nuclear materials"*	The development of nuclear MAPs and the qualification of advanced nuclear manufacturing represent an especially federating effort, by requiring the contribution from several disciplines in the field of materials science. This effort will therefore naturally encourage collaboration with non-nuclear materials experts, thereby contributing to a further expansion, as well as consolidation, of the European research community on nuclear materials.
2	*"Contribute to maintaining the high level of safety of nuclear installations for current and future fleets, in full compliance with relevant European regulations."*	The impact on safety and also sustainability of this research line is specifically illustrated in **Table 2.1e**.
5	*"Improved exchange of knowledge across the respective research communities, including for example fusion and non-nuclear energy generating technologies"*	The development of MAPs is the focus of several initiatives outside nuclear applications (e.g. BigMap, EU-Mace, Mission Innovation …) and these initiatives will likely be the starting point for the development of nuclear MAPs. Thus, this research line will especially contribute to improving exchange of knowledge between nuclear and non-nuclear field.
6	*"Improved quality of education and training of nuclear materials specialists, achieved in a coordinated manner across the EU in collaboration with existing nuclear education networks."*	MAPs and advanced manufacturing are cutting-edge research topics, on which tailored and possible hands-on education and training actions will need to be taken and these will be of inherently high quality. In this case, too, collaboration with external initiatives such as EU-MACE will contribute to increase the impact of the research of CONNECT-NM, also for educational purposes.

2.1.2.2 Materials and component qualification: testing, standardization and design rules

The accelerated qualification of nuclear materials and components will enable faster exploitation of innovative material solutions and deployment of innovative reactor concepts featuring improved safety and reduced cost. In addition, the actions proposed in this research line are expected to further consolidate EU Member States' research programmes and the EURATOM effort in the domain of nuclear materials, by clustering them around test-beds. Such joint approach should help European players to remain at the forefront of the nuclear materials R&D assuring, on the one hand, highest safety standards of nuclear installations in Europe, and, on the other, improved competitiveness of Europe at the world scale, in this dynamic technology domain. This will be done by:

- Improving technical knowledge and expertise on material qualification and standardization by the coordinated use of infrastructures and laboratories.
- Improving the interactions of the nuclear materials research community with stakeholders and industrial nuclear partners, nuclear regulatory bodies and standardization and codification institutions.

Table 2.1b highlights some expected impacts that are especially connected with this research line.

***Table 2.1b** – Expected impacts from the research line dedicated to 'Materials and component qualification: testing, standardization and design rules'.*

Nr.	Expected impacts from the call	CONNECT-NM contribution
1	*"Structured consolidation of the European research community on nuclear materials"*	The construction of test-beds, by integrating and coordinating the use of infrastructures for qualification of nuclear materials, will represent a strong step forward towards the consolidation of the relevant European research community.
2	*"Contribute to maintaining the high level of safety of nuclear installations for current and future fleets, in full compliance with relevant European regulations."*	The definition of accelerated qualification paths with the approval of the regulators, by enabling the fast deployment of better performing materials, including ATF, will provide a strong contribution not only to maintaining, but in fact also to strengthen the level of safety of current and future nuclear installations in Europe.
3	*"Develop scientific knowledge and technological expertise applicable to the nuclear materials domain, including the coordinated use of infrastructures for materials qualification with sustainable quality assurance, and the production of reliable nuclear databases that meet FAIR principles."*	The test-beds that are pursued as specific objectives of this research line will effectively be the result of the integration of infrastructures and facilities that are located in various European laboratories into a single delocalised entity. They will constitute an effective way to coordinate the use of infrastructures for nuclear materials. Their correct operation, in application of standardized and accelerated qualification paths, necessarily requires quality assurance practices to be followed, as well as FAIR data.
4	*"Improved interaction of the nuclear materials research community with European nuclear regulatory bodies and their technical support organisations."*	Within this research line the interaction with regulators and TSOs will be an integrating part of the relevant projects.

2.1.2.3 Non-destructive examination and materials health monitoring

The key for materials and health monitoring is the application of non-destructive testing and evaluation methods. These have the advantage of being able to characterise continuously the progressive change of the material properties of the same specimen in *operando* conditions, also applied to actual components, which is a unique feature of these techniques. In particular, continuous monitoring of the health of structural components has demonstrated its added value in several industries by now, while the *in situ*, *operando* and continuous application features of NDT&E are also crucial for the development of MAPs. NDT&E methods do more than purely detecting and locating defects in components: they address the characterization of material properties and their progressive evolution, providing valuable scientific insight, while contributing to improving all stages of the product lifecycle, from fabrication to operation, maintenance, repair and, finally, recycling or disposal. This is essential to further strengthen the safety and sustainability of nuclear energy as a whole. At design stage, assumptions need to be made with regard to actual material composition, microstructure state, mechanical properties, defect location, defect density, defect size, and overall degradation of mechanical properties in service, due to exposure to operational factors, such as temperature and/or pressure cycles, as well as neutron flux. While ever improved models can help in this endeavour (and a research line of CONNECT-NM is dedicated to their improvement), the evaluation of these parameters by *in situ* inspections will allow the actual estimation of the operational lifetime of NPPs and its components, providing a feedback to models and design rules, which can be in turn improved. **Table 2.1c** summarizes how this research line specifically meets some of the expected impacts from the call text.

***Table 2.1c** – Expected impacts from the research line dedicated to 'Non-destructive examination and materials health monitoring'.*

Nr.	Expected impacts from the call	Research line contribution
2	*"Contribute to maintaining the high level of safety of nuclear installations for current and future fleets, in full compliance with relevant European regulations."*	The impact on safety and also sustainability of the specific objective of each research line of CONNECT-NM is specifically illustrated in **Table 2.1e**.
3	*"Develop scientific knowledge and technological expertise applicable to the nuclear materials domain, including the coordinated use of infrastructures for materials qualification with sustainable quality assurance, and the production*	NDT&E and material health monitoring provide large quantities of materials relevant data. These serve both the nuclear and non-nuclear industry, contribute to populating a nuclear database which is of interest also beyond these applications, which can feed advanced methodologies.

Nr.	Expected impacts from the call	Research line contribution
	of reliable nuclear databases that meet FAIR principles."	
5	*"Improved exchange of knowledge across the respective research communities, including for example fusion and non-nuclear energy generating technologies"*	Non-destructive testing and evaluation techniques as well as materials health monitoring can provide additional / complementary information about the macroscopic material properties and improve the knowledge about the materials durability. This knowledge and especially the NDT&E methodology are of much wider application than just nuclear, while some techniques can be of interest and application also for fusion.

To conclude, this research will effectively support Member States', safety authorities' and industry's efforts to ensure that nuclear installations are designed, sited, constructed, commissioned, operated and decommissioned applying the highest standards of safety and achieving the highest level of sustainability.

2.1.2.4 Advanced materials modelling and characterization

The development of advanced predictive methodologies that blend physical multiscale and data-driven (i.e. machine-learning-based) models will combine strong physical rooting with the capability of exploring chemically or environmentally complex conditions, thereby moving towards direct application at industrial level. This research has also important safety and sustainability impacts (see **Table 2.1e**) and is an enabler for all other research lines, for instance:

- Advanced (physics-based and data-driven alike) materials behaviour models of applications to industrial materials and conditions can be used for a more reliable safety assessment, either underpinning and eventually replacing empirical or semi-empirical correlations used at industrial level, or else as a support for a more reliable evaluation of potential failure paths, which experimentally requires large and expensive execution programs, still often yielding simplistic results. In either case advanced predictive tools and capabilities are of major interest for both the industry and the regulators.
- Physically calculated parameters and properties can progressively replace empirical estimates in, e.g., fuel performance codes: better parameters yield better models. Physical models of various levels of fidelity also enter digital twins, enabling them to serve as more effective guides for improved safety in an operational environment.
- Physical models of varying levels of fidelity also support the use of few-shot learning methods, which are the necessary path for the field of nuclear materials, where hardly ever problems of big data analysis arise, but rather small data need to be supported by varying fidelity data, to be able to provide a prediction concerning the degradation of a given material in a given environment, even when the relevant data are scarce.
- Advanced modelling is also crucial for accelerated qualification, as it provides the required links between properties and should enable the effects of degradation processes to be more precisely assessed, also in the long term, based on physical insight.
- Digital technologies can finally reduce the amount of exposure and testing required on activated materials, as nuclear materials experimental programmes that involve irradiation produce nuclear waste through material activation, and contamination and debris from preparing, testing and examining those materials. Thus there can be an important effect on costs, as well as sustainability.

Table 2.1d summarizes how this research line specifically meets some of the expected impacts from the call text.

***Table 2.1d** – Expected impacts from the research line dedicated to 'Advanced materials modelling and characterization'.*

Nr.	Expected impacts from the call	Research line contribution
2	*"Contribute to maintaining the high level of safety of nuclear installations for current and future fleets, in full compliance with relevant European regulations."*	The impact on safety and sustainability of the specific objective of each research line of CONNECT-NM is specifically illustrated in **Table 2.1e**.
4	*"Improved interaction of the nuclear materials research community with European nuclear regulatory bodies and their technical support organisations."*	The development of reliable predictive methodologies in connection with nuclear operating environment is of crucial use to regulators and TSOs as tools that enable better safety assessments.
5	*"Improved exchange of knowledge across the respective research communities, including for example fusion and non-nuclear energy generating technologies"*	The development of reliable predictive methodologies in connection with nuclear operating environment is certainly of use beyond fission applications, being of interest for fusion, as well.
6	*"Improved quality of education and training of nuclear materials specialists, achieved in a*	Modelling tools have a proven usefulness and applicability in E&T environments, in order to enable students to virtually simulate, e.g.,

Nr.	Expected impacts from the call	Research line contribution
	coordinated manner across the EU in collaboration with existing nuclear education networks."	radiation effects. Thus, appropriate models, accompanied by advanced characterisation techniques' results, can greatly help students to improve the quality of their education on nuclear materials.

2.1.2.5 Knowledge and Data Management

The unique impact of this research line shall concern the establishment of a single open knowledge framework for European nuclear materials research, facilitating among others faster innovation in experiments and the discovery of new material properties. The final goal is to manage in a unified manner existing and still to be created databases, both belonging to partners that are willing to provide them and in open sources, under a single knowledge framework that links nuclear material data irrespective of their provenance, including an inherent quality control. Such a single and unique framework currently does not exist and is expected to benefit all categories of stakeholders, from research to industry, from designers to regulators. The focus of this challenge will be on semantic technologies and database integration, which corresponds to current cutting-edge practices.

Sharing and formalizing knowledge using semantic technologies offers significant advantages. A structured knowledge framework improves the organization and accessibility of information, facilitating efficient navigation and understanding. It enables quick retrieval of relevant data, saving time and effort. Knowledge frameworks encourage collaboration, minimizing duplication and integrating the expertise of different teams. They ensure consistency and facilitate continuous learning, adapting to new challenges. Such frameworks support structured learning paths, training and competence development. Well-designed frameworks improve operational efficiency by automating processes and streamlining workflows. A strong knowledge base fosters innovation by facilitating the discovery of ideas and the exploitation of existing knowledge.

The KM/DM efforts have in particular considerable potential to significantly impact nuclear systems development, by establishing a robust cross-disciplinary collaborative framework. By incorporating ontology expansion and the introduction of innovative metadata standards, this research line is expected to have a significant impact on all the other research lines of the Partnership. It provides a route for the creation of a unified or federated database system, capable of automated data processing, tailored data safeguarding, and extensive data analysis, thereby reinforcing the principles of Findability, Accessibility, Interoperability, and Reusability (FAIR).

This advanced KM/DM strategy is expected to improve not just data quality and consistency, but also to support the reproducibility of research findings, all of which are critical factors in scientific advancements. An optimized and well-structured KM/DM process offers enhanced efficiency in research workflows and facilitates broader utilization of comprehensive, data-driven models, in combination with traditional physically-based multi-scale tools, which is a considerable leap forward in the field of nuclear materials.

2.1.3 Unique contribution towards the expected impacts on safety and sustainability of nuclear energy

The ambition of CONNECT-NM is to strengthen safety and sustainability of nuclear energy, by promoting innovation in the field of nuclear materials for operation under extreme conditions (high temperature and irradiation dose, chemically aggressive environments), to ensure high safety standards in power generation, while accelerating the process of materials development, improvement and qualification, so reducing time-to-market. **Table 2.1e** illustrates how specifically each research line in CONNECT-NM shall impact on, precisely, nuclear safety and sustainability.

***Table 2.1e** – Impact of the research lines of CONNECT-NM on safety and sustainability of nuclear energy.*

	What is it?	Safety Impact	Sustainability Impact
Nuclear materials acceleration platforms	MAPs are integrated, highly autonomous systems that combine advanced fabrication, characterisation and modelling methods with modern digital techniques (machine learning, robotic systems,	New materials selected to exhibit better initial properties and performance in terms of resistance to irradiation, temperature and corrosion or other environmental effects enable safer design of installations. MAPs enable optimized material solutions to be identified more	New materials with better initial properties and performance in terms of resistance to irradiation, temperature and corrosion or other environmental effects enable components lifetime and installations availability to be increased, as well as better energy generation efficiency, leading to better use of resources and so minimization of environmental impact.

	high-performance computing, high throughput calculation …), to iteratively perform a screening in a wide space of possible material compositions and architectures, to achieve materials fitness, safety and sustainability by design. Similar approaches are used to fully test and qualify advanced manufacturing processes.	efficiently and to speed up their development, accelerating the safety improvements of nuclear industry. Advanced manufacturing techniques help increase the performance of components and enable their on-site repair or fast replacement, thus reducing negative effects of conservative safety approach. Advanced manufacturing techniques also enable the fabrication of inherently safer components without welds and joints, which are known to be critical points and require dedicated qualification.	Advanced manufacturing techniques can reduce raw materials use and increase materials recyclability and offer knew freedom of design, thus increasing efficiency and therefore sustainability. New materials research is long and costly both economically and environmentally. By accelerating this development time, MAPs can contribute to a more sustainable approach with minimal materials use. Other variables that increase sustainability, including reduced use of critical raw materials, can be included in the materials development equation, as well.
Nuclear materials' test-beds for accelerated qualification	Integrated networked systems of facilities located in different European laboratories, where advanced and suitably standardised and quality controlled experimental procedures and methodologies for materials (accelerated) qualification are applied for nuclear materials exposure, characterisation and testing, be they destructive, non-destructive or microstructural. These procedures need to comply with the indications and the requirements of regulators.	Standardized and quality controlled experimental procedures and methodologies enable the reliability of the data to be drastically increased, and thus the reliability of the qualification process, with subsequently increased safety. Test-beds designed for nuclear materials and relevant qualification paths accelerate the qualification of better performing new materials and thus accelerate the safety improvements of installations; i.e. higher safety levels can be reached earlier in time.	By optimizing and accelerating data collection, nuclear materials' test-beds will enable the use of materials along the qualification process to be reduced considerably. Nuclear test beds could develop more easily standardized experimental procedures with smaller specimens, reducing the use of materials for their qualification. Faster qualification also leads to higher economic sustainability, by reducing of time to market, with overall cost abatement. Use of resources: more rapid adoption of materials with higher sustainability in terms of lifecycle (reduced use of critical raw materials, component lifetime, recycling, …)
Intelligent materials health monitoring	Intelligent materials health monitoring systems combine non-destructive examination and testing through sensors with suitable machine-learning-based online data analysis for fast diagnostics, supporting digital twins of the real component.	Continuous monitoring of materials and components health enables timely identification, and even anticipation, of possible failures and intervention at convenient times to repair or replace the component affected, enabling the detection of degradations with kinetics that are too rapid to be captured by scheduled in service inspections. They therefore optimize the safety of components and also plant life management through the whole materials lifecycle.	Continuous and reliable monitoring of materials and components health also enables component lifetime to be increased, by repairing or replacing only what is needed, thus with benefits on economy and reduction of the resources used.
Advanced predictive methodologies	Blending physical and data-driven (i.e. machine-learning-based) multiscale models, to combine strong physical rooting with rapidity and efficiency, for direct	This objective is an enabler of the above ones, thus inherently contributes to safety. In general, better predictive capabilities enable more reliable safety assessments, better assessment of safety margins,	Better predictive capabilities provide the bases for a more sustainable materials selection, in terms of longer component lifetime, reduction of use of critical raw materials, and so on, thus better use of resources and also better economy.

	application at industrial level, taking into account the limited availability of nuclear materials data.	safer materials choice and, especially, safer component design. Advanced models and simulation tools foster knowledge and expertise development, by providing platforms for education, training and in general outreach activities, which also rebounds in higher safety.	Reliable predictive methodologies also reduce the number of long/costly experiments needed (support to accelerated qualification), thus reducing costs, time to market and use of materials along the qualification path.
Nuclear materials' knowledge organization system	Develop ontologies and data formats to ensure efficient collection, storage, management and use of nuclear materials data, respecting IPR and following FAIR principles	Simple access to a wealth of correlated materials data can only provide better support to more reliable safety assessment, safer materials choice and safer design, in addition to supporting all the above objectives, which also impact safety.	A wealth of easily accessible data is the basis for, e.g. a more sustainable materials selection, in terms of longer component lifetime (so better use of resources and also better economy), in addition to supporting all the above objectives, which also impact sustainability.

2.1.4 Barriers to impact

The barriers to impact for CONNECT-NM are related to the enforced regulatory environments and the extent of the nuclear energy market. The Partnership shall involve from the very beginning regulators in a dialogue that is meant to account for the regulatory aspects related to the change of paradigm that is pursued. However, the outcome of the dialogue cannot be foreseen, so some of the accelerated qualification paths might not, eventually, make it through the filter of the regulatory bodies. This would have the consequence of delaying the time to market of new or improved materials, irrespective of their being designed to be fit-for-purpose, safe and suistainable. The other aspect concerns whether or not an advanced nuclear materials market will exist. Europe is currently experiencing a resurgence of interest in nuclear energy, especially thanks to game-changers such as SMRs and AMRs. If an actual market expansion of these systems follows the current resurgence of interest, then indeed new or improved materials and all the innovative methodologies pursued in CONNECT-NM will be able to bring valuable fruits; otherwise, no favourable conditions may materialise for the new paradigm in nuclear materials science to flourish.

2.1.5 Transformational changes induced by the Partnership

CONNECT-NM is explicitly designed to be transformational, by pursuing a ground-breaking change of paradigm in nuclear materials science, in line with its modern approaches (materials informatics) that are finding their way in a large number of technological applications. Advanced and innovative materials, with better performance and higher sustainability features, are considered indeed to play a crucial role in the green and digital transition, irrespective of the specific application. It is likewise recognised that a systemic approach to develop innovative advanced materials is needed to offer faster, scalable and efficient responses to the challenges and opportunities for Europe's society, economy and environment. In this framework, the transformational nature of CONNECT-NM is twofold. On the one hand, reliance on modern data and knowledge management, including advancement in intelligent material health monitoring systems, incorporating machine learning into cognitive sensor systems, combined with materials acceleration platforms and accelerated qualification paths, with the support of advanced predictive methodologies, is expected to lead to a shift in the nuclear materials science approach, moving from traditional 'observation and qualification' methods towards a more progressive 'design and control' approach. On the other, the goal-oriented structure of the Partnership represents a revolution with respect to the previous research organisation, based on independent projects. While pursuing continuity, the creation of methodological research lines forces the nuclear materials community to reorganise itself and refocus its activities: projects cannot only be designed on the specific impact that they pursue for a specific nuclear system and component, and thus application, but need instead to have broader view, towards the realisation of a skill-boosting target. The community needs to develop new capabilities and new collaborative ways of working, fostering the involvement and education of new young researchers with the required knowledge and training, thus having an impact also on the research labour market. Through strategic collaborations and the careful orchestration of advanced knowledge and data management principles, the potential for innovative discoveries and advancements in the field of nuclear systems is enormous.

Table 2.1f (*next page*) summarises the Partnership's pathways to impact, assigning specific indicators. **Table 2.1g** illustrates the intervention logic.

***Table 2.1f** – Summary of the Partnership's pathways to impact and relevant indicators.*

European Partnership COORDINATION OF THE EUROPEAN NUCLEAR MATERIALS COMMUNITY FOR ENERGY INNOVATION (CONNECT-NM)			**Monitoring and evaluation framework**, October 2023		
Overall vision: CONNECT-NM's vision on nuclear energy and materials has been developed in the framework of the ORIENT-NM CSA, which lasted from October 2020 to March 2023. This vision covers: Sustainability: NPPs are crucial components, together with renewables, of a resilient and sustainable Energy Union, helping Europe to abate the use of fossil fuels, reduce European geopolitical dependence and become the first climate-neutral continent by 2050. Nuclear capacity maintenance and increase, however, need to go hand-in-hand with a continuous improvement of the sustainability of nuclear energy. In this context, the European nuclear materials science community, united in CONNECT-NM, is called to provide the tools, knowledge and skills to enable each European country to maintain the desired and needed nuclear capacity and, depending on national policies and priorities, to develop advanced nuclear systems, towards ever increasing sustainability. Innovation: Research on materials can play a crucial role in strengthening the safety, efficiency, economy and overall sustainability of nuclear energy, in support of: (1) safe and affordable long-term operation (LTO) of current generation (GenII, GenIII) light water-cooled and moderated reactors (LWRs); (2) increasingly safe design, licensing and construction of Gen III+ new builds; (3) deployment of light water small and medium size modular reactors (SMRs) within the next decade; (4) reduction of time and costs for the design, licensing and construction of competitive next generation, more sustainable nuclear reactors, including advanced SMRs (AMRs), within the time horizon of 2040. For this to happen, however, a strong push towards innovation is needed, in order for materials and materials science to effectively produce such impact. Promoting innovation in the field of nuclear materials is the main focus of CONNECT-NM. Acceleration: The development and qualification of innovative materials solutions in terms of advanced materials and advanced manufacturing processes needs to be accelerated, while also accounting for circularity and sustainability principles. Moreover, improving the ability to predict materials and component behaviour in operation, assisted and verified by continuous monitoring, is crucial in support of safe and effective nuclear plant life management and nuclear component design. Producing this acceleration and achieving these challenging capabilities requires a structured and continued collaboration between academia, research organisations and industrial partners all over Europe. The CEP instrument is especially suitable to build such a structured and continued cooperation, leveraging national capabilities and harmonising national and industrial goals to grow a single European strategy for nuclear materials. A goal-oriented CEP is thus the tool to produce the shift of paradigm in nuclear materials from 'observe and qualify' to 'design and control'.					
Objectives		**Indicators**	**Data source and methodology**	**Who monitors them / When are they monitored**	**Target after 5 years**
General objectives	To nurture the coordinated exploitation of national competences, facilities and infrastructures in Europe, by bringing together European entities that have a national mandate for research in nuclear materials, in pursuance of the common goal of a shift of paradigm in materials research, from the traditional 'observe and qualify', to the modern 'design and control'. This paradigm change in the field of nuclear materials mirrors the general principle currently targeted in materials science for any application, which reads: 'fit-for-purpose, safe and sustainable by design'.	Expected outcomes mentioned in HORIZON-EURATOM-2023-NRT-01-04 and addressed during the Partnership	Partnership's Project case-studies and data	Coordinator / End of reporting periods.	All
Specific objectives*	To reduce drastically the time required to improve, develop, and even discover new or advanced nuclear materials and elaborate advanced manufacturing processes	Development of nuclear MAPs Qualification of advanced manufacturing processes Research papers in this domain	Research Line Periodic Reports Publications Record	Research Line Leaders and Open Science Officer / End of reporting periods.	1 1-2 5-10
	To accelerate the qualification of nuclear materials for safe operation	Development of test-beds and qualification paths Research papers in this domain	Research Line Periodic Reports Publications Record	Research Line Leader and Open Science Officer / End of reporting periods.	2-3 5-10
	To enable safer and more efficient management of the lifetime of nuclear components	Development of intelligent health monitoring systems	Research Line Periodic Reports	Research Line Leader and Open Science	1-2 5-10

		Research papers in this domain	Publications Record	Officer / End of reporting periods.	
	To improve the capability of prediction of the behaviour of nuclear materials in operation	Development of advanced and innovative methodologies, blending physical and data-driven approaches Research papers in this domain	Research Line Periodic Reports Publications Record	Research Line Leader and Open Science Officer / End of reporting periods.	3-4 10-15
	To create the conditions for nuclear materials data to be correctly collected and stored, so as to be fruitfully analysed, used and exploited	Nuclear materials' knowledge organisation system Research papers in this domain	Research Line Periodic Report Open Science Officer	Research Line Leader and Open Science Officer / End of reporting periods.	1 5
Operational objectives*	Efficiently run the administrative environment and the governance system	Level of satisfaction of participants	Survey of satisfaction	Coordinator / End of reporting periods.	> 70%
	Design and apply an open and transparent procedure for the prioritization of case-studies used for the development of the methodologies within each research line	Submitted proposals Level of satisfaction of participants	Report on Project Call Survey of satisfaction	Coordinator / End of reporting periods.	10 > 70%
	Ensure the implementation of a monitoring system	Score assigned by the SAB	SAB recommendation	Coordinator / End of reporting periods.	> 70%
	Promote education and training	Schools and workshops for young researchers	Periodic reports & synthesis of organised events	WP2 and task 2.1 leaders / End of reporting periods and end of partnership.	4 schools 4 WS
	Promote mobility	ENEN++ and follow-up grants for mobility involving nuclear material research	Periodic Report	WP2 leader / End of reporting periods.	20
	Promote access to the specific infrastructures necessary for nuclear material research activities	OFFERR and possible follow-up grants for projects involving nuclear material research Connection with FIDES.	Periodic Report	WP2 leader / End of reporting periods.	10
	Maximise Impact	Communication and dissemination actions Score assigned by the IEG	Periodic Report	WP3 leader. End of reporting periods.	10 > 70%

Table 2.1g *- Intervention logic.*

Expected Impacts	Specific Objectives	Activities	Outcomes	KPIs
1. Structured consolidation of the European research community on nuclear materials. 2. Contribute to maintaining the high level of safety of nuclear installations for current and future fleets, in full compliance with relevant European regulations. 3. Develop scientific knowledge and technological expertise applicable to the nuclear materials domain, including the coordinated use of infrastructures for materials qualification with sustainable quality assurance, and the production of reliable nuclear databases that meet FAIR principles. 4. Improved interaction of the nuclear materials research community with European nuclear regulatory bodies and their technical support organisations. 5. Improved exchange of knowledge across the respective research communities, including for example fusion and non-nuclear energy generating technologies. 6. Improved quality of education and training of nuclear materials specialists, achieved in a coordinated manner across the EU in collaboration with existing nuclear education networks.	SO1: To reduce drastically the time required to improve, develop, and even discover new or advanced nuclear materials and elaborate advanced manufacturing processes SO2: To accelerate the qualification of nuclear materials for safe operation SO3: To enable safer and more efficient management of the lifetime of nuclear components SO4: To improve the capability of prediction of the behaviour of nuclear materials in operation SO5: To create the conditions for nuclear materials data to be correctly collected and stored, so as to be fruitfully analysed and used	WP5 RL2 - Advanced materials development and manufacturing WP6 RL3 - Materials and component qualification: testing, standardization and design rules WP7 RL4 - Non-destructive examination and materials health monitoring WP8 RL5 - Advanced materials modelling and characterization WP4 RL1 - Nuclear materials knowledge & data management	Development of nuclear MAPs - Qualification of advanced manufacturing processes Development of test-beds and qualification paths, approved by regulators Development of intelligent materials health monitoring systems Advanced methodologies, blending physical and data-driven approaches Nuclear materials' FAIR knowledge organisation system	Numbers of outcomes for each item Research papers on the domain
	Operational Objectives			
	OO1: Efficiently run the administrative environment and the governance system OO2: Design and apply an open and transparent procedure for the prioritization of case-studies used for the development of the methodologies within each research line OO3: Ensure the implementation of a monitoring system	WP1 CDM - Coordination and Daily Management	Efficient functioning procedures Call for proposals Monitoring procedure	Level of satisfaction of participants (survey) Number of submitted proposals Level of satisfaction of participants (survey) Score assigned by the SAB
	OO4: Promote access to the specific infrastructures necessary for nuclear material research activities OO5: Promote high quality and targeted education and training	WP2 ETI - Education, Training, mobility and Access to Infrastructures	Schemes of education and training Schemes to access nuclear materials facilities	Number of schools and workshops for young researchers Number of ENEN++ and follow-up grants for mobility involving nuclear material research Number of OFFERR and possible follow-up grants for projects involving nuclear material research Connection with FIDES.
	OO6: Maximise impact	WP3 CDE - Communication, Dissemination and Result Exploitation	Actions to maximize impact	Communication and dissemination actions - Score assigned by the IEG

2.2 Measures to maximise impact - dissemination, exploitation and communication

The main function of communication and dissemination actions for impact maximisation consists in creating a channel to transfer the results of the research to their end-users. It is important to emphasise that CONNECT-NM strives to maximise this transfer first of all in the most effective way, i.e. by involving *directly* the end-users in the Partnership and in its Projects. Both private companies (large industries and start-ups or SMEs) and safety organisations (regulators and TSOs), which are no doubt the main end-users of the research done in CONNECT-NM and are the most affected by the paradigm shift that it pursues, are to a significant extent participants of the Partnership, some of them being involved also in the elaboration of strategic choices, i.e. from the beginning of the research process. This is made possible by the inherent features of the co-funded European partnership instrument, which enables the direct inclusion of a large number of participants, some immediately active and some temporarily 'dormant', through the mechanism of creating clusters of affiliated entities around mandated beneficiaries, something that cannot happen in the case of ordinary research and innovation actions, i.e. ordinary projects.

Having said that, it is obvious that not all possible end-users, and stakeholders in general, can be directly involved in the Partnership. Thus, it remains crucial to amplify the capability of transferring results and information from the Partnership to an even wider spectrum of end-users and stakeholders, especially with a view to identifying new paths for the exploitation of the research results. The strategy that is followed in CONNECT-NM for this purpose is based on the following cornerstones:

1. Build a clear visual identity for the Partnership and use a variety of communication materials and tools
2. Build a categorised map of stakeholders, classified similarly to the already identified links in section 1.1.4, namely:
   a. International organisations and European associations
   b. Bodies active in the field of standardisation, materials data format and data management
   c. Regulators and TSOs (separately from each other)
   d. Fusion and non-nuclear energy
   e. Infrastructure managers and initiatives to give access to, and coordinate use of, nuclear research facilities
3. Elaborate a targeted communication and dissemination plan that is aimed at establishing appropriate interaction channels with each of these categories, with a view to extending the network of stake-holders beyond the one described in section 1.1.4 and to establish appropriate protocols of interaction.

The last point implies that there will be no such a thing as a single 'stakeholder group', but rather several groups, each of them interacting in a specific way with CONNECT-NM, with a specific organisation and person in charge, that is selected to ensure the most effective interaction.

The communication and dissemination master plan (CDMP) will analyse, for each stakeholder category, the following: (i) how to effectively communicate the project to the stakeholders through various channels, including websites, newsletters and social media with targeted key messages according to their interests; (ii) which outreach events, such as dedicated workshops and conferences, are the most suitable and beneficial for the relevant audiences.

Of special importance is the creation and management of representatives of European regulatory bodies (Board of Regulators, BoR), as well as of TSOs (Board of TSOs, BoTSO) as advisory bodies for the Partnership, with SSM and GRS being respectively in charge for these tasks, i.e. the Swedish regulator and the German TSO, which are both beneficiaries in CONNECT-NM. Both groups will define consensual terms for their way of working and expectations. During the Partnership, these groups will be informed about the research activities, their relevant results and the extent to which the paradigm for materials development and qualification is expected to change. Both will provide periodic feedback and recommendation for the further unfolding of the activities of the Partnership, together with SAB and IEG. These recommendations will be taken into account when developing the annual work plans of the various research lines, as well as for the revision of the SRA of CONNECT-NM.

In addition, with the support of the work-package dedicated to dissemination and communication, and in the framework of the overall CDMP, each research line will identify its own specific group of stake-holders (among those discussed in section 1.1.4), determining the best way of interacting, which will range from periodic information, to hands-on involvement of stake-holders in the activities, passing through a full range of possibilities. This is considered to be the most useful and efficient way to interact between Partnership and stake-holders, enabling the discussions to be focused.

In parallel to this, more 'traditional' dissemination activities will be pursued, i.e. through established nuclear materials-related conferences, workshops, and symposia in large conferences. In this context, providing support to established initiatives is the most cost-effective way to have an impact and achieve wide visibility. Among others, CONNECT-NM

may therefore provide support to the following conferences and workshops, based of course on appropriate consensual selection:

- International Workshop on Structural Materials for Innovative Nuclear Systems (SMINS): this workshop is organised since 2007 every third year by the NEA, with the support of the IAEA and, since 2016, in collaboration with the EERA JPNM. There is therefore already a deep involvement of CONNECT-NM members in its organisation. The location moves from one continent to another. The next edition of this workshop is planned to take place in Madrid in 2025 and it represents a very suitable framework to give visibility to CONNECT-NM and present there the very first results achieved in it. CONNECT-NM will therefore sponsor this workshop, turning it into one of its dissemination actions.
- Conference on COmputer Simulation of IRradiation Effects in Solids (COSIRES): this conference is organised since the 1990s every second year, each time in a different location and shifting through continents. The editions of 2026 or 2028 might be organised with the sponsorship of CONNECT-NM in Europe, leveraging the COSIRES steering committee members that are involved in CONNECT-NM, thus giving high visibility to the Partnership.
- ASME Pressure Vessels & Piping Conference® PVP®: this industry-led yearly event features advanced research and technical content of interest for a range of mechanical engineering industries, including energy production, energy sources, advanced manufacturing, and engineering sciences. It is organised each time in a different location of US, Canada and Europe. One or more of the editions 2026, 2027, 2028 and 2029 might be organised with the sponsorship of CONNECT-NM in Europe, leveraging the European representatives in the relevant steering committee that are involved in CONNECT-NM and giving high visibility to the Partnership.
- Nuclear Materials (NuMat) Conference: this large conference was created in 2012 in association with the Journal of Nuclear Materials to serve as an umbrella for international meetings on topics ranging from fission reactors to fusion systems' materials, including the overall nuclear fuel cycle. It combines several topic tracks organised in parallel sessions, covering nuclear fuels (cladding and actual fuel), structural materials (steels and refractory alloys) and, recently, also cements and ceramics, polymers, and advanced manufacturing processes. Contacts will be taken with Elsevier to be involved in the organisation of the next edition to be held in Europe, probably towards the end of the Partnership's 5 years.
- NuFuel workshop series: The goal of these workshops is to gather the research community working on nuclear fuels and fuel elements for all reactor generations. The series was initiated in 2015 by the CEA and JRC-Karlsruhe under the auspices of the EERA-JPNM, to establish stronger and more-lasting collaborative links between European institutes, providing a forum where dialogue between experts is fostered and, especially, giving space to students and young scientists to present their work and discuss with experts in the field. The workshop serves as a unique occasion for the European community on nuclear fuel research to exchange and debate on the latest research results. CONNECT-NM will most certainly support, and participate in, the co-organisation of the next editions of these workshops.

Additional cornerstones of the CONNECT-NM strategy to maximise impact are:

4. The organisation of the kick-off event and plenary meetings during the partnership, as part of the dissemination activities, carried out in order to foster the interaction with stake-holders and a wider audience.
5. The development of a convivial website, equipped with several functionalities, which is meant to be CONNECT-NM's showroom and communication channel, and to help its coordination and daily management.

Such a website will be organised following the pattern of the EERA-JPNM website, including functionalities such as project mailing, project management and follow up tools, deliverable approval workflow, poll tool, event organisation tool, news section and members pin-board, in addition of course to repositories for documents. These will not only host project management documents, as well as deliverables and milestones, but will also comprise those dedicated to open access and open science practices. The website will also guarantee access to many results of previous projects, at least those under the umbrella of the EERA-JPNM.

6. Creation of an Innovation and Exploitation Group:

The IEG is comprised of external and internal (to the Partnership) individuals with expertise in leading business, supporting entrepreneurship and commercializing technology, preferably in connection with materials development and/or nuclear energy, and definitely with a highly strategic vision. Some potential members have been already identified in industries such as Ansaldo Nucleare, EDF, ENGIE, Newcleo, Tecnatom and Vattenfall; other members will be sought for in various startups and the EIC accelerator, while NEA may also express a member. The IEG shall act as an advisory body to CONNECT-NM concerning strategic orientations in order to boost innovation. In particular, it will be in charge to suggest on a yearly basis specific R&D activities to be included in the CONNECT-NM portfolio with high innovation potential and/or to help identify paths towards result exploitation. For this, the IEG will have access to all deliverables and/or periodic reports produced within CONNECT-NM, after its members signed a non-disclosure agreement. It is also charged with contributing in due time to the revision of the SRA, with a view to

steering the activities towards innovation. Finally, selected IEG members may also be involved in the ranking of project calls (based on external reviewers' scores and after appropriate declaration of no-conflict of interest) and mobility applications, by being included in the EvaCo (*section 1.2.3.2*).

7. Development of dissemination guidelines for funded projects:

As part of the overarching goal to enhance the dissemination support for the partnership-funded projects and to amplify the communication on the impact of the partnership itself, the project will create a set of guidelines and organize a series of informative webinars. The initiatives will serve as a valuable resource for the funded projects to help them navigate the various aspects of dissemination effectively and provide a platform for the exchange of best practices. Through these initiatives, the aim is to facilitate a more structured and strategic approach to dissemination activities, ultimately increasing the visibility and impact of the partnership endeavours. Moreover, a procedure to monitor scientific output will be put in place and overseen by the Open Science Officer (*section 1.2.5*): Open Science Guidelines (OSG) will be prepared by the officer, to encourage the implementation of open science practices at the level of CONNECT NM and the partnership-funded projects.

Intellectual property management

The ownership of results and access to key knowledge will be regulated by the consortium agreement (CA), which will be signed by all legally required parties, as in the Grant Agreement (GA), after agreeing on its content. To facilitate consensus, a draft CA based on the DESCA model was prepared and circulated in **ORIENT-NM**. According to this draft CA, results are owned by the party/parties that generate(s) them. Joint ownership is governed by the GA. In addition: (1) each of the joint owners shall be entitled to use their jointly owned results for non-commercial research and teaching activities on a royalty-free basis, and without requiring the prior consent of the other joint owner(s), and (2) each of the joint owners shall be entitled to otherwise exploit the jointly owned results and to grant non-exclusive licenses to third parties (without any right to sub-license), provided that the other joint owner(s) are given either timely notice or fair and reasonable compensation. The joint owners shall agree on all protection measures and the division of related cost in advance. Each Party may transfer ownership of its own results, including its share in jointly owned results, as regulated in the GA. Each Party may identify specific third parties it intends to transfer the ownership of its results to, and the other Parties waive their right to prior notice, and their right to object. The transferring Party shall, however, inform the other Parties of such a transfer, and shall ensure that the rights of the other Parties will not be affected by such transfer.

All Parties are committed to dissemination of their research findings, ensuring fair distribution of opportunities to publish, the visibility of the collaborative effort and the inclusion of young researchers in publication and dissemination activities. The copyright of each Party remains with the author/the Party. Authors shall always have the right to be acknowledged for their authorship. The dissemination of own results by one or several Parties, including but not restricted to publications and presentations, shall be governed by the GA. In particular, no Party shall include in any dissemination activity another Party's unpublished results or background without obtaining the owning Party's prior written approval. In addition, all Parties undertake to cooperate to allow timely submission, examination, publication and defence of any dissertation or thesis for a degree that includes their results or background subject to the confidentiality and publication provisions agreed in the CA.

It is foreseen that all participants in a Partnership's Project will have to sign the Partnership's CA, if they have not done so before they join the Project, through their Beneficiary. There will be no request, nor obligation, to sign a specific and separate CA that applies to each Partnership's Project consortium. However, if a Project consortium considers that the Partnership's CA is not sufficiently detailed and precise for their specific needs, they will be allowed to sign a separate CA, or add an Annex to the general one. This separate CA, however, shall not contradict anywhere the Partnership's CA and, in case of discrepancy, the Partnership's CA shall prevail.

2.3 Summary

The canvas below provides the key elements of the Partnership's impact pathway and of the measures to maximise its impact.

KEY ELEMENT OF THE IMPACT SECTION

SPECIFIC NEEDS	EXPECTED RESULTS	D & E & C MEASURES
What are the specific needs that triggered this project? Accelerate the process of development and qualification of advanced or new nuclear materials with better resistance to the harsh environment of nuclear reactors (and not only), to strengthen safety, efficiency, economy and sustainability at large of nuclear energy, also moving to next generation reactors (including SMRs), thereby contributing to the energy transition with reduction of greenhouse gases emissions.	What do you expect to generate by the end of the project? **Consolidated nuclear materials research community** **Nuclear materials acceleration platforms** **Nuclear materials test-beds for accelerated qualification** **Intelligent materials health monitoring systems** **Advanced predictive methodologies** **Nuclear materials knowledge organization system** **Trained young researchers with expertise in new materials science practices**	What dissemination, exploitation and communication measures will you apply to the results? **Exploitation through direct involvement of end-users in the Partnership** and its research work and strategy **Targeted dissemination towards the various groups of stakeholders**, via mapping and identification of appropriate channels of communication, including creation of various stakeholder groups according to needs (e.g. Board of Regulators), together with **more 'traditional' dissemination** channels (conferences and workshops). **Targeted communication towards stakeholders and external world** **Innovation and Exploitation Group:** with industry and entrepreneurship and commercialization profile, dedicated to advising the Partnership on pathways to innovation and result exploitation.

TARGET GROUPS

Who will use or further up-take the results of the project? Who will benefit from the results of the project?

European industry (large ones, start-ups & SMEs), e.g.: Ansaldo Nucleare, EDF, ENGIE, Enusa, Framatome, Newcleo, Orano, Tecnatom, Vattenfall …

Regulators and TSOs, e.g.: SMM and EK-CER, ENEA, GRS, IRSN, JSI, PSI, RATEN, VTT …

Standardisation and data managing bodies, e.g.: AFCEN, CORDEL, ECCC, EMMC, EMCC, EPERC …

Fusion and non-nuclear energy (materials operating in harsh environment), e.g.: EUROfusion, EERA members, AMI2030 members …

International Organisations and European Associations, e.g.: GIF, IAEA, OECD/NEA, NuclearEurope, …

Nuclear materials scientific community at large

OUTCOMES

What change do you expect to see after successful dissemination and exploitation of project results to the target group(s)?

Accelerated development of advanced or new materials for nuclear: thanks to the widespread use of nuclear MAPs.

Accelerated qualification of nuclear materials using standardized procedures in interaction with regulators/TSOs: thanks to the creation of integrated nuclear test-beds.

Online monitoring of nuclear materials/components in operation and use of major components' **digital twins** for component lifetime management**; direct reparation/replacement of degraded pieces** using advanced manufacturing methods.

Predictive capability based on physical models extended to industrial use, in support of all the above practices.

FAIR management of extended nuclear materials data, through the use of a knowledge organization system

IMPACTS

What are the expected wider scientific, economic and societal effects of the project contributing to the expected impacts outlined in the respective destination in the work programme?

Safety: Higher safety standards thanks to rapidly marketed materials that better resist harsh conditions, timely identification of potential failures and immediate repair or replacement of components, safer design based on better knowledge of materials behaviour, from physics and data.

Sustainability: better use of available resources thanks to better managed materials and component lifetime, materials enabling higher energy efficiency, reduced use of materials (especially critical raw materials).

Economic: Reduced costs of development and qualification of advanced and new materials (time reduction down to 25% with respect to now), reduced replacement/repair costs, more energy produced from the same resources (nuclear fuel).

Societal: Safe and abundant low carbon energy thanks to more sustainable nuclear technology.

3 QUALITY AND EFFICIENCY OF THE IMPLEMENTATION

3.1 Work plan and resources

3.1.1 Breakdown of CONNECT-NM activities in WP

The work of CONNECT-NM is organised in work-packages (WP), all of them extended to the whole duration of the Partnership (5 years)[12]. The detailed description of the activities year by year will be the subject of the annual work plans (AWP), produced every year as deliverables. Here only the broad lines, valid until the end of the Partnership, are given. More details for the first year are given in the corresponding first AWP at the end of this Annex.

Two types of work-packages are distinguished:

- Transversal work-packages (t-WP): these WPs include all the activities of relevance towards the operational objectives of the Partnership. They are thus dedicated to all the non-R&D&I activities of the partnership, namely: coordination and daily management (CDM - WP1); education, training, mobility and access to infrastructures (ETI – WP2); communicaion, dissemination and result exploitation (CDE – WP3). **Table 3.1** shows the connection between t-WPs and OOs. The t-WPs therefore deal with all those activities that support R&D&I, denoted as 'transversal activities'.
- Research lines (RL): these WPs are dedicated specifically to each one of the research lines identified in section 1, Excellence, as associated to each one of the five specific objectives of the Partnership. Therefore, all R&D&I activities find their space in the RLs.

Table 3.1 *– Correspondence between transversal work-packages and operational objectives.*

Transversal work-package	Operational objectives
WP1 – CDM – Cooordination and Daily Management	OO1: Efficiently run the administrative environment and the governance system OO2: Design and apply an open and transparent procedure for the prioritization of case-studies used for the development of the methodologies within each research line[13]. OO3: Ensure the implementation of a monitoring system
WP2 – ETI – Education, Training, mobility and Access to Infrastructures	OO4: Promote access to the specific infrastructures necessary for nuclear material research activities OO5: Promote high quality and targeted education and training
WP3 – CDE – Communication, Dissemination and result Exploitation	OO6: Maximise impact

The t-WP are called *transversal* because their activities equally cross all RLs. This is graphically shown in **Figure 4**. The RLs will in turn contain the Partnership's Projects selected through calls, as well as the pre-selected projects (PSPs). The creation of specific WPs for each RL, thus for each specific objective, is considered instrumental to ensure the goal-oriented nature of the Partnership.

RL do have aspects in common and, importantly, they are complementary to each other. Specifically, RL 2, 3 and 4 represent successive steps in the materials adoption and use: development, fabrication, qualification and monitoring in operation, while modelling and characterization are in support of each step and knowledge and data management feeds all RL: this is illustrated in **Figure 5**. Therefore, projects may include features that make them cross-cutting between different RLs; for instance, the use of machine-learning is expected to be ubiquitous.

[12] Pending the option of extension, depending on the possibility of top up funding from the expected 2026-2027 Euratom Research and Training Programme in Horizon Europe, and the possible resulting second call project duration, *section 1.1.5*.

[13] This corresponds to preparing and launching project calls, managing a transparent evaluation and ranking procedure, and finally administratively enabling the start of the selected projects, as described in *section 1.2.3*.2.

However, when proposed, projects need to explicitly define and clearly state which of the five specific objectives they target, irrespective of links with other RLs (*see below, in the description of the research line leader's tasks, how cross-cutting aspects are managed*). In this way, each project is unambiguously assigned to one, and only one, RL. In the case of t-WP, a different viewpoint has been taken and each of them may deal with more than one operational objective, whenever these are intimately related or make use of similar tools and approaches. This enables the total number of WPs to remain reasonable, which is important for the efficiency of the governance, by limiting the size of the Executive Board (*see section 3.2*).

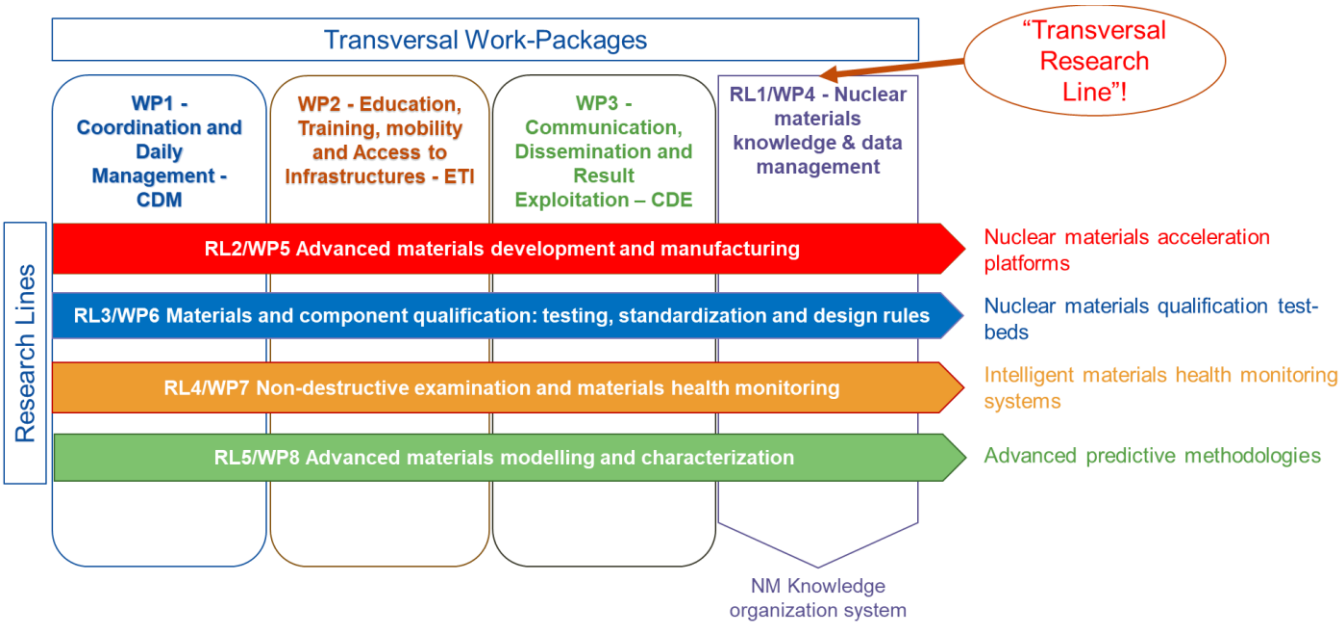

Figure 4 *– CONNECT-NM work-package breakdown.*

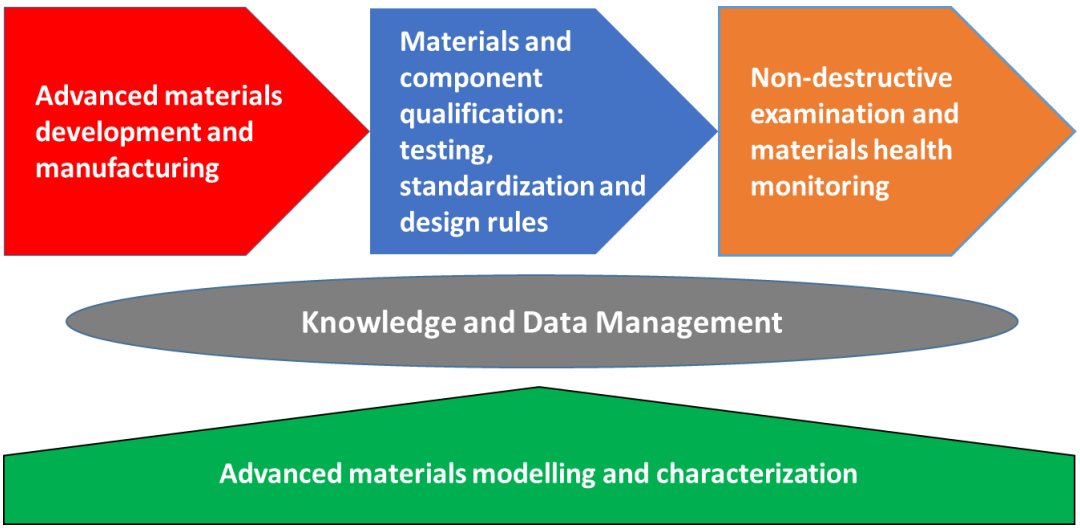

Figure 5 *– Logical connection between research lines.*

Each Project, either pre-selected, or selected through a call, will be formally a task of the corresponding RL. A task agreement will therefore be signed between the Coordinator and the Project Leader of each project, with a similar function as the Grant Agreement that is signed between the Commission and the Coordinator of a funded project, as described in *section 1.2.3.2*. All this is graphically shown in **Figure 6**. Projects will have internal deliverables and milestones (particularly

high level milestones dictated by the overall RL). These will remain as internal documents of the Partnership. The only formal deliverable associated with the results of the Projects and provided to the Commission is the annual Research Line Progress Report, which will contain the reports of each of the Projects.

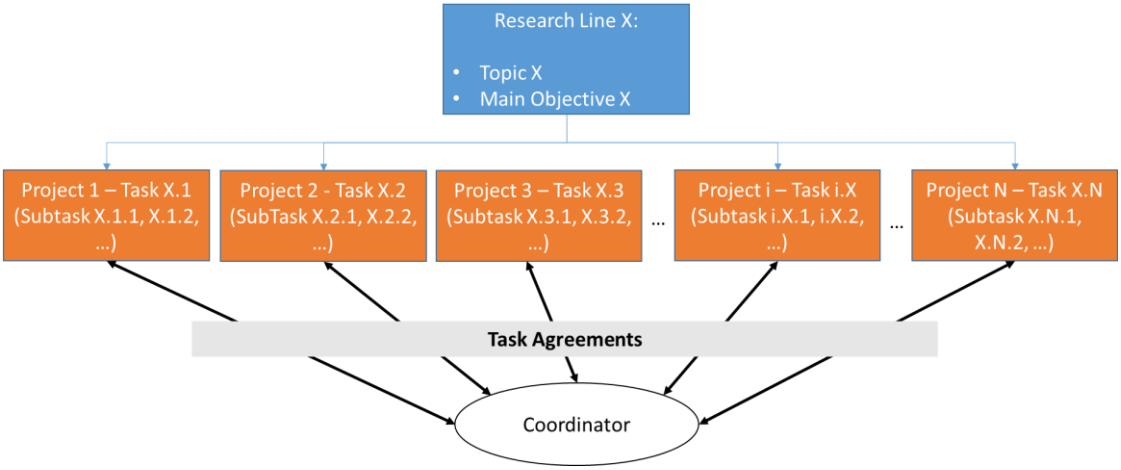

Figure 6 *– Research lines are the containers of goal-oriented projects (formally tasks of the corresponding WP).*

There is, however, one special case, which is the RL dedicated to nuclear materials knowledge and data management. This WP is simultaneously a t-WP, as it provides services of data management for all RLs, and a RL in full right, since R&D&I activities will be included there to enable the development of all the technologies that are required to build a specific knowledge organisation system for nuclear materials, particularly ontologies. This is clearly indicated in **Figure 4**.

3.1.2 Common features of research lines

Here the specific and common features of the RLs are described once and for all. This pattern repeats itself in all the corresponding WPs, the difference in the activities being made by the specific focus and the Projects that are included in each of them.

The Research Line Leaders (RLLs) will be the drivers towards the objective of their respective research line: they will be defining the strategy of the RL, managing the activities performed in it, and will be responsible to create the best environment possible to ensure that the RL goals are reached. Their tasks will include, but not be limited to:

- The identification of the major steps towards the objectives of the RL (high level milestones), also applying the advice of the SAB and the IEG, whenever relevant, including risk monitoring and management;
- The preparation of the project call text for the specific RL, specifying scope and expectations that the proposed projects should comply with, thereby setting part of the criteria for their evaluation;
- The monitoring of the progress of Projects within the RL, including the approval of internal Project deliverables according to the workflow in the PMT and the control of the application of the publication rules and open science practices, with the assistance of the Open Science Officer, for all RL Projects, thus acting as supervisor of the Project Leaders;
- The preparation of a consolidated annual RL progress report, with descriptions of the work performed until that moment, considerations about how steadily Projects are approaching the RL objective, forward planning, and proposal of research path corrections if relevant, thus contributing to the definition of the following AWP;

- The communication with and between Project Leaders, to optimise the flow of information, via organisation of suitable meetings within the same RL, while fostering communication between Projects belonging to different RLs, as a way to identify cross-cutting aspects of Projects.

- The communication with other RLs, within the Executive Board (*section 3.2.2*), in order to propose and promote measures to enhance internal collaboration on cross-cutting aspects, e.g. by partially reorienting some Project activities, whenever convergence is possible and Projects may benefit from it.

- The identification of E&T and mobility needs within the RL, to be addressed within WP2.

- The creation and maintenance of interactions with relevant external stakeholders (*overall list and discussion in section 1.1.4*), e.g. via dedicated workshops, webinars or meetings, in alignment with WP3, actively seeking for, and taking advantage of, opportunities of cooperation, to be further promoted in WP1.

Each RLL will be supported in these tasks by a few Research Line Advisors (RLAs), with less dedication than the RLL, thereby forming a RL coordination team (RLCT). Project Leaders will also progressively join this RLCT. Criteria to select the RLAs were: ensure in each RL expertise on all four selected classes of materials; inclusion in each RL of the industrial point of view; overall geographical and gender balance.

Accordingly, each RL (number X) will include the following set of tasks, and relevant deliverables, in addition to the relevant Projects:

Task X.1 – Preparation of project call(s) for the research line: definition of high level milestones, scope and expectations, possibly suggesting KPIs – Connected deliverable: RL-related part of the call for project proposals. This deliverable will only be produced in correspondence with the preparation of the call, in the first year of the Partnership; perhaps for a second call, too.

Task X.2 – Guidance and follow up of the projects within the RL: approval and collection in common workplace of internal deliverables; follow up of scientific output under the guidance of the Open Science Officer; organisation of project and inter-project meetings; promotion of cross-cutting activities, as needed; risk monitoring and management; participation in the AWP preparation – Connected deliverable: annual Research Line X Progress Report (RLXPR), using provided template. This Report will include the work until the M6 of each Partnership year, and will be produced shortly after, to enable the timely preparation of the AWP for the following year, based also on the evaluation of the SAB and the IEG.

Task X.3 – Interaction with internal and external stakeholders of specific relevance for the RL. This task will deal with ensuring that the RL has fruitful interactions both internally to the Partnership, e.g. with the SAB and IEG, or with any ongoing activities, internal and especially external to the Partnership, of relevance for the research line. The work done in this task will be reported in the annual RLXPR.

A complete overview of the planned tasks for the duration of the partnership can be found on the following pages (Gantt chart).

3.2 Capacity of participants and consortium as a whole

3.2.1 Description of the consortium

Consistently with the rules of the co-funded European Partnerships, the consortium is composed of three types of participants:

- Beneficiaries (BEN): EU (MS/AC) national organisation mandated by the corresponding ministry or agency (*programme owner*) to manage the participation of the MS/AC in the Partnership

(*programme manager*). Associations are also included in this category. Beneficiaries sign the Grant Agreement and are represented in the General Assembly (*section 3.2.2*).

- Affiliated Entities (AEs): EU (MS/AC) national organisations that have an established link with a Beneficiary. AEs do not sign the Grant Agreement and have no representative in the General Assembly, where they are represented by the corresponding Beneficiary, but are otherwise treated in exactly the same way as Beneficiaries.
- Associated Partners (APs): Non-EU national organisations (e.g. from CH, TR, UK) that participate entirely at their own cost (thus they have zero allocated budget), but have access to Project results according to the IPR that are detailed in the Partnership's Consortium Agreement, which they also sign.

The consortium comprises as many Beneficiaries as Affiliated Entities (19 in both cases), and three Associated Partners. Another possible category of participants are Third Parties:

- Third Parties: EU (MS/AC) national organisation that do not qualify as AEs. TPs can receive a maximum of 300 k€ from the corresponding Beneficiary and need to provide the remaining part of the funding in-cash or, under some circumstances, in-kind.

However, at the moment no third party is included in the consortium, although this situation will likely change when Projects are selected through calls.

If we consider the list of mandated organisations, we see that the large majority of them are national research centres; however, a university (STUBA), a TSO (GRS), and a regulator (SSM) are also in this category. Moreover, many mandated research centres are, in fact, also TSOs (EK-CER, ENEA, JSI, RATEN and VTT). This provides, already at the level of mandated organisations, satisfactory representativeness of most categories of potential Partnership's contributors and stakeholders. Representativeness is then enormously increased through the direct involvement of three European associations (international non-profit associations according to Belgian law) as Beneficiaries, namely EERA, ENEN and SNETP, following in this the seminal example of PIANOFORTE. Through the network of their members, associations play a big role to boost inclusiveness and enhance the possibilities of dissemination, communication and result exploitation, ENEN being in addition the best choice possible to support E&T activities and mobility. Finally, JRC is also participating, in the capacity that is permitted by the European Commission rules. The involvement of JRC is important not only because of the valuable contribution that it can provide to R&D&I activities, but also through the links it may enable the Partnership to establish at international level.

The mechanism of affiliation of entities, made it possible to include an even wider spectrum of participants, thereby further increasing representativeness and therefore amplifying the possibilities of access to national knowledge, skills, tools and facilities, which is crucial for the success of the Partnership. Namely, in addition to another TSO (IRSN), and various universities (Chalmers, KTH, Lille Centrale, Polimi, Unibo, University of Helsinki, UPM …), established nuclear industries (EDF, Framatome), startups that evolved to major industrial actors (Newcleo) and SMEs (Energorisk, Metaproject, Sintec) are directly and effectively contributing to the transversal (t-WPs) and strategic (RLs) tasks, as well, in addition to their expected contribution to R&D&I work through the Partnership's Projects. Crucially, also a non-nuclear research centre (BAM) has been included in the consortium, to reinforce its links with the renewables world. A strong inclusive criterion has been used to form the research line coordination teams, based on the principle that each Beneficiary should be involved in at least one RLCT (either directly or sometimes through an AE) or, when this was not possible, they should have at least one task in t-WPs. Moreover, each RLCT has been recommended to include at least one industrial representative. This inclusion is extremely important for the objectives of CONNECT-NM, in particular the change of paradigm that it puts forward, because the consortium comprises at the same time the research providers (research centres, academia) and the end-users (industries, TSOs, regulators), the latter being in fact in most cases directly active in the research work itself, as well as in the definition of the research strategy.

Even though not yet explicitly included, we also know already of 40 additional affiliated entities that are ready and willing to contribute to R&D&I work, by participating in Projects. These comprise many universities, but also industries, in addition to research centres. Importantly, through membership to associations, especially EERA and SNETP, the network of potential affiliated entities can be said to cover essentially the whole spectrum of possible contributors Europe-wide. The organisation of widely advertised brokerage events during Project proposal preparation will be the mechanism to

ensure full and complete openness, while the possibility offered by the CEP instrument of involving third parties enables also contributors that are currently not connected with the Partnership through any beneficiary to become part of Project consortia.

Finally, a Swiss (PSI) and a Turkish (METU) organisation, as well as two UK organisations (NNL and UKAEA), thus from countries that do not have association agreements with Euratom, have willingly joined as APs.

In geographical terms, 18 countries from all sides of Europe (north, south, east, west, and centre) are represented, and more are eventually expected to become involved, not only as affiliated entities and third parties, but perhaps also as beneficiaries. Of these 18 countries, 14 mandated an organisation (or two) as beneficiary (13 EU member states, plus Ukraine as associated country), one (Czech Republic) participates via an AE, while 3 are represented through APs. Importantly, also two MS that currently do not have nuclear power plants (Italy and Poland) and one that has completed phase out (Germany) are involved, thereby demonstrating that the interest in the materials science practices and approaches pursued in CONNECT-NM goes beyond strictly nuclear applications. The geographical coverage of CONNECT-NM is visually illustrated in **Figure 7**.

The richness of the consortium in terms of types of contributors (from research centres and academia to regulators and TSOs, as well as private companies), combined with its broad geographical coverage, sets excellent bases for the achievement of the Partnership's objectives, thanks to the mentioned fact that a wide range of knowledge, skills, tools, and, especially, facilities and infrastructures is inherently included. At a more strategic level, the dialectics between different types of direct contributors is expected to help enormously in terms of integration and convergence, taking into account all points of view, from safety (TSOs, regulators) to the need of higher efficiency and better economy (industries, startups). Connection with national activities and programmes, on the other hand, is guaranteed thanks to the intrinsic nature of a Co-funded European Partnership, which is effectively a consortium of MS/AC and receives funds from both Commission and MS/AC. This is also demonstrated by the alignment with not only past and present Euratom projects and activities pursued in international organisations, such as IAEA and NEA, and international/European initiatives (*section 1.1.4*), but also with on-going national initiatives that have been mentioned in the RL descriptions (*section 1.2*, methodology; *all sections nr. 1.2.2.X.5*). The richness of the consortium in terms of representativeness is also of crucial help for the success of the measures of maximisation of impact, as is exemplified by the engagement of SSM to create a network of regulators as advisory body of the Partnership, and of GRS to create an equivalent group of TSOs. Finally, the inclusion of end-users from the beginning and at the core of the Partnership (industries, regulators and TSOs) is crucial to ensure that eventually the Partnerships' results will have social impact, in terms of access to safe and abundant low carbon energy. Specifically concerning access to major infrastructures, including for neutron irradiation, the consortium is well-placed because, in addition to the facilities that it can count on that are managed directly by Partnership's participants, it has established links with initiatives such as **FIDES-II/III** and **OFFERR**, which are international frameworks explicitly dedicated to the coordination of the use of nuclear facilities.

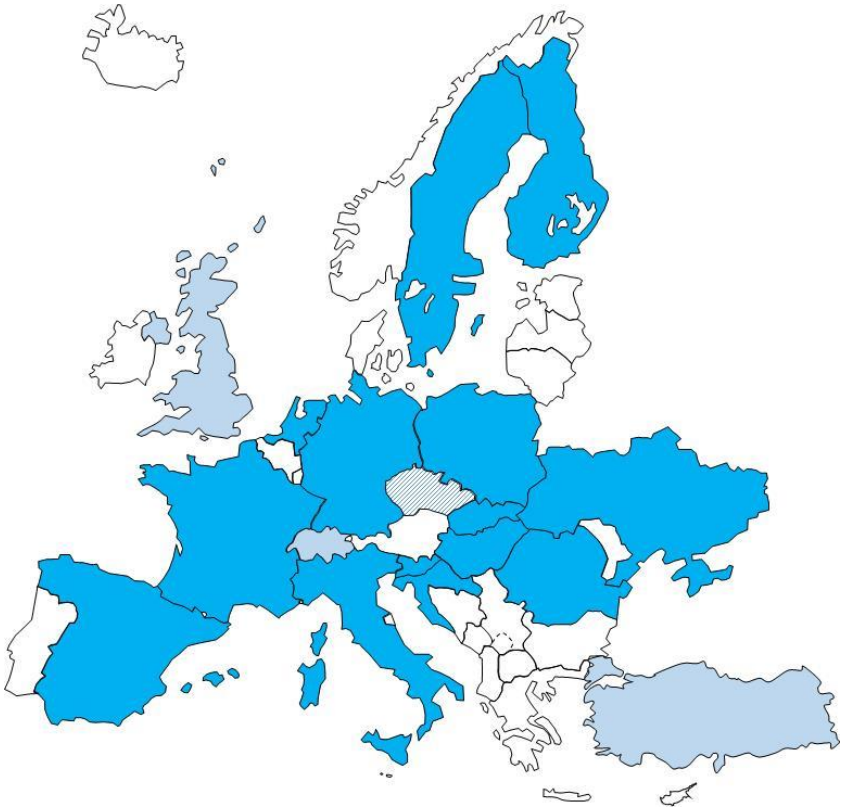

***Figure 7** – Geographical coverage of CONNECT-NM. Lighter blue denotes countries that participate through organisations, but have no association agreement with Euratom. Diagonal lines denote countries represented through AEs.*

3.2.2 Description of the governance

The governance structure of CONNECT-NM is schematically described in **Figure 8**. In general terms it is a commonly used structure, which largely reflects the provisions made in the DESCA model for the Consortium Agreement:

- The decisional body is the General Assembly (GA), in which all Beneficiaries are represented with one member. The GA will elect a chair and a vice-chair with the task of establishing the calendar of meetings and the agendas.
- The body in charge for executing the decisions of the GA (but also to propose procedures and solutions to the GA) is the Executive Board (ExB), which is composed of all WPL, both transversal WPs and RL, including the Coordinator.
- The Management Support Office (MSO) acts as transversal body, providing assistance for the daily functioning of the Partnership. It shall operate under the guidance of the ExB and shall be responsible to the Coordinator for the day-to-day management of CONNECT-NM.
- Two main bodies act as advisors, namely, the Scientific Advisory Board (SAB) and the Innovation and Exploitation Group (IEG), characterised by different features and objectives (*sections 1.2.2.3 and 2.2*).

The use of two advisory groups is a specificity of this Partnership and the creation of the IEG stems from the strong industrial involvement and interest in the Partnership's activities. However, as explained in section 2.2, the Partnership intends to be communicating in appropriate ways with all the various categories of stakeholders, thus other, more or less formal advisory groups will be created and involved. Especially important in this sense are the Boards of Regulators and TSOs.

Each WP leader within the ExB, with the assistance of advisors and collaborators, shall manage the key tasks within the corresponding work-package, ensuring adherence to protocols and procedures and the overall implementation of the WP, tracking progress and providing revisions. The WP leader

is also responsible for organizing internal meetings, where the advisors contribute their expertise, encouraging conversation and teamwork to solve problems. As a body formed by all WPL and the Coordinator, therefore, the ExB is the main body responsible for the correct functioning of the Partnership.

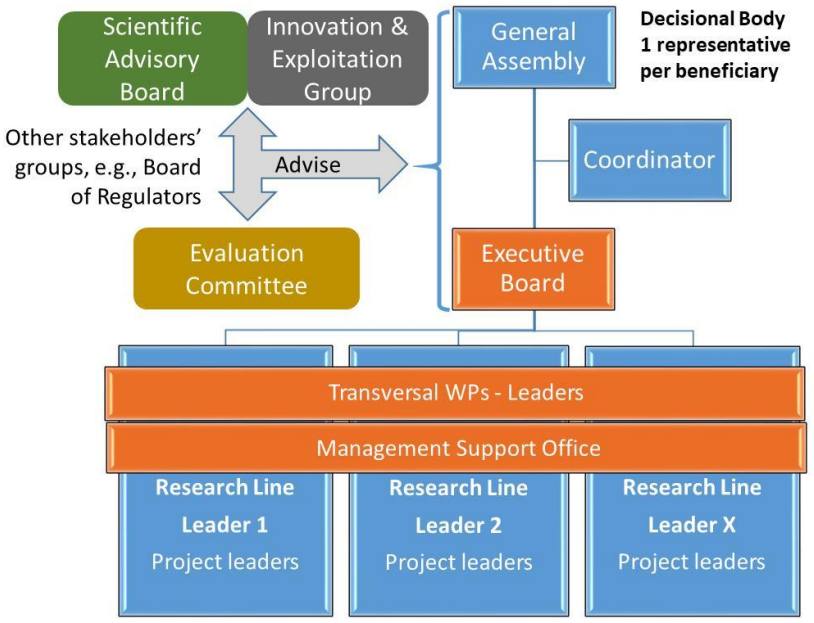

Figure 8 *– Schematic description of the governance structure of CONNECT-NM.*

In order to make sure EU public interest is pursued and defended, CONNECT-NM will be constantly communicating with the Commission, specifically the Euratom Unit of the DG R&I, mainly via the Scientific Officer of the Partnership, and, if required, consulting also members of the Commission at higher level. The officer shall be regularly invited to all plenary and GA meetings. Other representatives of the Commission from other units and/or directorates might be also invited, if relevant. CONNECT-NM may also consider the possibility of inviting the EURATOM Scientific and Technical Committee (STC) to send an observer to the GA. Observers from international organisations may also be invited to join the GA meetings, if relevant. Finally, the link with the Commission strategies will also be ensured by the direct participation of the JRC in the activities.

3.2.3 Partnership's openness and proactive inclusiveness

The already wide spectrum of contributors that have been identified so far, with broad geographical coverage, is open to further expansion. CONNECT-NM is designed so that openness is a key aspect and a quality contributor; therefore, no artificial barriers shall prevent any entity from participating in the initiative. All companies, organizations, associations, institutes and universities, regardless of their size and origin, will be welcome to bring value to CONNECT-NM, finding the appropriate legal status to enable that their contribution is integrated. Additional beneficiaries, affiliated entities, associated partners and of course third parties that express interest to join will be added to the Partnership's consortium, as part of its normal functioning dynamics, which is inherent to the used funding instrument. A pro-active policy to involve new members is embodied by the organisation of widely advertised brokerage events, which ensure that any eligible organisation can join Project consortia within the Partnership, if they can valuably contribute. To this regard, pivotal is the inclusion of platforms, such as EERA, ENEN and SNETP, which inherently guarantee and enable strong and well-oiled connection with hundreds of organisations of different type, from all over Europe, including from member states that did not join the Partnership through beneficiaries, while offering an even wider network for effective and transparent communication. This open design is based on the transparent leadership of the initiative. Transparency ensures credibility and is seen as an important factor for efficient processes in all stages of the implementation of CONNECT-NM, facilitating the on-boarding of new partners and interested parties during the process of application for funding. All

achievements and results which are linked to CONNECT-NM will be publicly accessible and will be widely disseminated, as a means to encourage further interest and promote recruitment.

3.3. Annual workplans

AWPs will be prepared ahead of the end of each Partnership's year. These documents shall describe in detail the tasks to be performed in a 12 month-period, following the definition of work and goals of each RL and transversal WP, in alignment with the reference strategic research agenda. The first AWP is part of the present proposal, following the template provided by the Commission. In the present case, it is simply a more focused description of what the proposal foresees for the first year. The subsequent AWPs will need to be produced taking into account the outcome of the previous one and shall be the result of a consultation that shall involve all the governing and advisory bodies, and stakeholders at large. This regular consultation procedure during the life of the Partnership gives the possibility of revising and updating the work planned in it every year, providing the required flexibility to react on latest developments, changing situations and new requirements or priorities. Specifically, the content of the AWPs, the activities defined in the RLs and WPs and the corresponding funding scheme, including the budget for the R&D calls whenever relevant, will be elaborated by the ExB after receiving the recommendations of the SAB and the IEG. In order for these bodies to be able to express their opinion on the work that is being performed, the reports from WPs and RL (including Projects) will be produced half way through the AWP. They will be substantial and shall include the work performed in the last 12 or even 18 months (except in the case of the 1st year, when it will cover only 6 months), but the AWP will be out of phase by 6 months with respect to the reports, implying that the annual reports will have to include an outlook section. This way of proceeding has two advantages: SAB and IEG and other stakeholders groups will be able to provide timely recommendations in preparation of the next AWP, and reports will be used for the end of the reporting periods, which are going to be out of phase with respect to AWP.

In the AWP the objectives and the activities to be performed by the partners of the consortium for the year to come shall be defined according to the strategy and content of CONNECT-NM. The decision for the focus of the activities, as well as the respective funding via the project, will be presented in an open, fair and transparent way. Most of the AWP will in fact be simply a more detailed plan for each of the selected on-going projects, as well as for the activities of the WPs. However, in some cases and depending on the still available budget, the consortium may decide to launch targeted activities, e.g. of the type equivalent to a coordination and support action, in order to elaborate specific plans and strategies, e.g. in connection with the design of an irradiation campaign, or with the revision of materials ID cards or of the SRA. Else, shifts of budget or revisions of activities in projects might be considered, if circumstances require to do so. The AWP will follow the standard template and shall describe the activities for each RL and each transversal WP for the next 12 month-period, with the same breakdown as in the project proposal i.e.: objectives, tasks, subtasks, deliverables and milestones. An overview per beneficiary and respective affiliated entities will be listed. Information about in-kind contribution and possible financial support for third parties shall be declared, as well as if tasks are foreseen for subcontracting (the need for this should be explained). In a summarizing chapter, in addition, the important facts will be presented in a table format. The same shall be done with the staff effort per partner. Major cost items (travel, equipment, infrastructure, goods and services) will be listed per partner and a justification given. After the approval of the AWP by the GA, the coordinator shall submit the AWP to the EC and discuss it. The feedback from the EC shall be communicated to the ExB and the GA, which will decide how to take it into account