EUROPEAN RESEARCH EXECUTIVE AGENCY (REA)

REA.A – Marie Skłodowska-Curie Actions & Support to Experts
A.1 – MSCA Doctoral Networks

GRANT AGREEMENT

Project 101119929 — DETOCS

PREAMBLE

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

on the one part,

the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and

on the other part,

1. 'the coordinator':

FLSMIDTH AS (FLS), PIC 893855680, established in VIGERSLEV ALLE 77, VALBY 2500, Denmark,

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

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

3. **RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN (RWTH)**, PIC 999983962, established in TEMPLERGRABEN 55, AACHEN 52062, Germany,

4. **TECHNISCHE UNIVERSITEIT DELFT (TUD)**, PIC 999977366, established in STEVINWEG 1, DELFT 2628 CN, Netherlands,

5. **UNIVERSITA DEGLI STUDI DI PADOVA (UNIPD)**, PIC 999995602, established in VIA 8 FEBBRAIO 2, PADOVA 35122, Italy,

6. **INSTITUTE FOR HOUSING AND URBAN DEVELOPMENT STUDIES BV (IHS)**, PIC 988824015, established in BURGEMEESTER OUDLAAN 50, ROTTERDAM 3062 PA, Netherlands,

7. **STATWOLF LIMITED (STW)**, PIC 935994420, established in 51/52 FITZWILLIAM SQUARE WEST, DUBLIN D02 X504, Ireland,

8. **C2CA TECHNOLOGY BV (C2CA)**, PIC 908356404, established in WESTKANAALDIJK 2, UTRECHT 3542 DA, Netherlands,

9. **MANNOK HOLDINGS DESIGNATED ACTIVITY COMPANY (MNK)**, PIC 884343278, established in 2ND FLOOR 1-2 VICTORIA BUILDINGS HADDINGTON ROAD, DUBLIN D04 XN32, Ireland,

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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DATA SHEET

1. General data

Project summary:

Project summary
Cement production is responsible for 8% of global CO2 emissions, mainly from limestone processing to produce clinker. Clinker can be replaced by other raw materials, such as clay, ashes, slags or recycled concrete fines. These materials can be processed into Supplementary Cementitious Materials (SCM), which have a lower CO2 footprint than Portland Cement. DETOCS proposes a new approach to rapidly increase the use of SCMs on existing production facilities: by exploiting the latest innovations in digital tools to predict and control the quality of cement and concrete blends with high amounts of SCMs compared to today's standards. Our network aims to lay the scientific foundations to create knowledge and new models to study the production of high quality SCMs and their impact on low-carbon cement and concrete mixes. The goal is to reduce clinker factor from ca. 70% today to 40% by 2030 and 25% by 2035, targeting a CO2 emissions of 0.2 t.CO2/t.cement (compared to today's global average of 0.65 t.CO2/t.cement). At DETOCS, the partners combine top-notch scientific expertise, interdisciplinary know-how, engineering solutions and real-world process data into an industry-driven network. The structured approach combines complementary research for each individual project in the academic and industry sectors. The top-level research work is accompanied by a balanced mix of the newest scientific courses and transferable skills training delivered by each partner locally and in dedicated training schools, seminars, and workshops at the network level. This way, each doctoral candidate builds up deep scientific expertise and interdisciplinary knowledge to deliver game-changing cleantech innovations during and after the project. DETOCS is impact-driven and strives for a portfolio of high-class joint publications, patents, and innovations along the value chain. The project will lay the foundations for first-of-its-kind engineering solutions to decarbonize cement and concrete products.

Keywords:

- Civil engineering
- Civil engineering, maritime/hydraulic engineering, geotechnics, waste treatment
- Environmental engineering and geotechnics
- Materials engineering
- Production technology, process engineering
- Cement, Concrete, Carbon dioxide, Supplementary Cementitious Materials, Digital solutions, Innovation

Project number: 101119929

Project name: Data to Enable Transformation and Optimisation for Concrete Sustainability

Project acronym: DETOCS

Call: HORIZON-MSCA-2022-DN-01

Topic: HORIZON-MSCA-2022-DN-01-01

Type of action: HORIZON TMA MSCA Doctoral Networks - Industrial Doctorates

Granting authority: European Research Executive Agency

Grant managed through EU Funding & Tenders Portal: Yes (eGrants)

Project starting date: fixed date: 1 September 2023

Project end date: 31 August 2027

Project duration: 48 months

Consortium agreement: Yes

2. Participants

List of participants:

N°	Role	Short name	Legal name	Ctry	PIC	Total eligible contrib.	Max grant amount
1	COO	FLS	FLSMIDTH AS	DK	893855680	829 917.00	829 917.00

N°	Role	Short name	Legal name	Ctry	PIC	Total eligible contrib.	Max grant amount
2	BEN	CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	FR	999997930	282 693.60	282 693.60
3	BEN	RWTH	RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN	DE	999983962	260 539.20	260 539.20
4	BEN	TUD	TECHNISCHE UNIVERSITEIT DELFT	NL	999977366	548 740.80	548 740.80
5	BEN	UNIPD	UNIVERSITA DEGLI STUDI DI PADOVA	IT	999995602	259 437.60	259 437.60
6	BEN	IHS	INSTITUTE FOR HOUSING AND URBAN DEVELOPMENT STUDIES BV	NL	988824015	274 370.40	274 370.40
7	BEN	STW	STATWOLF LIMITED	IE	935994420	143 244.00	143 244.00
8	BEN	C2CA	C2CA TECHNOLOGY BV	NL	908356404	453 473.30	453 473.30
9	BEN	MNK	MANNOK HOLDINGS DESIGNATED ACTIVITY COMPANY	IE	884343278	143 244.00	143 244.00
10	AP	ABD	UNIVERSITY OF ABERDEEN	UK	999929448	0.00	0.00
11	AP	IMP	IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE	UK	999993468	0.00	0.00
12	AP	ARGOS	CEMENTOS ARGOS SA	CO	936283286	0.00	0.00
13	AP	EPFL	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	CH	999973971	0.00	0.00
14	AP	ETHZ	EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH	CH	999979015	0.00	0.00
15	AP	MIT	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	US	998096827	0.00	0.00
16	AP	ECOS	ENVIRONMENTAL COALITION ON STANDARDS	BE	953502823	0.00	0.00
17	AP	PTECH	ParticleTech ApS	DK	905891634	0.00	0.00
18	AP	UOG	UNIVERSITE GRENOBLE ALPES	FR	897379108	0.00	0.00
Total						3 195 659.90	3 195 659.90

Coordinator:

– FLSMIDTH AS (FLS)

3. Grant

Maximum grant amount, total estimated eligible costs and contributions and funding rate:

Total eligible contributions (unit, flat-rate and lump sum contributions and financing not linked to costs)	Maximum grant amount (Annex 2)	Maximum grant amount (award decision)
3 195 659.90	3 195 659.90	3 195 659.90

Grant form: Unit

Grant mode: Action grant

Budget categories/activity types:

- A. Contributions for recruited researchers
  - A.1 Living allowance
  - A.2 Mobility allowance
  - A.3 Family allowance
  - A.4 Long-term leave allowance
  - A.5 Special needs allowance

- B. Institutional contributions
  - B.1 Research, training and networking contribution

- B.2 Management and indirect contribution

Cost eligibility options:

- In-kind contributions eligible costs

Budget flexibility: Yes (flexibility with conditions)

4. Reporting, payments and recoveries

4.1 Continuous reporting (art 21)

Deliverables: see Funding & Tenders Portal Continuous Reporting tool

4.2 Periodic reporting and payments

Reporting and payment schedule (art 21, 22):

Reporting					Payments	
Reporting periods			Type	Deadline	Type	Deadline (time to pay)
RP No	Month from	Month to				
					Initial prefinancing	30 days from entry into force/10 days before starting date – whichever is the latest
1	1	24	Periodic report	60 days after end of reporting period	Interim payment	90 days from receiving periodic report
2	25	48	Periodic report	60 days after end of reporting period	Final payment	90 days from receiving periodic report

Prefinancing payments and guarantees:

Prefinancing payment	
Type	Amount
Prefinancing 1 (initial)	2 556 527.92

Reporting and payment modalities (art 21, 22):

Mutual Insurance Mechanism (MIM): Yes

MIM contribution: 5% of the maximum grant amount (159 783.00), retained from the initial prefinancing

Restrictions on distribution of initial prefinancing: The prefinancing may be distributed only if the minimum number of beneficiaries set out in the call condititions (if any) have acceded to the Agreement and only to beneficiaries that have acceded.

Interim payment ceiling (if any): 90% of the maximum grant amount

No-profit rule: n/a

Late payment interest: ECB + 3.5%

Bank account for payments:

DK7620005005844267

Conversion into euros: n/a

Reporting language: Language of the Agreement

4.3 Certificates (art 24): n/a

4.4 Recoveries (art 22)

First-line liability for recoveries:

Beneficiary termination: Beneficiary concerned

Final payment: Each beneficiary for their own debt

After final payment: Beneficiary concerned

Joint and several liability for enforced recoveries (in case of non-payment):

Individual financial responsibility: Each beneficiary is liable only for its own debts (and those of its affiliated entities, if any)

Joint and several liability of affiliated entities — n/a

5. Consequences of non-compliance, applicable law & dispute settlement forum

Suspension and termination:

Additional suspension grounds (art 31)

Additional termination grounds (art 32)

Applicable law (art 43):

Standard applicable law regime: EU law + law of Belgium

Dispute settlement forum (art 43):

Standard dispute settlement forum:

EU beneficiaries: EU General Court + EU Court of Justice (on appeal)

Non-EU beneficiaries: Courts of Brussels, Belgium (unless an international agreement provides for the enforceability of EU court judgements)

6. Other

Specific rules (Annex 5): Yes

Standard time-limits after project end:

Confidentiality (for X years after final payment): 5

Record-keeping (for X years after final payment): 5 (or 3 for grants of not more than EUR 60 000)

Reviews (up to X years after final payment): 2

Audits (up to X years after final payment): 2

Extension of findings from other grants to this grant (no later than X years after final payment): 2

Impact evaluation (up to X years after final payment): 5 (or 3 for grants of not more than EUR 60 000)

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 to a beneficiary.

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 **101119929 — DETOCS** ('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

The grant is an action grant[8] which takes the form of a unit 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).
[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".

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

Not applicable

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 contributions for the action (unit contributions), broken down by participant and budget category.

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

The details on the calculation of the unit contributions will be explained in Annex 2a.

5.5 Budget flexibility

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

ARTICLE 6 — ELIGIBLE AND INELIGIBLE CONTRIBUTIONS

6.1 General eligibility conditions

The **general eligibility conditions** for the unit contributions are the following:

(a) 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

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

6.2 Specific eligibility conditions for each budget category

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

A. Contributions for recruited researchers

Contributions for recruited researchers (A.1 Living allowance, A.2 Mobility allowance, A.3 Family

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

allowance, A.4 Long-term leave allowance and A.5 Special needs allowance) are eligible, if they fulfil the general eligibility conditions and are calculated as unit contributions in accordance with the method set out in Annex 2a, and if:

for A.1 Living allowance and A.2 Mobility allowance:

(a) the number of units declared:

(i) corresponds to the number of months spent by the recruited researchers on the research training activities

(ii) does not exceed the maximum number of months (per researcher) set out in the call conditions and

(iii) comply with the requirements for non-academic exposure set out in the call conditions (for industrial doctorates only)

(b) the recruited researchers comply with the following conditions:

(i) be — at the date of recruitment — a doctoral candidate (i.e. not already in possession of a doctoral degree[10])

(ii) be enrolled in a doctoral programme leading to the award of a (for joint doctorates: joint, multiple or double) degree in at least one EU Member State or Horizon Europe associated country (for joint doctorates: at least two)

(iii) be recruited by the beneficiaries under an employment contract (or other direct contract with equivalent benefits, including social security coverage) or — if not otherwise possible under national law — under a fixed amount fellowship agreement with minimum social security coverage, including during periods of secondment

(iv) be employed full-time, unless the granting authority has approved a part-time employment for personal or family reasons

(v) be working exclusively for the action

(vi) not have resided or carried out their main activity (work, studies, etc.) in the country of the recruiting beneficiary for more than 12 months in the 36 months immediately before the recruitment date — unless as part of a compulsory national service or a procedure for obtaining refugee status under the Geneva Convention[11]

For beneficiaries that are international European research organisations or international organisations: not have spent with the beneficiary more than 12 months in the 36 months immediately before the recruitment date

(c) the contributions have been fully incurred for the benefit of the recruited researchers

This condition is met if:

[10] As defined in the call conditions.
[11] 1951 Refugee Convention and the 1967 Protocol.

{{**total remuneration costs** (salaries, social security contributions, taxes and other costs included in the remuneration under the employment contract or other direct contract) or **total fixed-amount fellowship costs** for the researcher during the action

plus

total mobility costs (household, relocation and travel expenses and, if they must be paid under national law, taxes, duties and social security contributions) for the researcher during the action}

divided by

the number of actual units}.

is equal to or higher than the following amount:

{amount per unit contribution set out in Annex 2 as living allowance

plus

amount per unit contribution set out in Annex 2 as mobility allowance}.

for A.3 Family allowance:

(a) the recruited researchers have a family.

'Family' means persons linked to the researcher by marriage (or a relationship with equivalent status to a marriage recognised by the legislation of the country where this relationship was formalised) or dependent children who are actually being maintained by the researcher.

(b) the number of units declared:

(i) corresponds to the number of months spent by the recruited researchers with a family on the research training activities and

(ii) does not exceed the maximum number of months (per researcher) set out in the call conditions.

(c) the contributions have been incurred for the benefit of the recruited researchers

This condition is met if they have been fully used for the recruited researchers for whom they are claimed.

for A.4 Long-term leave[12] allowance:

(a) the general and specific eligibility conditions for the living and mobility allowances were fulfilled before the long-term leave and

(b) the number of units declared corresponds to the number of months paid by the beneficiary.

for A.5 Special needs allowance:

(a) they are used for recruited researchers with disabilities whose long-term physical, mental, intellectual or sensory impairments are certified by a competent national authority and of such

[12] Long-term leave includes maternity, paternity, parental, sick or special leave of more than 30 days.

nature that their participation in the action would not be possible without the special needs items or services

(b) the special needs items or services are not already covered from another source (such as social security or health insurance)

(c) the number of units declared corresponds to the number of special needs units that were needed for implementing the action.

B. Institutional contributions

Institutional contributions (B.1 Research, training and networking contribution and B.2 Management and indirect contribution) are eligible, if they are calculated as unit contributions in accordance with the method set out in Annex 2a, and if the living and mobility allowances are eligible.

Moreover, no more than 40% of the maximum grant amount may be allocated to beneficiaries located in the same country or to any one international European research organisation or international organisation.

6.3 Ineligible contributions

'Ineligible contributions' are:

(a) units that do not comply with the conditions set out above (see Article 6.1 and 6.2)

(b) units implemented during grant agreement suspension (see Article 31) and

(c) units for activities already funded 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 case:

(i) Synergy actions: not applicable

(d) other:

(i) country restrictions for eligible costs: not applicable.

6.4 Consequences of non-compliance

If a beneficiary declares unit 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

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. Unit 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'[13] (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

[13] 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."

Not applicable

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':

- **UNIVERSITY OF ABERDEEN (ABD)**, PIC 999929448
- **IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE (IMP)**, PIC 999993468
- **CEMENTOS ARGOS SA (ARGOS)**, PIC 936283286
- **ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE (EPFL)**, PIC 999973971
- **EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH (ETHZ)**, PIC 999979015
- **MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)**, PIC 998096827
- **ENVIRONMENTAL COALITION ON STANDARDS (ECOS)**, PIC 953502823
- **ParticleTech ApS (PTECH)**, PIC 905891634
- **UNIVERSITE GRENOBLE ALPES (UOG)**, PIC 897379108, associated partner of CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS)

Associated partners must implement the action tasks attributed to them in Annex 1 in accordance with Article 11. They may not charge contributions to the action (no unit contributions) 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 contributions to the action (no unit contributions) and their costs are considered entirely covered by the unit contributions paid to the beneficiaries.

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

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 beneficiaries' costs for subcontracting are considered entirely covered by the unit contributions (irrespective of the actual subcontracting costs incurred, if any).

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[14]
- 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.).

[14] 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 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.

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[15] and its implementing rules).

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

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

[15] 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).

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[16].

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[17]).

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.

[16] 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 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).

[17] 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).

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:

(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):

Funded by the
European Union

Co-funded by the
European Union

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 unit 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 adequate records and supporting documents to prove the number of units declared; beneficiaries do not need to keep specific records on the actual costs incurred.

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, unit 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): not applicable.

The **financial statements** must detail the contributions for the units implemented in the reporting period.

Unit contributions which are not declared in a financial statement 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 unit contributions declared are eligible (see Article 6)
- the 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)

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.

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

At beneficiary termination there will be no payment, but the grant must be provisionally closed for the beneficiary which leaves the consortium (and the affiliated entities which had to end their participation together with the beneficiary, if any).

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 unit contributions for the accepted units.

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 contributions claimed for the units implemented 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 first calculate the 'accepted EU contribution' for the action for the reporting period, by calculating the unit contributions for the accepted units.

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 eligible contributions claimed for the remaining units implemented (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 unit contributions for the accepted units.

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

Not applicable

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 unit 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 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[18] 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).

[18] 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

Not applicable

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 unit 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.

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.

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 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

[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).

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 unit 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, unit 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 CONTRIBUTIONS

27.1 Conditions

The granting authority will — at beneficiary termination, interim payment, final payment or afterwards — reject any unit 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 unit 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 unit contributions, it will deduct them from the 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. Moreover, no units may be implemented. Ongoing units must be interrupted and no new units may be started. Unit 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

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. Moreover, no units may be implemented Ongoing units must be interrupted and no new units may be started. Unit 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 unit contributions for activities implemented before the end of work date (see Article 22).

If the granting authority does not receive the report within the deadline, only unit contributions which

are included in an approved periodic report will be taken into account (no 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 and the explanation on the use of resources

(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 unit contributions for activities implemented before the end of work date (see Article 22).

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 unit contributions which are included in an approved periodic report will be taken into account (no 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

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 (see Article 22). Only units implemented until termination will be accepted.

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 unit contributions which are included in an approved periodic report will be taken into account (no 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, and the explanation on the use of resources

(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 (see Article 22). Only units implemented until termination will be accepted.

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 unit contributions included in an approved periodic report will be taken into account (no 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).

[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).

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).

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

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

[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).

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

Bodil Recke with ECAS id n00bbtoc signed in the Participant Portal on 12/07/2023 at 12:23:52 (transaction id SigId-268159-zueGLqSiAn9nqf044BSJVmoNwjv4Lzmqw0FiCqLoKOkvhHFnZ9rODoOmUeOoF90oLJgSjFWGTh7ISZYder5L2zm-jpJZscgsw0K4epxy2XYw0y-mzHts6pIf6qC4t3CyzVv0qgZCMnbteoqA7zlGhkOgsXVswC1CwvsBwVKpRIaIsyYd7aqUY4kQ56rBRVGh4foxam). Timestamp by third party at 2023.07.12 12:23:57 CEST

For the granting authority

Signed by Frank MARX with ECAS id marxfra as an authorised representative on 13-07-2023 11:29:02 (transaction id SigId-282706-zXqJLQ3SkxmjGbLlexQiGcVfNYO0qmTtGycsxrerTPAwSKW5l6If4KduCOQftSi3QMXBzzS2gJFUKe2yYKhCjBW-jpJZscgsw0K4epxy2XYw0y-oLS8NGMOT1g5YBXDoRl8zfWvQezWScB4uwzo3t7QvkZDHeqmK6VBK0cpKLCYgL8vzLscKQrkgyhgLPTzXmXkgw3)
2023.07.13 11:38:08 CEST

ANNEX 1

Horizon Europe (HORIZON)

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:	101119929
Project name:	Data to Enable Transformation and Optimisation for Concrete Sustainability
Project acronym:	DETOCS
Call:	HORIZON-MSCA-2022-DN-01
Topic:	HORIZON-MSCA-2022-DN-01-01
Type of action:	HORIZON-TMA-MSCA-DN-ID
Service:	REA/A/01
Project starting date:	fixed date: 1 September 2023
Project duration:	48 months

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List of milestones (outputs/outcomes) 30
List of critical risks 32
Project reviews 34

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.

Cement production is responsible for 8% of global CO2 emissions, mainly from limestone processing to produce clinker. Clinker can be replaced by other raw materials, such as clay, ashes, slags or recycled concrete fines. These materials can be processed into Supplementary Cementitious Materials (SCM), which have a lower CO2 footprint than Portland Cement. DETOCS proposes a new approach to rapidly increase the use of SCMs on existing production facilities: by exploiting the latest innovations in digital tools to predict and control the quality of cement and concrete blends with high amounts of SCMs compared to today's standards. Our network aims to lay the scientific foundations to create knowledge and new models to study the production of high quality SCMs and their impact on low-carbon cement and concrete mixes. The goal is to reduce clinker factor from ca. 70% today to 40% by 2030 and 25% by 2035, targeting a CO2 emissions of 0.2 t.CO2/t.cement (compared to today's global average of 0.65 t.CO2/t.cement). At DETOCS, the partners combine top-notch scientific expertise, interdisciplinary know-how, engineering solutions and real-world process data into an industry-driven network. The structured approach combines complementary research for each individual project in the academic and industry sectors. The top-level research work is accompanied by a balanced mix of the newest scientific courses and transferable skills training delivered by each partner locally and in dedicated training schools, seminars, and workshops at the network level. This way, each doctoral candidate builds up deep scientific expertise and interdisciplinary knowledge to deliver game-changing cleantech innovations during and after the project. DETOCS is impact-driven and strives for a portfolio of high-class joint publications, patents, and innovations along the value chain. The project will lay the foundations for first-of-its-kind engineering solutions to decarbonize cement and concrete products.

LIST OF PARTICIPANTS

PARTICIPANTS

Grant Preparation (Beneficiaries screen) — Enter the info.

Number	Role	Short name	Legal name	Country	PIC
1	COO	FLS	FLSMIDTH AS	DK	893855680
2	BEN	CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	FR	999997930
3	BEN	RWTH	RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN	DE	999983962
4	BEN	TUD	TECHNISCHE UNIVERSITEIT DELFT	NL	999977366
5	BEN	UNIPD	UNIVERSITA DEGLI STUDI DI PADOVA	IT	999995602
6	BEN	IHS	INSTITUTE FOR HOUSING AND URBAN DEVELOPMENT STUDIES BV	NL	988824015
7	BEN	STW	STATWOLF LIMITED	IE	935994420
8	BEN	C2CA	C2CA TECHNOLOGY BV	NL	908356404
9	BEN	MNK	MANNOK HOLDINGS DESIGNATED ACTIVITY COMPANY	IE	884343278
10	AP	ABD	UNIVERSITY OF ABERDEEN	UK	999929448

PARTICIPANTS

Grant Preparation (Beneficiaries screen) — Enter the info.

Number	Role	Short name	Legal name	Country	PIC
11	AP	IMP	IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE	UK	999993468
12	AP	ARGOS	CEMENTOS ARGOS SA	CO	936283286
13	AP	EPFL	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	CH	999973971
14	AP	ETHZ	EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH	CH	999979015
15	AP	MIT	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	US	998096827
16	AP	ECOS	ENVIRONMENTAL COALITION ON STANDARDS	BE	953502823
17	AP	PTECH	ParticleTech ApS	DK	905891634
18	AP	UOG	UNIVERSITE GRENOBLE ALPES	FR	897379108

LIST OF WORK PACKAGES

Work packages

Grant Preparation (Work Packages screen) — Enter the info.

Work Package No	Work Package name	Lead Beneficiary	Effort (Person-Months)	Start Month	End Month	Deliverables
WP1	Prediction and control of binder quality	1 - FLS	4.00	7	42	D1.1 – Experimental protocol to evaluate SCMs reactivity D1.2 – Prediction model of clinker mineralogy (basic framework and input parameters) D1.3 – SCMs activation process control & reactivity models (thermal, chemical, mechanical) D1.4 – Summary report on numerical models applied to predict SCM reactivity
WP2	Quality prediction and performance-based design of low-carbon cement and concrete mixes produced therewith	3 - RWTH	7.00	7	42	D2.1 – Prediction tool for clinker interaction with SCMs – Blender optimization tool D2.2 – Life cycle environmental impacts of low carbon cement D2.3 – Economic and environmental impact of material variability on concrete production D2.4 – Durability models at the concrete scale (description of physical models) D2.5 – Durability models at the concrete scale (upscaling from cement paste to concrete) D2.6 – Performance-based design tool for low-carbon concrete mixes
WP3	Digital solutions applied to low-carbon cement and concrete materials	7 - STW	6.00	7	42	D3.1 – Validated Soft sensor for in-process

Work packages

Grant Preparation (Work Packages screen) — Enter the info.

Work Package No	Work Package name	Lead Beneficiary	Effort (Person-Months)	Start Month	End Month	Deliverables
						quality monitoring of cement grinding / blending D3.2 – ML methodology to predict product quality in cement/concrete production D3.3 – Report on the environmental impact of digitalization in cement production D3.4 – RFID technology to monitor and track the quality of materials in cement value chain D3.5 – Characterisation of SCM reactivity via computer vision based system D3.6 – Integration of hyperspectral technology to SCM characterisation method D3.7 – Process data sheet for SRM
WP4	Market acceptance of low-carbon cement	6 - IHS	4.00	7	42	D4.1 – List of bottlenecks related to low-carbon cement market acceptance D4.2 – Environmental and economic impacts of concrete made with low-carbon cement D4.3 – Report on “The future of cement and concrete industry”
WP5	Scientific and Transferrable Skills Training	5 - UNIPD	9.00	1	48	D5.1 – First network-wide training event D5.2 – Career Development Plans
WP6	Dissemination and Outreach	1 - FLS	9.00	1	48	D6.1 – Project Website D6.2 – Plan for the dissemination and exploitation of results, including communication activities (2 deliverables but with different timing for submission) – Version 1

Work packages

Grant Preparation (Work Packages screen) — Enter the info.

Work Package No	Work Package name	Lead Beneficiary	Effort (Person-Months)	Start Month	End Month	Deliverables
						D6.3 – Plan for the dissemination and exploitation of results, including communication activities (2 deliverables but with different timining for submission) – Version 2 D6.4 – Project video or animation D6.5 – International Workshops I D6.6 – International Workshops II D6.7 – International Workshop III
WP7	Management and Coordination	1 - FLS	9.00	1	48	D7.1 – Supervisory Board of the network D7.2 – Report on DC recruitment D7.3 – Progress Report D7.4 – Data Management Plan D7.5 – Risk Management Plan D7.6 – Report on collaboration activities with other projects

Associated with document Ref. Ares(2023)4821121 - 11/07/2023

Work package WP1 – Prediction and control of binder quality

Work Package Number	WP1	Lead Beneficiary	1. FLS
Work Package Name	Prediction and control of binder quality		
Start Month	7	End Month	42

Objectives

1) Develop a model to predict the clinker mineralogy for a given chemical composition;
2) Develop a predictive model correlating process conditions for thermal-activated SCMs to optimise process efficiency and product performance;
3) Optimise SCM reactivity of chemical activation and carbonation, correlate SCM characterization data with its reactivity and interactions with admixture dosage;
4) Develop a novel protocol to optimise SCM reactivity by means of mechanical activation.

Description

SCM are commonly used as partial clinker replacements, resulting in cement blends with a reduced carbon footprint. SCMs' physico-chemical characteristics alter cement hydration, affecting the evolution of cement microstructure. Existing numerical models (reaction-kinetics models) for cement lack accuracy when applied to modern cement blends, especially in multicomponent systems with high volume of clinker replacement, where chemical interactions between clinker, water, SCMs and fillers occur concurrently. Also, the solutions to enhance SCMs reactivity, which can be thermal, chemical (including via carbonation) or mechanically activated, have not been studied on an industrial scale, and consequently lack adaptive process control and quality prediction tools to maintain a stable output material quality. To overcome these challenges, WP1 introduces novel first-principle models to enable high-fidelity prediction of time-dependent reactions of clinker and its interactions with SCMs. WP1 targets SCM activation and cement production, with research work ranging from thermodynamics models for clinker as well as thermal-, chemical- and mechanical-activated SCMs using process parameters and physicochemical characteristics as input variables. To complement first-principle models, ML approaches will be used as to identify correlations between process data and reactivity of each component in blended cements, serving as the building block for the development of a holistic cement blend expert model in WP2. The SCMs targeted in this study are clays, fly-ash, slag, RCF, limestone and natural pozzolans, which will be supplied by our industrial partners ARGOS, C2CA, and MNK. These will also provide data from cement and SCM production. WP1 will develop models to predict the clinker mineralogy as well as correlate thermal, chemical and mechanical process conditions for SCM, helping improve their reactivity.

Task 1.1
1.1.1 Develop a set of Gibbs energy data to simulate the clinker mineralogy (CNRS, RWTH).
1.1.2 Develop a model based on the commercial Factsage FTOxid databases (CNRS); 1.1.3 Benchmark calculations using clinker data from the open literature and cement plants (FLS, ARGOS); 1.1.4 Develop a clinker mineralogy prediction model (CNRS, FLS, ARGOS).

Task 1.2
1.2.1 Development of flash / rotary kiln process model for thermal activation of SCMs (UOA); 1.2.2 Correlate the SCM reactivity with material and process data, including clinker interaction (PTECH, FLS, ARGOS). 1.2.3 Test SCM reactivity via the R3 method (RWTH). 1.2.4 Develop Machine Learning approaches to provide an additional correlation layers
material composition and process data (FLS, ARGOS)

Task 1.3
1.3.1. Chemical and physical characterisation of cementitious materials produced with SCMs and chemical admixtures (C2CA, FLS, MNK);
1.3.2 Develop a predictive model for chemically activated blended cements accounting for material variations from traditional SCMs or SCMs modified by carbonation (FLS, C2CA); 1.3.3 Apply Machine Learning methods to complement to the proposed predictive models from Task 1.3.2 (ETH, FLS).

Task 1.4
1.4.1 Production and characterisation of mechanically-activated SCMs – physical and chemical properties (RWTH, PTECH,FLS, ARGOS);
1.4.2 Experimental evaluation of the reactivity of mechanically-activated SCMs and impact of these on fresh state

properties of cementitious-based materials (RWTH, ARGOS); 1.4.3 Identification of key process parameters to enhance the reactivity of mechanically-activated SCMs (RWTH, FLS, PTECH); 1.4.4 Develop a model

Work package WP2 – Quality prediction and performance-based design of low-carbon cement and concrete mixes produced therewith

Work Package Number	WP2	**Lead Beneficiary**	3. RWTH
Work Package Name	Quality prediction and performance-based design of low-carbon cement and concrete mixes produced therewith		
Start Month	7	**End Month**	42

Objectives

1) Enable a custom optimisation of the design of blended cements as function of clinker mineralogy and SCM reactivity;
2) Develop physical models to predict concrete performance (mechanical properties and durability) and integrate this method with environmental life cycle assessment to create a performance-based design tool for low-carbon concrete mixes;
3) Provide an economical and environmental analysis of the impact of material variability on concrete production.

Description

A variety of blended cements are being developed and used to address the urgent need to reduce CO2 from cement. Today, less than 25% of the cements sold globally are Ordinary Portland Cement (>95% clinker). In fact, the prescriptive EU standards specify 34 cement types [EN 197-1 and -5], with more to be added by upcoming standards (EN 197-6). To achieve the decarbonization challenge, cement composition must continue diversify to use locally available alternatives to clinker. Given this diversification of cement composition and the expanding levels of SCM content, the number of blended cements is to exponentially increase, as is the complexity in their formulations, affecting not only cement production but also its utilisation in modern concrete formulations. To enable a rapid introduction of new SCMs, while reducing complexity from existing prescriptive standards, this WP provides a means to shift from specifications based composition to a performance-based approach in cement and concrete. Specifically, WP2 targets aspects related to the prediction of phase relations of cementitious systems and to further engineer phase assemblages towards an optimum performance by adjusting the chemical composition of blended cements; such development builds upon the numerical models developed in WP1. Also, WP2 explores the impact of sustainable cement blends on the concrete production process: a performance-based approach will be tested to design concrete materials optimized for mechanical strength, durability, and environmental performance, while considering the impact on the concrete production process parameters and the inherently variability in the input material composition. In WP2, the partners MNK and ARGOS provide data from cement and concrete plants, while C2CA provide data on RCF. WP2 will enable a custom optimisation of blended cements composition; develop physical models to predict concrete performance and integrate this method with environmental life cycle assessment to create a performance-based design tool; and provide an economical & environmental analysis of the impact of material variability on concrete production.

Task 2.1
2.1.1 Experiments on clinker/cement blends to obtain a “reactivity footprint” (RWTH, CNRS, MNK).
2.1.2. Thermodynamic predictions of the hydration reactions and phase distribution (RWTH, CNRS).
2.1.3 Identification of materials parameters related to low-carbon cement strength (RWTH, MNK).
2.1.4 Design tool for optimisation blended cements (RWTH, SWT, CNRS)

Task 2.2
2.2.1 Develop a physical model to predict material properties and life cycle environmental impacts of cement binders and concrete mixes (MNK, ARGOS).
2.2.2 Refinement of physical models via domain expertise and machine learning model (STW, MNK, ARGOS)
2.2.3 Integration of durability indicators based on developments in DC8 (MNK, ARGOS);
2.2.4 Validation of mix design tool via standardised lab experiments and/or literature data (MNK, ARGOS).

Task 2.3
2.3.1 Literature review and expert interviews (including DC3,5&6) to create a hierarchy of materials and their expected modes of interaction (TUD, C2CA, ARGOS, MNK);

2.3.2 Complementary experimental work (strength and durability tests) to enrich the database on materials variability and their expected modes of interaction (C2CA, TUD);
2.3.3 Principal Component Analysis (PCA) to identify the most important independent material variables on concrete performance (TUD, ARGOS, MNK)

Task 2.4
2.4.1 Durability tests - experimental data collection at the cement paste and concrete scale (RWTH, C2CA, ARGOS);
2.4.2 Microstructure characterization and identification of microstructure indicators related to durability (C2CA);
2.4.3 Constrained concrete models – upscaling data from cement paste tests to concrete (ARGOS).

Work package WP3 – Digital solutions applied to low-carbon cement and concrete materials

Work Package Number	WP3	**Lead Beneficiary**	7. STW
Work Package Name	Digital solutions applied to low-carbon cement and concrete materials		
Start Month	7	**End Month**	42

Objectives

1) Develop soft sensors for monitoring in-process quality of cement grinding and blending;
2) Development and application of RFID technology to monitor and track the quality of materials across the value chain;
3) Develop a machine learning methodology to predict product quality in cement and concrete productions;
4) Develop a rapid Supplementary Cementitious Materials characterisation method based on computer vision;
5) Develop a decentralized production model applied to the production of cementitious binders from Secondary Raw Materials.

Description

An important lever to decarbonize of cement and concrete industries consists of digital solutions for optimization of cement production and utilization. WP3 focuses on developing these digital solutions for implementation on the existing industrial base at low CAPEX and OPEX. The focus is to build on the vast amounts of data available from cement and concrete plants control systems (i.e. MNK and ARGOS) and Secondary Raw Materials processing (C2CA). Based on data analytics know-how from the industrial partner STW, WP3 will develop a general ML framework to predict cement quality attributes (this framework is supported by the first-principle models studied in WP1&2), to be applied on blended cement (grinding/blending) and concrete production with the industrial partners ARGOS and MNK, and C2CA. Similarly, PTECH contributes with optical measurements to devise a novel method to assess the reactivity of SCMs quickly and reliably, which is to be implemented in cement production lines by FLS and ARGOS. The ML framework is the basis for the development of soft-sensors for in-line measurements in cement production. Next, building upon technologies available at C2CA, WP3 conducts research on using sensors to track materials quality along the value chain, filling a critical need for material information at all stages. Altogether, WP3 develops the digitalization backbone for reducing the CO2 footprint in cement and concrete industries by developing soft sensors and computer vision technologies for monitoring in-process quality of cement production, including the processing of Secondary Raw Materials (SRM); RFID technology to monitor and track the quality of materials across the value chain; and ML to predict cement and concrete productions quality.

Addressing the robustness of Artificial Intelligence Systems: The Machine Learning methodologies addressed in many DCs in the DETOCS project may suffer from robustness issues associated with a) model errors/inaccuracies, b) unknown phenomena, and c) shifts in the process behaviour. To deal with model errors, techniques from probabilistic inference and robust optimisation are often used to provide some robustness guarantee metric [Kha2021]. To deal with unknown phenomena, techniques include anomaly detection methods, using causal models, the construction of ensembles and reinforcement learning. Finally, to deal with shifts in the process behaviour, techniques from adaptive control and adaptive/recursive multivariate methods will be exploited. Moreover, in the project, the support of first-principles models and the development of hybrid modelling techniques will alleviate robustness problem thanks to higher reliance of knowledge-based approaches (i.e. physicochemical-based models for clinker and SCM reactions). By doing so, and with the integration of explainable-AI approaches [Ar2020], we also guarantee a robust level of explanation to the model's decision-making process.

Task 3.1

3.1.1 Development of deep learning-based soft sensors for time-series analysis (STW, UNIPD);
3.1.2 Development of monitoring approaches for in-line measurements of cement production (STW, UNIPD, FLS, MNK);
3.1.3 Development of deep learning-based soft sensors for handling heterogenous sampling time (STW, UNIPD);
3.1.4 Development of interpretability approaches for in-line measurements of cement production (UNIPD, STW, FLS);

Task 3.2
3.2.1 Study the performance of different RFID tags to identify the critical design elements that contribute to robustness (TUD,C2CA, ARGOS);
3.2.2 Propose and manufacture new RFID design based on physical modelling (C2CA, TUD);
3.2.3 RFID tests in industrial steps (e.g. cement packing and transportation) (C2CA, ARGOS, MNK).

Task 3.3
3.3.1 Propose optimal formulations for data treatment and dataset augmentation (UPD, STW, FLS, ARGOS, MNK);
3.3.2 Application of latent variable model inversion to adjust the process settings to ensure the target profile of the product quality (STW, UNIPD, MNK, ARGOS);
3.3.3 Development of hybrid model strategies – in combination with the first-principle models from DC1-4 (UPD, STW, FLS).

Work package WP4 – Market acceptance of low-carbon cement

Work Package Number	WP4	**Lead Beneficiary**	6. IHS
Work Package Name	Market acceptance of low-carbon cement		
Start Month	7	**End Month**	42

Objectives

1) Provide a detailed perspective on innovation pathways and bottlenecks of low-carbon cement market acceptance;
2) Provide a detailed analysis of the environmental & economic impacts of low-carbon cement.

Description

While many technical decarbonization pathways are explored in WP1-3, there exist non-technical barriers hindering the spread of low-carbon cement blends. These barriers are associated with the use of prescriptive standards for cement (and concrete) that define authorized compositions, as well as end-user reluctance based on ease-of-use, technical and market risks, the need for confidence in long-term material performance, bias, and others. Though some of these barriers are identified, they remain largely understudied. WP4 tackles this gap via research on normative aspects, industry characteristics, and end user firm factors related to the adoption of low carbon cement & concrete materials. Furthermore, WP4 provides a holistic picture on the performance of low-carbon cement based with an analysis of environmental impacts and economic competitiveness of blended cements with high replacement rates of SCMs, including traditional and unconventional SCMs. The industrial partners play a key role as providers of market knowledge along the entire value chain – from OEM (FLS) to cement and concrete production, utilisation, and standards (FLS, ARGOS, MNK, C2CA ECOS). WP4 will provide a detailed perspective on innovation pathways and bottlenecks related to low-carbon cement market acceptance; and analysis of the environmental & economic impacts of low-carbon cements.

Task 4.1
4.1.1 Normative analysis (IHS, ECOS, ARGOS, MNK, C2CA);
4.1.2 Mapping Cement and Concrete Industry structures (IHS, ARGOS, MNK, C2CA);
4.1.3 Mapping end-user firm factors (IHS, ARGOS, MNK);

Task 4.2
4.2.1 Analyses of the environmental impacts of low carbon cement and inclusion of ecotoxicity as a new environmental impact category (FLS, ARGOS, MNK);
4.2.2 Economic performance in the use of low carbon cement (C2CA, ARGOS, MNK);
4.2.3 Life cycle assessment of cement and concrete plants (ARGOS, MNK).

Work package WP5 – Scientific and Transferrable Skills Training

Work Package Number	WP5	Lead Beneficiary	5. UNIPD
Work Package Name	Scientific and Transferrable Skills Training		
Start Month	1	End Month	48

Objectives
1) Creation of DC's scientific and transferable knowledge in agreement with the individual needs of our DCs defined in the CDPs.

Description
This WP oversees all activities related to Scientific and Transferrable Skills Training. Task 5.1 Create, review and agree on the individual training needs of each DC and the Career Development Plans that includes e.g. conference visits, secondments, short-term visits, training through local courses (FLS, all Beneficiaries and DC hosts). Task 5.2 Establish extended Individual Research Project (IRP) descriptions for each DC, including an update of the state-of-the-art as basis for the research work and the DC projects (FLSMIDTH, all Beneficiaries and DC hosts). Task 5.3 Plan and organise the network-wide training events on scientific and transferable skills (regular announcements via our social media channels, the website and our newsletter), monitor the effectiveness and quality of the training events (FLS, all partners) and cluster with other EU projects or national initiatives. Task 5.4 Create the inventory of training materials such as online lectures, scripts and slide decks (UNIPD). Task 5.5 Monitor the planning, implementation, and progress of the local trainings (scientific and transferable skills) and the employment periods and secondments as well as hands-on training for each DC and ensure uniform progress of the whole team (FLS).

Work package WP6 – Dissemination and Outreach

Work Package Number	WP6	Lead Beneficiary	1. FLS
Work Package Name	Dissemination and Outreach		
Start Month	1	End Month	48

Objectives
1) Organise and oversee the widespread use of our results to maximise the impact of the project towards different target audiences; 2) Support the assessment of our IPs and the creation/utilisation of IPRs, disseminate the scientific results, and inform the wider public about our activities.

Description
This WP oversees all activities related to Dissemination and Outreach. Task 6.1 Build the website and our social media presence and form new relationships with the wider public through our channels and link our communication activities with the existing communication channels of the partners (FLS, UNIPD). Task 6.2 Further develop, update, and internally communicate our Dissemination and Exploitation Strategy (see Sec. 2.3). Monitor the creation of scientific papers and conference contributions as well as public-private joint publications, act as helpdesk (UNIPD). Task 6.3 Engage with editors of scientific journals, conference chairs, science journalists, science bloggers and the

professional communication channels of the European Commission to encourage the dissemination and communication of our results and to create additional training opportunities for our DCs (FLS, UNIPD).

Task 6.4 Create a general presentation, flyer, poster and 3 infographics to inform on the project goals and methods (FLS, UNIPD).

Task 6.5 Create and distribute newsletters, monitor the registration/download rates and create new connections to stakeholders (UPD).

Task 6.6 Coordinate the participation in fairs/exhibitions/roadshows conferences and other relevant events (UNIPD).

Task 6.7 Create and coordinate specific stakeholder sessions and meetings, e.g. at the International Workshops, to foster the exploitation of results and in particular make sure that cement companies and policymakers are informed and participate (FLS, UNIPD).

Task 6.8 Establish the background IP overview and support the identification of new IPs, suitable protection measures (e.g. patent), costs, and valuation of each asset, facilitate the flow of information between all parties involved, act as helpdesk (UNIPD).

Work package WP7 – Management and Coordination

Work Package Number	WP7	**Lead Beneficiary**	1. FLS
Work Package Name	Management and Coordination		
Start Month	1	**End Month**	48

Objectives
1) Conduct the full administrative and financial management, reporting and progress monitoring of research and training.

Description
This WP oversees the Management and Coordination of the DETOCS project. Task 7.1 Manage the Grant & Consortium Agreement and their implementation, establish the internal and external project communication (EC), timely distribution of all information, collection of feedback, manage any issue and act as helpdesk (FLSMIDTH). Task 7.2 Implement and execute the Recruitment Strategy as described in Sec. 3.2 (FLS, all Beneficiaries and DC hosts). Task 7.3 Monitor progress and assure research and training quality: coordinate deliverables and milestones as well as the internal and external reports to the EC (e.g. progress reports), monitor the collaboration inside the WPs (FLS, all WP Leaders). Task 7.4 Monitor the risks and adjust in case needed; implement risk mitigation measures: develop, update and distribute the Risk Management Plan every six months (FLS) with contributions from all other partners. Task 7.5 Develop, update and distribute the Data Management Plan every six months, ensure the creation of metadata and uniform storage standards among all DCs, monitor the implementation of the Open Access Policy (FLS). Task 7.6 Collaborations with other EU projects to exchange best practices and leverage for communication and exploitation (FLS).

STAFF EFFORT

Staff effort per participant

Grant Preparation (Work packages - Effort screen) — Enter the info.

Participant	WP1	WP2	WP3	WP4	WP5	WP6	WP7	Total Person-Months
1 - FLS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	7.00
2 - CNRS	1.00	1.00			1.00	1.00	1.00	5.00
3 - RWTH	1.00	1.00			1.00	1.00	1.00	5.00
4 - TUD		1.00	1.00		1.00	1.00	1.00	5.00
5 - UNIPD			1.00		1.00	1.00	1.00	4.00
6 - IHS				1.00	1.00	1.00	1.00	4.00
7 - STW		1.00	1.00		1.00	1.00	1.00	5.00
8 - C2CA		1.00	1.00	1.00	1.00	1.00	1.00	6.00
9 - MNK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	7.00
Total Person-Months	4.00	7.00	6.00	4.00	9.00	9.00	9.00	48.00

LIST OF DELIVERABLES

Deliverables

Grant Preparation (Deliverables screen) — Enter the info.

The labels used mean:

Public — fully open (⚠ automatically posted online)
Sensitive — limited under the conditions of the Grant Agreement
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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D1.1	Experimental protocol to evaluate SCMs reactivity	WP1	3 - RWTH	R — Document, report	SEN - Sensitive	10
D1.2	Prediction model of clinker mineralogy (basic framework and input parameters)	WP1	2 - CNRS	R — Document, report	SEN - Sensitive	24
D1.3	SCMs activation process control & reactivity models (thermal, chemical, mechanical)	WP1	2 - CNRS	R — Document, report	SEN - Sensitive	30
D1.4	Summary report on numerical models applied to predict SCM reactivity	WP1	1 - FLS	R — Document, report	SEN - Sensitive	36
D2.1	Prediction tool for clinker interaction with SCMs – Blender optimization tool	WP2	9 - MNK	R — Document, report	SEN - Sensitive	34
D2.2	Life cycle environmental impacts of low carbon cement	WP2	8 - C2CA	R — Document, report	PU - Public	28
D2.3	Economic and environmental impact of material variability on concrete production	WP2	4 - TUD	R — Document, report	PU - Public	24
D2.4	Durability models at the concrete scale (description of physical models)	WP2	8 - C2CA	R — Document, report	SEN - Sensitive	24
D2.5	Durability models at the concrete scale (upscaling from cement paste to concrete)	WP2	8 - C2CA	R — Document, report	SEN - Sensitive	36

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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D2.6	Performance-based design tool for low-carbon concrete mixes	WP2	3 - RWTH	R — Document, report	SEN - Sensitive	36
D3.1	Validated Soft sensor for in-process quality monitoring of cement grinding / blending	WP3	1 - FLS	R — Document, report	SEN - Sensitive	32
D3.2	ML methodology to predict product quality in cement/concrete production	WP3	7 - STW	R — Document, report	SEN - Sensitive	32
D3.3	Report on the environmental impact of digitalization in cement production	WP3	5 - UNIPD	R — Document, report	PU - Public	24
D3.4	RFID technology to monitor and track the quality of materials in cement value chain	WP3	8 - C2CA	R — Document, report	SEN - Sensitive	36
D3.5	Characterisation of SCM reactivity via computer vision based system	WP3	1 - FLS	R — Document, report	SEN - Sensitive	20
D3.6	Integration of hyperspectral technology to SCM characterisation method	WP3	1 - FLS	DEM — Demonstrator, pilot, prototype	SEN - Sensitive	30
D3.7	Process data sheet for SRM	WP3	8 - C2CA	R — Document, report	SEN - Sensitive	13
D4.1	List of bottlenecks related to low-carbon cement market acceptance	WP4	6 - IHS	R — Document, report	PU - Public	18
D4.2	Environmental and economic impacts of concrete made with low-carbon cement	WP4	4 - TUD	R — Document, report	PU - Public	32

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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D4.3	Report on "The future of cement and concrete industry"	WP4	6 - IHS	R — Document, report	PU - Public	36
D5.1	First network-wide training event	WP5	1 - FLS	R — Document, report	PU - Public	10
D5.2	Career Development Plans	WP5	5 - UNIPD	R — Document, report	SEN - Sensitive	13
D6.1	Project Website	WP6	1 - FLS	DEC —Websites, patent filings, videos, etc	PU - Public	2
D6.2	Plan for the dissemination and exploitation of results, including communication activities (2 deliverables but with different timing for submission) – Version 1	WP6	1 - FLS	R — Document, report	SEN - Sensitive	13
D6.3	Plan for the dissemination and exploitation of results, including communication activities (2 deliverables but with different timining for submission) – Version 2	WP6	1 - FLS	R — Document, report	SEN - Sensitive	48
D6.4	Project video or animation	WP6	1 - FLS	DEC —Websites, patent filings, videos, etc	PU - Public	24
D6.5	International Workshops I	WP6	1 - FLS	R — Document, report	SEN - Sensitive	16
D6.6	International Workshops II	WP6	1 - FLS	R — Document, report	SEN - Sensitive	28
D6.7	International Workshop III	WP6	1 - FLS	R — Document, report	SEN - Sensitive	40
D7.1	Supervisory Board of the network	WP7	1 - FLS	OTHER	SEN - Sensitive	2

Deliverables

Grant Preparation (Deliverables screen) — Enter the info.

The labels used mean:

Public — fully open (automatically posted online)
Sensitive — limited under the conditions of the Grant Agreement
EU classified —RESTREINT-UE/EU-RESTRICTED, CONFIDENTIEL-UE/EU-CONFIDENTIAL, SECRET-UE/EU-SECRET under Decision 2015/444

Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D7.2	Report on DC recruitment	WP7	1 - FLS	R — Document, report	SEN - Sensitive	12
D7.3	Progress Report	WP7	1 - FLS	R — Document, report	SEN - Sensitive	13
D7.4	Data Management Plan	WP7	1 - FLS	R — Document, report	SEN - Sensitive	13
D7.5	Risk Management Plan	WP7	1 - FLS	R — Document, report	SEN - Sensitive	18
D7.6	Report on collaboration activities with other projects	WP7	1 - FLS	R — Document, report	SEN - Sensitive	48

Deliverable D1.1 – Experimental protocol to evaluate SCMs reactivity

Deliverable Number	D1.1	Lead Beneficiary	3. RWTH
Deliverable Name	Experimental protocol to evaluate SCMs reactivity		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	10	Work Package No	WP1

Description
An experimental protocol (report) for evaluating the reactivity of SCMs used in cement production. The protocol will be designed to provide a standardized approach for evaluating the performance of different SCMs under various activation conditions. The experimental protocol will include detailed instructions on the preparation of the SCM samples and testing procedures. The protocol will be designed to evaluate the reactivity of SCMs by measuring key parameters such as the degree of reaction, the rate of reaction, and/or the extent of phase transformations.

Deliverable D1.2 – Prediction model of clinker mineralogy (basic framework and input parameters)

Deliverable Number	D1.2	Lead Beneficiary	2. CNRS
Deliverable Name	Prediction model of clinker mineralogy (basic framework and input parameters)		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	24	Work Package No	WP1

Description
A prediction model of clinker mineralogy that provides a basic framework and input parameters for predicting the mineralogical composition of clinker in cement production. The model will be based on a comprehensive understanding of the chemical and physical processes that govern clinker formation. The model will consider the impact of various factors on clinker mineralogy, e.g. raw material composition, fuel type and quality, kiln operation parameters, and / or clinker cooling rate. The prediction model will be developed using a combination of experimental data and modelling approaches. It will be validated using data from industrial-scale cement production processes. The model will provide a basic framework for predicting clinker mineralogy that can be used by cement producers to optimize their production processes.

Deliverable D1.3 – SCMs activation process control & reactivity models (thermal, chemical, mechanical)

Deliverable Number	D1.3	Lead Beneficiary	2. CNRS
Deliverable Name	SCMs activation process control & reactivity models (thermal, chemical, mechanical)		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	30	Work Package No	WP1

Description
A set of process control and reactivity models for SCMs activation. The models will be developed for each of the three main activation methods: thermal, chemical, and mechanical activation (each of the three activation methods will have a separate set of models developed, with input parameters specific to the method). In general, the “process control models” will provide a basic framework for controlling the activation process, considering the input parameters such as temperature, pressure, duration, and activation agent (admixtures) dosage. Whereas the “reactivity models” will be used to predict the reactivity of SCMs based on the activation method used. The models will consider the impact of various

factors on SCM reactivity, e.g. chemical composition, particle size distribution, and curing conditions. The models will be developed using a combination of experimental data and modelling approaches and will be validated using data from industrial-scale cement production processes or laboratory data.

Deliverable D1.4 – Summary report on numerical models applied to predict SCM reactivity

Deliverable Number	D1.4	**Lead Beneficiary**	1. FLS
Deliverable Name	Summary report on numerical models applied to predict SCM reactivity		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	36	**Work Package No**	WP1

Description
A report evaluating the accuracy and reliability of different modelling approaches, including empirical, semi-empirical, and/or mechanistic models developed within the project. The report will include a short review on the factors impacting SCM reactivity with CEM I, e.g. chemical composition, particle size distribution, and curing conditions. The report will also provide an overview of the most used numerical models for predicting SCM reactivity, including their strengths and limitations. The report will also consider the practical applications of these models, including their use in optimizing SCM blends in cement production, assessing the potential for modelling approaches to improve the sustainability and cost-effectiveness of low-carbon cement production.

Deliverable D2.1 – Prediction tool for clinker interaction with SCMs – Blender optimization tool

Deliverable Number	D2.1	**Lead Beneficiary**	9. MNK
Deliverable Name	Prediction tool for clinker interaction with SCMs – Blender optimization tool		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	34	**Work Package No**	WP2

Description
A prediction model that estimates the strength development of mixes produces with blended cements (i.e. CEM I + SCMs) as the main binder system. The model is built upon first-principle model and a database of laboratory test results generated during the project (from DC1-5 and DC11, and complemented by existing data from cement laboratories and obtained from literature reviews).

Deliverable D2.2 – Life cycle environmental impacts of low carbon cement

Deliverable Number	D2.2	**Lead Beneficiary**	8. C2CA
Deliverable Name	Life cycle environmental impacts of low carbon cement		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	28	**Work Package No**	WP2

Description
A report summarising the preliminary life cycle inventory data and environmental life cycle assessment results for low and very-low clinker content cements analysed in DCs 6 and 13.

Associated with document Ref. Ares(2023)4821121 - 11/07/2023

Deliverable D2.3 – Economic and environmental impact of material variability on concrete production

Deliverable Number	D2.3	**Lead Beneficiary**	4. TUD
Deliverable Name	Economic and environmental impact of material variability on concrete production		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	24	**Work Package No**	WP2

Description
The report will be based on a comprehensive review of literature and data analysis from concrete production. It will consider the impact of variability in raw and recycled materials, such as aggregates, cement, and water content, on concrete properties and performance, helping estimate the impact of material variability on CO2 emissions in concrete production (including the emissions from the concrete mixes). The economic analysis will consider the cost of producing concrete with varying material properties, including the cost of raw / recycled materials, transportation, and processing.

Deliverable D2.4 – Durability models at the concrete scale (description of physical models)

Deliverable Number	D2.4	**Lead Beneficiary**	8. C2CA
Deliverable Name	Durability models at the concrete scale (description of physical models)		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	24	**Work Package No**	WP2

Description
A report describing selected physical models (with their relevant parameters) that describe concrete durability. The model description captures a relevant degradation mechanism (or mechanisms) that affect concrete performance over time.

Deliverable D2.5 – Durability models at the concrete scale (upscaling from cement paste to concrete)

Deliverable Number	D2.5	**Lead Beneficiary**	8. C2CA
Deliverable Name	Durability models at the concrete scale (upscaling from cement paste to concrete)		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	36	**Work Package No**	WP2

Description
A preliminary durability model that scales up from the cement paste level to the concrete level. The model provides an estimate of concrete's long-term performance under a selected exposure conditions and material type.

Deliverable D2.6 – Performance-based design tool for low-carbon concrete mixes

Deliverable Number	D2.6	**Lead Beneficiary**	3. RWTH
Deliverable Name	Performance-based design tool for low-carbon concrete mixes		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive

Due Date (month)	36	Work Package No	WP2

Description
A report summarising the status of development of the tool for performance-based design of concrete in terms of durability, mechanical properties, and life cycle environmental impacts. This tool will be developed in DC6 and relies on additional data produced across DC5 to 8 (complemented by data obtained from literature reviews).

Deliverable D3.1 – Validated Soft sensor for in-process quality monitoring of cement grinding / blending

Deliverable Number	D3.1	Lead Beneficiary	1. FLS
Deliverable Name	Validated Soft sensor for in-process quality monitoring of cement grinding / blending		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	32	Work Package No	WP3

Description
The soft sensor will be validated using historical data and will be trained to recognize the relationships between the input variables (such as temperature, pressure, and humidity) and the output variables (such as fineness and strength) that affect the quality of the cement blend. The sensor will be designed to work in real-time, allowing operators to adjust the process parameters and take corrective actions to maintain quality standards.

Deliverable D3.2 – ML methodology to predict product quality in cement/concrete production

Deliverable Number	D3.2	Lead Beneficiary	7. STW
Deliverable Name	ML methodology to predict product quality in cement/concrete production		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	32	Work Package No	WP3

Description
The ML methodology will be a set of procedures, algorithms, and tools that will be designed to analyse and interpret the data collected from the cement/concrete production process. The methodology will use advanced statistical and machine learning techniques to develop a predictive model that can forecast the quality of the final product (cement / concrete)

Deliverable D3.3 – Report on the environmental impact of digitalization in cement production

Deliverable Number	D3.3	Lead Beneficiary	5. UNIPD
Deliverable Name	Report on the environmental impact of digitalization in cement production		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	24	Work Package No	WP3

Description
A report with qualified estimates of CO2 emission savings due to the implementation of digital technologies in cement production, particularly on process optimization and monitoring (by soft-sensors, numerical models, artificial intelligence).

Associated with document Ref. Ares(2023)4821121 - 11/07/2023

Deliverable D3.4 – RFID technology to monitor and track the quality of materials in cement value chain

Deliverable Number	D3.4	**Lead Beneficiary**	8. C2CA
Deliverable Name	RFID technology to monitor and track the quality of materials in cement value chain		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	36	**Work Package No**	WP3

Description
This deliverable comprises a) an online database of materials properties, b) a document / report with user requirements, c) an optimized user interface to access database and sensor data, and d) a commercial proof-of-concept of the RFID technology.

Deliverable D3.5 – Characterisation of SCM reactivity via computer vision based system

Deliverable Number	D3.5	**Lead Beneficiary**	1. FLS
Deliverable Name	Characterisation of SCM reactivity via computer vision based system		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	20	**Work Package No**	WP3

Description
A report describing the new metric of SCM reactivity based on computer vision analysis. The metric should be tested for at least one type of SCM, e.g. calcined clay.

Deliverable D3.6 – Integration of hyperspectral technology to SCM characterisation method

Deliverable Number	D3.6	**Lead Beneficiary**	1. FLS
Deliverable Name	Integration of hyperspectral technology to SCM characterisation method		
Type	DEM — Demonstrator, pilot, prototype	**Dissemination Level**	SEN - Sensitive
Due Date (month)	30	**Work Package No**	WP3

Description
A hyperspectral imaging sensor is integrated and tested in the computer vision setup utilised for characterising th ereactivity of SCMs.

Deliverable D3.7 – Process data sheet for SRM

Deliverable Number	D3.7	**Lead Beneficiary**	8. C2CA
Deliverable Name	Process data sheet for SRM		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	13	**Work Package No**	WP3

Description
Process diagram (mass and energy flows) describing the necessary parts (equipemt) to process a range of Secondary Raw Materials into Supplementary cementitious materials.

Deliverable D4.1 – List of bottlenecks related to low-carbon cement market acceptance

Deliverable Number	D4.1	**Lead Beneficiary**	6. IHS
Deliverable Name	List of bottlenecks related to low-carbon cement market acceptance		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	18	**Work Package No**	WP4

Description
A report with detailed analysis of the factors that are affecting the market acceptance of low-carbon cement, including technical, economic, regulatory, and social factors. The technical analysis considers challenges related to the development and production of low-carbon cement, e.g. the availability and cost of raw materials, the performance and durability of the cement, and the compatibility with existing construction practices and standards. The economic analysis considers the cost competitiveness of low-carbon cement compared to conventional cement, as well as the potential for market growth and investment opportunities. The regulatory analysis considers the impact of government policies, regulations, and incentives on the adoption of low-carbon cement, including building codes, standards, and certification programs. The social analysis considers the attitudes and perceptions of stakeholders towards low-carbon cement, including their awareness, knowledge, and preferences.

Deliverable D4.2 – Environmental and economic impacts of concrete made with low-carbon cement

Deliverable Number	D4.2	**Lead Beneficiary**	4. TUD
Deliverable Name	Environmental and economic impacts of concrete made with low-carbon cement		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	32	**Work Package No**	WP4

Description
A report summarising the final life cycle inventory data and environmental life cycle assessment results for low and very-low clinker content cements analysed in DCs 6 and 13. Data on different concrete mixes from DC7 and 12 will complement the analysis provided in this report. The report also provides an economic analysis for exemplary low and very low clinker content cements.

Deliverable D4.3 – Report on “The future of cement and concrete industry”

Deliverable Number	D4.3	**Lead Beneficiary**	6. IHS
Deliverable Name	Report on “The future of cement and concrete industry”		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	36	**Work Package No**	WP4

Description
The report will provide an overview of the current state of the cement and concrete industry, including production

volumes, consumption patterns, and market trends. The report will evaluate the impact of new and emerging technologies, (focus on alternative raw materials, and digitalization – core topics in DETOCS) on the cement and concrete industry. It will also assess the potential for circular economy approaches, e.g. recycling and reuse, to reduce waste and emissions, while considering the role of the cement and concrete industry in sustainable development.

Deliverable D5.1 – First network-wide training event

Deliverable Number	D5.1	**Lead Beneficiary**	1. FLS
Deliverable Name	First network-wide training event		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	10	**Work Package No**	WP5

Description
A document that gives a retrospective view on the first international DETOCS Training School, including an overview of the event, participants, lectures, lessons learned and outlook to next events.

Deliverable D5.2 – Career Development Plans

Deliverable Number	D5.2	**Lead Beneficiary**	5. UNIPD
Deliverable Name	Career Development Plans		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	13	**Work Package No**	WP5

Description
Document describing how the individual Career Development Plans have been established (listing also the researchers for whom such plans have been put in place). This document is to be submitted before the mid-term meeting.

Deliverable D6.1 – Project Website

Deliverable Number	D6.1	**Lead Beneficiary**	1. FLS
Deliverable Name	Project Website		
Type	DEC —Websites, patent filings, videos, etc	**Dissemination Level**	PU - Public
Due Date (month)	2	**Work Package No**	WP6

Description
Deliver the DETOCS project website to support recruitment and inform about the challenges, objectives, methodology, team, major project outcomes and public training events

Deliverable D6.2 – Plan for the dissemination and exploitation of results, including communication activities (2 deliverables but with different timing for submission) – Version 1

Deliverable Number	D6.2	**Lead Beneficiary**	1. FLS

Deliverable Name	Plan for the dissemination and exploitation of results, including communication activities (2 deliverables but with different timing for submission) – Version 1		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	13	**Work Package No**	WP6

Description
A document that outlines the DETOCs plans for the dissemination of the results among scientists and industrial innovators, the targeted use of the results to generate benefits and major communication activities to inform different audiences about the project. Note: Plan for the dissemination and exploitation of results, including communication activities, submitted at mid-term (M13) and an update towards the end of the project (M48). This plan should be periodically updated, and an updated version is required by M48. More information on how to prepare this deliverable can be found online at https://rea.ec.europa.eu/horizon-europe-dissemination-and-exploitation_en and in the Horizon Europe Programme Guide

Deliverable D6.3 – Plan for the dissemination and exploitation of results, including communication activities (2 deliverables but with different timining for submission) – Version 2

Deliverable Number	D6.3	**Lead Beneficiary**	1. FLS
Deliverable Name	Plan for the dissemination and exploitation of results, including communication activities (2 deliverables but with different timining for submission) – Version 2		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	48	**Work Package No**	WP6

Description
A document that outlines the DETOCs plans for the dissemination of the results among scientists and industrial innovators, the targeted use of the results to generate benefits and major communication activities to inform different audiences about the project. Note: Plan for the dissemination and exploitation of results, including communication activities, submitted at mid-term (M13) and an update towards the end of the project (M48). This plan should be periodically updated, and an updated version is required by M48. More information on how to prepare this deliverable can be found online at https://rea.ec.europa.eu/horizon-europe-dissemination-and-exploitation_en and in the Horizon Europe Programme Guide

Deliverable D6.4 – Project video or animation

Deliverable Number	D6.4	**Lead Beneficiary**	1. FLS
Deliverable Name	Project video or animation		
Type	DEC —Websites, patent filings, videos, etc	**Dissemination Level**	PU - Public
Due Date (month)	24	**Work Package No**	WP6

Description
Creation of a project video that explains the overall problem, the DETOCS objectives and how each Doctoral Candidate will tackle the challenges and generate new scientific knowledge for tomorrow’s technologies.

Deliverable D6.5 – International Workshops I

Deliverable Number	D6.5	Lead Beneficiary	1. FLS
Deliverable Name	International Workshops I		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	16	Work Package No	WP6

Description
A document that gives a retrospective on the workshop with its elements such as poster sessions, DC presentations, keynotes, podium discussions, etc. to train the DCs in scientific reasoning and networking.

Deliverable D6.6 – International Workshops II

Deliverable Number	D6.6	Lead Beneficiary	1. FLS
Deliverable Name	International Workshops II		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	28	Work Package No	WP6

Description
A document that gives a retrospective on the workshop, including lessons learned, the art of scientific reasoning and networking with internal and external stakeholders.

Deliverable D6.7 – International Workshop III

Deliverable Number	D6.7	Lead Beneficiary	1. FLS
Deliverable Name	International Workshop III		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	40	Work Package No	WP6

Description
A document showing the engagement with potential future academic and industrial employers and stakeholders from other sectors such as finance and NGOs.

Deliverable D7.1 – Supervisory Board of the network

Deliverable Number	D7.1	Lead Beneficiary	1. FLS
Deliverable Name	Supervisory Board of the network		
Type	OTHER	Dissemination Level	SEN - Sensitive
Due Date (month)	2	Work Package No	WP7

Description
A document that defines the way of working, the members of the supervisory board, including the representatives and

deputy representatives, as well as the procedures to monitor progress and quality, career development, and decision-making.

Deliverable D7.2 – Report on DC recruitment

Deliverable Number	D7.2	**Lead Beneficiary**	1. FLS
Deliverable Name	Report on DC recruitment		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	12	**Work Package No**	WP7

Description
A document summarizing the general recruitment procedure and the individual recruitment activities for each Doctoral Candidate position to show compliance with the Code of Conduct for Recruitment of Researchers.

Deliverable D7.3 – Progress Report

Deliverable Number	D7.3	**Lead Beneficiary**	1. FLS
Deliverable Name	Progress Report		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	13	**Work Package No**	WP7

Description
Mandatory report according to the Grant Agreement to monitor the progress of the action (covering the first year implementation of the project) and to outline potential project adjustments to fulfil the needs of the Doctoral Candidates

Deliverable D7.4 – Data Management Plan

Deliverable Number	D7.4	**Lead Beneficiary**	1. FLS
Deliverable Name	Data Management Plan		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	13	**Work Package No**	WP7

Description
A document that describes the life cycle for DETOCS data that will be collected, generated and processed in order to make the research data findable, accessible, interoperable and re-useable (FAIR). Note that this document will be updated towards the end of the project if needed.

Deliverable D7.5 – Risk Management Plan

Deliverable Number	D7.5	**Lead Beneficiary**	1. FLS
Deliverable Name	Risk Management Plan		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	18	**Work Package No**	WP7

Description
Extended risk analysis and update of the initially identified risks through a risk assessment workshop to enhance awareness and to adjust the risk mitigation measures and contingency plans.

Deliverable D7.6 – Report on collaboration activities with other projects

Deliverable Number	D7.6	**Lead Beneficiary**	1. FLS
Deliverable Name	Report on collaboration activities with other projects		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	48	**Work Package No**	WP7

Description
A report on collaboration activities to identify further potential synergies that benefit the Doctoral Candidates and supports the exploitation of the DETOCS results.

LIST OF MILESTONES

Milestones

Grant Preparation (Milestones screen) — Enter the info.

Milestone No	Milestone Name	Work Package No	Lead Beneficiary	Means of Verification	Due Date (month)
1	Executive Board kick-off meeting	WP7	1-FLS	Documentation of the meeting such as minutes, agendas, and attendance lists. Stakeholder interviews and action item tracking can also provide additional verification.	3
2	Planned recruitments completed	WP7	1-FLS	Document with a list of planned recruitments against the list of completed recruitments. Documentation such as contracts can be used to confirm that the recruitment process has been completed for all planned positions.	12
3	All communication measures put in place	WP7	5-UNIPD	Document with the project communication plan. This confirms that all identified communication measures have been prepared and distributed to the project partners.	7
4	All recruited fellows enrolled in PhD programme	WP7	1-FLS	All recruited fellows have completed the necessary paperwork and formalities required for enrollment in the PhD programme.	12
5	Training School / Online Training 1 and 2 are completed	WP6	2-CNRS	The Training School and Online Training 1 and 2 have been successfully completed by all participants. Verification will be provided through attendance records.	20
6	Training School / Online Training 3 and 4 are completed	WP6	1-FLS	The Training School and Online Training 3 and 4 have been successfully completed by all participants. Verification will be provided through attendance records.	38
7	Best RFID tag type and manufacturer are identified	WP3	8-C2CA	Verification will be provided through a report documenting the testing methodology, results,	17

Milestones

Grant Preparation (Milestones screen) — Enter the info.

Milestone No	Milestone Name	Work Package No	Lead Beneficiary	Means of Verification	Due Date (month)
				and conclusion, as well as the procurement of the selected RFID tags from the identified manufacturer.	
8	Dataset with process and material data from concrete plants are collected	WP2	9-MNK	A dataset containing relevant process and material data from concrete plants has been successfully collected. The collected data will be used for further analysis and development of the project's objectives. Verification will involve confirming the availability and accessibility of the collected dataset.	24
9	Interview with cement and concrete stakeholders / end-users is finalised	WP4	6-IHS	A report summarising the findings and insights obtained from the interviews with cement and concrete stakeholders/end-users is completed and submitted to the project team.	32
10	Consortium Agreement	WP7	1-FLS	The agreement should be signed by all consortium members.	2
11	Project mid-term check	WP7	1-FLS	The project team will provide an overview of the work that has been completed so far, as well as the work that remains to be done. This will be done via a mid-term report and meeting with the EU Project Officer.	13

LIST OF CRITICAL RISKS

Critical risks & risk management strategy

Grant Preparation (Critical Risks screen) — Enter the info.

Risk number	Description	Work Package No(s)	Proposed Mitigation Measures
1	Insufficient supervision	WP5	1. Coordinator collects feedback from DCs every 3 months; 2. Coordinator collects feedback from the supervisors every 3 months; 3. Cross-monitoring from the SB and DC representatives.
2	Insufficient participation of the private sector in the training	WP5	1. Early communication of the events and expectations; 2. Request for additional training from companies outside the network based on existing contacts of the participating organisations.
3	Low participation from outside the network	WP5	1. Early advertising of network events; 2. Utilisation of the contact network of all participating organisations; 3. Collaboration with local grad-schools and advertising of the events on university, company and association channels.
4	Training material not sufficiently prepared	WP5	1. Preparation of all information in advance, schedule and quality check by the coordinator; 2. WP leader provides templates, follow-up, progress monitoring.
5	Unstructured datasets (time series)	WP1, WP3	1. Pre-select reliable data (ARGOS, MNK); 2. Combine first-principle model and ML.
6	Fragmented value chain leading to loss of information	WP3	1. Instant quality indicators through measurement techniques or material passports logging quality information; 2. Develop tracing technology; 3. Early Testing.
7	Lack of correlation between input and output	WP3	1. Combine first-principle model and ML; 2. Advancing the data science approach to identify hidden correlations; 3. Early and frequently testing.
8	TU Delft studies reveals barriers cannot be overcome	WP4	1. Intrinsic risk related to research and useful outcome to consider alternative means to decarbonize the industry.
9	Insufficient contribution of DCs to dissemination	WP6	1. Update and review the CDPs every three months; 2. Meet with supervisor every week and discuss results ready for exploitation or dissemination.
10	Conflicts in creation and utilisation of IP	WP6	1. Clear definition of the foreground and background IP; 2. Carefully drafted Grant/ Consortium Agreement; 3. Involvement of a neutral third party for decision making.

Critical risks & risk management strategy

Grant Preparation (Critical Risks screen) — Enter the info.

Risk number	Description	Work Package No(s)	Proposed Mitigation Measures
11	Lack of excellent applicants	WP7	1. Preparation of well-defined job offers; publication on relevant job-related websites (Monster.com, Euraxess.eu, etc.); 2. Networks of supervisor/co-supervisor.
12	Delay in recruitment	WP7	1. Start of job interviews one week after application deadline; 2. Strong administrative support to avoid delays due to visa issues, invitation letters etc.
13	Resigning of DC before end of contract	WP7	1. Strong supervision process and early conflict resolution; 2. Fast publication of the open position (while contract of DC is still valid); 3. Review of past applications and eventually re-contact of candidates; 4. Direct contact of peer scientists abroad.
14	Less participation of WP leaders in the management	WP7	1. Performance tracking by NC and SB; 2. Fast replacement of the WP leader with a new person based on a majority decision by the supervisory board.
15	Computer vision cannot capture SCM Reactivity of several material types	WP3	Limit the scope of the project to the materials that can be tested used computed vision, e.g. calcined clays.
16	The high variability in the chemical composition of Secondary Raw Materials hinders the development of a general process model with self adapting capabilities	WP3	Selection of a limited number of Secondary Raw Materials; specifically, those that have a greater relevance to cement production and that have a greater share of process data available in order to train ML models.

PROJECT REVIEWS

Project Reviews

Grant Preparation (Reviews screen) — Enter the info.

Review No	**Timing** (month)	**Location**	**Comments**
RV1	24	REMOTE	
RV2	48	REMOTE	

Horizon Europe (HORIZON)
Marie Skłodowska-Curie Actions
Doctoral Networks (MSCA-DN)

ANNEX 1

Description of the action (DoA)

Part B

DETOCS

Data **E**nabling **T**ransformation
and **O**ptimization towards **C**oncrete **S**ustainability

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History of changes

Associated with document Ref. Ares(2023)4821121 - 11/07/2023

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Page Nr.	Change	Justification
7 (All)	Partner list updated	The partners number and short name were updated to match the data available in SYGMA. Also, IMP and ABD status was changed to Assoc. Partner. The DC numbers were updated in the entire document.
13	Partner list updated for DC6	C2CA took the leading role in DC6 and RWTH has replaced IMP as the academic partner.
17	The former DC13 is now labelled DC15	To keep the DC numbering consistent, we moved the original DC13 (led by IMP) to DC15. No changes to the scope of the project were made. Refer to “Report with proposed modifications” document.
15 - 16	Description of DC13 and DC14 included	New positions were added to provide additional opportunities for talented DCs to carry out research on complementary aspects to the scope of DETOCS, namely digital solutions applied to cement production with the aim to reduce CO2 emissions. Refer to “Report with proposed modifications” for more details.
29	Table 3.1f – the description of DC13 & 14 tasks and deliverables were included.	This is necessary to align the scope and deliverables of DC13 and DC14 with the entire project. The Individual research projects, including secondment plan for the new DC13 and 14 were included. Also, the deliverables number in Table 3.1c was updated to match the data from SyGMa.
22	Table 1.4a updated for IMP, ABD and TUD	IMP and ABD are now placed in the Associated Partner list. For TUD staff, we added the researcher Yongli Wu (who will be the academic supervisor to DC14).
23	Table 1.4b modified (DC6, Joint supervision arrangements, new DC13 and DC14)	Joint supervision arrangements checked based on the identified weakness in the Evaluation Summary Report. Two Inconsistencies in document B2 were identified and corrected (MNK and ECOS). The arrangement for the DC6 and the new DC13 & 14 were included. An academic supervisor from RWTH was included for DC8 (in collaboration with EPFL – which is from Switzerland)
29	The allocation of the DCs is updated in Table 3.1e	The table presents the updated Hosts / Secondments in the project after the inclusion of 2 new DCs and change of roles from UK Partners from Beneficiary to Assoc. Partner.

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LIST OF PARTICIPATING ORGANISATIONS

Consortium Member	Legal Entity Short Name	Academic	Non-academic	Awards Degree	Country	Dept. / Division / Laboratory	Scientist-in-Charge	Role of Partner Organisation
Beneficiaries								
1 FLSMIDTH A/S	**FLS**		X		DK	Cement R&D and Innovation	Bodil Recke*	
2 Centre national de la recherche scientifique	**CNRS**	X		X	FR	Thermodynamics	Alexander Pisch	
3 RWTH Aachen	**RWTH**	X		X	DE	Construction materials	Thomas Matschei	
4 TU Delft	**TUD**	X		X	NL	Recycling and waste materials	Peter Rem	
5 University of Padova	**UNIPD**	X		X	IT	Information Engineering	Fabrizio Bezzo	
6 University of Rotterdam	**IHS**	X		X	NL	Erasmus School of Economics	Beatriz Olvera*	
7 Statwolf	**STW**		X		IE	Data Analytics	Chiara Masiero*	
8 C2CA Technology B.V.	**C2CA**		X		NL	Process Development and Scale-up	Frank Rens	
9 Mannok Holdings	**MNK**		X		IE	Cement and concrete production	Hoda Beltagui*	
Associated Partners								
10 University of Aberdeen	**ABD**	X		X	UK	Chemical Engineering	Marcus Bannerman	
11 Imperial College London	**IMP**	X		X	UK	Material science	Rupert Myers	
12 Cementos Argos S.A.	**ARGOS**		X		CO	Cement and Concrete R&D	Daniel Duque	Secondments, SB and training
13 EPFL	**EPFL**	X		X	CH	Laboratory of Construction Materials	Karen Scrivener*	DC, training, SB, visits
14 ETH Zürich	**ETHZ**	X		X	CH	Physical Chemistry of Materials	Timothy Wangler	DC, training, SB, visits
15 Massachusetts Institute of Technology	**MIT**	X		X	US	Computing	Elsa Olivetti*	Training, SB, career advice
16 Environmental Coalition on Standards	**ECOS**		X		BE	Standardisation	Joren Verschaeve	Secondments, SB and training
17 ParticleTech ApS	**PTECH**	X		X	DK	Measurement technologies	Trine Andersen*	Training, SB, career advice
Associated Partner linked to a Beneficiary								
18 Université Grenoble Alpes (CNRS)	**UOG**	X		X	FR	Thermodynamics	Alexander Pisch	Graduation of DC1
External Advisory Board								
19 Breakthrough Energy	**BE**		X		BE	Foundation	Pénélope le Ménestrel*	Training, SB, career advice
20 German Cement Association	**VDZ**		X		DE	Policy Making	Jörg Rickert	Training, SB, career advice
21 Kline Consulting	**KLINE**		X		US	Innovation Management	John Kline	Training, SB, career advice
22 Kompas Venture Capital	**KVC**		X		NL	Venture Capital	Sebastian Peck	Training, SB, career advice

***Influential DETOCS female leaders**

Data for non-academic beneficiaries:

Name	Location of research premises	Type of R&D activities	No. of full-time employees	No. of employees in R&D	Web site	Annual turnover (Euro)	Enterprise status	SME status
FLS	DK	R&I	12,000	175	www.flsmidth.com	2.2 Bn	x	
C2CA	NL	R&I	12	8	www.c2ca.eu	1.5 Mn		x
MNK	IE	R&I	8,000	250	www.mannokbuild.com	3.3 Bn	x	
STW	IE	R&I	14	7	www.statwolf.com	3.4 Mn		x

Declarations

No inter-relationship between different participating institutions or individuals (e.g. family ties, shared premises or facilities, joint ownership, financial interest, overlapping staff or directors, etc.) has been identified in the consortium.

United Kingdom: The UK government gives a Horizon Europe guarantee and funds the participation of ICL and ABD through UK Research and Innovation (UKRI). The associated DCs will implement all research tasks, obtain co-supervision, participate in all network-wide trainings, conduct the local trainings, and contribute to dissemination, exploitation, and communication activities - as described here. The Letters of Commitments are included in part B2 and partner descriptions are adjusted.

Switzerland: The Swiss Government will fund two DC hosts: ETHZ and EPFL. Therefore, funding is not requested from the EU for the two related DC projects described in the proposal. Instead, funding will be provided by the State Secretariat for Education, Research and Innovation, SERI under the condition that the full project application is assessed as eligible for funding by the European Commission or by the agency commissioned for this purpose (see Letters of Commitments, part B2).

List of abbreviations:

AI	*Artificial Intelligence*
BET	*Brunauer, Emmett and Teller*
CA	*Consortium Agreement*
CAPEX	*Capital Expenditure*
CC	*Calcined Clay*
CDP	*Career Development Plan*
DC	*Doctoral Candidate*
DFT	*Density Functional Theory*
DIFFI	*Depth-based Isolation Forest Feature Importance*
DMP	*Data Management Plan*
DOI	*Digital Object Identifier*
EAB	*External Advisory Board*
EC	*European Commission*
ECTS	*European Credit Transfer System*
EIT	*European Institute of Innovation & Technology*
ERA	*European Research Area*
ERC	*European Research Council*
ET	*Executive Team*
EU	*European Union*
EUDP	*Energy Technology Development and Demonstration Programme*
GA	*Grant Agreement*
ICT	*Information and Communication Technology*
IP	*Intellectual Property*
IPR	*IP Rights*
IRP	*Individual Research Project of DC*
IT	*Information Technology*
ITN	*Innovative Training Networks*
KPI	*Key Performance Indicator*
LoC	*Letter of Commitment*
MGA	*Model Grant Agreement*
ML	*Machine Learning*
NC	*Network Coordinator (FLS)*
NLP	*Natural Language Processing*
NGO	*Non-governmental Organisation*
OEM	*Original Equipment Manufacturer*
OPC	*Ordinary Portland Cement*
OPEX	*Operating Expenses*
OS	*Open Science*
PBD	*Performance-based Design*
PCA	*Principal Component Analysis*
PSD	*Particle Size Distribution*
QXRD	*Quantitative X-ray Diffraction*
R&D	*Research and Development*
R&I	*Research and Innovation*
RCF	*Recycled Concrete Fines*
RFID	*Radio Frequency Identification*
ROI	*Return of Investment*
SB	*Supervisory Board*
SCM	*Supplementary cementitious materials*
SHAP	*Shapley Additive Explanations*
SSA	*Specific Surface Area*
TC	*Technical Committee*
UHF	*Ultra-High Frequency*
VP	*Vice president*
UOG	*University of Grenoble*
WP	*Work Package*
XRD	*X-ray Powder Diffraction*
XRF	*X-ray Fluorescence*

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1. Excellence

1.1 Quality and pertinence of the project's research and innovation objectives (and the extent to which they are ambitious, and go beyond the state of the art)

1.1.1 Introduction, objectives, and overview of the research programme

Introduction: The project "Data Enabling Transformation and Optimization towards Concrete Sustainability" (DETOCS) addresses the most urgent environmental battle there is: to decarbonize industrial emissions and achieve net zero emissions in 2050. Specifically, **DETOCS targets the cement industry, which contributes 8% of global man-made CO_2 emissions and, if left unattended, will increase to 26% by 2050**.

Cement is used to make concrete, the premier building material in the world that is made up of aggregates, water, and ca. 20% cement. The latter is made by fusing limestone with other minerals to produce an intermediate product called clinker, which has large CO_2 emissions (ca. 0.8 t.CO_2/t.clinker) resulting from limestone calcination and required fuel combustion. As such, the cement industry is a hard-to-abate sector and **replacing clinker is the easiest, fastest, and most industrially feasible lever to decarbonize the cement industry**.

Today, cement comprises clinker, gypsum, and Supplementary Cementitious Materials (SCMs). SCMs account for ca. 25% of cement (1.0 Gt/year) and are found as natural minerals (clays, shales, and pozzolans) or as industrial biproducts (fly ash, slag, silica fume, mine tailings, and recycled concrete fines). The global clinker-to-cement ratio is ca. 75%, which translates to 3.0 Gt/year of clinker.

From now to 2050, cement production is expected to grow from 4.2 to 5.0 Gt/year, driven by population growth and urbanization – 90% of which is in developing countries. With the utilization rate of cement plants stagnating at 70%, there is sufficient clinker production capacity to meet future urbanization needs. Thus, the industrial **focus is towards using less clinker and more SCMs to lower the carbon footprint of concrete**. This must be enabled by solutions compatible with developing economies that can repurpose existing industrial assets, i.e., low investments required. While the use of SCM is common, the global average clinker content in cements is ~75% today. Reducing clinker content will allow the industry to meet today's imperative environmental demands, and laboratory tests indicate that cement blends with only 25% clinker can be produced with equal quality to the existing solutions. To accommodate these new blends, the current "prescriptive" cement standards need to evolve towards performance-based specifications. For instance, the current EU standards [EN197] now specify 34 unique cement types, many of which utilize SCMs that meet stringent specifications. This diversification in cement composition raises new operation challenges, since the high volume of SCMs has an impact on how cement reacts, implying changes in concrete production and durability. To overcome this challenge, **DETOCS focuses on research actions to fast-track technologies that enable decarbonization of cement**, i.e., a) novel models to predict the reactivity of blended cement, b) process control of clinker and SCM production, c) mix optimization of cement blends; d) concrete quality prediction and process control, e) performance-based design of concrete, and f) material quality tracing methods along the value chain. For that, DETOCS relies on a combination of advanced first-principle models (based on thermodynamics and hydration kinetics), experimental analysis, and Machine Learning (ML) to couple process and material data. The DETOCS developments aim to enable three game-changers:

1. At the cement plant: make it possible to adjust blends in real-time, optimizing usage of low-CO_2 materials and minimizing clinker content. The solution should predict the synergistic effect between clinker and SCMs - then feed instructions back to the production process to optimize composition and production.

2. In SCM activation methods (thermal, chemical, mechanical, carbonation): increasing their performance as a clinker replacement and enabling investments into new production facilities.

3. At the concrete plant: define optimal operational parameters based on performance-based design approach. This will help improve the concrete quality (strength and durability), while enabling the use of locally available materials to achieve optimal environmental, economic, and durability performance.

From a materials and process engineering outlook, DETOCS research focuses on understanding clinker and SCM production and the chemical interactions between these materials. For clinker, it is understanding what makes it reactive and how it interacts with SCM. For SCMs, it is understanding their basic properties and activation methods: thermal, mechanical, chemical, and carbonation - which are far from optimal today. DETOCS also includes research on **non-technical barriers** e.g. investment in processing facilities, risks related to unknown future performance, reluctance to depart from prescriptive standards, and scepticism for new cement and concrete formulations that are pervasive in the industry. This is addressed by projects on normative aspects, industry characteristics, and factors linked to end user adoption of material innovation in the cement and concrete sector.

In conclusion, **DETOCS addresses a critical challenge and proposes a solution, which is environmentally efficient, can be deployed quickly and at low cost, without compromising quality, and without significant capital investments.** Our approach exploits newly available digital tools to enable cement production with locally

available raw materials while ensuring competitiveness (cost & quality), using the existing industrial installed base, and ensuring ease of use along the value chain.

Research objectives and metrics:

Exploit the latest advances in data science that couple material models to process data, enabling high rates of clinker substitution with SCMs: a decrease in clinker factor on a reference cement plant from 70% to 40% by 2030, followed by 25% as the next milestone in 2035 – equivalent to 0.2 t.CO_2/t.cement.

Develop leaders with skills to effectively develop and commercialize sustainable cement solutions, as well as specify the performance-based standards for future use by Architects & Designers.

Create a new field of research and engineering through the combination of data science, industrial process data, numerical modelling, and the fundamentals of cement and concrete chemistry.

1. Through the use of first-principle models and artificial intelligence, DETOCS researches the links between materials' chemical, physical properties, and process conditions to explain and predict the reactivity of clinker blended activated SCMs, through WP1:

- Develop a new clinker mineralogy prediction model to calculate liquid phase amount and optimal burning temperature in clinker production, while investigating currently unexplored composition ranges to discover process and material correlations – model accuracy > 95% based on process data.
- Develop model-based understanding for the activation of SCMs, i.e. thermal, mechanical, chemical, carbonation. The goal is to increase SCMs reactivity by 15 to 20% versus their current performance when used in blended cements.
- Close the knowledge gap of SCM reactivity based on chemical & physical properties, process data, and clinker interaction via the use of first-principle models and artificial intelligence, enabling to reduce clinker factor to 40%.
- Develop the first numerical model describing RCF reactivity – with accuracy > 75% validated on controlled setups.
- Propose a novel rapid test protocol to measure SCM reactivity – enabling quantification of SCM quality in 1 day.

2. Develop accurate prediction models for low-carbon blended cements to enable environmental and performance-based design by concrete producers, through WP2:

- Develop a tailormade optimisation algorithm of the cement blend mix design tool that accounts for clinker mineralogy and SCM chemical properties – with accuracy > 90% validated on process data from cement plants.
- Develop a performance-based design tool through modelling and data-enabled learning for concrete mixes produced with low-carbon cement, maximising locally available SCMs use –accuracy > 90% for at least 4 types of SCMs.
- Describe the interaction between raw material and process variability on concrete performance– reduce cement content in concrete by at least 15% and reduce process variability by at least 25% in existing concrete plants.
- Develop an upscaling framework to predict concrete durability from cement-paste experiments, helping create a generic approach that explains the impact of SCMs on long-term properties of concrete – with accuracy > 85% validated on concrete samples produced in industrial setups.

3. Develop the backbone for digitalizing the cement industry via novel soft-sensors for product quality monitoring, frameworks for deploying machine learning-based models, and hardware technology that enables material traceability, through WP3:

- Develop of a novel Interpretable Unsupervised Anomaly Detection method – accuracy > 96% validated at 3 cement production processes (specifically, in the blending stage of clinker and SCMs).
- Develop and test a novel Radio Frequency Identification (RFID) technology to monitor and document raw material quality across the value chain – we focus on the two main stages of the value chain (blended cements to concrete production) ensuring robustness, durability, and reliability; the validation is conducted via full scale tests on site.
- Develop a novel strategy for the integration and fusion of data from cement production with a novel hybrid modelling approach. The model integrates machine learning models and first principles models to predict cement quality with accuracy > 95% – validated on at least two cement plants.
- Develop a novel fast characterisation method based on computer vision to assess the reactivity of SCMs in low-carbon cement blends.

4. Develop new knowledge on the barriers to innovation and global roll-out from environmental, regulatory and market points of view, through WP4:

- Provide insight into regulatory standard related barriers for 4 new low-carbon cement blends; while studying the drivers of environmental innovations in the cement/concrete industries and understanding how regulatory bodies hinder low-carbon cement blends – the target is to reduce market adoption time by 25%.
- Define the techno-economic landscape of low-carbon blended cement that can be produced at scale in 3 geographical markets (focus on developing countries) and have the potential to reduce product-specific OPEX by 25%, enhancing competitiveness in concrete applications by 20%, and reducing CO_2 emissions by at least 30%.

Overview of the research programme: The DETOCS objectives are highly relevant to the cement and concrete sector since they focus on technological solutions to deliver on EU policies and priorities (*Green Deal, Digitalization, Industrial Leadership, Growth, Circular Economy*) to decarbonize hard-to-abate sectors. A company or research organisation are not enough to develop the underlying knowledge because of missing capabilities, knowledge, data, and industry know-how. The scientific questions that we try to answer are: can we predict quality metrics such as reactivity (of SCMs, cement and concrete) to develop new product compositions that significantly reduce CO2 emissions? Can we predict future performance with enough certainty to enable performance-based standards?

1.1.2 Pertinence and innovative aspects of the research programme

We describe the state-of-the-art for each objective and work package as part of the methodology, see Section 1.2.1. The following section highlights our level of ambition and progress and the change that we seek to make.

Towards objective 1: **Protocols for SCM activation and selection through new computational methods:** While the use of SCMs in blended cements and concrete are an industrial reality, the application of high-volume SCMs (i.e. beyond substitution rates prescribed in standards) is limited though; constraining the actual impact that SCMs can provide to reduce the overall CO_2 emission from cement. There exists a knowledge gap on the scientific links between SCM material properties (calcined clay, ashes, RCF), activation mechanisms (thermal, chemical, mechanical), interaction with chemical admixtures, and long-term effects when translating low-carbon cement. Through hybrid models that combine first-principle approaches and machine learning, we will develop the new models that predict SCMs' reactivity as a function of its chemical composition, physical properties, process conditions, and clinker mineralogy. This development helps optimise low-carbon blended cement manufacturing.

Towards objective 2: **From traditional mixing protocols to data-enabled workflows and model-based quality prediction for cement and concrete:** The targeted prediction of concrete properties (mechanical and durability) produced with low-carbon blended cement is a significant technical breakthrough, since this enables the use of SCMs at significant higher amounts compared to today's industrial practices. Concrete properties are key for end-users in the construction industry and each mix is designed to match given property. It is our ambition to make a significant leap forward in the understanding physicochemical mechanisms from SCMs, to cement, to concrete and to end-user products, while accounting for technical, environmental, and economic impacts in the use of high-volume SMC replacement in cement blends – providing a new basis for performance-based design of low-CO_2 concrete mixes.

Towards objective 3: **New measurement technologies and traceability for a timeseries analysis in production processes:** Documenting and tracking materials quality are critical steps to optimize all operations in cement and concrete production, enabling a confident use of high SCMs replacement rates in a wide spectrum of applications. Our project addresses this challenge from a software and hardware outlook. The former relates to soft-sensing, data analytics, and computer vision for in-line measurements in cement production; and our ambition is to provide an industrial solution that will help cement plants to get rapid feedback on the final product quality by identifying and correcting production anomalies (accelerating the feedback loop in cement quality control). The latter, conversely, relates to traceability of concrete materials along the value chain by means of RFID tags; and our ambition is to provide the first of its kind tracking technology that can be used to store/read information related to the materials' properties, technologies used to produce and process them, and for the handling and transportation of the final product.

Towards objective 4: **Understanding and overcoming barriers to innovation and global roll-out from environmental, regulatory and market points of view:** The DETOCS project significantly extends the state-of-the-art knowledge on non-technological and regulatory barriers that hinder the introduction and roll-out of sustainable solutions. Our analysis of the technical, economic, and environmental impacts along the value chain is complemented with a dedicated study on end-user barriers to low-carbon cement adoption. The study cover aspects associated to regulation & standards, industry-specific characteristics, and firm-level characteristics. DETOCS will allow the world to move beyond prescriptive standards to performance-based standards by producing proven performance models for low clinker cements and concrete produced therewith.

— **New knowledge to enable market-creating innovations in the cement and concrete industry:** the results and knowledge from this project have the potential to generate new workflows, business models and marketing tools to commercially deploy new SCMs, low-clinker cement blends and sustainable concretes. Potentially creating an entirely new market segment for technology companies and producers of building materials that can drastically reduce the CO_2 emissions and contribute to mitigating climate change.

— **High-risk/high-gain effort mobilising different scientific and technological disciplines to advance engineering science.** Given the ambition and novelty, outcomes may be radical and unpredictable. DETOCS builds bridges between multiple fields: civil engineering, material science, chemical engineering, data science, process engineering, information science, and economics to create transformative knowledge and technologies, that can be scaled-up in a rapid and cost-effective way based on already existing facilities to a size that the market requires (3,000-4,000 t/day per cement plant and 800 to 3,000 m^3/day per concrete plant).

Other European and national research initiatives linked to the project: Through its participants, the project is connected to *Innovandi* (the research network of the Global Cement and Concrete Association), which includes supporting research topics such as AI for predicting clinker reactivity and calcined clay optimization. DETOCS relies on prior research on blended cements focused on synergies between calcined clay, limestone, and clinker, particularly the *LC3* Project (2014-22) supported by the Swiss Agency for Development and Cooperation, *FUTURECEM* (2008-11) and *Green Concrete II* (2014-19) projects supported by the Danish National Advanced Technology Foundation. DETOCS will use SCM materials and insights produced in MSCA-DN project *CO2Valorize* (2022-26) for carbonated SCMs and Horizon 2020 project *ICEBERG* (Circular Economy of Building Materials, 2020-24) for recycled concrete fines – these projects may also share findings related to properties and control of SCM. We are aware of the outcomes of the EU project *ChemShaleChemTower* (2020-22), that investigates a solution for activation of shale as SCM in a novel reactor and Danish EUDP project *EcoClay* (2022-26) that aims to demonstrate carbon-neutral activation of clay through electric heat – these may provide insights into activation process parameters and techno-economics. We have created a dedicated task (See Section 3.1, WP7, T6.6) to follow-up with the national, EU-wide, and global projects to exchange knowledge and data to further enhance the scientific excellence.

1.2 Soundness of the proposed methodology (including interdisciplinary approaches, consideration of the gender dimension and other diversity aspects if relevant for the research project, and the quality and appropriateness of open science practices)

1.2.1 Overall methodology

In **WP1,** DC1-4 perform research on the prediction of binder quality. The models will describe processes to create highly reactive SCMs, reflecting different raw material classes. Validation data comes from industrial processes or are generated using pilot plants. In **WP2,** DC4-8 works on new cement and concrete mixes and study the influence of SCMs on material properties to unlock the CO2 reduction potential. The WP will create new knowledge on the optimal (maximal) amounts of SCMs that can be added to mixtures, while maintaining or improving the required properties. In **WP3,** DC9-11, 13 & 14 research on data aspects of advancing process control and the flow of information along the value chain. The DCs will partner with the industry on data science aspects and model validation using real-world data. In **WP4**, DC12 & 15 investigate the environmental and techno-economic aspects as well as barriers and drivers to innovations through strong interaction with the non-academic sector. This approach provide feedback to the scientific questions and applied methodologies to make adaptation more likely and the outcomes more impactful.

1.2.1 Integration of methods and disciplines to pursue the objectives

Work Package 1: Prediction and control of binder quality. Background: SCM are commonly used as partial clinker replacements, resulting in cement blends with a reduced carbon footprint. SCMs' physico-chemical characteristics alter cement hydration, affecting the evolution of cement microstructure. Existing numerical models (reaction-kinetics models) for cement lack accuracy when applied to modern cement blends, especially in multicomponent systems with high volume of clinker replacement, where chemical interactions between clinker, water, SCMs and fillers occur concurrently. Also, the solutions to enhance SCMs reactivity, which can be thermal, chemical (including via carbonation) or mechanically activated, have not been studied on an industrial scale, and consequently lack adaptive process control and quality prediction tools to maintain a stable output material quality. To overcome these challenges, WP1 introduces novel first-principle models to enable high-fidelity prediction of time-dependent reactions of clinker and its interactions with SCMs. WP1 targets SCM activation and cement production, with research work ranging from thermodynamics models for clinker as well as thermal-, chemical- and mechanical-activated SCMs using process parameters and physicochemical characteristics as input variables. To complement first-principle models, ML approaches will be used as to identify correlations between process data and reactivity of each component in blended cements, serving as the building block for the development of a holistic cement blend expert model in WP2. The SCMs targeted in this study are clays, fly-ash, slag, RCF, limestone and natural pozzolans, which will be supplied by our industrial partners ARGOS, C2CA, and MNK. These will also provide data from cement and SCM production. WP1 will develop models to predict the clinker mineralogy as well as correlate thermal, chemical and mechanical process conditions for SCM, helping improve their reactivity.

DC1: CNRS | **Title:** Accurate prediction of clinker quality and process related information using a high temperature thermodynamic approach | **Partners:** FLS, ARGOS, RWTH | **Background:** [Bog1929] developed a set of equations to calculate the potential clinker mineralogy from its chemical composition. Many attempts were made to improve it [Shim2021], but it remains largely used in cement industry despite its low accuracy. A modern way to predict phases in multicomponent systems is thermodynamic equilibrium calculations via the Calphad approach, validated for clinker in [Taz2018]. The underlying principle of this approach is the minimization of the total Gibbs energy of the system; thus, it is universal and can be applied to a full clinker chemistry if the thermodynamic database with relevant

clinker elements is available. **Methods:** We will use the Factsage Gibbs energy minimization software (thermodynamic databases) and insert data on minor elements in the clinker phases by calculations using Density Functional Theory (DFT) and experiments (calorimetry, XRD). Based on this new set of Gibbs energy data, a clinker mineralogy prediction model will be developed. This is the key cornerstones of a full reactivity model of a clinker in a cement. The clinker mineralogy model will be benchmarked on cement plant data and will be used as input for a ML model to reveal the key chemical parameters to maximize clinker reactivity. **Description:** A set of Gibbs energy data to simulate the clinker mineralogy is developed by *a) Critical literature review*: i.e. maximum solubility levels and insertion mechanisms of minor elements in the clinker (thermodynamic properties); *b) New model development*: based on the Factsage FTOxid and FTPs databases by an iterative approach of DFT calculations/experiments; and *c) Benchmark calculations*: using clinker data from the literature and cement plants (ARGOS, FLS). This dataset will be used to develop a clinker mineralogy prediction model covering the full potential composition ranges.

DC2: ABD | **Title:** Thermal activation of SCMs: Process Models and Quality prediction | **Partners:** FLS, PTECH, RWTH | **Background:** [Ha2022] shows that thermal processing conditions, e.g. temperature, combustion atmosphere, and residence time, are critical in achieving optimal Calcined Clay (CC) reactivity. To rapidly transition to a greener process, the ability to iterate, optimise, and innovate on the clay calcination process is urgent. Thus, the development of a process model that captures and predict process output from raw materials to SCM performance unlocks the transition to low-carbon cements. Studies on process modelling enabled the development of alternative clinkers [Ha2016], and a combination of process heat transfer and thermodynamic models [Ha2017, Ha2020] can capture the influence of process conditions on clinker phases. We assume these can be adapted for CC process directly. Also, to close the gap between calcination process and clay reactivity, we rely on ML models (successfully applied on rather limited data [Lap2021]) to link the scales between process and material microstructure. **Methods:** We will develop a process model integrating a thermodynamic model for the gas-solid-melt interactions coupled to a heat transfer model for thermal treatment (kiln or flash calciner). The model provides insight into the process that cannot be measured in-situ. CC samples are to be characterised to capture how process variations have influenced the SCM performance. This data enables us to make sense of differences in lab/full-scale calcination. The final step is to investigate how the predicted thermal treatment profile of the solid material might correlate to material variables e.g. SSA, to enable integration with existing cement performance predictors. **Description:** DC2 comprised two steps: a) *Development of flash / rotary kiln process model for thermal activation of SCMs*: For that, clinker bed models coupled to heat-transfer and thermodynamic models will be used. Thermodynamic and kinetic models for calcination will be coupled to these bed and particle models to capture the activation progression. Then, atmospheric inhibition of calcination will be captured from mass-balance and thermodynamic model; and b) *Correlate the clay reactivity with material and process data:* The calcination using rotary kiln (ARGOS) and Flash Calciner (FLS) will provide process and material data for the model. SCM reactivity will be assess via the R3 test [Sne2019] and ML approaches will be used to provide a correlation layer between material and process data.

DC3: ETHZ | **Title:** Chemical activation of SCMs via carbonation and admixtures: Quality Prediction | **Partners:** FLS, C2CA, MNK | **Background:** Chemical activation of SCMs has received increased focus as the cement industry seeks to valorise SCM to reduce clinker content [Sne2019], and ever higher levels of clinker substitution make it difficult to meet strength requirements. Chemical activation of SCMs is done via admixtures in the mixing water to enhance early reactivity. The use of admixtures with varied formulations can lead to difficulties in mix design of concretes that behave adequately in fresh and hardened state [Bos2021], since admixture effects can compete and clash. This hinders the use of existing models to predict the behaviour of low-carbon cement, e.g. with clays and RCF. The latter has gained attention due to their contribution to circularity in construction. RCFs can replace clinker, holding high potential as a carbon sink and reactive binder [Za2020a]. Therefore, DC3 will research on chemical admixtures and their influence on the properties of mixes produced with low-carbon cement. **Methods:** The SCMs characterisation include chemical, mineralogical, and physical methods (XRF, XRD, BET). For RCF, a similar characterization approach used, but with the added wet carbonation process from FLS. RCFs have shown rather high reactivity and this portion of the project will focus on chemical admixture compatibility and impact on hydration of carbonated RCFs. The R3 test [Sne2019] will be used to correlate SCMs reactivity. The cement design framework from ETH [Bos2021] will serve as a basis for initial blend design and adapted for the SCMs with the inclusion of ML models to correlate material and process parameters. **Description:** DC3 focuses on *a) development of predictive models for chemically-activated blended cements* considering material variations, whether this is natural or modified by carbonation (for RCFs). The model should serve as advice for cement plants to ensure downstream admixture compatibility; and *b) use of ML methods* to complement to the proposed predictive models, helping identify correlations between process and material parameters with the reactivity of the SCM.

DC4: RWTH | **Title:** Mechanical activation of SCMs: Process Models and Quality prediction | **Partners:** FLS, ARGOS, PTECH | **Background:** One pathway to optimise the performance of blended cements is a tailormade mechanical activation of the individual cement constituents. This principle is widely applied, e.g. for slag cement

where slag and clinker are individually ground and blended later. Recently, [Pal2011] showed that it is feasible to tailor properties such as early age reactivity by adjusting the components grain size to obtain optimum particle packing and reactivity. In DC4, we propose to integrate a novel data-driven application-based testing regime in cement plants to enable the optimization of mechanical processing parameters for SCMs. The main approach will be to test the mortar fraction of a typical SCM-rich concrete composition with respect to fresh properties. Next, these results are correlated with parameters derived from process control data (e.g. SSA & PSD). Similar approaches were used to assess the concrete properties [Sch2000], but the combination of process data to application-based properties is a new pathway we propose. **Methods:** The main approach will be to test the mortar fraction of a typical concrete composition with respect to fresh mortar properties (rheology), strength behaviour, and reactivity via a calorimetric fingerprint. These experiments will be related to process data (grinding), so we can identify optimum performance indicators of the SCMs. Finally, we derive protocols to optimise SCM and clinker constitution by tailored mechanical activation mechanisms to achieve the best possible performance. The proposed test approach may serve a novel performance testing regime for SCM´s. **Description:** Today, there are no performance-related application tests available for SCM´s in blended cement which link mechanical process data to concrete performance. Standard tests based on constant w/c ratio are insufficient to describe the performance of blended cements containing high fractions of SCM. Hence, we propose novel application-based test method that can be applied in a cement plant to derive conclusions for later performance in the field. By assuming a constant clinker quality, the method will mainly detect fluctuations in the SCM constitution related to its mechanical activation process parameters.

Work Package 2: Quality prediction and performance-based design of low-carbon cement and concrete mixes produced therewith. Background: A variety of blended cements are being developed and used to address the urgent need to reduce CO_2 from cement. Today, less than 25% of the cements sold globally are Ordinary Portland Cement (>95% clinker). In fact, the prescriptive EU standards specify 34 cement types [EN 197-1 and -5], with more to be added by upcoming standards (EN 197-6). To achieve the decarbonization challenge, cement composition must continue diversify to use locally available alternatives to clinker. Given this diversification of cement composition and the expanding levels of SCM content, the number of blended cements is to exponentially increase, as is the complexity in their formulations, affecting not only cement production but also its utilisation in modern concrete formulations. To enable a rapid introduction of new SCMs, while reducing complexity from existing prescriptive standards, this WP provides a means to shift from specifications based composition to a performance-based approach in cement and concrete. Specifically, WP2 targets aspects related to the prediction of phase relations of cementitious systems and to further engineer phase assemblages towards an optimum performance by adjusting the chemical composition of blended cements; such development builds upon the numerical models developed in WP1. Also, WP2 explores the impact of sustainable cement blends on the concrete production process: a performance-based approach will be tested to design concrete materials optimized for mechanical strength, durability, and environmental performance, while considering the impact on the concrete production process parameters and the inherently variability in the input material composition. In WP2, the partners MNK and ARGOS provide data from cement and concrete plants, while C2CA provide data on RCF. WP2 will enable a custom optimisation of blended cements composition; develop physical models to predict concrete performance and integrate this method with environmental life cycle assessment to create a performance-based design tool; and provide an economical & environmental analysis of the impact of material variability on concrete production.

DC5: RWTH | **Title:** Quality prediction of low-carbon cement blends | **Partners:** MNK, CNRS, STW | **Background:** The use of thermodynamic models in cement science was often doubted since a strong impact of kinetics apparently interferes with the achievement of equilibrium conditions. Concerning hydration modelling, progress has been made to derive missing thermodynamic data [Lot2019a] and establishing know-how on phase relations [Geo2022], resulting in new thermodynamic models [Lot2019b]. This know-how enabled researchers to predict the phase relations of hydrating cement and to engineer phase assemblages towards an optimum application, e.g. of ternary-blended calcined clay limestone cements [An2012]. **Methods:** DC5 is strongly related to DC1&4. Within DC1, we carry on isothermal calorimetry and quantitative XRD tests to obtain a “reactivity footprint” of the resulting clinker composition. This composition serves as input for the subsequent thermodynamic predictions of the hydration reactions and the resulting phase distribution (from DC1). Based on this, we will calculate relevant parameters to obtain QC strength data (e.g. porosities and gel-space factors) of the resulting OPC. Finally, we include a reactivity profile of potential SCM´s, where we establish the relations to clinker mineralogy (from DC1) and SCM constitution (from DC2-4) and strength data (provided by quality control data in this project). **Description:** Currently, cement blending optimisation is typically obtained by empirical trial and error approaches. In DC5, we target the use of first-principle approaches based on thermodynamic methods coupled to standard experimental tools (described above) to obtain a predictive model that enables optimum cement design based on modelled key performance indicators. This

can be related to the QC data of the binder and enable a faster prediction of the performance of low carbon cements. Ultimately the goal is to enable a tailormade optimisation of the mix design of blended cements.

DC6: C2CA | **Title:** Environmental and technical performance-based design of concrete produced with low carbon cement | **Partners:** MNK, ARGOS, RWTH, EPFL | **Background:** Performance-based design (PBD) offers a way to achieve a step change improvement in concrete quality. Today, concrete is designed using prescriptive method. This has limited effectiveness and has often stifled innovation since there are i) many potentially viable combinations of raw materials and applications and ii) design lifetimes of structures are generally long for an empirical approach to cover a vast landscape of viable materials [Je2011]. The main concrete PBD approaches are a) durability indicator (DI) [Ale2018], which predicts long-term performance, and b) service life modelling [Ale2008], which predicts design lifetime of structures based on a specified concrete mixes and exposure conditions. These methods are limited by their empirical nature and, thus, time- and resource-consuming. As a results, it virtually impossible to apply them for the increasingly large number of SCMs. Also, these methods have not been developed to include environmental performance, which is utterly important for the cement and concrete industry. Thus, a general method for concrete PBD that can inform both technical and environmental performance remains needed, such development is the main research target in DC6. **Methods:** DC6 will develop a new, quicker-yet-reliable, and more general approach to assess mechanical and durability performance of concrete mix designs using thermodynamic modelling and simplified first-principle models for deterioration mechanisms. The latter will be based on theoretical physical mechanisms of concrete deterioration, building on research from DC8, and their predictions may be enhanced using ML (e.g. to quantify extent of chemical reactions). The key innovation in DC6 is the development and validation of a streamlined form of physical modelling [My2022] that is applicable to many concrete types and indicates performance reliably. **Description:** DC6 comprises two stages: *numerical modelling* and *experimental validation* on concrete mixes. These stages are accomplished by *1) Cement binder evaluation:* An algorithm to predict material properties and life cycle environmental impacts of cement binders and concrete mixes will be developed and validated using physical models (leveraging on models from DC1-4 and 11). *2) Algorithm refinement:* Domain expertise used to initially set input values for physical models will be augmented by ML models, improving the reliability of the algorithm in predicting material properties. *3) Durability indicators:* physical models will be developed, complementing to DC8, that convert known environmental exposure conditions, mix design, and thermodynamic modelling into durability indicators; and *4) Concrete selection:* The PDB will be applied to select optimal concrete materials regarding compressive strength, durability, and environmental performance, and then validate via lab experiments and/or literature data.

DC7: TUD | **Title:** Impact of material variability on concrete performance | **Partners:** ARGOS, MNK, C2CA | **Background:** Concrete performance (durability and mechanical strength) are related to the components' distribution and composition within the cement matrix. Also, its performance depends on the production process, mix design, binder composition, and aggregates type. Concrete production has been studied and optimized to address the ever-increasing societal need for infrastructure. Yet, its manufacturing process is affected by variations in quality due to a lack of control over process variables. To increase variability even further, the sector is actively searching for ways to improve sustainable concrete production, i.e. through the use of recycled materials and SCMs [Lo2017, Shah2022]. DC7 aims to identify how and to what extent the variability of the concrete components affects the final concrete properties. Such understanding provides a level of confidence (acceptable threshold) on the performance prediction that are studied in DC6&8, while providing guidance to the utilisation of recycled materials streams e.g. RCF. **Methods:** Complementary to literature search and concrete mix design data from field experts (MNK, ARGOS, C2CA), the experimental methods in DC7 rely on mechanical characterisation (strength) and durability (carbonation and chloride migration) tests on concrete mixes. Since DC7 is interconnected with DC6&8, experimental protocol and results are shared between the projects. In the case of materials with inherently greater variability (i.e. RCF), complementary mechanical tests will be carried out. For the aggregate property's measurement, a LIBS-based set-up (built within the EU project ICEBERG) will be expanded with NIR sensor to arrive at a facility with integrated LIBS, NIR, and 3D particle imaging. **Description:** DC7 comprised three steps: *a) Data exploration:* i.e. combined literature review and interviews with centres of expertise to create a hierarchy of relevant RCF properties, binder compositions, and use of SCMs (e.g. fly ash, limestone) with their expected modes of interaction. This is carried out in collaboration with the projects addressing novel SCM and binders (in DC3,5&6); *b) Laboratory experiments:* available data on the strength and durability of specific case systems will be collected (DC6&8) and, where needed, expanded with tests samples produced with different SCMs and aggregates; and *c) Principal Component Analysis (PCA):* the resulting experimental dataset will be analysed using PCA to identify the most important independent variables and assess the onset of non-linearity for material variables in the final concrete performance.

DC8: EPFL | **Title:** Quantifying concrete properties from cement paste scale tests | **Partners:** C2CA, ARGOS, RWTH | **Background:** An important fraction of the CO_2 emission of cement is due to the intrinsic chemistry of the clinker [Scriv2018]. Thus, most mitigation strategies involve a shift from the traditional Portland Cement, whether by the substitution with SCM [Lot2011], or the binding of calcium by carbon capture and utilization by mineralization [Sko2020]. The durability of these novel binders has been an important area of study [Dha2022]; however, we still

lack the tools to assess the long-term durability in a reliable and fast manner. Recent studies [Wil2021] show that reliable data can be obtained on experiments at the cement paste level, though the impact of the concrete formulation on these results is yet unexplored. Thus, we aim to refine existing concrete durability models by a) constraining them using cement paste scale tests and b) using recent advancements in the fundamental transport mechanisms; providing a framework that relates concrete performance to its cement composition. **Methods:** DC8 uses durability testing methods and microstructure characterization methods from EPFL, i.e. carbonation and chloride tests [Dha2022, Wil2021] will assess the binder durability. Also, standard tests at the concrete scale will be carried out using several concrete formulations. The microstructure of selected cement pastes and concrete will be assessed to quantify how both scales are related. Finally, this info will help refine existing life-prediction models. **Description:** Supported by the findings from [Le2015, Fje2021], we assume that the interfacial transition zone is not a dominant factor compared to the impact of the binder, so tests on hardened cement paste are sufficient to obtain a good first order approximation of the concrete mix performance. DC8 aims to verify and leverage this assumption in three steps: *a) data collection at the cement paste and concrete*, *b) microstructure characterization and quantification* of microstructure indicators on cement pastes and concretes, and *c) constrained concrete models*, where we analyse how durability and microstructure at the cement paste scale can be used in durability models of low-carbon cement at the concrete scale.

Work Package 3: Digital solutions applied to low-carbon cement and concrete materials. Background: An important lever to decarbonize of cement and concrete industries consists of digital solutions for optimization of cement production and utilization. WP3 focuses on developing these digital solutions for implementation on the existing industrial base at low CAPEX and OPEX. The focus is to build on the vast amounts of data available from cement and concrete plants control systems (i.e. MNK and ARGOS) and Secondary Raw Materials processing (C2CA). Based on data analytics know-how from the industrial partner STW, WP3 will develop a general ML framework to predict cement quality attributes (this framework is supported by the first-principle models studied in WP1&2), to be applied on blended cement (grinding/blending) and concrete production with the industrial partners ARGOS and MNK, and C2CA. Similarly, PTECH contributes with optical measurements to devise a novel method to assess the reactivity of SCMs quickly and reliably, which is to be implemented in cement production lines by FLS and ARGOS. The ML framework is the basis for the development of soft-sensors for in-line measurements in cement production. Next, building upon technologies available at C2CA, WP3 conducts research on using sensors to track materials quality along the value chain, filling a critical need for material information at all stages. Altogether, WP3 develops the digitalization backbone for reducing the CO_2 footprint in cement and concrete industries by developing soft sensors and computer vision technologies for monitoring in-process quality of cement production, including the processing of Secondary Raw Materials (SRM); RFID technology to monitor and track the quality of materials across the value chain; and ML to predict cement and concrete productions quality.

DC9: UNIPD | **Title:** Soft-sensing and data analytics for in-line measurements in low-carbon cement production | **Partners:** FLS, PTECH, STW | **Background:** The capability to monitor the cement production process in real time is paramount to assess whether it is being operated according to specifications, and to optimise energy consumption and a more effective usage of SCMs. However, physical instrumentation may be difficult or even impossible to implement due to severe operating conditions and the presence of particulate material. Thus, Soft sensors are a viable alternative and several approaches have been proposed for cement or concrete [Su2022]. Another typical issue is the lack of tagged data that makes monitoring a complex task when dealing with multivariate and multimodal processes [Ca2019], and advocates for data-driven unsupervised anomaly detection approaches [Au2020]. Despite that, challenges remain open in the development of Soft Sensors for the cement industry: i) the lack of a comprehensive assessment of which variables should be measured; ii) a common platform capable of handling different measurements; and iii) the development and implementation of algorithms capable of providing reliable real-time estimates. **Methods:** we will borrow methods from statistics and ML to develop effective data-driven soft sensors and interpretable anomaly detection approaches. The uniqueness of the planned activities will be associated to i) the ad-hoc design of such approaches for the cement industry; ii) the usage of tree-based approaches for Anomaly Detection (Isolation Forest and its extensions); iii) the usage of interpretability methods (e.g. SHAP, DIFFI); iv) the employment of ML architecture for sequence learning for handling heterogenous time-series. **Description:** DC9 has four steps: *a) development of ML-based soft sensors* for handling time-series in in-line measurements from cement production [Ba2021]; *b) development of smart monitoring approaches for in-line measurements* of cement production [Gu2016]; *c) development of ML-based soft sensors* for handling in data with heterogenous sampling time [Bon2021] – leveraging on the results from WP1 and data collected in WP1&2; and *d) development of interpretability approaches* for smart monitoring of in-line measurements of cement production.

DC10: TUD | **Title:** Traceability of concrete materials along the value chain | **Partners:** ARGOS, C2CA, MNK | **Background:** Checking, monitoring, and tracking materials quality is critical to optimize concrete production. Today, RFID technology is used to convey product information [Ia2018] by linking a passive electronic tracer to the

product. The technology promise for a sustainable concrete production is in the possibility of rigorous certification of intermediate and final products and automation of information handling via a material passport [Ho2021]. Linking information to the product at any point in the value chain allows optimal use of data from previous steps. This allows the processing of materials with larger but known variability. So far, ultra-high frequency RFID tags were mixed into mortars to establish a proof of principle by C2CA. In DC10, we propose an optimized design of hardware and software to enable the technology to serve in cement and concrete production. This supports the documentation of materials with a high SCM replacement rate and, when integrated with the models from DC6, it enables the optimisation of concrete mix design. **Methods:** The performance of RFID tags will be analysed to identify the critical design elements that contribute to robustness and readability. This step will propose a new design based on physical modelling (FEM/Electromagnetic). Finally, the RFIDs will be tested in industrial setups (ARGOS, MNK) to validate the RFID model and design. Based on these, the best performing RFID designs will be extended to create a design performing with >80% durability and readability at conditions proposed by the supply chain parties. **Description:** To date, there are no suitable monitoring tags that can be used to store information related to the materials' properties, technologies used to produce and process them, and for the handling and transportation of the final product. Tags must be designed and optimized to withstand hostile environments. As soon as cement and aggregate flows have been produced for use in concrete and RFID have been added to these flows, the tags must be robust and readable while passing through phases of material transport and handling all the way to its final application.

DC11: UNIPD | **Title:** A machine learning framework to predict low-carbon cement and concrete quality attributes | **Partners:** STW, FLS, MNK, ARGOS | **Background:** The use of ML is a well-established approach to process monitoring [Qin2016]. Cement and concrete production could greatly benefit to enhance product, to improve formulations, and to maximize the use of SCMs. The exploitation data for quality monitoring and control is scarcely applied in the cement and concrete [Lap2021], particularly to integrate process and material data with product design [Pal2020]. One reason is because the cement industry prevalently processes solids and particulate materials, and the characterization of such flows is not trivial [Fa2017]. Also, the final quality of both cement and concrete is governed by raw materials properties, which may be described in terms of complex data and formulation. Hence, it is evident that a methodology for merging data at different frequencies, dimensions, and types is required, and accordingly, a modelling approach for exploiting such information to predict the product multivariate quality profile. An additional gap to bridge is how to complement data-information with data deriving from soft sensors (DC8) and, most critically, with knowledge embedded in first-principles models from DC1-4. **Methods:** Multiway data methodologies will be used to deal with dynamic data, while multivariate/multi-block methods will serve for the fusion of different data types. Techniques of data mining, unsupervised learning methods, and pattern recognition will be adopted for process understanding. Modelling techniques will be based on multivariate latent variables regression techniques, e.g. partial least squares, elastic nets, and random forests. Latent variable model inversion will be used to optimize product formulations and orient both the identification of the major sources of variability impacting on process/product quality [Dal2017]. Finally, hybrid monitoring strategies will be developed to complement the first-principle models developed in WP1&2. **Description:** A methodology will be developed for preliminary data treatment to manage data, remove outliers, and treat and impute missing data. Predictive models [Fac2009] will be built for forecasting the products' quality. Latent variable model inversion [Pal2020] will be used to: 1) propose optimal formulations; and 2) manipulate and adjust process settings to ensure the target profile of the product quality. Finally, hybrid monitoring strategies [Des2020] will be built upon the above data-based models and the first principles models to enhance the prediction performance of process phenomena, i.e. the hydration kinetics of multi-component cementitious systems.

DC13: FLS | **Title:** Rapid SCM characterisation method based on computer vision | **Partners:** ARGOS, RWTH, PTECH | **Background:** The most accepted method to characterise the reactivity of SCMs is by measuring the strength development of cement and SCM blends up to 28 days [EN196-5]. This development is then compared to that from a reference binder without SCM, resulting in the so-called Strength Activity Index (SAI). Such method, however, is rather cumbersome and lengthy; limiting is application as means to quickly measure and control the quality of the final cement blend (i.e. cement and SCMs) from a cement plant. To overcome that, DC13 will explore the use of computer vision technology (PTECH) to correlate the chemistry and rate of dissolution of SCMs (i.e. clays and fly ash) in alkaline environment with their reactivity in low-carbon cement blends, providing a fast measurement of reactivity (under 20 minutes of testing). **Methods:** Clays and fly ashes will be tested by means PTECH's optical system at various temperatures, alkaline solutions, and solid concentrations. With the aid of image analysis techniques (image thresholding, segmentation, and use of spatial filters [Me2012]), such system can capture changes in the particle structure (shape and size) over time. The data from optical measurements will be correlated to isothermal calorimetry and strength development tests (by means of statistical models and/or machine learning), identifying a) the reactivity of the tested SCMs under 20 minutes of test and b) the correlation between SCMs' chemical and physical properties to their reactivity in low-carbon cement blends. This development has the potential to become a

fast characterisation method for cement production, improving the quality control and reducing process variability. In addition, DC13 will explore the use of hyperspectral imaging as means to quantify impurities that compromise the reactivity of SCMs, e.g. SiO and Fe_2O_3, to mention a few. **Description:** DC13 comprised three steps: a) *Development of an image analysis technique for capturing SCM dissolution*: For that, control samples provided by FLS and ARGOS will be used to evaluate the most suitable configuration of image filters and segmentation techniques (PTECH) that can be sued to capture the phenomena controlling SCM reactivity, i.e. dissolution of silicate and aluminate phases; *b) Integration of hyperspectral imaging in the optical analysis of SCMs:* DC13 will explore the use of hyperspectral imaging (PTECH) as means to identify the chemical composition of particles from XRF and XRD tests (FLS and RWTH) that are responsible for the reactive fraction of SCMs as well as the impurities within that; and c) *Correlate the SCM reactivity in low-carbon cements with optical data:* SCMs' chemistry will be assessed via XRF and XRD measurements, whereas its reactivity will be assessed via isothermal calorimetry and strength measurements (RWTH), following the R3 test protocol from [Sne2019]. The experimental and optical characterisation data will be correlated using ML approaches and/or statistical analysis.

DC14: TUD | **Title:** Development of a decentralized production model for production of cementitious binders from Secondary Raw Materials | **Partners:** C2CA, TUD, PTECH, STW | **Background:** [My2022] highlights the availability of 3.5Gt of Secondary Raw Materials (SRM) that can be processed as cementitious materials within their region of production if adequate processing facilities are established. In contrast with limestone deposits, which are consistent in quality, SRM's quality fluctuate significantly, which requires predictive and adaptive process controls to maintain stable output material quality. Due to their more dispersed distribution and quality variation, activating these materials is a shift from the traditional cement industry towards a more decentralized model. While the production model can be summarized generically with the steps of downsizing, separation, pre-treatment and activation, there are several uncertainties which DC14 aims to solve, namely: a) balancing input material quality, its activation potential, selection of machines, process energy needs, environmental impact, and ultimate output material quality; b) implementing novel at-line characterization solution for input waste materials and output SCM (addressed in DC13); c) establishing the extent of the process model's applicability to various SRMs; and d) defining the range of variability acceptable for input material to produce an adequate SCM. **Methods:** DC14 will develop a comprehensive process model covering the requisite equipment to produce SCMs from SRMs. The relevant process steps involve downsizing, separation, and activation (studied in DCs2-4), with a production capacity scaling from 40 to 400 tons per day. Initial development of the model will focus on integrating all potential processing steps (C2CA), enabling calculations of mass flows, chemical compositions, process settings, energy consumption, and output material quality. An inventory of sensors, including at-line characterization of input and output materials (C2CA, PTECH), will be prepared. Following this, the model will be subjected to validation, juxtaposing its predictions with existing data from the C2CA pilot plant in Hoorn. **Description:** DC14 involves the creation of a digital process model for decentralized production of cementitious binders. As such, it comprises the following tasks: *a) Develop a digital process model for SRM:* the model is intended to compute mass flows, chemical composition, process settings, and energy consumption data, while also predicting the quality and range of variability of the output material (C2CA); b) *Optimise process steps based on SRM type*: that includes operations such as downsizing, separation, pre-treatment, activation of SRMs – this builds upon knowledge from DC2-4 and additional material characterization tests at TUD; c) *Develop a self-adaptive process controls for SRM*: based on available process data (C2CA), process models, and ML (STW), this tasks focuses on maximizing the output material quality via a self-adapting the SRM process, the foreseen input data includes material quality, activation potential, process energy needs, and environmental impact.

Work Package 4: Market acceptance of low-carbon cement. Background: While many technical decarbonization pathways are explored in WP1-3, there exist non-technical barriers hindering the spread of low-carbon cement blends. These barriers are associated with the use of prescriptive standards for cement (and concrete) that define authorized compositions, as well as end-user reluctance based on ease-of-use, technical and market risks, the need for confidence in long-term material performance, bias, and others. Though some of these barriers are identified, they remain largely understudied. WP4 tackles this gap via research on normative aspects, industry characteristics, and end-user firm factors related to the adoption of low carbon cement & concrete materials. Furthermore, WP4 provides a holistic picture on the performance of low-carbon cement based with an analysis of environmental impacts and economic competitiveness of blended cements with high replacement rates of SCMs, including traditional and unconventional SCMs. The industrial partners play a key role as providers of market knowledge along the entire value chain – from OEM (FLS) to cement and concrete production, utilisation, and standards (FLS, ARGOS, MNK, C2CA ECOS). WP4 will provide a detailed perspective on innovation pathways and bottlenecks related to low-carbon cement market acceptance; and analysis of the environmental & economic impacts of low-carbon cements.

DC12 IHS | **Title:** Drivers and barriers to the end-user adoption of low-carbon cement | **Partners:** ECOS, ARGOS, MNK, C2CA | **Background:** The adoption of innovative low-carbon cement blends by end users is constrained by

several non-technical issues. While prescriptive cement standards are identified as the most important barrier [Mil2021], there exist industry- and firm-specific characteristics such as end-user avoidance of technical & market risks and/or a high level of price sensitivity [Ris2020]. These, together with the high investment and learning costs, represent an essential consideration in the decarbonization of the concrete industry. However, the specific barriers to the adoption of low-carbon emission cement blends are largely understudied. **Methods:** We will adopt a multiple case study approach. The cases to be identified include different regulatory and normative frameworks pertaining to the cement industry, and several firm-level cases with varying degrees of adoption of low-carbon industries. This approach helps identify and contrast relevant cases to outline barriers and drivers to innovation as well as to capture the details of the phenomenon and its context e.g. industry organization [Pat1990]. **Description:** Our aim is to explore the topic "non-technological drivers and barriers" from several angles: *1) from a normative one:* how do current industry regulations and standards hinder the adoption of low-carbon cement blends and what alternative normative approaches successfully allow for their adoption? *2) from industrial characteristics*: oligopoly and value chain structure – and how they drive and/or hinder the adoption of low-carbon cement blends? *3) from end-user firm factors*: profitability, skill level, and culture - and how they drive and/or hinder such adoption? A detailed perspective on innovation pathways and bottlenecks can inform both cement innovators on end user viewpoints and international agencies or local authorities in their efforts to provide a coherent and effective regulatory and policy framework.

DC15 IMP | **Title:** Environmental and economic performance of low carbon cement | **Partners:** FLS, ECOS, ARGOS, MNK, C2CA | **Background:** There are many potentially viable combinations of conventional SCMs than standardised ones, and many useful, yet unconventional SCMs, including RCF, bauxite residue, rice ashes, maize ashes, wheat straw ash, etc. Intelligent mix design utilising multiple SCMs is feasible at scale, which can result in significantly reduced clinker-to-cement ratios. However, mixes incorporating several SCMs at high replacement rates are not common, and life cycle assessment studies of these more ambitious blends are limited to a theoretical level [Sha2022]. **Methods:** D13 will use life cycle assessment and technoeconomic analysis to quantify the environmental impacts and economic competitiveness of highly substituted cements containing high SCMs replacement rates. Prospective life cycle assessment will be used, which is an emerging approach [Ste2021]. **Description:** We start with a detailed analyses of the environmental impacts of blended cements containing high replacement rates of SCMs, providing reliable data for their upstream processing from their points of generation. Then, we extend the analysis to include other potentially environmental impact categories (e.g. ecotoxicity), and we study their economic performance. From this information (and building upon the studies in DCs2-5), optimal cement binder mix designs will be selected based on domain expertise, literature evidence, and laboratory testing. Prospective life cycle assessment will be conducted following IMP's experience in using process modelling in Aspen Plus. Raw material, by-product, disposal/landfilling, staffing. Costs will be included, and the economic analysis (CAPEX, OPEX) will be conducted for a typical production site (ARGOS, MNK) including transportation and related logistics issues.

1.2.2 Integration of methods and disciplines to pursue the objectives

DETOCS seeks knowledge that can be translated into technical solutions that are beyond the scope of a single discipline or research practice. We join the forces of distinctive disciplines and sectors to create results that have a transformative potential for the cement industry in terms of its production and utilisation:

Objective 1 (WP1) is to advance our basic knowledge on the production of suitable SCMs regarding their reactivity when combined to form low-carbon blended cement. WP1 builds upon first-principle models to describe the chemical reactions between cement components and uses data science to correlate process parameters to material reactivity. DETOCS gathers knowledge from thermodynamics (CNRS), thermal process and chemical engineering (ABD), physical chemistry (ETH), material characterisation (RWTH), mechanical engineering (FLS), and SCM and cement production with knowhow on process and material engineering (ARGOS, MNK) and RCF (C2CA). **Objective 2** (WP2) creates the fundaments to model and systematically study the behaviour and properties of low-carbon cement as well as concrete produced therewith; as such, WP2 comprises a paramount step to maximise the use of SCMs. This will be achieved by bringing together the theoretical methods of building materials (RWTH), concrete processing (TUD), material characterisation and durability models (EPFL), environmental engineering (IMP) and the incorporation of rich field data from cement and concrete plants (ARGOS, MNK, C2CA). **Objective 3** (WP3) lays down the scientific fundamentals from knowledge on sensors, material traceability in the value chain and data science. The latter is the backbone for the use of ML framework to predict low-carbon cement and concrete quality. This requires expertise on electronics and informatics (UNIPD), on material processing (TUD), on process engineering (UNIPD), on data science (STW), and on measurement technologies (PTECH, C2CA), and field data and knowhow on industrial workflows (FLS, ARGOS, MNK). **Objective 4** (WP4) focuses on incorporating a broader scientific view on the environmental benefits and innovation drivers as well as non-technological barriers to improve the research agenda and to support evidence-based policy and decision making. We use LCA methods of environmental science and engineering (IMP), the tools from economics to locate the innovation barriers (IHS) and field data (ARGOS, MNK, C2CA) and knowhow and perspectives on standards and policy making (ECOS).

1.2.3 Gender dimension and other diversity aspects

Gender dimension: The methodologies of WP1-4 are classified as basic and applied research on the physico-chemical and engineering science phenomena, so their outcomes are not influenced by differences in gender. Thus, no specific measures are foreseen. **Other diversity aspects:** We are aware that taking diversity into account on research and the user side enhances the methodology and improve results and overall outcomes of research and innovation actions. The cement and concrete research as well as industry is today heavily dominated by males. This project aims with a more diverse gender pool in the advisors to work as role models for future female STEM candidates in the field. *At the level of the researchers carrying out the research work:* the nature of the research work and its outcomes are not influenced by the person's gender, age, race, or ethnicity. However, we provide training sessions for the DCs, so they understand the gender dimension and diversity and how this can enhance research.

1.2.4 Open Science practices

High Quality Data is the starting point of the DETOCS Open Science (OS) practices to enrich the research methodology (WP1-4) and ensure the highest quality of the research outcomes. The data generation and processing before/during scientific work will be analysed and monitored for each project at team and supervisory board level. **Open Reproducible Research** is the goal through appropriate training and open documentation (we will develop detailed procedures, guidelines, and checklists, and have open lab-books). This includes the documentation of experimental setups, conditions, measurements, models, data processing workflow descriptions, codes, and other computational settings. **Open Access to Research Data and Outputs** and wide sharing will be implemented for all projects to encourage other scientists and industrial innovators to use, process and incorporate this data into their research, e.g., to test, validate or train other algorithms and demonstrate reproducibility. Data and results will be published according to the FAIR principles (see Sec. 1.2.5). Knowledge that will be shared through peer-reviewed articles will be accessible as early as possible through our Open Access policy (Green or Gold Route in a case-by-case decision based on our MGA). **Open Research Output Management** helps define the right procedures and technical tools to decide on storage of data and outputs in alignment with the FAIR principles to foster, uptake and use of the data for the benefits of the scientific community, the industry, and the society at large (see Sec.1.2.5). **Open Metrics and Impact** helps distribute notifications on results (e.g., via social media, available databases) to enhance the probability of reaching the right people, including interested citizens, and of getting valuable feedback / engagement from diverse and distributed groups. **Open Science Tools** helps enhance the quality of the research outputs via open repositories (see Sec.1.2.5), transparent workflows/tools, data collection, which all encourage and spread scientific excellence. **Incorporate knowledge actors and end-users** in co-creation of the DETOCS project with the EAB to ensure scientific excellence and usefulness of the results.

1.2.5 Research data management and management of other research outputs

Data Management Plan: The DETOCS project will help develop sustainable models for the use of our research data and findings - the consortium will make sure that all data can be re-used among the partners and by external stakeholders. Each WP produces a unique set of files, data formats and data quantities (Table 1.2). The data will be particularly useful to other scientists, industrial innovators and regulatory authorities. The network-wide procedures to manage and exchange data will be detailed through the deliverable Data Management Plan and are based on **FAIR data principle,** i.e. DETOCS will apply a common core data model when organising our data, making data accessible and reusable (standard data types, persistent identifiers and detailed metadata with proper keywords). We will store data and research outputs in a trusted common repository (e.g. OpenAire/EU, Zenodo/CERN), a local repository at FLS (or distributed but interconnected at each partner). Embargos for data sharing may occur only in case of protection activities (patents, trademark and trade secrets) and commercial utilisation in alignment with the requirements of the MGA. The data will be licenced using a standard re-use licence that will be free of cost (see MGA). **Allocation of resources:** The costs for data management will be covered by the grant (see MGA) and the partners, which will make sure that the data sharing will continue for a minimum period of 5 years after the project. At network level, we will seek practical solutions and conduct trainings to guarantee uniform procedures, data security and compliance with data ethics. **Management of other research outputs:** The consortium will monitor all research outputs (including scholarly books, creative works, case studies, agreements, etc.) and ensure they become available for re-use and sharing in alignment with the FAIR principles and our dissemination and protection measures (see annotated MGA). The DETOCS DMP will also involve the partner organisation's procedures for data management to facilitate a two-way exchange of information.

Table 1.2: Data Management, Expected Formats and Size.

No.	DETOCS File Formats	Size, GB	No.	DETOCS File Formats	Size, GB
WP1	.docx, .pptx, .xlsx,. cas, .stp, .dat, .csv	400	WP5	.jpg, .mp4, .xlsx, .cas, .dat, .stp, .docx, .pptx	600
WP2	.jpg, .mp4, .xlsx, .dat/txt, , .docx, .pptx	400	WP6	.docx, .pptx, .pdf, .xlsx, .jpg, .mp4, .mov	400

WP3	.jpg, .mp4, .xlsx, , .dat/txt, , .docx, .pptx	500	WP7	.jpg, .mp4, .xlsx, .cas, .dat, .stp, .docx, .pptx	200
WP4	.jpg, .mp4, .xlsx, , .dat/txt, , .docx, .pptx	100			

1.2.6 Artificial intelligence

Addressing the robustness of Artificial Intelligence Systems: The Machine Learning methodologies addressed in many DCs in the DETOCS project may suffer from robustness issues associated with a) model errors/inaccuracies, b) unknown phenomena, and c) shifts in the process behaviour. To deal with model errors, techniques from probabilistic inference and robust optimisation are often used to provide some robustness guarantee metric [Kha2021]. To deal with unknown phenomena, techniques include anomaly detection methods, using causal models, the construction of ensembles and reinforcement learning. Finally, to deal with shifts in the process behaviour, techniques from adaptive control and adaptive/recursive multivariate methods will be exploited. Moreover, in the project, the support of first-principles models and the development of hybrid modelling techniques will alleviate robustness problem thanks to higher reliance of knowledge-based approaches (i.e. physicochemical-based models for clinker and SCM reactions). By doing so, and with the integration of explainable-AI approaches [Ar2020], we also guarantee a robust level of explanation to the model's decision-making process.

1.3 Quality and credibility of the training programme (including transferable skills, inter/multidisciplinary, inter-sectoral and gender as well as other diversity aspects)

1.3.1 Overview and content structure of the doctoral training programme

— **Motivation and training needs.** The DETOCS project success depends on developing cutting-edge research and an easy knowledge transfer between academia and industry. We base our educational and training structures via specialisation and incorporation of new methods to have breakthrough findings that can be translated in innovations that spread out across Europe and beyond. DETOCS is a serious attempt to train **the next generation of researchers** who will obtain **highly relevant knowledge and skills for the European Union's science system**, the European Research Area (ERA) and the cement and concrete industry. The specific DETOCS training objectives include:

— Training Objectives

1. To foster excellence-driven talents and train them at the highest possible level to empower game-ganging innovations for the decarbonization of the cement industry.

2. To create new training structures and content that will be delivered through a blend of methods from professionals from academia, industry, and decision makers and that shall remain relevant post-project.

3. To further advance the principles of European doctoral training through a training in the context of industrial research that can complement academic and more fundamental research to enrich the toolkit to fight climate change.

1 Individual research projects and training needs. The 15 PhD projects (see 3.1, and note that DC3 and DC15 are financed in full by the SERI and UKRI) are at the cutting edge of their field and supervised by distinguished scientific leaders and industrial innovators (see 1.4) and carried out at the participating organisations (see 3.1). The research projects are an attractive framework for both learning in science and technology, as well as practising communication skills and teamwork. **Each DC will conduct their own original PhD research work in at least two different research/industrial environments** to utilise the capabilities and infrastructure of the network in the best possible way. The training objectives will be achieved through conducting original research work that is complemented by network-wide training events and local trainings as outlined below. The training plan contains scientific knowledge and methods and key transferable skills that allow the research to succeed in a broader context. The DETOCS training programme will be adapted to the individual needs of each DCs, who will together with the supervisors prepare a Career Development Plan and frequently review it (D4.4).

2 Network-wide training events to foster broader exchange among the DCs and networking. Network-wide training sessions are designed to ensure that all DCs obtain deep interdisciplinary knowledge and gain a broad understanding of the physicochemical phenomena of material properties, equipment engineering, process design and application aspects of the project as well as knowledge on transferable skills (D4.2, D5.5, D5.6, and D6.6).

— **In-person Training Schools and Workshops.** Each Training School delivers scientific training (2/3 of the content) and transferable skills sessions (1/3 of the content) that are accompanied by a one-day International Workshop on scientific and technology transfer topics, where DCs train their presentation skills and engage with stakeholders from industry and academia. Our courses/workshops are open to PhD students outside the network, so they can build new ties to peers and enhance the impact of the DETOCS network. The network-wide events will be combined with Executive Board and Supervisory Board Meetings, where the DCs will present their results and training progress and obtain feedback. We are aware that DC12&13 address non-technological aspects; consequently, with the help from their supervisors, these DCs will select specific courses to develop relevant skills in economics, policy making, standardisation, market analysis, etc.

Table 1.3a: Main Network-Wide Training Events, Conferences and Contribution of Beneficiaries

1	**Training School 1**	**M9**	**3 days**	**CNRS**/STW/ARGOS	**Grenoble, FR**	**ECTS**
	Scientific Training: Design of experiments; Advanced process control; Clinker chemistry					2
	Transferrable Skills Training: How to organise your PhD project at your host, Project managements and Data management, Literature tools.					1
2	**Training School 2**	**M14**	**4 days**	**FLS**/IMP	**Copenhagen, DK**	
	Scientific Training topics: Decarbonization in the cement industry; cement production; process design; CAPEX & OPEX;					2
	Transferrable Skills Training: Research Integrity; Gender Aspects; Diversity.					1
	International Workshop		**1 day**			
	Topic: Poster presentation of the scientific progress of the DCs; Stakeholder meeting with industry.					1
	EU project review		**1 day**			-
	Topics: Presentation by the NC and all DCs; Showcasing of the posters; Meeting of DCs with EU Project Officer.					
3	**Training School 3**	**M26**	**4 days**	**EPFL**/C2CA/ECOS	**Lausanne, CH**	
	Scientific Training topics: Cement chemistry; Cement characterisation; Performance-based design; Technical standards					2
	Transferrable Skills Training: Communication to different audiences. Scientific Misconduct. Data Analysis.					1
	International Workshop		1 days			
	Topic: Modelling of new cement processes. Keynote: Presentation of the scientific results of the DCs. Podium discussion.					1
4	**Training School 4**	**M38**	**4 days**	**MNK**/ABD/IHS	**Cavan, IR**	
	Scientific Training topics: Industrial Practices; cement and concrete market;					2
	Transferrable Skills Training: Innovation Management, IPRs, Mentoring and Supervising Student.					1
	International Stakeholder Workshop		**2 days**			
	Topic: Engage with potential future employers e.g. cement producers (e.g. CRH, Vicat, Cementos Molins, Cementir, HeidelbergMaterials), start-ups (Material Evolution, Alcemy, Betolar, Ecolocked, Carbon8 Systems, C2CA), and venture funds (e.g. Chrysalix VC, Breakthrough Energy) to create new ideas and networks.					1

— **Network-wide online trainings:** These are additional online courses to optimize knowledge transfer.

Table 1.3b: Online Network-Wide Training Events.

5	**Online Training 1**	**M10**	**1 day**	**FLS**/ABD	**ECTS**
	Topics: Industrial project management; online presentation skills; MSCA Green Charter.				1
	Format: Online presentation with parallel breakout section for ideation and career progress.				
6	**Online Training 2**	**M20**	**2 days**	**RWTH**/ARGOS	
	Topics: Thermodynamic modelling – fundamentals and applications in cement industry.				2
	Format: Online presentation with parallel breakout section for hands on exercises.				
7	**Online Training 3**	**M30**	**2 days**	**STW**/UNIPD	
	Topic: Machine Learning methodologies and their use in industry.				2
	Format: Online presentation with parallel breakout section for ideation and product development sprints.				
8	**Online Training 4**	**M36**	**1 day**	**FLS**/EPFL	
	Topic: Career options, professional job search, preparation of CVs and job applications, interview training with HR experts.				2
	Format: Online presentation. Meet with all internal stakeholders plus additional companies from outside (e.g. Vicat).				

— **Training course on computational material design (MIT's professor Elsa Olivetti and STW's Dr. Chiara Masiero, M12 & M30, Copenhagen, DK):** One intensive training week on advanced computational material design using data and new models. Learning the workflow for analysis of scientific publications and datasets through computation Natural Language Processing, the extraction of synthesis routes, data mining and the prediction of novel synthesis routes for SCMs, cements and eventually concrete. The DCs learn how to extract relevant data (e.g. chemical, structural, and physical properties) from the literature and apply these data in ML models.

— **Entrepreneurship training week - from idea to product (KVC, C2CA STW, PTECH, and ICL, M28, Dublin):** One-week training with successful venture capitalist and entrepreneurs (Topics: development of ideas for start-up companies; funding strategies, team composition, critical milestones, valuation, ownership, exit strategies).

3 Local training at participating institutions to address individual training needs. Structured scientific/technical and transferable skills training sessions will be provided to our DCs at all beneficiaries and partner organisations during their placement periods. Examples of relevant courses are shown in Table 1.3.c.

— **Local courses and trainings.** ECTS credits are indicated for comparability and planning. We expect that, in addition to the training sessions (Table 1.3b), each DC will take at least 2 advanced scientific courses and 2 transferable skills courses, selected in alignment with the personal training needs according to his/her scientific topic and personal vision. Course selection and successful participation will be monitored through the CDP and the SB.

Table 1.3c: Local Training Opportunities for the Doctoral Candidates Delivered as In-person or Online Courses according to individual needs.

Host and scientific/technical courses (ECTS credits)	**Transferable skills courses (ECTS credits)**
FLS: Cement innovations (1); Equipment, Operation and Maintenance (1); Process Simulation (2); Process Safety (1).	Project Management (2); Design Thinking (1); IP Management (2); Remote work (0.5); Innovation Management (0.5);
CNRS: Material characterisation fundamentals (1); Cement process engineering and design (5).	Writing and presenting scientific articles (2); Design and analysis of experiments (3); Projects planning and monitoring (2).

ABD: Process modelling and simulation (2); Fundamentals of material characterisation (1).	Scientific writing (3); Data management plan (2); Oral presentation of results (2); Project management (2)
ETHZ: Cement admixtures (2); Cement plant technologies (2); Admixtures compatibility (1); cement characterisation (2).	Research integrity and ethics (3); Planning research and publications/ presentations (3); Digital research management (3)
RTWH: Design of Experiments (2); Scientific measurements and error propagation (1): Cement chemistry (3)	Creation and utilisation of IPs (1); Data management (1); Marketing of high-tech products (0.5).
IMP: Design of Experiments (3), Alternative binders (2), Performance-based design of concrete (2)	Research integrity and ethics (3); Planning research and publications/ presentations (3); Digital research management (3).
TUD: Process Measurement Technologies (2). Recycled Concrete Aggregates and Recycled Concrete Fines (3).	Data analysis (2); English language (3); Project planning and management (2); Conducting professional meetings (1).
EPFL: Durability of cementitious based materials (3), Chemistry of SCMs (2), characterisation of cement materials (2)	Innovation management (0.5); Planning research and publications/ presentations (3); Tutoring and Supervision of Students (0.5).
UNIPD: Sensors in the process industry (4); Flow Modelling (2), High-performance Computing (2); Data Post- processing (2); Data Analytics (2); Data Science applied to engineering (3)	Structuring your PhD project (0.5); Writing Scientific Papers (0.5); Communication Skills for Researchers (0.5); Gender and diversity (0.5); Tutoring and Supervision of Students (0.5).
IHS: Innovation Management (2); Economical analysis (2); Design of Experiments from a social science outlook (2)	IP Management (0.5); Data management For Distributed Teams (0.5; Data Visualization (1); Data Science I + II (2)
MNK: Cement characterisation (2); Process Control Systems (1); Green Technologies in cement and concrete plants (3)	IP Management (0.5); Data management (0.5); Project Management (0.5); Conducting professional meetings (1)
STW: Data analytics (2), ML models (1), AI frameworks (2); Professional coding (2), dataset management (1),	Data management (0.5); Project Management (0.5); Design Thinking (1); IP Management (2); Metadata (1); Remote work (1)
ECOS: Standardisation beyond cement industry (1), Policy makers (2); environmental analysis (2); Sustainability & Standards (2).	Project Management (0.5); Dissemination of project results (1); Dynamic reading (1); Data Visualization (1)

— **Training through secondments and short visits to learn to thrive in different research environments.** Our planned secondments are designed not only to train the DCs in industrial research methods and technology development but also to ensure horizontal knowledge transfer across the organisations and exchange expertise and knowhow. Each DC will learn the latest methods relevant to his/her PhD topic and strengthen their network, the number and quality of their acquired skills and help them adapt better to ever-changing work environments, which in turn greatly enhances their employability. Overall, this will further strengthen the scientific outputs of the project, the technology transfer between the partners, and the quality of the PhD theses. The longer intersectoral secondments will be complemented at least by one short visit of 2 to 3 weeks length of each DC. These visits will allow the DC to learn additional scientific methods, perform complementary work/tests in a new research environment and strengthen the contact network. Details on the duration, timing, and purpose of the secondments and short visits are listed in Section 3.1. Our plan makes sure that all DCs get balanced exposure and opportunities.

— **Training in tutoring lectures and supervision (additional opportunity):** Since research-based training in our respective institutions (CNRS, ABD, ETHZ, RTWH, IMP, EPFL, IHS, TUD) starts at the Master's degree level, all DETOCS DCs will be involved in supporting projects of at least one Master student. They will thus acquire hands-on experience in supervision and leadership, which are important aspects of their CDP. The academic supervisors will also encourage our DCs to prepare and give two full lectures for Master level students in a university to enrich teaching with the latest scientific findings and to report on industrial research to the students. This will be organised and overseen by the main academic supervisor.

1.3.2 Role of the non-academic sector in the training programme

1) Provide data and contribute to scientific advancement: **All** representatives of the non-academic sector will contribute to supervision, mentoring, career development, project governance and support joint contributions with academic institutions (publications, conference presentations). The non-academic sector is heavily involved in all WPs, conducting progress monitoring, helping identify new opportunities. Their specific roles are listed as follows:

FLS as global technology company and service provider for the cement industry offers access to their high-tech cement research centre, where DC1-3, 9, 13 and 15 will conduct their research (utilizing characterisation techniques and pilot plants for SCM and cement testing). **ARGOS** is a highly innovative cement and concrete producer that provides data and reference cases for DC1, 4, 6-8, and 10-13, and modern cement and SCM characterisation lab in DC 7 and 10. Similarly, **MNK** provides cement and concrete process data and reference cases for DC3, 5, 6, 10, 11, 12 & 13. **STW** is a SME focused on data analytics, they support the research work in DC9, 11 and 14. **PTECH** is a SME that supports the research work of DC2, 9, 13 and 14 by offering access to latest particle characterisation technologies. **C2CA** is a SME focused on concrete and RCF; they support the research work in DC 6, 8 and 14 through data from concrete production and recycling as well as SRM. **ECOS** is an international NGO focused on preparation for reuse and material-efficient recycling in policies and standards; they support the research in DC12 & 15. **2) Contribute to the network-wide training with lectures, round table discussion, workshops:** The multinational enterprises and SMEs will deliver lectures and provide information on business models (FLS, STW, C2CA), customer expectation (ARGOS, MNK), career pathways in industry (FLS), and the creation and management of IPRs and entrepreneurship (PTECH, C2CA, STW). Also, FLS and MNK will host training events on their premisses and providing insights into their innovation centres as indicated in Table 1.3a. **3) Deliver local training**

on scientific/technical and transferable skills: Bringing the DCs into contact with local specialists and providing access to in-person courses and seminars as well as in-house training courses during secondments and during short visits up on request (see Section 3.1 and Tables 1.3a, 1.3b and 1.3c). **4) Contribute to agendas for doctoral training and participate in committees:** All non-academic partners provide feedback on the structured graduation projects and support case-by-case the graduation of our DCs, e.g. by becoming a member of the doctoral committee. **5) Participate in Open Science and Data Management:** All non-academic partners will bring a new perspective and supports to make research data findable, available, and re-usable (refer to Section 1.2.5).

1.4 Quality of the supervision (incl. mandatory joint supervision for industrial and join doctorate projects)

1.4.1 Qualifications and supervision experience of supervisors

Qualification: All supervisors work at the forefront of their respective disciplines and are highly experienced in the disciplines required to ensure the completion of the multidisciplinary and inter-sectoral research and training (see Table 1.4a and B2). **Experiences:** Together they have supervised about 150 PhDs, published 360 peer-reviewed scientific papers, 40 patents and have more than 10,000 citations reflecting their scientific relevance and contribution.

Table 1.4a: DETOCS Supervisors / Details of Supervisors, Co-supervisors and Referees (Table 1.4b) – **Part B2** detailed information.

Supervisors	Qualification and Expertise	Supervision Experience
BENEFICIARIES		
Bodil Recke FLS	VP and Head of R&D Cement Process and Systems; PhD Chemical Engineering; Expert in modelling and process control; h-index 10; R&D experience: 20 years.	Co-supervision and mentoring of 50+ graduates, PhDs, PostDocs and young professionals.
Wilson R.L. da Silva FLS	Senior Scientist, Head of SCM research and digital tools; PhD Civil Engineering; h-index 15; industrial R&D experience: 9 years; Former MSCA-ITN-Fellow: PostDoc. on sustainable cement and concrete.	Supervision and co-supervision of 20+ graduates, PhDs and young professionals.
Mariana Canut FLS	Senior Scientist, PhD Civil Engineering; 10 years of process and materials quality experience; part of RILEM calcined clay commission;	Co-supervision of 25+ PhDs, Masters and Bachelor theses.
Mette Moesgaard FLS	Material Characterization Expert in the Cement Lab, PhD in Chemical Engineering at Aalborg University; 11yrs. of experience on process systems and cement chemistry.	Co-supervision of 10+ PhDs, Masters and Bachelor theses.
Poul Fogh FLS	Technology Manager at FLSmidth. eMBA, M.Sc., Graduate Diploma, International Business.	Supervision of 10 + young professionals and students.
Susanne V. Hjuler FLS	PhD in environmental biomaterials from DTU. Sustainability manager; competencies on environmental sustainability in a broader context, incl. sustainable production, eco-design, and energy savings.	Supervision of 10+ PhD, MSc, and BSc students.
Alexander Pisch CNRS	PostDoc (TU Clausthal) in metallurgy, PostDoc (KHT) in solid-state electronics. PhD in Material Science (ING UGA). Former Senior R&D specialist and team leader at the LafargeHolcim in thermodata.	Supervision of 50+ young professionals and students.
Thomas Matschei RWTH	Chair of Building Materials and Institute of Building Materials. PhD in "Thermodynamics of Cement Hydration" at Aberdeen University; h-index 20.	Supervision of 30+ graduates, PostDocs, and PhDs.
Peter Rem TUD	PhD in physicals. Professor and head of Resources & Recycling Section at TU Delft. Modes of behaviour of complex systems in physics, electromagnetics and fluid dynamics, separation science & technology.	Supervision of 70+ graduates, PhDs, PostDocs and young researchers.
Yongli Wu TUD	PhD in Chemical Engineering. Assistant Professor of Resources & Recycling Section at TU Delft. Digital recycling technologies, modelling of particle/particle–fluid dynamics, process design and optimization.	Assisted the supervision of 3 students including both PhD and Masters.
Fabrizio Bezzo UNIPD	PhD in chemical engineering (Imperial College). Professor of Chemical Engineering at Università degli Studi di Padova. Chair of the Energy section of the European Federation of Chemical Engineering (EFCE). Over 170 scientific papers in journals and conference proceedings.	Supervision of 40+ PostDocs, PhDs, Master/Bachelor.
Hoda Beltagui MNK	Graduated with an MEng in Structural and Architectural Engineering and PhD in Engineering from Belfast University. 10+ years of research experience.	Supervision of 10+ undergraduate and postgraduate students.
Eric van Roekel C2CA	Experienced Director working in the environmental services industry. Skilled in Sustainable Development, Waste, Innovation Management, Operations Management, and Coaching.	Industry leader, director of several companies, coaching 40+ young professionals.
Chiara Masiero STW	PhD in Information Engineering from Università degli Studi di Padova. Data Scientist, 10 years of experience with data analytics, predictive maintenance, ML and deep learning. Authored several scientific articles; h-index:10.	Training 20+ students and young professionals.
Beatriz Olvera IHS	PhD in Economics and Policy Studies from Technical Change from Maastricht University School of Business and Economics. Economics researcher and lecturer at the Erasmus University Rotterdam - IHS.	Supervision of 20+ Master/Bachelor theses.
ASSOCIATED PARTNERS		

Daniel Duque ARGOS	Mechanical Engineer. R&D director of Argos Cement. Specialized in improving the sustainability of the cement and concrete industry. Represents Argos in the Steering Committee of Innovandi, GCCA.	Supervision and mentoring of 60+ graduates and young professionals.
Joren Verschaeve ECOS	Programme manager at ECOS. PhD and postdoctoral researcher at the Centre for EU Studies from Ghent University. Lecturer om quantitative research methods at the Department of Political Science of Ghent University.	Mentoring of 30+ PhDs, PostDocs and young professionals.
Karen Scrivener EPFL	Prof. and head of the Laboratory of Construction Materials at EPFL. PhD in Materials Science from Imperial College of London. Founder of Nanocem and GGCA Innovandi Committee. 100+ publications, H-index 100, 40564 citations.	Supervision and mentoring of 70+ graduates, PhDs, PostDocs and young researchers.
Timothy Wangler ETHZ	Postdoctoral researcher and senior research assistant in Physical Chemistry of Building Materials. Expert in digital fabrication and concrete; h-index: 21.	Supervision of 30+ undergraduates, graduates, PhDs and PostDocs.
Elsa Olivetti MIT	Assoc. Prof.in Materials Science and Engineering. PhD from MIT. Founder and head of the Olivetti Group at MIT (focuses on improving the environmental and economic sustainability of materials); 100+ publications; h-index 38	Supervision and mentoring of 50+ graduates, PhDs, PostDocs and young researchers.
Rupert Myers IMP	PostDoc (UC Berkeley) in chemistry and performance of fresh cement and concrete. Senior Lecturer in Sustainable Materials Engineering (Imperial College London). Industrial ecologist/chemical engineer/materials scientist, working on sustainable resources; h-index 27.	Supervision of 50+ graduates, PhDs, PostDocs and young professionals.
Marcus Bannerman ABD	PostDoc from Erlangen-Nuremberg Uni. Senior lecturer at ABD. Specialist in computational techniques to database of thermodynamic data.	Supervision of 60+ students and coordinator for undergraduate projects.

1.4.2 Quality of the joint supervision arrangements

— **Framework for joint supervision.** Each DC will receive high-quality supervision from two top-level researchers representing the academic and non-academic sectors (Table 1.4b). The joint supervision is guided by the *MSCA Guidelines on Supervision* and the *European Charter and Code for Researchers* as well as best practices. For each research period, we have clearly identified a supervisor 1 and 2 and supporting staff (see Table 1.4a and B2). The supervisors identified in Table 1.4a are sufficiently expert in supervising research, have the time, knowledge, experience, expertise, and commitment to be able to offer the research doctoral candidate appropriate support and provide for the necessary progress and review procedures, as well as the necessary feedback mechanisms.

— **Supervisor tasks.** *General tasks of the supervisors:* support, direct, advise and mentor the DC and make sure that the DC can pursue his/her career path. Supervisor 1 is identified as main supervisor for the DC and to whom the DC can refer for the performance of their professional duties. *Specific tasks of the academic supervisor*: secure access to the required university infrastructure and ensure group integration; *Specific tasks of the non-academic supervisor:* secure access to the required industrial infrastructure and link to internal professionals. *Specific tasks of the PhD supervisor:* promote the student at the PhD awarding institution, supervise the PhD thesis, ensure compliance with local rules. The supervisors identified in Table 1.4b form joint supervision committees for each DC to ensure true collaboration, establish the CDP, problem-solving, decision-making, and scientific excellence.

— **Career Development Plan (CDP).** The DC and the supervisors will develop together the CDP as planning tool for specific activities, professional development needs and career objectives as well as new opportunities (D4.4). This plan is individual to each DC and will be jointly review and updated with the supervisors twice per year.

— **Supervision process and quality assurance.** DCs will hold regular weekly meetings with their supervisor(s) to discuss work progress, challenges, and additional training needs (the DC makes the minutes). The DC and his/her joint supervision committee will meet four times a year to discuss the scientific progress, the progress of the doctoral thesis and the CDP. All DCs and supervisors will meet bi-weekly (coordinated by project manager) to share information and give the DCs a platform to report on scientific progress (rotating). Group meetings will be mostly online but in-person when coupled to a network event. In addition, bi-annual reports will be submitted by all DCs to the corresponding supervisors (followed by submission to the Supervisory Board to monitor the progress).

Table 1.4b: Joint Supervision Arrangements.

DC	Supervisor 1	Institution	Supervisor 2	Institution	PhD supervisor
DC1	Alexander Pisch	CNRS	Mette Moesgaard	FLS	Alexander Pisch
DC2	Marcus Bannerman	ABD			Marcus Bannerman
			Mariana Canut	FLS	Alex Pisch
DC3	Timothy Wangler	ETHZ	Wilson R Leal da Silva	FLS	Robert Flatt
DC4	Bodil Recke	FLS	Thomas Matschei	RWTH	Thomas Matschei
DC5	Thomas Matschei	RWTH	Daniel Duque	ARGOS	Thomas Matschei
DC6	Thomas Matschei	RWTH	Eric van Roekel	C2CA	Thomas Matschei
DC7	Peter Rem	TUD	Daniel Duque	ARGOS	Peter Rem
DC8	Karen Scrivener	EPFL			Karen Scrivener
	Thomas Matschei	RWTH	Eric van Roekel	C2CA	Thomas Matschei
DC9	Fabrizio Bezzo	UNIPD	Poul Fogh	FLS	Fabrizio Bezzo
DC10	Peter Rem	TUD	Hoda Beltagui	MNK	Peter Rem

DC11	Fabrizio Bezzo	UNIPD	Chiara Masiero	STW	Fabrizio Bezzo
DC12	Beatriz Olvera	IHS	Joren Verschaeve	ECOS	Beatriz Olvera
DC13	Thomas Matschei	RWTH	Wilson R. Leal da Silva	FLS	Thomas Matschei
DC14	Eric van Roekel	C2CA	Yongli Wu	TUD	Yongli Wu
DC15	Rupert Myers	IMP	Susanne V. Hjuler	FLS	Rupert Myers

2. Impact

2.1 Contributing to structuring doctoral training and to strengthening European innovation capacity

2.1.1 Meaningful contribution of the non-academic sector to the doctoral training, as appropriate to the implementation mode and research field

The DETOCS industrial doctoral training programme involves the non-academic sector through **3 multinational corporation** (FLS, MNK, ARGOS), **3 SMEs/Start-ups** (C2CA, PTECH, STW), **2 NGOs** (ECOS, VDZ) a **technical consulting firm** (KLINE), **1 foundation** (BE) and **1 venture capital firm** (KVC), contributing to:

— **Access to industrial research infrastructures and process data** through secondments and short visits to improve the quality of results through broader use of methods, from lab-scale to pilot-scale to demonstration- and industrial plants; — **Joint supervision, mentoring and guidance** on the use of methods, data processing, interpretation of data as well as guidance on appropriate training events, skills development, and career options for informed decisions**;**— **Network-wide lectures** on scientific/technical, management and product-related topics to support skills development, interdisciplinary knowledge accumulation and strategic thinking among our DCs; – – **Feedback on engineering curricula, teaching** at the academic institutions through access to case studies and sharing of technical data, for example to validate models; — **Entrepreneurships weeks** led by the industrial partners, start-up representatives, KVC and academic tech transfer offices, where the DCs are encouraged to think about their work in an entrepreneurial way; — **Participation in project governance and monitoring activities** through participation in the Supervisory Board and work package activities and by building bridges to the in-house training managers to exchange best practice; — **Providing in-house training sessions** through access of in-person courses or to a relevant portfolio of high-quality online resources and courses that typically only access employees (e.g. FLS Institute); — **Taking part in the outreach activities** through joint publications, exploitation measures, and providing access to the established communication channels and audiences (press releases, social media, website, etc.); – – **Providing access to new contacts for future collaboration** with technology suppliers, emerging start-ups (Material Evolution, Alcemy, Betolar, Ecolocked, Carbon8 Systems, C2CA), cement producers (e.g. CRH, Vicat, Cementos Molins, Cementir, HeidelbergMaterials, etc.), associations (VDZ) and research organisations (e.g. EIT); – – **Providing career advice** and contacts to Human Resources and company Talent Scouts to learn about career development opportunities and programmes in industry and what is necessary to succeed on the job market post-graduation. — **Support the transferable skills development** through lectures by dedicated industry specialists such as patent attorney, communication specialists, IT specialists, product managers, sales teams, and informal training during periods of industrial placements (e.g. through participation in meetings and decision-making, shadowing staff, supporting internal and external communication, etc.).

2.1.2 Developing sustainable elements of doctoral programmes

The training content is new and delivered by industry and academia for the first time. We see DETOCS as an initiative that will continue and further grow after the end of the project. The network thrives for the following:

1) **Enrich academic teaching with new content:** We aim to enrich Bachelor and Master level lectures with inspiring academic/industrial content as well as transferable skills established during the project. The new educational material and non-business sensitive data will be shared publicly on the project and/or institutional websites (D5.1), and remains available for at least *5 years* after the end of the project.

2) **Continuation of the DETOCS Training School:** The network is intended to continue for at least 5 years with the annual Training School (hosting institution rotates) established as a major European training event for PhD students, young research associates, and industry professionals working on green cement and concrete.

3) **Creation of new scientific methods and R&D capabilities for future training:** The project will enhance the scientific modelling methods, development of optimal material blends with predictable properties, new control strategies, and stakeholder knowledge that is the basis for further academic collaboration.

4) **Publishing a textbook on the topic for students:** Towards the end of the project, a textbook (e.g. Wiley, McGraw Hill or Princeton Press) is intended to be published as a major reference work that includes, e.g. the value chain and how data-driven transformation in the industry enables CO_2 emission reduction, etc.

5) **Improve the working conditions and female participation:** The project will help further improvement of working conditions in research by demonstrating transparency, diversity, international exchange, flexible working times, remote work, access to industrial stakeholders, mentoring to act as a role model in Europe.

6) **Forming new collaborations for future research and scale-up:** The network will seek opportunities to continue collaborations between industry and research organisations to discover knowledge, create innovations and educate

students. Potential targets are InnovFund, EIT and EIC Pathfinder open grants.

2.2 Credibility of the measures to enhance the career perspectives and employability and skills development

Career perspectives – beyond the academic world: The DETOCS research and training programme prepares our DCs for jobs with science-related activities at the core. Our programme enhances perspectives for *careers in leading academic organisations* (from distinctive postdoc positions towards full professorship at top-level universities) and in the *non-academic organisations* (scientist in a research organisation, corporate scientist, specialist, industrial innovator, science manager or even analyst in companies, governmental organisations, or NGOs). Through DETOCS, we enable our DCs to develop an individual set skills, understandings, and personal attributes – that make them more likely to gain the targeted top-level employment and be successful and satisfied in their chosen occupations, which benefits themselves, the workforce, the society, and the European economy through satisfactory work on the green industry transition. New career perspectives and improved employability comparted to their peer colleagues is a direct function of skills development through the DETOCS programme.

Development of future-relevant skills and competences: Major skills and competences that will be developed through the DETOCS, namely: *Enhanced research potential and creativity* aligned with global challenges and business aspects. | *Becoming familiar with new and advanced scientific methods* in an interdisciplinary context and network-wide training that greatly enhances the quality of research in the medium-term. | *Profound knowledge on a diverse set of specialised equipment and software* including, but not limited to, an extensive overview of relevant state-of-the-art research, process equipment, ML tools for prediction and control of industrial processes (see B2). | *Proficiency in report and proposal writing* through dedicated training and frequent practice on both topics. The supervisors will help students to master these highly relevant skills. | *Understanding the dissemination mechanisms and publishing cultures* through recognition and documentation of high-impact research, and how to avoid any scientific misconduct. | *Becoming familiar with impact-driven project management* by all DCs and unlocking resources and leveraging the ecosystems of FLS, ARGOS, MNK. | *Profound teamwork and leadership competencies* are strengthened by DCs in collaborative environments through understanding effective relationships with peers, colleagues, specialised scientists, and industrial leaders (WP5). | *Mastering research-related software use* e.g., Python, GEMS, Aspen, digital collaboration tools (*Miro and Remo*), lab journals, and idea and innovation management (*PICC*). | *Ability to communicate globally with high efficiency and across disciplines* through daily interactions with scientists, industrial innovators, managers, and the public to generate outputs and impact. Gaining proficiency in a secondary language is supported. | *Profound understanding of industrial environments, innovations, and entrepreneurship*: DCs will develop competences on how to bring an idea or scientific result to a product closer to the market (including IP handling). | *Becoming familiar with work ethics, social understanding, and inclusion* by all DCs via e.g., applying principles of ethical conduct of research, and avoiding research misconduct, encouraged diversity, open science, and adaptation to new environments. | *Self-management and the ability to work in an efficient and structured manner* by strict requirements for each DC as well as time restriction of 36 months for each DC.

Enhanced career perspectives through valuable obtained skills: The 13 DCs will have an enhanced chance of employment upon completion of the study. They will acquire industry-relevant skills, unique personal development, and a diverse network composition. We will particularly encourage cross-sectoral and transnational mobility throughout the DCs' careers. This includes higher education, research organisations, NGOs, private or large SME companies, the public body, and international organisations or within the countries of residence. This makes our DCs highly valuable on knowledge transfer, leadership tasks, and large-scale transformative projects. They will thrive in interdisciplinary environments and have great potential to contribute to breakthroughs, address societal problems, and champion innovation – all of which is underpinned by corresponding DETOCS training modules (see Section 1.3). It is expected that our DCs will promote interdisciplinary research in Europe after the project. We expect all our DCs to move to more senior positions after the MSCA fellowship with the potential of a permanent position in academia (with tenure track offers at a top-notch European university or research organisation), or permanent positions at multinational enterprises with ambitious sustainability goals.

2.3 Suitability and quality of the measures to maximise expected outcomes and impacts, Suitability and quality of the measures to maximise expected outcomes and impacts, as set out in the dissemination and exploitation plan, including communication activities

2.3.1 Plan for the dissemination and exploitation activities, including communication activities

The DETOCS consortium ensures that all research results and outputs will be screened and evaluated to protect their commercial use within and/or outside the network. The results that have no direct commercial value to the network will be immediately published for further use by other research communities and innovators (*see annotated MGA*). All activities are guided by our **Dissemination and Exploitation Strategy (D5.3)**, which will be reviewed and updated every six months. The partner that intends to disseminate or exploit results will give notice in advance to other relevant partners to ensure legitimation. Our strategy has the three following major elements:

Dissemination activities — Goal: The first part of the strategy aims to report original research results to advance global knowledge on the activation of SCMs as well as digital solutions for new cement and concrete blends. We expect a high degree of joint publications due to the programme setup and several presentations. **Target audiences:** Bachelor and Master students, PhD students, Postgraduates, librarians, researchers, lecturers, senior lecturers, associate professors, and full professors, as well as interested citizens from fields such as civil engineering, chemical engineering, environmental engineering, material science, chemistry, and physics. The results and outputs shall generate impact through the following quantified targets and pathways:

— **30 peer-reviewed publications in high-ranking scientific journals**. The plan is for each DC to achieve at least three peer-reviewed publications in top 20% peer-reviewed journals with at least 24 joint publications. We fully support the mandatory EU **open access** policy (license type: CC-BY) to all publications and underlying research data related to our results. Journals foreseen for publication include *J. Civ. & Env. Eng., J. Architectural Eng. Tech., Cement and Concrete Res., Cement and Concrete Composites, Int. J. Cement Composites and Lightweight Concrete.*

— **20 scientific presentations at international conferences**. DCs are expected to present at least three times at distinguished international conferences, such as *International Congress on the Chemistry of Cement, International Conference on Cement and Concrete Technology, Future Cement Conference and Exhibition, International Conference on Cement, Concrete and Building Materials* to get feedback from the scientific community, establish relationships with other researchers and gain confidence in scientific environments within and outside of Europe.

— **20 oral and poster presentations by DCs at DETOCS progress meetings / workshops** to constantly train communication skills and disseminate the results with all participating organisations and external ones. The events will be an informal platform to share ideas, knowledge and acquire feedback from peers and to enlarge the network.

— **At least 22 presentations at local PhD and industry seminars not directly related to DETOCS** encouraging a dialogue with a broader range of scientists and decision makers and to report on the progress of the research, as well as to ensure that local academic standards are met, and faculties are informed about the MSCA programme.

Exploitation activities — Goal: To organise an uptake of the results and outcomes by stakeholders, facilitate technology transfer, and unlock greater value of the results and outcomes from a transfer into commercial settings. **Target audiences:** Industrial DETOCS partners/commercialization teams, researchers, industrial innovators, start-up companies, SMEs, members of professional associations, policy makers, business investors, national governments, regional authorities. The results shall generate impact through quantified targets and pathways, i.e.:

— **Protection of results with 3-6 IPRs and utilization for commercial use:** The starting point is proper IP protection through the creation of Intellectual Property Rights (IPRs) such as patents to secure freedom to operate (see below) and the right to exploit the knowhow and assets. These can be kept for own business purposes and exploited through a new product licenced to third party or transferred exclusively or non-exclusively to a new owner to generate a new stream of revenues. Besides, DETOCS IPR assets can form the basis for the creation of a start-up company (independent or joint venture). *KPI: Number IPR assets generated.*

— **Knowledge transfer & know-how protection:** by pairing experienced personnel with the students during their industrial stays, the partner companies aim to improve the relevance of generated know-how, exploit synergies with existing know-how and retain it within the business.

— **Make use of results in at least 3 further research activities and collaborations**: Make contacts and plan new R&I projects in uncovered directions and at higher TRLs. It is our goal to extend our network through participation in events, conducting our own events and clustering activities with other EU projects. *KPI: Number of additional projects created during the project lifetime (public, private or blended funding).*

— **Extend links to representatives of 3 international and national funding agencies,** such as *EUDP or MUDP (DK), DFG (DE), CINEA (EU), EISMEA (EU), EIT KICs (EU)*. Show decision-makers and programme coordinators that R&I in this direction is important. Get into contact through events, invitations and supporting evaluations. *KPI: Number of contacts created.*

— **Reach out to 3 professional associations and non-governmental organisations (NGOs) and participate at events, together with our DCs,** such as the *Verein Deutscher Zementwerke, World Cement Association* through participation in their events and invitations to our events. This will create awareness of our scientific outcomes and support decision-making. *KPIs: Number of contacts created, and strategy papers contributed.*

— **Create links to political stakeholders** such as local authorities, research ministries and agencies to encourage dialogues about the opportunities, challenges and future needs to enable support from politicians and to support evidence-based policymaking. We will organise invitations to company visits and our events and participate in public discussions with our DCs. *KPI: Number of events participated*.

— **Participation in at least 3 fairs, exhibitions, and roadshows together with DCs:** The network, including our DCs, will participate in several major events to engage with companies and other stakeholders to form new contacts and learn about other technologies. *KPI: Number of events visited.*

— **Participation in 3 investors and start-up forums together with DCs:** Our DCs will be encouraged to take part in such forums to see successful start-ups, understand investors, and anticipate future technologies in cleantech.

Examples are the annual *DESCA Investors Forum* and the *Cleantech Forum Europe*. *KPI: Number of events visited.*
— **Present at least 2 outcomes at the EU HORIZON Results Platform:** to advertise the major business-relevant outcomes of the project to find interested stakeholders and to generate new partnerships for the commercialization of these outcomes (e.g. soft sensor technology). *KPI numbers of outcomes presented.*

Communication measures and public engagement strategy — Goals and Message: To inform the public about research activities, careers in science, the benefits from science and public-private partnerships, innovation, new products and business growth in Europe. To highlight the potential of our solutions to effectively reduce CO_2 emissions, guide informed decision making in Europe and beyond.
The project shall generate impact through the following quantified targets and pathways:
— **1 project website:** To form two-way contact with different audiences and stakeholders and share knowledge and materials, progress reports, including educational presentations. *KPI: Target number of visits 1000 in the first year with a growth rate of 500 per year.* — **16 newsletters:** a quarterly electronic newsletter to announce training events, share results and announce new opportunities to stakeholders. *KPI: Distribution to at least 100 individuals and organisations.* — **1 social media channel and 12 posts on websites/blogs of our partners** to efficiently engage with the broader public, NGOs, and social movements. The most suitable channel is LinkedIn to communicate with a professional network. Together with the FLS media centre, we will generate 3 short interview videos with our DCs and 1 video about our decarbonization approaches. *KPI: number of LinkedIn user reached, target 3,000.* — **6 participations in the annual, open-door events and the MSCA Researcher's Nights** of IMP, ABD, UNIPD, ETHZ, EPFL, TUD, CNRS to showcase the project and its relevance to the people to high-school students, parents, interested citizens, and other students. Our DCs will act as ambassadors to showcase their interesting research topics. *KPI: all DCs participate in at least one event.* — **2 participations of our DCs in European or national science festivals** in the third year of the project, such as the *European Science Festival* and *Falling Walls Science Summit in Berlin* to engage with research policymakers, business representatives, decision makers, science journalists, bloggers and NGOs. *KPI: all DC participate in at least one event.* — **2 popular scientific magazine articles for a layperson audience:** Communication of the research results in popular science magazines, for example, the British *"New Scientist"*, the German *"Spektrum der Wissenschaften"*, the American *"Scientific American"*, or the European Magazine *"EuroScientist"* with a readership above 100,000 people. — **18 in-house media mentions:** All partners are committed to presenting the project in in-house media, e.g. newsletters, reports, stories to employees. The utilisation of these established in-house communication channels will reach several thousand people, upper management and decision makers. *KPI: number of mentions.* — **2 professional interviews:** We leverage our network to get contacts to professional journalists and science and technology podcasters to get the chance for an interview, creating an opportunity to reach the public at large. *KPI: to reach at least 500 people per activity.* — **4 school visits:** Each academic partner will organise at least one school visit and talks to high-school students on the contribution of science and engineering to reducing carbon emissions and the barriers to overcome. *KPI: to reach at least 100 pupils.*

2.3.2 Strategy for the management of intellectual property, foreseen protection measures

From results to value: All DETOCS beneficiaries will use their best efforts for an exploitation of the Assets that shall be generated during the project which are: 1) New models predicting the properties of SCMs, cements, and concrete that shall be protected through licenses and copyrights; 2) New measurement techniques and control strategies for different parts of the process/value chain that shall be protected through patents; 3) New software tools that shall be protected through licenses and copyrights.

Assets generated shall be utilized for i) an expansion of the current business, either by DETOCS partners or licensed third parties, ii) sale (i.e. transfer of ownership) and iii) entering the market by creating a start-up company. The IP management process will be done using an online tool with focus on: 1) Background IP to be shared royalty-free among DETOCS partners during the project; 2) Frequent monitoring, review and reporting of DETOCS partners' research results and outcomes; 3) Decision on protection measures and shareholding of joint inventions by the involved parties through negotiations. The NC will act as coordinator and arbitrator of the IP management process. In addition, our DCs will receive training in IP management by industry and technology transfer specialists.

2.4 The magnitude and importance of the project's contribution to the expected scientific, societal and economic impacts (project's pathways towards impact)

DETOCS is impact-driven and committed to make progress towards the objectives of the EU priorities defined, in the *EU Strategic Agenda*, the *Green Deal* and the *United Nations Sustainability Development Goals (SDGs)* that network partners monitor and adapted to their own strategic agendas such as *MissionZero* (FLS), *Green Solutions* (ARGOS; MNK). As DETOCS aims to be a transformative project in the cement industry, we have identified 9 significant impacts accompanied by individual pathways ranging from short- to long-term (Table 2.1a-c).

2.4.1 Expected scientific impacts

Table 2.1a: Project's pathways to scientific impact

P*	Results and outputs during the project	Outcomes in the longer-term	Targeted impacts
Expected scientific impacts			
1	Generation of 39 high-quality publications in the top 10% journals of the disciplines involved that become influential in the field.	Several of the publications (3-6) reach very high Field-weighted Citation Impacts and are seen as core contributions to cement research.	New, high-quality knowledge as a basis for engineering solutions and decarbonization.
2	4 public industry-driven training events to educate our 13 DCs and 50-60 Master and PhD students in the field of sustainable cement and concrete and SCMs.	Continuation of the Training School as major event in Europe that connects stakeholders and young professionals. From which 50% achieve influential positions in the cement ecosystem.	Strengthening the human R&I capital and scientific leadership in Europe (patents, publications).
3	Open access, open data and FAIR data handling to amplify the DETOCS results and act as role model.	Uptake of data, results and outcomes by other organisations and creation of 6-8 new R&I networks to explore higher TRLs	Free diffusion of knowledge and Open Science as new standard in both sectors.

2.4.2 Expected economic//technological impacts

Table 2.1b: Project's pathways to economic impact

P*	Results and outputs during the project	Outcomes in the longer-term	Targeted impacts
Expected economic impacts			
4	The results will be protected via at least 3 patents and 1 trademark, and evaluation of the potential of a new venture (similar to C2CA).	Additional 3-10 IPR assets, 3-4 new commercial solutions launched, growth of the market segment for SCMs, 2-3 start-ups created.	Innovation based growth of stakeholder e.g. CRH, Vicat, Holcim etc. | transformation of start-ups to grown-ups.
5	Partners hire 4 to 6 scientists and engineers beside the 13 DCs for support. Improved working conditions + mission to attract talent.	Partners and adopter will hire 40 to 60 scientists, engineers, and technicians to support R&I and scale-up activities	Creating high-quality jobs that diffuse in other industries and accelerate going green
6	New collaborations (10) and joint R&I projects (5) with expected investments from FLS, ARGOS, MNK between 8 and 10 mEUR. New software solutions to minimize clinker content, maintain process stability and high-quality output.	Conversion of existing facilities and erection of new ones dedicated to SCM activation, low-clinker cement and concrete production, with at least 20 to 40 mEUR investments. Commercialization of processing solutions and hardware-enabled process control to maximize the use of SCMs.	Shift to performance-based standards, investments (1-5 bn. EUR) and global roll-out of new solutions. Industry transition to decentralized facilities using SCMs.

2.4.3 Expected societal impacts

Table 2.1a: Project's pathways to societal impact

P*	Results and outputs during the project	Outcomes in the longer-term	Targeted impacts
Expected societal and environmental impacts			
7	Enable decrease in clinker factor from 75% to 40%, Technoeconomic analysis reveals 35-50% CO_2 savings per ton of cement is achievable without compromising on quality and cost.	Demonstration of CO_2 reduction by a cement and concrete producer (ARGOS, 3000 t/d) by at least 0.3 M t/year. Linear scale-up with replacement of clinker by SCM. Enable decrease in clinker factor down to 25%.	Decrease CO_2 emissions of a cement by 50% by 2030 while maintaining competitiveness. Bring the cement industry in line with the net zero emissions goal.
8	Develop content (e.g. 4 new courses), disseminate knowledge in broader context and make green cement workplaces more attractive for women.	Enhance societal knowledge and involve 40-60 non-scientist in citizen science and foster female participation in the workforce (achieve 35% women in green industry solutions).	Enhance the quality of education and achieve gender balance and more inclusion and diversity.
9	Involve citizens, decision makers (e.g. via VDZ) and exchange with policymakers to inform them about the approach and results (e.g. through 2 policy briefs and 2 case studies).	Enable science-based informed policy- and decision-making to support GD milestones and goals (carbon neutral or better by 2050) through 5-10 new high-level contacts (e.g. via expert groups, academies, etc.)	Enhance the understanding of EU citizens and support the green and digital EU transition.

3. Quality and Efficiency of the Implementation

3.1 Quality and effectiveness of the work plan, assessment of risks and appropriateness of the effort assigned to work packages

3.1.1 Work packages list | Table 3.1a: Work packages list

No	WP Title	Start Month	End Month	Activity Type[1]	Lead Name	DCs
1	Prediction and control of binder quality	7	42	RES	FLS	1-4
2	Quality prediction and performance-based design of low-carbon cement and concrete mixes produced therewith	7	42	RES	RWTH	5-8
3	Digital solutions applied to low-carbon cement and concrete materials	7	42	RES	STW	9-11, 13, 14
4	Market acceptance of low-carbon cement	7	42	RES	IHS	12, 15

5	Training	1	48	TRA	UNIPD	All
6	Outreach	1	48	DIS	FLS	All
7	Management	1	48	MGT	FLS	All

[1] *MGT: Management; RES: Research; TRA: Training; DIS: Dissemination, exploitation and communication*.

3.1.2 Recruitment Table per beneficiary | Table 3.1e

No.[1]	Host-1[2]	Start[4]	D[5]	Host-2[2]	D[5]	Second. [6]	D[5]	Industry	PhD[3]	D[5]
DC1	CNRS	M7	36			FLS	18	50%	UOG	36
DC2	FLS	M7	27	ABD***	9	CNRS	9	50%	UOG	36
DC3	ETHZ***	M7	36			FLS	18	50%	ETHZ	36
DC4	FLS	M7	18	RWTH	18			50%	RWTH	36
DC5	RWTH	M7	18	MNK	18			50%	RWTH	36
DC6	C2CA	M7	36			RWTH	12	67%	RWTH	36
DC7	TUD	M7	36			ARGOS	18	50%	TUD	36
DC8	EPFL***	M7	18	C2CA	18			50%	RWTH & EPFL	36
DC9	UNIPD	M7	18	FLS	18			50%	UNIPD	36
DC10	TUD	M7	36			ARGOS	18	50%	TUD	36
DC11	UNIPD	M7	18	STW	18			50%	UNIPD	36
DC12	IHS	M7	36			ECOS	18	50%	IHS	36
DC13	FLS	M7	36			PTECH RWTH	12 12	67%	RWTH	36
DC14	C2CA	M7	5.5					100%	TUD	5.5
DC15	IMP***	M7	36			FLS	12	33%	IMP	36
Total of PM (for all DCs) including the non-AC.			**410.5**		**99**					**509.5**
Total PM that will receive EU contribution			**320.5**		**90**					**410.5**

[1] Researcher No.; [2] Recruitment Participant; [3] PhD-awarding entities; [4] Planned Start Month; [5] Duration in months; [6] secondment. *) at least 50% of the time in industry. **) Total excluding Associated Partners, UK & CH (in DC2, DC3, DC8, DC15); *** Associated Partners

3.1.3 Individual research projects, including secondment plan | Table 3.1f

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC1	**CNRS**	**UOG**	**Month 7**	**36 months**	**D1.2, D1.4, D2.1**

Title: Accurate prediction of clinker quality and process related information using a high temperature thermodynamic approach

Objectives: 1) Development of a numerical model to predict the clinker mineralogy for a given chemical composition. 2) Combination with DC5 to develop a blended cement reactivity model. 3) Investigation of unexplored composition ranges using state of the art machine learning techniques to detect hidden correlations with impact on clinker mineralogy and related to clinker reactivity in the final cement.

Expected results: 1) Full clinker mineralogy prediction model based on the chemical composition. 2) A coherent set of Gibbs energy thermodynamic data for the main clinker phases which can be used in hydration modelling (GEMS). 3) Detection of unknown correlations between chemical and mineralogical composition of a clinker with impact on reactivity.

Placements: 36 months CNRS, **Secondment:** 18 months FLS, **Short visits:** 3 weeks RWTH, 2 weeks ARGOS.

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC2	**FLS/ABD**	**UOG**	**Month 7**	**36 months**	**D1.3, D1.4, D2.1**

Title: Thermal activation of SCMs: Process Models and Quality prediction.

Objectives: 1) Develop a flash and rotary kiln process model for thermal activation of SCMs, e.g. calcined clays. 2) Experimentally investigate the correlation between real process operation conditions and the SCM / calcined-clay activity. 3) Close the gap between models correlating the reactivity of thermal-activated SCMs based on physical & mechanical properties, process data, and clinker interaction.

Expected results: 1) A process model for the rotary and flash calcination process, including low-resolution models for the unit operations, detailed models for the high-temperature kiln/calciner, and a thermodynamic model for the solids. 2) A dataset of calcined clay properties including activity, and corresponding raw material characterisation and process conditions. 3) A predictive model correlating process conditions with calcined clay performance, for the use in optimising the process efficiency and product performance.

Placements: 27 months FLS, 9 months ABD , **Secondment:** 9 months CNRS, **Short visits:** 2 weeks PTECH

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC3	**ETHZ**	**ETHZ**	**Month 7**	**36 months**	**D1.4, D2.1**

Title: Chemical activation of SCMs via carbonation and admixtures: Quality Prediction

Objectives: 1) Identify the key parameters in SCM composition that impact required admixture dosages. 2) Identify the key parameters in admixture formulation that impact low carbon cement performance. 3) Insights towards prediction of the SCM reactivity based on blend and admixture dosage.

Expected results: 1) Model correlating SCM characterization data with reactivity, and ultimately with activator/admixture dosage. 2) Predicted activator/admixture dosage limitations based on flowability and durability requirements in low carbon cement. 3) Characterized admixture impact on the performance RCF produced at different carbonation rates.

Placements: 18 months ETHZ, 18 months FLS, **Short visits:** 2 weeks C2CA, 2 weeks MNK.

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC4	**FLS/RWTH**	**RWTH**	**Month 7**	**36 months**	**D1.1, 1.4, 2.1**

Title: Mechanical activation of SCMs: Process Models and Quality prediction

Objectives: 1) Identify the key material properties driving the reactivity of mechanically activated SCMs. 2) Identify the key process parameters driving the final quality of mechanically activated SCMs. 3) Predict the SCM performance based on process parameters and SCM material properties. 4) Validate the SCM performance (reactivity) based on a novel application-based testing method.

Expected results: 1) Novel protocol to optimise SCM and blended cement constitution by means of grinding/mechanical activation e.g. optimum fineness range of SCM versus clinker to optimise early strength, relations between SCM and clinker PSD to rheological properties. 2) New application-based testing regime to enable assessment of concrete performance in cement plant labs. 3) Draw conclusions on the impact of tailored early age reactivity of SCM vs clinker in multi-component cements via mechanical activation on mechanical concrete properties. 4) Draw conclusions on the impact of tailored early age reactivity of SCM vs clinker in multi-component cements via mechanical activation.

Placements: 18 months FLS, 18 months RWTH **Short visits:** 2 weeks ARGOS, 3 weeks PTECH.

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC5	**RWTH/MNK**	**RWTH**	**Month 7**	**36 months**	**D2.1, D2.6, D4.3**

Title: Quality prediction of low-carbon cement blends

Objectives: 1) Integration of predictive models to estimate the performance of the final cement blend. 2) Development of pragmatic test methods (rapid test) to verify the quality of cement blends. 3) Enable a tailormade optimisation of the mix design of blended cements as function of clinker mineralogy and SCM reactivity.

Expected results: 1) Validation of thermodynamic model of clinkering with QXRD plant data and additional KPI´s e.g. free lime variation. 2) Kinetic reaction profile of individual cement components (clinker and SCM) validated by selected hydration studies. 3) Phase distribution model of hydrated blended cement as function of time. 4) Derivation of mix design rules for optimal performance of future blended cements.

Placements: 18 months RWTH, 18 months MNK, **Short visits:** 2 weeks CNRS, 2 weeks STW.

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC6	**C2CA**	**RWTH**	**Month 7**	**36 months**	**D2.2, D2.5, D4.3**

Title: Environmental and technical performance-based design of concrete

Objectives: 1) Develop streamlined physical models to predict key early (strength development) and late (resistance to concrete deterioration i.e. durability) age performance of concrete, for all concrete types. 2) Integrate this method with environmental life cycle assessment and data obtained from industrial plants, enabling both technical and environmental performance of concrete to be optimized simultaneously. 3) Apply the method to predict optimal concrete mixes based on locally available materials. 4) Validate the model predictions using data from laboratory experiments and industrial plants.

Expected results: 1) A streamlined physical model for carbonation resistance of concrete. 2) An updated Python code that can quantify the durability, mechanical, and environmental performance of concrete based on its mix design and prevailing environmental conditions. 3) Identification of the optimal concrete types in terms of these performance attributes and carbonation resistance. 4) Validation of the modelling results through experimental testing and industrial plant data.

Placements: 36 months C2CA, **Secondment:** 12 months RWTH, **Short visits:** 1 week MNK, 1 week ARGOS, 3 weeks RWTH.

Fellow	Host Institution	PhD Enrolment	Start Date	Duration	Deliverables
DC7	**TUD**	**TUD**	**Month 7**	**36 months**	**D2.3, D2.6, D4.2, D4.3**

Title: Impact of material variability on concrete performance

Objectives: 1) Identify the primary sources of variability in concrete production based on existing material data. 2) Assess the impact of raw materials (aggregates, cement, SCMs) variability on concrete performances. 3) Provide an economical & environmental analysis of the impact of material variability on concrete production.

Expected results: 1) The key parameters that cause variability will be defined and their acceptable range of variability in concrete production will be studied. 2) A correlation of process variables with concrete property to predict the concrete performance (in collaboration with DC6 and DC8). 3) A correlation between circularity, resources use and environmental impact will be addressed**.**

Placements: 36 months TUD, **Secondment:** 18 months ARGOS, **Short visits:** 2 weeks C2CA, 2 weeks MNK.

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC8	**EPFL/C2CA**	**RWTH & EPFL**	**Month 7**	**36 months**	**D2.4, D2.5, D2.6**

Title: Quantifying concrete properties from cement paste scale tests

Objectives: 1) Develop streamlined physical models to predict durability of concrete mixes produced with blended binders that have a high SCM content and exposed to chloride migration and carbonation. 2) Identify the key Durability Indicators (DI) to be measured at cement paste scale for rapid assessment of concrete durability. 3) Validate the model predictions and I based on lab tests and concrete plants data.

Expected results: 1) Reduce the time to adoption of novel low-carbon cement. 2) A streamlined testing framework to analyse the relevance of a given SCM. 3) Guidelines to concrete formulation of novel binders with respect to durability. 4) Pathway to a performance-based approach to concrete formulation.

Placements: 18 months EPFL, 18 months C2CA, **Short visits:** 2 weeks ARGOS, 3 weeks RWTH.

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC9	**UNIPD/FLS**	**UNIPD**	**Month 7**	**36 months**	**D3.1, D3.4**

Title: Soft-sensing and data analytics for in-line measurements in low-carbon cement production

Objectives: 1) Develop novel deep learning-based mathematical approaches fit to the blended cement production processes. 2) Develop soft sensors for monitoring in-process quality of cement grinding and blending.

Expected results: 1) Definition of the most effective deep learning approaches in view of available datasets in cement processes; 2) Demonstration of efficacy and accuracy of soft sensors and their potential to digitalize cement industry.

Placements: 18 months UNIPD, 18 months FLS, **Short visits:** 1 weeks PTECH, 3 weeks STW.

Fellow	Host Institution	PhD Enrolment	Start Date	Duration	Deliverables
DC10	**TUD**	**TUD**	**Month 7**	**36 months**	**D3.3, D3.4, D4.3**

Title: Traceability of concrete materials along the value chain

Objectives: 1) Development and application of Radio Frequency Identification (RFID) technology to monitor and track the quality across the value chain of concrete materials. 2) Design a robust hardware system that can withstand a typical concrete production process. 3) Design software to enable adding and verifying information across the value chain.

Expected results: 1) RFID tags will be used to track and trace info about the quality of construction materials along the value chain. 2) Durable RFID tags will be designed, tested, and applied in concrete production. 3) Establishing a robust communication system between RFID tags and the cloud system to access and update product information.

Placements: 36 months TUD, **Secondment:** 18 months ARGOS, **Short visits:** 2 weeks C2CA, 2 weeks MNK.

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC11	**UNIPD/STW**	**UNIPD**	**Month 7**	**36 months**	**D2.1, D3.2, D3.3, D4.3**

Title: A machine learning framework to predict cement and concrete quality attributes

Objectives: 1) Development of a machine learning methodology to predict product quality in cement and concrete productions. 2) Development of a hybrid data-driven and knowledge-driven approach to represent/monitoring process kinetics.

Expected results: 1) Machine learning method capable of estimating product quality attributes within experimental accuracy. 2) Hybrid methodology demonstrated to outperform both data-driven and knowledge-driven models to predict process kinetics.

Placements: 18 months UNIPD, 18 months STW, **Short visits:** 1 week FLS, 2 weeks MNK, 2 weeks ARGOS.

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC12	**IHS**	**IHS**	**Month 7**	**36 months**	**D4.1, D4.2, D4.3**

Title: Drivers and barriers to the end-user adoption of low-carbon cement blends

Objectives: 1) Determine how industry regulations and standards affect the adoption of low-carbon cement blends. 2) Determine how industry-specific characteristics affect the adoption of low-carbon cement blends. 3) Determine how firm-level internal characteristics affect the adoption of low-carbon cement blends.

Expected results: 1) Detailed outline of end user barriers to low-carbon cement blends adoption associated to regulation and standards, as well as alternative approaches that facilitate it. 2) Detailed outline of end user barriers to low-carbon cement blends adoption associated industry-specific characteristics, as well as strategies that facilitate it. 3) Detailed outline of end user barriers to low-carbon cement blends adoption associated firm-level characteristics, as well as strategies that facilitate it.

Placements: 36 months IHS, **Secondment:** 18 months ECOS, **Short visits:** 1 week FLS, 1 week ARGOS, 1 week MNK, 1 week C2CA.

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC13	**FLS**	**RWTH**	**Month 7**	**36 months**	**D3.5, D3.6**

Title: Rapid SCM characterisation method based on computer vision

Objectives: 1) Develop of an image analysis technique for capturing SCM dissolution. 2) Integrate hyperspectral imaging in the optical analysis of SCMs. 3) Correlate the SCM composition and reactivity in low-carbon cements with optical data.

Expected results: 1) Image analysis algorithm to capture the dissolution rate of various components in SCMs exposed to alkaline environments. 2) Novel hyperspectral imaging setup capable of capturing the chemical composition (or an indicator thereof) and the presence of impurities in SCMs. 3) .

Placements: 36 months FLS, **Secondment:** 12 months RWTH, 12 Months PTECH; **Short visits:** 2 weeks ARGOS

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC14	**C2CA**	**TUD**	**Month 7**	**5,5 months**	**D3.7**

Title: Development of a Decentralized Production Model for production of Cementitious Binders from Secondary Raw Materials.

Objectives: 1) Develop a digital process model for SRM. 2) Optimise of process steps based on SRM type. 3) Develop a self-adaptive process control for SRM.

Expected results: 1) Framework for the process model capable of predicting output quality of processed SRMs. 2) Optimized balance between material input, process energy requirements, environmental impact, and output quality. 3) Real-time process control mechanism for efficient material processing.

Placements: 5.5 months C2CA, **Secondment:** 1 month TUD, **Short visits:** 2 weeks PTECH.

Fellow	Host Institutions	PhD Enrolment	Start Date	Duration	Deliverables
DC15	**IMP**	**IMP**	**Month 7**	**36 months**	**D4.1, D4.2, D4.3**

Title: Environmental and economic performance of low carbon cement blends

Objectives: 1) Define the landscape of very low clinker cement mix designs that can be produced at scale and have the potential for sufficient technical performance. 2) Evaluate the environmental impacts of these cement mix designs in concrete, including the benefits from implementing data-driven cement mix designs, using process-based prospective life cycle assessment. 3) Evaluate the economic competitiveness of these cement mix designs in concrete using techno-economic analysis.

Expected results: 1) Life cycle inventory data for very low clinker cements and concretes. 2) Quantification of the environmental impacts of very low clinker cements and concretes. 3) Quantification of the economic competitiveness of very low clinker cement and concretes

Placements: 36 months IMP, **Secondment:** 12 months FLS, **Short visits:** 1 week ECOS, 1 week ARGOS, 1 week MNK, 1 week C2CA.

3.1.4 Network organisation

DETOCS is an ambitious consortium, slightly larger than the standard MSCA industrial doctorate consortia (that comprise on average 5 beneficiaries, 2 partner organisations and 5 DCs). However, the development of new knowledge that has the potential to transform the cement and concrete industry and significantly reduce CO2

emissions globally necessitates a larger consortium covering a broad spectrum of technologies, industrial solutions, non-technical instruments and geographical markets. The network organisation comprises the following consortium bodies:

Coordinator. The coordinator is the intermediary between the partners and the EC and performs all tasks assigned to and defined in the GA and CA. *Responsibilities:* monitoring compliance by the partners with their obligations under this Consortium Agreement and the Grant Agreement, keeping the address list up to date, collecting, reviewing and submitting reports, deliverables (including financial statements and related certification) and specific requested documents to the EC, preparing the meetings, proposing decisions and preparing the agenda of supervisor board meetings, chairing the meetings, preparing the minutes of the meetings and monitoring the implementation of decisions taken at meetings, transmitting documents and information connected with the project to any other Party concerned, and administering the financial contribution of the EC. The coordinator has prior experience in the coordination of MSCA European industrial doctorates (FlotSim, CO2Valorize), which will be an additional advantage for this project. **DETOCS will be coordinated by Dr Bodil Recke** (FLS, VP Cement R&D and Innovation). She is a highly experienced industrial researcher who now manages a portfolio of transformative R&D projects with global impact within FLSmidth (publicly announced are *inter alia* EcoClay, CO2Valorize, Circfuel, NEWCEMENT, PROBU). Besides her scientific background, she has a broad experience in transforming ideas into commercial innovations that have successfully served customers globally for the past 20 years. The deputy coordinator is Dr. Wilson Leal da Silva, a materials and digital technologies specialist who is the R&D lead for SCM materials and process research. FLS develops and promotes new technologies in alignment with the company's MissionZero strategy, which aims to enable cement producers to achieve carbon-neutral cement production by 2030. DETOCS fits perfectly in the company's strategic portfolio of initiatives towards this goal.

Project Manager. The coordinator will be supported by a professional project manager, who: a) assists the coordinator in the execution of the project and WP7; b) acts as a helpdesk for the all participating organisations; c) collects all information for monitoring and reporting purposes from the partners; d) coordinates the network-wide events, and supports the DCs in all aspects related to the international mobility during short technical visits, secondments, placements, conference visits in aspects such as visa applications, work permits (if needed) housing, travel, handling of offers and invoices and keeps contact to the host organisations in this regards. Additional support comes from FLS internal departments, such as HR, Legal, Process Engineering and Sales. Our past experience supports our belief that industrial coordination of DETOCS will bring new insights and knowledge to our academic partners.

Supervisory Board. The supervisory board is the general assembly and the decision-making body of the consortium. The coordinator chairs the supervisory board (invites, agenda, minutes, moderation). *Composition:* The DETOCS supervisory board consists of 19 representatives with voting rights and is composed of 11 beneficiaries, 7 associated partners, 2 DC, 1 representative of the external advisory board. *Tasks:* 1) oversees that proper implementation of the action, 2) conflict resolution, 3) final voting on training aspects (e.g. confirmation of place, schedule, content) 4) monitoring of the scientific and training progress of each DC against the CDP and the progress of the thesis including dissemination activities. *Decision making:* Decisions shall be taken by a majority of two-thirds (2/3) of the votes cast. *Meetings:* The meetings will take place twice per year preferably together with DETOCS events.

Executive Bord: As recommended by DESCA for medium to large projects, DETOCS establishes an executive board as intermediary governance structure. It acts as supervisory body for the execution of the project. *Tasks:* a) organise smaller organisational aspects that do not require the presence of the whole supervisory board; b) plans the content, agenda, and material of all meetings; c) plans the content of the network-wide training events (see Section 1.3). All more significant proposals made by the board shall be considered and decided upon by the supervisory board. *Composition:* The board shall consist of the coordinator and representatives appointed by the supervisory board (e.g. WP leaders of WP 5, 6, 7). The board will be chaired by Prof. Dr. Karen Scrivener (EPFL). *Meetings:* The coordinator will plan the meetings quarterly, such as online gatherings (MS-Teams, Zoom) or in-person when together with DETOCS events. Additional meetings can be scheduled upon request to address risks and opportunities. *Reporting:* Activities will be reported twice a year to the supervisory board.

External Advisory Board. The external advisory will bring a broader international and stakeholder dimension to the project. The board will be appointed and steered by the executive board. *Tasks:* assist and facilitate decision-making, support the network-wide training, provide career advice, link our DCs to career opportunities (at the end of the project), contribute to our risk mitigation strategy through the broad network of contacts in the industry, contribute to communication activities and exploitation results in new markets, support new business ventures (e.g. a high-tech startup) created by our DCs. *Composition:* Pénélope le Menestrel (Breakthrough Energy Foundation) represents Breakthrough Energy (BE), a network of entities including investment funds, non-profit and philanthropic programs founded by Bill Gates with a strong focus on decarbonizing the cement industry, Pénélope brings a unique perspective to this project combining advocacy and impact investing. Sebastian Peck (KVC - Kompas VC) provides knowledge on the private venture capital funding of cleantech innovations in the building sector, and what it takes to create and

run a start-up company. Joerg Rickert (VDZ – German Cement Association) provides deep scientific expertise, and the viewpoint of in independent association with ties to policymakers that supports decision-making at national and EU level. John Kline (KLINE - Kline Consulting) brings specialized industry knowledge on green technologies and how industry approaches innovations. The external advisors will also deliver technical input and innovation barriers, standards and impact analysis to the individual research projects of DC12 and 13. *Meetings:* The advisors will participate in the annual SB meetings (the board represents one vote) and network-wide training events according to requests and availability. Furthermore, the dedicated meetings for example with WP leaders and DCs are encouraged. *Reporting:* The advisors will report to the supervisory board at the end of each event through an oral note.

Temporary Exploitation Committees. Such committees will be formed as soon as potential IP assets have been identified within the scientific WP1-4. *Tasks:* a) analyse results and outcomes regarding IP protection measures; b) create a strategy for protecting and exploiting foreground IP; c) explore utilisation pathways; d) discuss with internal stakeholders e) draft and submit applications with attorney support, f) manage and negotiate any additional agreements for example regarding joint ownership, the transfer of results or licenses to partners or third parties. *Composition:* This committee consists of the DC(s) involved, the supervisor(s), the coordinator, the WP leader responsible for exploitation and, if relevant, the partner organisations and technology transfer specialists. The EU Project Officer will be kept informed to ensure proper alignment with EU regulations. *Meetings:* Meetings will be scheduled as soon as IP has been identified. *Reporting:* Such temporary committees will report to the internal administration and the supervisory board.

DC Forum: This forum will support the exchange of experiences and to learn from each other. *Tasks:* a) annual election of two DC representative for the supervisory board; b) provision of feedback on supervision training and outreach; c) conflict resolution at the lowest level, and d) dissemination of information among DCs (e.g. accommodation during secondments, payments, contracts, travel, conferences, reports etc.), joint publications. *Composition:* our 13 DCs. *Meetings:* DCs will be encouraged to set up a MS-Team group for online meetings and chat under the responsibility of the elected DC representative. Separate time slots during DETOCS events (typically 1-2 hours) will be allocated for informal gatherings. *Reporting:* Th DC forum will report to the executive board and the supervisory board.

Work Package Leader: The scientific/technical work package leaders will group the DCs in their WP quarterly, facilitate the discussion and mitigate technical risks within the WP, and keep the WP connected to the others. The leaders of the non-scientific WPs will engage with all 13 DCs more frequently (bi-monthly) to monitor training progress, outreach and management. They are an additional management instrument to ensure that no DC falls behind or feels overwhelmed with work or other tasks. These will also help to avoid conflicts and contribute to conflict resolutions.

3.1.5 Progress monitoring and evaluation of individual research projects

— **At the level of the project.** The project monitoring is conducted by the coordinator and is based on a detailed plan (project monitoring plan – PMP) that will be generated at month 1 of the project. The plan will be implemented in a project management software tool (e.g. Monday) that all partners can see and report progress in almost real-time. We will review and update the responsibilities and timeline (Gantt chart) for the key performance indicators, tasks, work packages, deliverables, milestones as well as secondments, short visits and major training networkwide training events. We will record project bottlenecks to improve the quality of future initiatives and for feedback to the funding agency (REA). Furthermore, we will create an evaluation plan (timeline) and conduct accordingly monthly internal evaluations by the coordinator/project manager and additional evaluations during executive and supervisory board meetings as well as meetings with and reporting to the funding agency.

— **At the level of the individual research projects.** This will be achieved through weekly in-person meetings of about 1 hour with supervisor 1 or 2 (see Section 1.4) depending on the location of the DC to discuss work progress, problems, possible risks, and additional training needs (the DC makes the minutes). The DC and his/her joint supervision committee will meet four times a year to discuss the scientific progress, the progress of the doctoral thesis and the CDP; supervisor 1 will make and distribute the agenda and meeting notes and progress evaluation through an appropriate online tool (e.g. myIDP/ScienceCareer). All DCs and supervisors will meet monthly to share information, opportunities and give the DCs a platform to report on scientific progress (rotating) through short presentations; the coordinator/project manager makes and distributes the agenda and the meeting notes. Group meetings will be mostly online but in-person when coupled to a network event. In addition, bi-annual reports as well as the reports on the deliverables will be submitted by all DCs to the corresponding supervisors (followed by submission to the coordinator and supervisory board where progress will be monitored.

— **At the level of the funding agency.** We will continuously upload our deliverables and reports on milestones according to our proposed plan as well as submit the progress, periodic and mid-term and final reports and questionnaires according the terms of the Grant Agreement. Additionally, we keep the risk register and mitigation measures up-to-date.

3.1.6 Supervisory board (SB)

Supervisory Board. The supervisory board is the general assembly and the decision-making body of the consortium. The coordinator chairs the supervisory board (invites, agenda, minutes, moderation). *Composition:* The DETOCS supervisory board consists of 19 representatives with voting rights and is composed of 11 beneficiaries, 7 associated partners, 2 DC, 1 representative of the external advisory board. *Tasks:* 1) oversees that proper implementation of the action, 2) conflict resolution, 3) final voting on training aspects (e.g. confirmation of place, schedule, content) 4) monitoring of the scientific and training progress of each DC against the CDP and the progress of the thesis including dissemination activities. *Decision making:* Decisions shall be taken by a majority of two-thirds (2/3) of the votes cast. *Meetings:* The meetings will take place twice per year preferably together with DETOCS events. The coordinator together with the executive board will organise the meetings in an transparent and democratic way.

3.1.7 Recruitment strategy (including gender aspects in the selection process)

1) Strategy and guiding principles: DETOCS is committed to open, transparent, and merit-based recruitment on the principles of the *European Charter for Researcher* and the *Code of Conduct for their Recruitment* together with the *'Human Resources Strategy for Researchers' (HRS4R)* by: a) advertise the positions as widely as possible; b) providing transparent information on the selection process; c) posting a clear job advertisement on popular platforms (e.g. EURAXESS and Academicpostions.com, career portals of each beneficiary); d) ensure appropriate qualifications/ competencies requirement for each position; e) ensuring selection committees for each DC, with gender balance; f) the selection is open and potential restriction due to the programme mobility will be mitigated by encouraging ineligible candidates to apply for other positions in the project; f) keeping the administrative burden for the DC low (proof of qualifications, translations). **2) Selection:** All applications will be reviewed according to the published requirements. The five best candidates for each DC will be invited for an interview held by the beneficiaries and PhD awarding institutions. **3) Quality control:** DETOCS establishes quality control mechanisms (NC, SB) that support beneficiary HR departments with guidance, to ensure compliance to MSCA rules. Each candidate obtains a clear assessment of qualifications. The network ensures proper training and support to all those involved in the recruitment process (see Table 1.4a). **4) Diversity and inclusion:** e-recruitment to avoid discriminating based on geographical location and/or financial means. **5) Enhance female participation:** The supervisors will mobilise their networks to notify potential female candidates and ensure equal opportunities and anti-discrimination on women and minority groups. Gender preference will be given to a candidate only among equally qualified candidates to achieve better gender balance. **6) Enrolment in a doctoral programme:** All DCs will be enrolled in a doctoral programme (see Table 1.3a) and tuition fees will be covered by the grant (organised through the CA). **7) Promote excellent working conditions:** All DETOC partners promote a healthy work-life balance and family-friendly work environments. This includes support with childcare and schooling provisions, parental leave, part-time work, etc. Each beneficiary encourages an inclusive work environment and actively supports networking and exchange. The coordinator ensures the content is understood clearly by the DCs and extra material, e.g., the proposal and the code of conduct, will be handed over. We placed a milestone (MS4) as a control point for our recruitment.

3.1.8 Environmental aspects in light of the MSCA Green Charter

Framework: A core element of MSCA activities is mobility across boarders for recruitment, secondments, short visits, network-wide training and international networking, e.g., at conferences. The importance of such activities and the associated mobility to skills development is paramount. Nevertheless, the DETOCS consortium will implement and promote the MSCA Green Charter principles (and go partly beyond) to minimise energy usage, waste creation, and CO_2 emissions to contribute to decarbonation and maintain biodiversity.

Strategy: We will implement dedicated training sessions on the MSCA Green Charter for the DCs (Table, 1.3a). It is our goal to reduce waste by reusing and recycling test material through appropriate planning (DoE) and material circulation. We will only organise sustainable network events in Europe's 'green cities' in locations that have sustainability certifications (e.g. Green Globe, Ecolabel). Events will be accompanied by digital materials and sustainable food and beverages (local and vegetarian). The network is fully committed to low-emission forms of travel (prioritising train and bus) and meetings at central, easy-to-reach locations (e.g. Copenhagen). Promoting online, were possible, communication, collaboration, training, conferences will also be key in staying environmentally friendly (using Teams, Zoom, Miro, etc.). Part of the training programme will be delivered through online sessions (see Section 1.3) **Creating change:** We strive to develop awareness on sustainability and monitor KPIs (e.g., number of online events, event footprint) and will share ideas and lessons learned with the scientific community, our local hosts and the public at large. We will use the DETOCS to enhance awareness and trigger changes at local institutions and with other EU project networks to multiply the positive effects beyond the MSCA community.

3.2 Quality, capacity, and role of each participant, hosting arrangements and how the consortium ties together the necessary expertise

3.2.1 Appropriateness of the infrastructure and capacity of each participating organisation

All partners have ample resources to conduct the project tasks and achieve the objectives (see B2). The fit between the participating organisation are: **Research-related major infrastructure and capacity – FLS** is a Danish engineering company that provides technology for ore processing and cement production globally. The company will coordinate DETOCS and provide access to data from cement plants, access to pilot plants and characterisation methods for T1.1-T1.4, T2.1, T3.1 & T4.2. **CNRS** has knowledge on thermodynamical models applied to clinker mineralogy models and appropriate software and hardware to implement machine learning modelling using material and process data in T1.1. The graduation of the DC from CNRS will take place at UOG, which is an associated research university. **ABD** is a recognised university from the UK that drives the research work on thermal activation of SCMs, with deep expertise on thermodynamic modelling and process control. **ETHZ** is a leading university in cement chemistry and chemical admixtures and will lead the work on chemical activation of SCMs – it has all capacity and infrastructure for T1.3. **RWTH** will guide the research on mechanical activation of SCMs and cement blending, it has a fully equipped characterisation lab for T1.4 and T2.1. **IMP** has made bold research strides with their work on the use of SCMs in cement and concrete, they will focus on performance-based concrete design, environmental aspects and technoeconomic analysis for T2.2 and 4.1. **TUD** is specialist in concrete recycling and concrete property measurements for T2.3 and T3.2. **EPFL** has one of the best fully equipped cement characterisation labs for T2.4. **UNIPD** has the infrastructure, know-how, and latest computational tools to implement the relevant tasks for T3.1 and 3.3. **IHS** leads the work on market innovations and barriers with specialised knowledge on capital intensive industries in the raw and construction materials sector relevant for T4.1. **ARGOS** is a multinational cement and concrete producer with modern and relevant production plants in CO and the US that are relevant for T2.3, T3.2 and process data in T1.1, T1.4, T2.2, T3.3. The company is fully committed to SCMs and new cement and concrete products that minimize the use of clinker. **C2CA** is a start-up that commercialises a new concrete recycling process and has a pilot plant in operation for T2.2 and T2.4. C2CA is partly owned by GBN, a recycling company committed to implementing circular economy in the building industry, first and foremost at its precast concrete factories. **MNK** is a large cement and concrete producer that provides access to data, lab facilities and characterisation methods that are relevant to T1.3, T2.1, T2.3, T3.3 and T4.1. **ECOS** is an international NGO and brings special knowledge on technical standards of cement and concrete products to enable performance-based standards, as well as expertise related to policies and laws to T4.1 and T4.2. **MIT** is one of the leading universities in the world and supports DETOCS with special training on machine learning and data recognition, which are of relevance for T1.2-1.4 and T3.1-3.3. UOG will support the graduation of DC1. **PTECH** is a SME from DK specialized in particle characterization and it contributes to DETOCS via a new ai-line particle characterization tool that can measure both particle size distribution and specific surface, serving as an additional process input in T1.2, T1.4, T3.1.

Non-technical infrastructure, support services, hosting arrangements and capacity. The DETOCS partners have appropriate services to support the DCs such as HR and legal departments, IP support or dedicated offices for EU projects and technology transfer, communications and multimedia departments, and people trained as ombudsman that can act as third party in case of issues on research integrity, gender, etc. Each DC will be integrated in a team environment with international networking opportunities. Typically, teams include social activities such as innovation events, joint dinners, sport events so that the DC will not work in a silo or feel lonely.

3.2.2 Consortium composition and exploitation of participating organisations' complementarities

Each research project combines expertise of two or three partners to achieve its objectives. To develop scientific methods for prediction binder quality and improve SCM reactivity, **WP1** will exploit knowhow of the university partners on numerical methods to predict clinker mineralogy (CNRS), thermal activation of SCM (ABD), chemical activation (ETHZ), and mechanical activation (RWTH), complemented by material samples and industrial data from large-scale plants (ARGOS, MNK, FLS, C2CA), and industrial knowhow on at-line PSD measurements (PTECH). WP1 delivers knowledge on processing of clinker and SCMs and methods to improve their reactivity. **WP2** exploits material characterisation capabilities for cement (RWTH), know-how on SCMs and custom concrete mixes (ICL), RCF and characterisation techniques (TUD), and chemical/physical characterisation methods and life-prediction models (EPFL). This will be complemented by industrial process data and characterisation methods (ARGOS, MNK, C2CA). **WP3** exploits knowhow on digitalization applied to the cement and concrete - production process and quality management. the university partners on soft-sensing development (UNIPD) and the creation of a ML framework to enable the prediction of cement and concrete quality attributes (UNIPD). These methods are verified and complemented by data from ARGOS, C2CA, FLS and MNK, knowhow on data mining and ML from STW and MIT, at-line PSD sensor from PTECH. The RFID technology to trace material properties (TUD) will be tested for feasibility along the cement and concrete value chain by ARGOS, C2CA, and MNK. Finally, to understand drivers and barriers to the introduction of the cement and concrete innovations in WP1-3, **WP4** will exploit research methods of economics (IHS) and scientific methods for environmental and economic performance assessment (ICL), complemented by access to insights and data from ARGOS, MNK, FLS, the SMEs/start-ups C2CA, PTECH, BE, KLINE, KVC, the NGO ECOS, and the professional association VDZ.

3.2.3 Commitment of beneficiaries and associated partners to the programme

Beneficiaries: All beneficiaries are fully committed to the project, as indicated by the large team of specialists and internal support services (HR, legal, public relations) that will be involved, and their significant time contribution to the project (see B2). Furthermore, all infrastructure, equipment and support methods can be used free of charge by the DCs, facilitating knowledge transfer between partners. **Associated Partners:** These provided support letters that officially prove their commitment and describe the roles. **ABD** and **IMP** participate as Associated Partner but implement 2 DC projects with funding from the UK government (UKRI). **ARGOS** will provide access to data, production plants and material characterisation methods. They also provide longer secondments to DC2.3 and 3.2 and short visits for DC1, 4, 6, 8 & 11. **ETHZ** (DC3) and **EPFL** (DC8) fulfil a role akin to being a beneficiary that gets funding from the Swiss government. **ECOS** is fully committed and will provide a secondment to DC12, a short visit for DC13 and lectures on cement standards, policies, and laws. **C2CA** is a well-funded start-up with many years financial runway that (along with its parent company GBN) is committed to DETOCS by hosting DC6 & 8 and short visits for DC3, 7, 10, 12 - the company will provide training on concrete recycling methods and circular concrete. **PTECH** is a SME focussed on particle measurement techniques relevant for DC2 & 4. They are committed to provide training and technology for particle measurements. **MIT** is a leader in the development of ML technologies and NLP. The university is committed to provide high level training on this aspect to all our DCs.

3.2.4 Funding of non-associated third countries

United Kingdom: The UK government gives a Horizon Europe guarantee and funds the participation of ICL and ABD through UK Research and Innovation (UKRI). The associated DCs will implement all research tasks, obtain co-supervision, participate in all network-wide trainings, conduct the local trainings, and contribute to dissemination, exploitation, and communication activities - as described here. The Letters of Commitments are included in part B2 and partner descriptions are adjusted.

Switzerland: The Swiss Government will fund two DC hosts: ETHZ and EPFL. Therefore, funding is not requested from the EU for the two related DC projects described in the proposal. Instead, funding will be provided by the State Secretariat for Education, Research and Innovation, SERI under the condition that the full project application is assessed as eligible for funding by the European Commission or by the agency commissioned for this purpose (see Letters of Commitments, part B2).

4. Ethics issues

4.1 Ethical dimension of the objectives, methodology and likely impact

DETOCS does not involve (1) Human embryonic stem cells (hESCSs) and human embryos (hEs), (2) work with human beings that are not part of the staff of the participants, (3) the use of human cells or tissues, (4) use of personal data, (5) animals, (6) non-EU countries, (7) artificial intelligence. DETOCS involves as part of methodology materials (chemicals) that my adversely affect the environment or health and safety of the persons working on the project. Any associated risks will be mitigated through full compliance with all local, national, and EU rules and regulations and particular laboratory procedures, including training of staff. DETOCS does not involve or generate materials, methods, technologies, or knowledge that could be misused for unethical purposes. The developed materials, methods, technologies, and knowledge cannot harm humans, animals, or the environment if they were released, modified or enhanced.

4.2 Compliance with ethical principles and legislations

Health and safety of all human participants are priority. Nevertheless, the work involves eventually toxic chemical: The staff obtains adequate training in storing, handling, and disposing of such substances. We provide adequate risk analysis for the development of any chemical formulation. DETOCS might involve the use of substances, processes and technologies that may cause harm to the environment, to animals, to plants, and to humans during the implementation of the activity. The prevention of any damage at the host institution is ensured due to our (1) the application of precautionary principles in chemical laboratories, (2) laboratory safety measures and (3) health and safety procedures. We will monitor any potential ethical risk during the project in dedicated review sessions and self-assessment procedures. DETOCS complies with the highest ethical standards and applicable international, EU, and national law: (i) for environment: precautionary principle and legislation on nature conservation and pollution control and (ii) for health and security: legislation on public-health control (e.g. regulating conduct in animal epidemics, food imports, consumer protection, etc.) and safety at work (e.g. Directive 2006/25 on the standards for exposure of workers to risks arising from physical agents (artificial optical radiation).

4.3 DETOCS procedures

4.3.1 Experimental work

For all experimental activities, both at laboratory and industrial scale, a specific safety training for the DCs at each working place will be delivered, and the safety documents will be kept on file and submitted to the EC if requested.

4.3.2 Data standards

For workshops, conferences, and other engagement activities, which imply individual participants or stakeholders and the use of personal data of participants, their consent will be obtained before such activities are put in practice. The documents will be kept on file and submitted to the EC if requested.

4.3.3 Ethics check

The consortium is confirming that in case of an Ethics Check, relevant documents, authorisations, and approvals will be obtained, kept on file and sent to the REA upon request.

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ANNEX 2

ESTIMATED BUDGET FOR THE ACTION

	Estimated EU contribution								
	Estimated eligible unit contributions (per budget category)							Total	Maximum grant amount[1]
	A. Contributions for recruited researchers					B. Institutional contributions			
	A.1 Living allowance	A.2 Mobility allowance	A.3 Family allowance	A.4 Long-term leave allowance	A.5 Special needs allowance	B.1 Research, training and networking contribution	B.2 Management and indirect contribution		
Forms of funding	Unit contribution[2]	Unit contribution[2]	Unit contribution[2]	Unit contribution[2]	Unit contribution[2]	Unit contribution[2]	Unit contribution[2]	h = a + b + c + d + e + f + g	i
	a	b	c	d	e	f	g		
1 - FLS	444 312.00	59 400.00	49 005.00	0.00	0.00	158 400.00	118 800.00	829 917.00	829 917.00
2 - CNRS	142 473.60	21 600.00	17 820.00	0.00	0.00	57 600.00	43 200.00	282 693.60	282 693.60
3 - RWTH	120 319.20	21 600.00	17 820.00	0.00	0.00	57 600.00	43 200.00	260 539.20	260 539.20
4 - TUD	268 300.80	43 200.00	35 640.00	0.00	0.00	115 200.00	86 400.00	548 740.80	548 740.80
5 - UNIPD	119 217.60	21 600.00	17 820.00	0.00	0.00	57 600.00	43 200.00	259 437.60	259 437.60
6 - IHS	134 150.40	21 600.00	17 820.00	0.00	0.00	57 600.00	43 200.00	274 370.40	274 370.40
7 - STW	73 134.00	10 800.00	8 910.00	0.00	0.00	28 800.00	21 600.00	143 244.00	143 244.00
8 - C2CA	221 720.80	35 700.00	29 452.50	0.00	0.00	95 200.00	71 400.00	453 473.30	453 473.30
9 - MNK	73 134.00	10 800.00	8 910.00	0.00	0.00	28 800.00	21 600.00	143 244.00	143 244.00
10 - ABD									
11 - IMP									
12 - ARGOS									
13 - EPFL									
14 - ETHZ									
15 - MIT									
16 - ECOS									
17 - PTECH									
18 - UOG									
Σ consortium	1 596 762.40	246 300.00	203 197.50	0.00	0.00	656 800.00	492 600.00	3 195 659.90	3 195 659.90

[1] The 'maximum grant amount' is the maximum grant amount fixed in the grant agreement (on the basis of the sum of the beneficiaries' estimated units).
[2] See Annex 2a 'Additional information on the estimated budget' for the details (units, amount per unit).

ANNEX 2a

ADDITIONAL INFORMATION ON UNIT COSTS AND CONTRIBUTIONS

HE MSCA Doctoral Networks/Post-doctoral Fellowships and HE ERA fellowships

See Additional information on unit costs and contributions (Annex 2a and 2b)

HE MSCA Staff Exchanges

See Additional information on unit costs and contributions (Annex 2a and 2b)

HE MSCA COFUND

See Additional information on unit costs and contributions (Annex 2a and 2b)

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

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

hereby agrees

to become beneficiary

in Agreement No 101119929 — DETOCS ('the Agreement')

between FLSMIDTH AS (FLS) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

AUBERT Clément with ECAS id n0071g3e signed in the Participant Portal on 17/07/2023 at 10:18:18 (transaction id SigId-6149-eWFxuqTv8xCp6F8ts8Fqq3eTdXOAzKiruD5znSaKYsb97vSSx3SW0zaEmlXsRQGlWcbvQ1YUC3t3e1H6n3HCiO0-rS0vSrmBGYC1U0cxe0N3vW-7f4WzUtzvAAtDjlPT1MOJmqph2SzljLi8mCGny6M24b3cd73aYNoohQHGrVaSarKaSfxdw6DFGYCnDiwupf0QG0). Timestamp by third party at 2023.07.17 10:18:23 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN (RWTH), PIC 999983962, established in TEMPLERGRABEN 55, AACHEN 52062, Germany,

hereby agrees

to become beneficiary

in Agreement No 101119929 — DETOCS ('the Agreement')

between FLSMIDTH AS (FLS) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Lukas Krott with ECAS id n005pabu signed in the Participant Portal on 18/07/2023 at 11:38:18 (transaction id SigId-23269-kt42zuZuCS hG404Chcvm9fs8K4lozIRoZuWONFSXuh6XY72YmNUNdgVJSYkJr4 miQUsb85T4BdfMPVfw7omNXR-rS0vSrmBGYC1U0cxe0N3vW-JMtZ x9rjHt6jwhY1TuTkZcKNT6cfp08wrdmmxgevLcisC7VQ3kc2YQQCUB BXEaLzNKZdX68h6q6gYFxWiHuX4q). Timestamp by third party at 2023.07.18 11:38:23 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

TECHNISCHE UNIVERSITEIT DELFT (TUD), PIC 999977366, established in STEVINWEG 1, DELFT 2628 CN, Netherlands,

hereby agrees

to become beneficiary

in Agreement No 101119929 — DETOCS ('the Agreement')

between FLSMIDTH AS (FLS) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Ronald van den Mosselaar with ECAS id n00d3ogn signed in the Participant Portal on 14/07/2023 at 17:25:45 (transaction id SigId-304600-5MvHibpDNpChmQVW64TsYPzi74fxZGWEqVS3zGE9PGv6vmRCGlVeHbW58hMfCGhgrR58zgwNNlnvq89hhRUFFEG-jpJZscgsw0K4epxy2XYw0y-fsXcQAj51yDYrbJE5LsSyiQgKnFNHjAHIZPYA9M8gRaoiYpUuTfaEYq7znlTftKlO8prBPxN69VpDc5LNWRtbe). Timestamp by third party at 2023.07.14 17:25:49 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

UNIVERSITA DEGLI STUDI DI PADOVA (UNIPD), PIC 999995602, established in VIA 8 FEBBRAIO 2, PADOVA 35122, Italy,

hereby agrees

to become beneficiary

in Agreement No 101119929 — DETOCS ('the Agreement')

between FLSMIDTH AS (FLS) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Stefania BRUSCHI with ECAS id nbrusste signed in the Participant Portal on 13/07/2023 at 11:46:20 (transaction id SigId-283188-r4dQs0ZgMLzpqmzxFMqORRiF1bT55MQE5zRob1NWwpiofj5Yi6P9ZJ12yVizdkNIoxXjvkPXqRiUCO0GPPRbCqW-jpJZscgsw0K4epxy2XYw0y-FtYoweAEUwGZ7YbatdKs5NdJn3PpIuu5v3sHLib8EtOspUME8rh70zJHptt28PcM37Hy18FJEkNr40nj5697bS). Timestamp by third party at 2023.07.13 11:46:24 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

INSTITUTE FOR HOUSING AND URBAN DEVELOPMENT STUDIES BV (IHS), PIC 988824015, established in BURGEMEESTER OUDLAAN 50, ROTTERDAM 3062 PA, Netherlands,

hereby agrees

to become beneficiary

in Agreement No 101119929 — DETOCS ('the Agreement')

between FLSMIDTH AS (FLS) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

David Dodman with ECAS id n00blesc signed in the Participant Portal on 14/07/2023 at 17:08:50 (transaction id SigId-304432-AziD15HrVxJObsieEamBGzSGGjQP2hoP5IOxTJoG6GpPLcPvg3huE0zZX1unwSH4RWBHCHV7owfNtukIiGzuiBq-jpJZscgsw0K4epxy2XYw0y-OdrlFkzq444MIJvKbxpzmuMnNUc1eY5Y31zPl7uRegqhWyRjtIL7cziRXqIuOb0zq1W4eihFyGonoiojESsECzim). Timestamp by third party at 2023.07.14 17:08:56 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

STATWOLF LIMITED (STW), PIC 935994420, established in 51/52 FITZWILLIAM SQUARE WEST, DUBLIN D02 X504, Ireland,

hereby agrees

to become beneficiary

in Agreement No 101119929 — DETOCS ('the Agreement')

between FLSMIDTH AS (FLS) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Simone PAMPURI with ECAS id npampsim signed in the Participant Portal on 13/07/2023 at 12:55:56 (transaction id SigId-284787-4N4T c8TFyh0SPOntRlAjNtIqzyh34iNe8aT3VLdQ7A6JxCpUMUM5E7B6MQ 9CcqISI271pAsc6Zbzy58ARLk6uD-jpJZscgsw0K4epxy2XYw0y-gzQie2 BzzajmC1stZKOze9OKBNcoswi3MHsb9174J7R0bfJS2mKzeeKKELznB MbehkElOpWxCFNGmUWJzqAS4Kzzm). Timestamp by third party at 2023.07.13 12:56:01 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

C2CA TECHNOLOGY BV (C2CA), PIC 908356404, established in WESTKANAALDIJK 2, UTRECHT 3542 DA, Netherlands,

hereby agrees

to become beneficiary

in Agreement No 101119929 — DETOCS ('the Agreement')

between FLSMIDTH AS (FLS) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Thomas PETITHUGUENIN with ECAS id n00ccaie signed in the Participant Portal on 14/07/2023 at 20:18:12 (transaction id SigId-536-37Qs7ktB3TwryiQzzKyndszRAtMiRvzXvYiebIQc8yAAhXEVHZcwFiGHPJIASkt9ngzUAIe40mdyOLpYzhFQLMrG-rS0vSrmBGYC1U0cxe0N3vW-zHCneTwzzf7AD1Jlh4GIAo4WhBkcIFYzV7CLSBR6KVPAtWLD0jWeRo8sxQnsl7LJ8pGurxv99dMbxzpxSOV34Bzm). Timestamp by third party at 2023.07.14 20:18:16 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

MANNOK HOLDINGS DESIGNATED ACTIVITY COMPANY (MNK), PIC 884343278, established in 2ND FLOOR 1-2 VICTORIA BUILDINGS HADDINGTON ROAD, DUBLIN D04 XN32, Ireland,

hereby agrees

to become beneficiary

in Agreement No 101119929 — DETOCS ('the Agreement')

between FLSMIDTH AS (FLS) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Kevin Lunney with ECAS id n00bdwxi signed in the Participant Portal on 13/07/2023 at 11:55:39 (transaction id SigId-283461-zKichl r9THfahTDzLgEF9nTqWqg4Pe6ZvBJ9VEG96ztziIhNbWzeidHjINJ92s5J OzGcjQpCEn9NckEhfjw6D12W-jpJZscgsw0K4epxy2XYw0y-8hW9WEY RYCWC9IZzfJHm4ZJMt0pgqWtMD8YzQwSRjkUdOmeowcoIZ96VZha xo4fuvUh3d2Prx6fyhzWjAzR97sS). Timestamp by third party at 2023.07.13 11:55:44 CEST

FINANCIAL STATEMENT FOR [PARTICIPANT NAME] FOR REPORTING PERIOD [NUMBER]

	EU contribution								
	Eligible unit contributions (per budget category)								**Requested EU contribution**
	[OPTION for all MSCA ToA except COFUND: **A. . Contributions for** *[* **recruited researchers***]* *[* **seconded staff members***]][OPTION for COFUND:* **A. COFUND contributions***]*					*[OPTION for all MSCA ToA except COFUND:* **B. Institutional contributions***]*		**Total**	
	[OPTION for DN and PF : A.1 Living allowance*]* *[OPTION for SE:* A.1 Top - up allowance*]* *[OPTION for COFUND:* A.1 COFUND allowance*]*	*[OPTION for DN and PF:* A.2 Mobility allowance*]*	*[OPTION for DN and PF:* A.3 Family allowance*]*	*[OPTION for all MSCA ToA except SE:* A.4 Long-term leave allowance*]*	A.5 Special needs allowance	*[* B.1 Research, training and networking contribution*]*	*[* B.2 Management and indirect contribution*]*		
Forms of funding	Unit contribution[1]	*[* Unit contribution[1] *]*	*[* Unit contribution[1] *]*	*[* Unit contribution[1] *]*	Unit contribution[1]	*[* Unit contribution[1] *]*	*[* Unit contribution[1] *]*	h = a *[* + b *][* + c*]* *[* + d*]* + e *[* + f*]* *[* + g*]*	i
	a	*[* b*]*	*[* c*]*	*[* d*]*	e	*[* f*]*	*[* g*]*		
XX – [short name beneficiary/affiliated entity]									

The beneficiary/affiliated entity hereby confirms that:

The information provided is complete, reliable and true.

The unit contributions declared are eligible (see Article 6).

The contributions can be substantiated by adequate records and supporting documentation that will be produced upon request or in the context of checks, reviews, audits and investigations (see Articles 19, 20 and 25).

[1] See Annex 2a 'Additional information on the estimated budget' for the details (units, amount per unit).

ANNEX 5

SPECIFIC RULES

CONFIDENTIALITY AND SECURITY (— ARTICLE 13)

Sensitive information with security recommendation

Sensitive information with a security recommendation must comply with the additional requirements imposed by the granting authority.

Before starting the action tasks concerned, the beneficiaries must have obtained all approvals or other mandatory documents needed for implementing the task. The documents must be kept on file and be submitted upon request by the coordinator to the granting authority. If they are not in English, they must be submitted together with an English summary.

For requirements restricting disclosure or dissemination, the information must be handled in accordance with the recommendation and may be disclosed or disseminated only after written approval from the granting authority.

EU classified information

If EU classified information is used or generated by the action, it must be treated in accordance with the security classification guide (SCG) and security aspect letter (SAL) set out in Annex 1 and Decision 2015/444[1] and its implementing rules — until it is declassified.

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

Action tasks involving EU classified information may be subcontracted only with prior explicit written approval from the granting authority and only to entities established in an EU Member State or in a non-EU country with a security of information agreement with the EU (or an administrative arrangement with the Commission).

EU 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.

ETHICS (— ARTICLE 14)

Ethics and research integrity

The beneficiaries must carry out the action in compliance with:

- ethical principles (including the highest standards of research integrity)

[1] 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).

and

- applicable EU, international and national law, including the EU Charter of Fundamental Rights and the European Convention for the Protection of Human Rights and Fundamental Freedoms and its Supplementary Protocols.

No funding can be granted, within or outside the EU, for activities that are prohibited in all Member States. No funding can be granted in a Member State for an activity which is forbidden in that Member State.

The beneficiaries must pay particular attention to the principle of proportionality, the right to privacy, the right to the protection of personal data, the right to the physical and mental integrity of persons, the right to non-discrimination, the need to ensure protection of the environment and high levels of human health protection.

The beneficiaries must ensure that the activities under the action have an exclusive focus on civil applications.

The beneficiaries must ensure that the activities under the action do not:

- aim at human cloning for reproductive purposes
- intend to modify the genetic heritage of human beings which could make such modifications heritable (with the exception of research relating to cancer treatment of the gonads, which may be financed)
- intend to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer, or
- lead to the destruction of human embryos (for example, for obtaining stem cells).

Activities involving research on human embryos or human embryonic stem cells may be carried out only if:

- they are set out in Annex 1 or
- the coordinator has obtained explicit approval (in writing) from the granting authority.

In addition, the beneficiaries must respect the fundamental principle of research integrity — as set out in the European Code of Conduct for Research Integrity[2].

This implies compliance with the following principles:

- reliability in ensuring the quality of research reflected in the design, the methodology, the analysis and the use of resources
- honesty in developing, undertaking, reviewing, reporting and communicating research in a transparent, fair and unbiased way

[2] European Code of Conduct for Research Integrity of ALLEA (All European Academies).

- respect for colleagues, research participants, society, ecosystems, cultural heritage and the environment

- accountability for the research from idea to publication, for its management and organisation, for training, supervision and mentoring, and for its wider impacts

and means that beneficiaries must ensure that persons carrying out research tasks follow the good research practices including ensuring, where possible, openness, reproducibility and traceability and refrain from the research integrity violations described in the Code.

Activities raising ethical issues must comply with the additional requirements formulated by the ethics panels (including after checks, reviews or audits; see Article 25).

Before starting an action task raising ethical issues, the beneficiaries must have obtained all approvals or other mandatory documents needed for implementing the task, notably from any (national or local) ethics committee or other bodies such as data protection authorities.

The documents must be kept on file and be submitted upon request by the coordinator to the granting authority. If they are not in English, they must be submitted together with an English summary, which shows that the documents cover the action tasks in question and includes the conclusions of the committee or authority concerned (if any).

VALUES (— ARTICLE 14)

Gender mainstreaming

The beneficiaries must take all measures to promote equal opportunities between men and women in the implementation of the action and, where applicable, in line with the gender equality plan. They must aim, to the extent possible, for a gender balance at all levels of personnel assigned to the action, including at supervisory and managerial level.

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

Definitions

Access rights — Rights to use results or background.

Dissemination — The public disclosure of the results by appropriate means, other than resulting from protecting or exploiting the results, including by scientific publications in any medium.

Exploit(ation) — The use of results in further research and innovation activities other than those covered by the action concerned, including among other things, commercial exploitation such as developing, creating, manufacturing and marketing a product or process, creating and providing a service, or in standardisation activities.

Fair and reasonable conditions — Appropriate conditions, including possible financial terms or royalty-free conditions, taking into account the specific circumstances of the request for access, for example the actual or potential value of the results or background to which access is requested and/or the scope, duration or other characteristics of the exploitation envisaged.

FAIR principles — ‘findability’, ‘accessibility’, ‘interoperability’ and ‘reusability’.

Open access — Online access to research outputs provided free of charge to the end-user.

Open science — An approach to the scientific process based on open cooperative work, tools and diffusing knowledge.

Research data management — The process within the research lifecycle that includes the organisation, storage, preservation, security, quality assurance, allocation of persistent identifiers (PIDs) and rules and procedures for sharing of data including licensing.

Research outputs — Results to which access can be given in the form of scientific publications, data or other engineered results and processes such as software, algorithms, protocols, models, workflows and electronic notebooks.

Scope of the obligations

For this section, references to ‘beneficiary’ or ‘beneficiaries’ do not include affiliated entities (if any).

Agreement on background

The beneficiaries must identify in a written agreement the background as needed for implementing the action or for exploiting its results.

Where the call conditions restrict control due to strategic interests reasons, background that is subject to control or other restrictions by a country (or entity from a country) which is not one of the eligible countries or target countries set out in the call conditions and that impact the exploitation of the results (i.e. would make the exploitation of the results subject to control or restrictions) must not be used and must be explicitly excluded from it in the agreement on background — unless otherwise agreed with the granting authority.

Ownership of results

Results are owned by the beneficiaries that generate them.

However, two or more beneficiaries own results jointly if:

- they have jointly generated them and
- it is not possible to:
    - establish the respective contribution of each beneficiary, or
    - separate them for the purpose of applying for, obtaining or maintaining their protection.

The joint owners must agree — in writing — on the allocation and terms of exercise of their joint ownership (‘**joint ownership agreement**’), to ensure compliance with their obligations under this Agreement.

Unless otherwise agreed in the joint ownership agreement or consortium agreement, each joint owner may grant non-exclusive licences to third parties to exploit the jointly-owned results (without any right to sub-license), if the other joint owners are given:

- at least 45 days advance notice and
- fair and reasonable compensation.

The joint owners may agree — in writing — to apply another regime than joint ownership.

If third parties (including employees and other personnel) may claim rights to the results, the beneficiary concerned must ensure that those rights can be exercised in a manner compatible with its obligations under the Agreement.

The beneficiaries must indicate the owner(s) of the results (results ownership list) in the final periodic report.

Protection of results

Beneficiaries which have received funding under the grant must adequately protect their results — for an appropriate period and with appropriate territorial coverage — if protection is possible and justified, taking into account all relevant considerations, including the prospects for commercial exploitation, the legitimate interests of the other beneficiaries and any other legitimate interests.

Exploitation of results

Beneficiaries which have received funding under the grant must — up to four years after the end of the action (see Data Sheet, Point 1) — use their best efforts to exploit their results directly or to have them exploited indirectly by another entity, in particular through transfer or licensing.

If, despite a beneficiary's best efforts, the results are not exploited within one year after the end of the action, the beneficiaries must (unless otherwise agreed in writing with the granting authority) use the Horizon Results Platform to find interested parties to exploit the results.

If results are incorporated in a standard, the beneficiaries must (unless otherwise agreed with the granting authority or unless it is impossible) ask the standardisation body to include the funding statement (see Article 17) in (information related to) the standard.

Additional exploitation obligations

Where the call conditions impose additional exploitation obligations (including obligations linked to the restriction of participation or control due to strategic assets, interests, autonomy or security reasons), the beneficiaries must comply with them — up to four years after the end of the action (see Data Sheet, Point 1).

Where the call conditions impose additional exploitation obligations in case of a public emergency, the beneficiaries must (if requested by the granting authority) grant for a limited period of time specified in the request, non-exclusive licences — under fair and reasonable conditions — to their results to legal entities that need the results to address the public emergency and commit to rapidly and broadly exploit the resulting products and services at

fair and reasonable conditions. This provision applies up to four years after the end of the action (see Data Sheet, Point 1).

Additional information obligation relating to standards

Where the call conditions impose additional information obligations relating to possible standardisation, the beneficiaries must — up to four years after the end of the action (see Data Sheet, Point 1) — inform the granting authority, if the results could reasonably be expected to contribute to European or international standards.

Transfer and licensing of results

Transfer of ownership

The beneficiaries may transfer ownership of their results, provided this does not affect compliance with their obligations under the Agreement.

The beneficiaries must ensure that their obligations under the Agreement regarding their results are passed on to the new owner and that this new owner has the obligation to pass them on in any subsequent transfer.

Moreover, they must inform the other beneficiaries with access rights of the transfer at least 45 days in advance (or less if agreed in writing), unless agreed otherwise in writing for specifically identified third parties including affiliated entities or unless impossible under the applicable law. This notification must include sufficient information on the new owner to enable the beneficiaries concerned to assess the effects on their access rights. The beneficiaries may object within 30 days of receiving notification (or less if agreed in writing), if they can show that the transfer would adversely affect their access rights. In this case, the transfer may not take place until agreement has been reached between the beneficiaries concerned.

Granting licences

The beneficiaries may grant licences to their results (or otherwise give the right to exploit them), including on an exclusive basis, provided this does not affect compliance with their obligations.

Exclusive licences for results may be granted only if all the other beneficiaries concerned have waived their access rights.

Granting authority right to object to transfers or licensing — Horizon Europe actions

Where the call conditions in Horizon Europe actions provide for the right to object to transfers or licensing, the granting authority may — up to four years after the end of the action (see Data Sheet, Point 1) — object to a transfer of ownership or the exclusive licensing of results, if:

- the beneficiaries which generated the results have received funding under the grant
- it is to a legal entity established in a non-EU country not associated with Horizon Europe, and

- the granting authority considers that the transfer or licence is not in line with EU interests.

Beneficiaries that intend to transfer ownership or grant an exclusive licence must formally notify the granting authority before the intended transfer or licensing takes place and:

- identify the specific results concerned
- describe in detail the new owner or licensee and the planned or potential exploitation of the results, and
- include a reasoned assessment of the likely impact of the transfer or licence on EU interests, in particular regarding competitiveness as well as consistency with ethical principles and security considerations.

The granting authority may request additional information.

If the granting authority decides to object to a transfer or exclusive licence, it must formally notify the beneficiary concerned within 60 days of receiving notification (or any additional information it has requested).

No transfer or licensing may take place in the following cases:

- pending the granting authority decision, within the period set out above
- if the granting authority objects
- until the conditions are complied with, if the granting authority objection comes with conditions.

A beneficiary may formally notify a request to waive the right to object regarding intended transfers or grants to a specifically identified third party, if measures safeguarding EU interests are in place. If the granting authority agrees, it will formally notify the beneficiary concerned within 60 days of receiving notification (or any additional information requested).

Limitations to transfers and licensing due to strategic assets, interests, autonomy or security reasons of the EU and its Member States

Where the call conditions restrict participation or control due to strategic assets, interests, autonomy or security reasons, the beneficiaries may not transfer ownership of their results or grant licences to third parties which are established in countries which are not eligible countries or target countries set out in the call conditions (or, if applicable, are controlled by such countries or entities from such countries) — unless they have requested and received prior approval by the granting authority.

The request must:

- identify the specific results concerned
- describe in detail the new owner and the planned or potential exploitation of the results, and
- include a reasoned assessment of the likely impact of the transfer or license on the strategic assets, interests, autonomy or security of the EU and its Member States.

The granting authority may request additional information.

Access rights to results and background

Exercise of access rights — Waiving of access rights — No sub-licensing

Requests to exercise access rights and the waiver of access rights must be in writing.

Unless agreed otherwise in writing with the beneficiary granting access, access rights do not include the right to sub-license.

If a beneficiary is no longer involved in the action, this does not affect its obligations to grant access.

If a beneficiary defaults on its obligations, the beneficiaries may agree that that beneficiary no longer has access rights.

Access rights for implementing the action

The beneficiaries must grant each other access — on a royalty-free basis — to background needed to implement their own tasks under the action, unless the beneficiary that holds the background has — before acceding to the Agreement —:

- informed the other beneficiaries that access to its background is subject to restrictions, or
- agreed with the other beneficiaries that access would not be on a royalty-free basis.

The beneficiaries must grant each other access — on a royalty-free basis — to results needed for implementing their own tasks under the action.

Access rights for exploiting the results

The beneficiaries must grant each other access — under fair and reasonable conditions — to results needed for exploiting their results.

The beneficiaries must grant each other access — under fair and reasonable conditions — to background needed for exploiting their results, unless the beneficiary that holds the background has — before acceding to the Agreement — informed the other beneficiaries that access to its background is subject to restrictions.

Requests for access must be made — unless agreed otherwise in writing — up to one year after the end of the action (see Data Sheet, Point 1).

Access rights for entities under the same control

Unless agreed otherwise in writing by the beneficiaries, access to results and, subject to the restrictions referred to above (if any), background must also be granted — under fair and reasonable conditions — to entities that:

- are established in an EU Member State or Horizon Europe associated country
- are under the direct or indirect control of another beneficiary, or under the same direct or indirect control as that beneficiary, or directly or indirectly controlling that beneficiary and

- need the access to exploit the results of that beneficiary.

Unless agreed otherwise in writing, such requests for access must be made by the entity directly to the beneficiary concerned.

Requests for access must be made — unless agreed otherwise in writing — up to one year after the end of the action (see Data Sheet, Point 1).

Access rights for the granting authority, EU institutions, bodies, offices or agencies and national authorities to results for policy purposes — Horizon Europe actions

In Horizon Europe actions, the beneficiaries which have received funding under the grant must grant access to their results — on a royalty-free basis — to the granting authority, EU institutions, bodies, offices or agencies for developing, implementing and monitoring EU policies or programmes. Such access rights do not extend to beneficiaries' background.

Such access rights are limited to non-commercial and non-competitive use.

For actions under the cluster 'Civil Security for Society', such access rights also extend to national authorities of EU Member States for developing, implementing and monitoring their policies or programmes in this area. In this case, access is subject to a bilateral agreement to define specific conditions ensuring that:

- the access rights will be used only for the intended purpose and

- appropriate confidentiality obligations are in place.

Moreover, the requesting national authority or EU institution, body, office or agency (including the granting authority) must inform all other national authorities of such a request.

Additional access rights

Where the call conditions impose additional access rights, the beneficiaries must comply with them.

COMMUNICATION, DISSEMINATION, OPEN SCIENCE AND VISIBILITY (— ARTICLE 17)

Dissemination

Dissemination of results

The beneficiaries must disseminate their results as soon as feasible, in a publicly available format, subject to any restrictions due to the protection of intellectual property, security rules or legitimate interests.

A beneficiary that intends to disseminate its results must give at least 15 days advance notice to the other beneficiaries (unless agreed otherwise), together with sufficient information on the results it will disseminate.

Any other beneficiary may object within (unless agreed otherwise) 15 days of receiving notification, if it can show that its legitimate interests in relation to the results or background would be significantly harmed. In such cases, the results may not be disseminated unless appropriate steps are taken to safeguard those interests.

Additional dissemination obligations

Where the call conditions impose additional dissemination obligations, the beneficiaries must also comply with those.

Open Science

Open science: open access to scientific publications

The beneficiaries must ensure open access to peer-reviewed scientific publications relating to their results. In particular, they must ensure that:

- at the latest at the time of publication, a machine-readable electronic copy of the published version or the final peer-reviewed manuscript accepted for publication, is deposited in a trusted repository for scientific publications

- immediate open access is provided to the deposited publication via the repository, under the latest available version of the Creative Commons Attribution International Public Licence (CC BY) or a licence with equivalent rights; for monographs and other long-text formats, the licence may exclude commercial uses and derivative works (e.g. CC BY-NC, CC BY-ND) and

- information is given via the repository about any research output or any other tools and instruments needed to validate the conclusions of the scientific publication.

Beneficiaries (or authors) must retain sufficient intellectual property rights to comply with the open access requirements.

Metadata of deposited publications must be open under a Creative Common Public Domain Dedication (CC 0) or equivalent, in line with the FAIR principles (in particular machine-actionable) and provide information at least about the following: publication (author(s), title, date of publication, publication venue); Horizon Europe or Euratom funding; grant project name, acronym and number; licensing terms; persistent identifiers for the publication, the authors involved in the action and, if possible, for their organisations and the grant. Where applicable, the metadata must include persistent identifiers for any research output or any other tools and instruments needed to validate the conclusions of the publication.

Open science: research data management

The beneficiaries must manage the digital research data generated in the action ('data') responsibly, in line with the FAIR principles and by taking all of the following actions:

- establish a data management plan ('DMP') (and regularly update it)

- as soon as possible and within the deadlines set out in the DMP, deposit the data in a trusted repository; if required in the call conditions, this repository must be federated in the EOSC in compliance with EOSC requirements

- as soon as possible and within the deadlines set out in the DMP, ensure open access — via the repository — to the deposited data, under the latest available version of the Creative Commons Attribution International Public License (CC BY) or Creative Commons Public Domain Dedication (CC 0) or a licence with equivalent rights,

following the principle 'as open as possible as closed as necessary', unless providing open access would in particular:

- be against the beneficiary's legitimate interests, including regarding commercial exploitation, or
- be contrary to any other constraints, in particular the EU competitive interests or the beneficiary's obligations under this Agreement; if open access is not provided (to some or all data), this must be justified in the DMP

- provide information via the repository about any research output or any other tools and instruments needed to re-use or validate the data.

Metadata of deposited data must be open under a Creative Common Public Domain Dedication (CC 0) or equivalent (to the extent legitimate interests or constraints are safeguarded), in line with the FAIR principles (in particular machine-actionable) and provide information at least about the following: datasets (description, date of deposit, author(s), venue and embargo); Horizon Europe or Euratom funding; grant project name, acronym and number; licensing terms; persistent identifiers for the dataset, the authors involved in the action, and, if possible, for their organisations and the grant. Where applicable, the metadata must include persistent identifiers for related publications and other research outputs.

Open science: additional practices

Where the call conditions impose additional obligations regarding open science practices, the beneficiaries must also comply with those.

Where the call conditions impose additional obligations regarding the validation of scientific publications, the beneficiaries must provide (digital or physical) access to data or other results needed for validation of the conclusions of scientific publications, to the extent that their legitimate interests or constraints are safeguarded (and unless they already provided the (open) access at publication).

Where the call conditions impose additional open science obligations in case of a public emergency, the beneficiaries must (if requested by the granting authority) immediately deposit any research output in a repository and provide open access to it under a CC BY licence, a Public Domain Dedication (CC 0) or equivalent. As an exception, if the access would be against the beneficiaries' legitimate interests, the beneficiaries must grant non-exclusive licenses — under fair and reasonable conditions — to legal entities that need the research output to address the public emergency and commit to rapidly and broadly exploit the resulting products and services at fair and reasonable conditions. This provision applies up to four years after the end of the action (see Data Sheet, Point 1).

Plan for the exploitation and dissemination of results including communication activities

Unless excluded by the call conditions, the beneficiaries must provide and regularly update a plan for the exploitation and dissemination of results including communication activities.

SPECIFIC RULES FOR CARRYING OUT THE ACTION (— ARTICLE 18)

Implementation in case of restrictions due to strategic assets, interests, autonomy or security of the EU and its Member States

Where the call conditions restrict participation or control due to strategic assets, interests, autonomy or security, the beneficiaries must ensure that none of the entities that participate as affiliated entities, associated partners, subcontractors or recipients of financial support to third parties are established in countries which are not eligible countries or target countries set out in the call conditions (or, if applicable, are controlled by such countries or entities from such countries) — unless otherwise agreed with the granting authority.

The beneficiaries must moreover ensure that any cooperation with entities established in countries which are not eligible countries or target countries set out in the call conditions (or, if applicable, are controlled by such countries or entities from such countries) does not affect the strategic assets, interests, autonomy or security of the EU and its Member States.

Specific rules for MSCA actions

When implementing MSCA Doctoral Networks (DN), Postdoctoral Fellowships (PF) and COFUND actions, the beneficiaries must respect the following conditions:

- take all measures to implement the principles set out in the Commission Recommendation on the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers[3] and ensure that the researchers and all participants involved in the action are aware of them

- ensure that the researchers enjoy at the place of the implementation at least the same standards and working conditions as those applicable to local researchers holding a similar position

- ensure that the employment contract, other direct contract or fixed-amount-fellowship agreement (see Article 6) specifies:

    - the name of the supervisor(s) for the research training activities

    - the starting date and duration of the research training activities

    - the monthly support for the researcher under this Agreement (in euro and, if relevant, in the currency in which the remuneration is paid)

    - the obligation of the researcher to work exclusively for the action, unless part-time for professional reasons is allowed and has been approved (and for MSCA-DN and MSCA-PF: not to receive, for activities carried out in the frame of the action, other incomes than those received from the beneficiary or other entities mentioned in Annex 1)

    - the working pattern of the researcher

    - the arrangements related to the intellectual property rights (during implementation of the action and afterwards), in particular full access — on

[3] Commission Recommendation 2005/251/EC of 11 March 2005 on the European Charter for Researchers and on a Code of Conduct for the Recruitment of Researchers (OJ L 75, 22.3.2005, p. 67).

a royalty-free basis — for the researcher to background and results needed for their activities under the action

- the obligation of the researcher to inform as soon as possible about events or circumstances likely to affect the implementation of the action or the compliance with requirements under the Agreement (see Article 19)
- the obligation of the researcher to maintain confidentiality (see Article 13)
- the obligation of the researcher to ensure the visibility of EU funding in communications or publications and in applications for the protection of results (see Articles 17)
- where set out in the call conditions, the obligation of the researcher to carry out a mandatory return period of 12 months

- assist the researchers in the administrative procedures related to the recruitment
- inform the researchers about:
  - the description, conditions, location and timetable for the implementation of the research training activities
  - the rights and obligations toward the researchers under this Agreement
  - the obligation of the researchers to complete and submit — at the end of the research training activities — the evaluation questionnaire and — two years later — follow-up questionnaire provided by the granting authority
- ensure full access — on a royalty-free basis — for the researchers to background and results needed for their activities under the action
- ensure that the researchers do not have to bear any costs for the implementation of the action as described in Annex 1
- provide training and the necessary means for implementing the action (or ensure that such training and means are provided by other participants in the action)
- ensure that the researchers are adequately supervised and receive appropriate career guidance
- ensure that personalised career development plans are established, support their implementation and update in view of the needs of the researchers
- ensure an appropriate exposure to the non-academic sector (if applicable)
- respect the maximum limit for secondments set out in the call conditions
- respect the conditions for the outgoing and return phases set out in the call conditions (if any)
- ensure that the researchers are informed that they are 'Marie Skłodowska-Curie fellows'
- for MSCA-DN and MSCA-COFUND:

- advertise and publish vacancies internationally, including on the web-sites requested by the granting authority, indicating the gross salary (not including employer's social contributions) to be offered to the researcher
- recruit the researchers, following an open, transparent, merit-based, impartial and equitable recruitment procedure (for postdoctoral programmes in MSCA-COFUND: with regular selection rounds and international peer review), on the basis of:
  - their scientific skills and the relevance of their research experience
  - the impact of the proposed training on the researcher's career
  - a fair gender representation (by promoting genuine equal access opportunities throughout the recruitment process)

  The selection committees must bring together diverse expertise, have an adequate gender balance and include members from different countries and with relevant experience to assess the candidates.
- ensure that no conflict of interest exists in or arises from the recruitment

- for MSCA-DN and MSCA-PF:
  - ensure that the researchers do not receive, for activities carried out in the frame of the action, other incomes than those received from the beneficiaries (or other entities mentioned in Annex 1)
  - host the researchers at their premises (or at the premises of other participants in the action)
- for MSCA-COFUND where doctoral or post-doctoral programmes are implemented as financial support to third parties through implementing partners:
  - ensure that the implementing partners comply with the same standards and procedures for implementing the research training activities, including the recruitment and working conditions for researchers, the specific rules for MSCA-COFUND actions and the specific rules on ethics and research integrity set out in Annex 5
  - implement effective monitoring and oversight arrangements towards the implementing partners, covering all aspects relating to the action
  - ensure effective and reliable reporting by the implementing partners, covering the activities implemented, information on indicators, as well as the legality and regularity of the expenditure claimed
  - ensure that the implementing partners provide that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the final recipients.

When implementing Horizon Europe MSCA Staff Exchanges (MSCA-SE), the beneficiaries must respect the following conditions:

- take all measures to implement the principles set out in the Commission Recommendation on the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers[4] and ensure that the seconded staff and all participants involved in the action are aware of them
- ensure that the seconded staff enjoys at the place of the implementation at least the same standards and working conditions as those applicable to local staff holding a similar position
- assist the seconded staff with the administrative procedures related to their secondment
- inform the seconded staff about:
  - the description, conditions, location and timetable for the implementation of the secondment
  - the rights and obligations of the beneficiary toward the seconded staff under this Agreement
  - the obligation of the seconded staff to complete and submit — at the end of the secondment — the evaluation questionnaire and — two years later — the follow-up questionnaire provided by the granting authority
  - the arrangements related to the intellectual property rights between the beneficiary and the seconded staff (during the secondment and afterwards), in particular full access — on a royalty-free basis — for the staff to background and results needed for their activities under the action
  - the obligation of the seconded staff to maintain confidentiality (see Article 13)
  - the obligation of the seconded staff to ensure the visibility of EU funding in communications or publications and in applications for the protection of results (see Article 17)
- ensure that the seconded staff do not have to bear any costs for the implementation of the action as described in Annex 1
- provide training and the necessary means for implementing the action (or ensure that such training and means are provided by other participants in the action)
- ensure that the seconded staff are adequately mentored
- ensure that the rights and obligations of the seconded staff remain unchanged during the secondment
- ensure full access — on a royalty-free basis — for the staff to background and results needed for their activities under the action

[4] Commission Recommendation 2005/251/EC of 11 March 2005 on the European Charter for Researchers and on a Code of Conduct for the Recruitment of Researchers (OJ L 75, 22.3.2005, p. 67).

- if appropriate, ensure that seconded staff are reintegrated after the secondment
- ensure that the seconded staff are covered by an adequate medical insurance scheme
- ensure that the seconded staff have the relevant expertise for the action
- use the top-up allowance (see Article 6) to contribute to the subsistence, accommodation and travel of the seconded staff.

Specific rules for ERA Fellowship actions

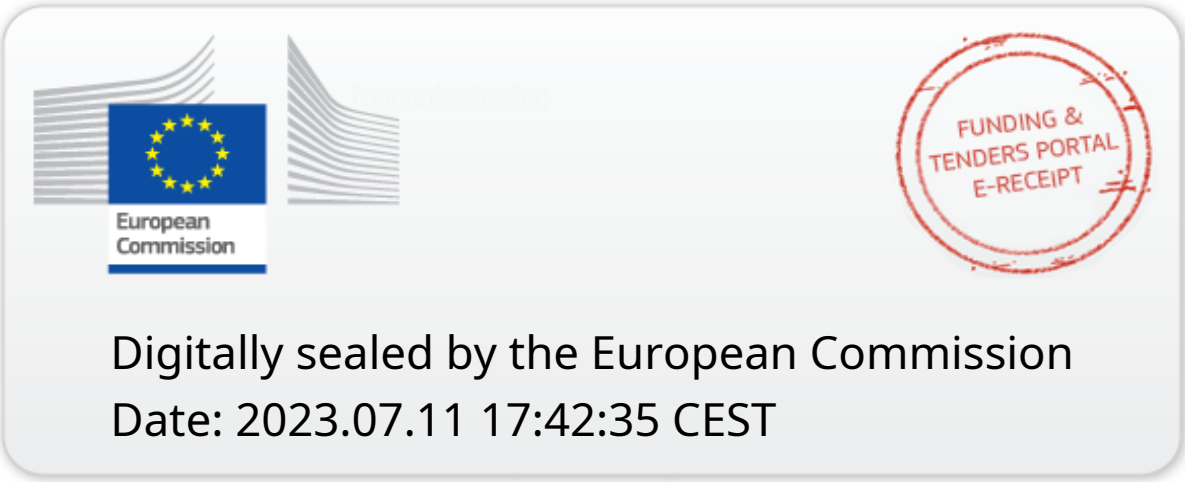
When implementing ERA Fellowships, the beneficiaries must respect the following conditions:

- take all measures to implement the principles set out in the Commission Recommendation on the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers[5] and ensure that the researchers and all participants involved in the action are aware of them
- ensure that the researchers enjoy at the place of the implementation at least the same standards and working conditions as those applicable to local researchers holding a similar position
- ensure that the employment contract, other direct contract or fixed-amount-fellowship agreement (see Article 6) specifies:
    - the name of the supervisor(s) for the research training activities
    - the starting date and duration of the research training activities
    - the monthly support for the researcher under this Agreement (in euro and, if relevant, in the currency in which the remuneration is paid)
    - the obligation of the researcher to work exclusively for the action, unless part-time for professional reasons is allowed and has been approved (and not to receive, for activities carried out in the frame of the action, other incomes than those received from the beneficiary or other entities mentioned in Annex 1)
    - the working pattern of the researcher
    - the arrangements related to the intellectual property rights (during implementation of the action and afterwards), in particular full access — on a royalty-free basis — for the researcher to background and results needed for their activities under the action

[5] Commission Recommendation 2005/251/EC of 11 March 2005 on the European Charter for Researchers and on a Code of Conduct for the Recruitment of Researchers (OJ L 75, 22.3.2005, p. 67).

  - the obligation of the researcher to inform as soon as possible about events or circumstances likely to affect the implementation of the action or the compliance with requirements under the Agreement (see Article 19)
  - the obligation of the researcher to maintain confidentiality (see Article 13)
  - the obligation of the researcher to ensure the visibility of EU funding in communications or publications and in applications for the protection of results (see Articles 17)
  - where set out in the call conditions, the obligation of the researcher to carry out a mandatory return period of 12 months
- assist the researchers in the administrative procedures related to the recruitment
- inform the researchers about:
  - the description, conditions, location and timetable for the implementation of the research training activities
  - the rights and obligations toward the researchers under this Agreement
  - the obligation of the researchers to complete and submit — at the end of the research training activities — the evaluation questionnaire and — two years later — follow-up questionnaire provided by the granting authority
- ensure full access — on a royalty-free basis — for the researchers to background and results needed for their activities under the action
- ensure that the researchers do not have to bear any costs for the implementation of the action as described in Annex 1
- provide training and the necessary means for implementing the action (or ensure that such training and means are provided by other participants in the action)
- ensure that the researchers are adequately supervised and receive appropriate career guidance
- ensure that personalised career development plans are established, support their implementation and update in view of the needs of the researchers
- ensure an appropriate exposure to the non-academic sector (if applicable)
- respect the maximum limit for secondments set out in the call conditions
- respect the conditions for the outgoing and return phases set out in the call conditions (if any)
- ensure that the researchers are informed that they are ‘ERA fellows’
- ensure that the researchers do not receive, for activities carried out in the frame of the action, other incomes than those received from the beneficiaries (or other entities mentioned in Annex 1)

- host the researchers at their premises (or at the premises of other participants in the action)



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