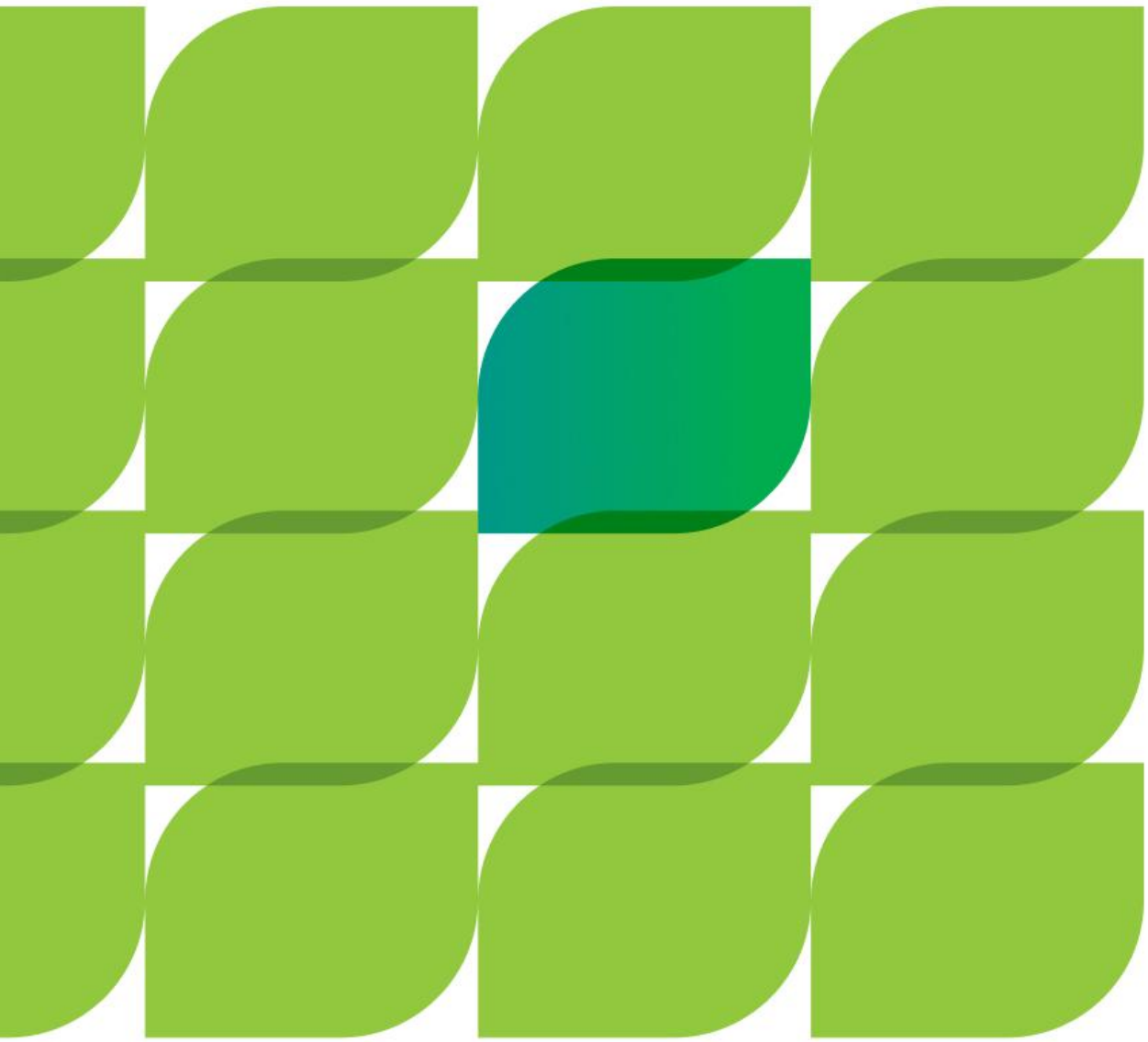
Digital 4 Sustainability
Skills for Europe's Twin Transition

D3.3 Digital Sustainability Certification/Micro-Credentialling Framework



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About the Digital4Sustainability project

Digital4Sustainability is a pioneering initiative aimed at accelerating Europe's twin transition by equipping the workforce with the essential skills needed to drive sustainability-focused innovation. In response to the pressing need to achieve climate neutrality and meet the Sustainable Development Goals (SDGs), the project will develop a forward-thinking Digital Sustainability Skills Strategy as well as cutting-edge learning programmes. These efforts will address the urgent and emerging skills needs of the European industry, empowering the workforce to develop sustainable technologies that support Environmental, Social, and Governance (ESG) practices. By aligning closely with industry needs throughout the project, Digital4Sustainability will help European companies, particularly small and medium-sized enterprises (SMEs), achieve long-term competitiveness and growth through digital and sustainable transformation.

Funded by the Erasmus+ Programme of the European Union, this 4-year project unites 28 members of the Digital Large-Scale Partnership (Digital LSP) under the Pact for Skills, spanning 13 EU countries. The consortium includes digital and sustainability experts, business associations, universities, and Vocational Education and Training (VET) providers.

The Digital4Sustainability Project Consortium

The Digital4Sustainability project consortium is an Erasmus+ Alliance for Sectoral Cooperation on Skills, bringing together 28 partners and Associated partners from 13 EU countries.

	Partners	Acronym	Country
1	Adecco Formazione Srl	Adecco Training	Italy
2	Adecco Italia Holding Spa	Adecco Holding	Italy
3	AS BCS Koolitus	BCS KOOLITUS	Estonia
4	Asociatia Cluj IT	CLUJ IT CLUSTER	Romania
5	Badgebox Srl	BadgeBox	Italy
6	CEFRIEL Societa Consortile A Responsabilita Limitata	CEFRIEL	Italy
7	Cooperatie Eduserpro U.A.	Eduserpro	Netherlands
8	Digital Technology Skills Limited	DTSL	Ireland
9	DIGITALEUROPE AISBL	DIGITALEUROPE	Belgium
10	European DIGITAL SME Alliance	DIGITAL SME	Belgium
11	Fast Lane Institute For Knowledge Transfer GmbH	FAST LANE	Germany
12	Gospodarska Zbornica Slovenije	GZS CCIS	Slovenia
13	Gospodarska Zbornica Slovenije Center Za Poslovno Usposabljanje	GZS CPU	Slovenia
14	IVSZ - Digitalis Vallalkozasok Szovetsege	IVSZ	Hungary
15	Matrix Internet Applications Limited	MATRIX INTERNET	Ireland
16	National College Of Ireland	NCI	Ireland
17	Profil Klett D.O.O.	PK	Croatia
18	Sdruzenie Bulgarska Asociacia Na Softuernite Kompanii - Basscom	BASSCOM	Bulgaria
19	Stichting Hogeschool Utrecht	HU	Netherlands
20	Tekenable Limited	TEKenable	Ireland
21	Universidad De Alcala	UNI ALCALA	Spain
22	Universidad Internacional De La Rioja SA	UNIR	Spain
23	Universität Koblenz	UNI KO	Germany
24	National University of Science and Technology *Politehnica* Bucharest	POLITEHNICA Bucharest	Romania

	Associated partners	Acronym	Country
1	Asociacija Infobalt	INFOBALT	Lithuania
2	SKILLNET IRELAND Company Limited By Guarantee	SKILLNET IRELAND	Ireland
3	The Council of European Professional Informatics Societies	CEPIS	Belgium
4	Universidad Complutense de Madrid	UCM	Spain

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Executive Summary

D3.3 defines the design specifications for a micro-credential framework in digital sustainability developed under Task 3.4 of the Grant Agreement. Building on the five educational profiles and associated curricula established in D3.1 Digital Sustainability Educational Profiles and Core Curricula, it specifies a stackable architecture in which smaller credentials combine systematically into larger qualifications through defined accumulation rules. The framework is built on 51 modular learning units (0.5–7.5 ECTS) from D3.1 that aggregate into upskilling micro-credentials (0.5–2.5 ECTS), substantial micro-credentials (5–7.5 ECTS), and thematic clusters (10–15 ECTS), which in turn can stack towards five comprehensive qualifications of 60–90 ECTS via Recognition of Prior Learning pathways. D3.3 sets out the certification architecture, quality assurance procedures, assessment approach, and recognition pathways that operationalise the educational profiles, while implementation and credential issuance remain institutional decisions for partners.

Key framework components

- ECTS and EQF implementation specifications covering credit allocation and level assignment using a standardised methodology.
- Quality assurance procedures aligned with ESG 2015 and EQAVET at framework, institutional, and consortium levels.
- Recognition pathway documentation for three implementation tracks with realistic timelines informed by EU project experience.
- Partner readiness assessment for ten partners across seven criteria using a 0–7 scoring scale to identify implementation capacity.
- Technical specifications compliant with Europass EDCI v3 to ensure credentials are interoperable and verifiable.
- Templates and tools, including credential templates, assessment rubrics, quality assurance procedures, and a consortium mutual recognition agreement.

Outside the scope of D3.3

D3.3 does not: (i) implement an operational credential system, (ii) guarantee partner adoption, (iii) issue credentials during the project, or (iv) establish binding post-project commitments. Implementation is the responsibility of individual partners and depends on institutional resources, regulatory conditions, and strategic priorities.

Foundation and Evidence Base

This deliverable builds on five educational profiles (Data Analyst for Sustainability, Data Professional for Sustainability, Digital Sustainability Consultant, Digital Sustainability Manager, Sustainability Technical Specialist) and six upskilling curricula (Circular Economy in Digital Systems, Cybersecurity for Sustainable Systems, Digital Sustainability Foundations, EU Policy and Legislation, Green Software Fundamentals, Sustainability Data Essentials). Its design is informed by analysis of recent EU-funded micro-credential projects (2020–2025). On this basis, patterns such as three-level stackability, institutional anchoring, and embedded programmes are adopted, while known pitfalls such as standalone credentials without institutional legitimacy and technology-first approaches are avoided.

Recognition Strategy Options

Three recognition tracks are proposed as implementation options, with partners free to decide whether and how to pursue them:

- Track 1 – Institutional or consortium implementation: estimated 6–12 months from institutional decision, leveraging existing degree-awarding powers and quality assurance systems, with moderate investment in technical infrastructure and staff time.
- Track 2 – Sectoral recognition: estimated 3–6 months, based on employer co-design and professional body validation to support workforce recognition independently of formal higher education accreditation.
- Track 3 – National or European recognition: typically, 12–18 months or more from application submission in countries with established frameworks, involving accreditation and registration costs and substantial documentation effort; documentation prepared in D3.3 enables post-project applications, but full cycles exceed current project resources.

Next Steps for WP4 Validation

WP4 pilots will involve 700 learners across seven partner institutions without formal credential issuance. The piloting partners will validate curriculum specifications, assessment instruments, learning outcomes, the likelihood of attainment, and quality assurance procedures, but do not validate the credentialling process itself. Partners may choose to award credentials at their own discretion if approval processes are completed and resources allocated. Feedback collected between M28 and M36 informs specification refinements documented in final project reporting.

1. Introduction and Context

1.1 Purpose and Scope of D3.3

D3.3 develops comprehensive design specifications for a certification and micro-credential framework designed to support transparent recognition, validation, and accumulation of learning within Digital4Sustainability, supporting national and cross-border career mobility. The specifications enable an outcomes-based, stackable system of certifications (including micro-credentials) with specifications for mapping each training programme, module, and learning outcome to relevant job roles and sectoral skills needs as specified in Task 3.4.

Terminology

Throughout this document, "micro-credential" refers to the certificate awarded upon successful completion, while "micro-credential programme" (or "upskilling curriculum" per D3.1 terminology) refers to the learning programme leading to it. "Stackable" means that smaller credentials systematically combine into larger qualifications through defined accumulation rules—multiple micro-credentials from upskilling programmes stack toward learning units, which combine into comprehensive qualifications, enabling learners to build credentials progressively over time and across contexts.

Operationalisation of D3.1

This deliverable operationalises D3.1 (Educational Profiles and Core Curricula) by defining the credentialling process, quality assurance mechanisms, and recognition pathways based on EU standards (Council Recommendation 2022/C 243/02, ESG 2015, EQAVET) and evidence from recent EU micro-credential projects (systematic analysis of ten projects 2020-2025, detailed in Section 2.3). D3.1 provided foundational educational content and pedagogical structures; D3.3 establishes how this learning will be recognised and certified through systematic credentialling architecture. The framework articulates clear design principles, provides detailed methodologies for mapping competencies to learning outcomes through a five-stage systematic process (job role identification → competence framework mapping via e-CF and GreenComp → learning outcome specification at programme and unit levels → module and curriculum design → assessment and credential issuance), establishes quality assurance procedures operating at framework, institutional, and consortium levels, and defines recognition pathways at institutional (Track 1), sectoral (Track 2), and national/European levels (Track 3) with partner readiness assessment identifying implementation capacity across consortium partners.

D3.3 Provides (Framework Specifications)

Complete credential architecture (three aggregation levels, stackability rules, ECTS/EQF specifications); detailed quality assurance procedures (assessment design requirements, authentication approaches, moderation methods); recognition pathway documentation (institutional, consortium, sectoral, national routes with timelines and requirements); implementation tools (credential templates Annex A, Europass metadata structures Annex B, quality assurance checklists, assessment rubrics); partner readiness assessment (capacity evaluation across seven criteria, implementation pathway recommendations); technical specifications (Europass EDCI v3 compliance, verification mechanisms, open standards adoption).

D3.3 Does Not Provide (Operational Implementation)

Operational credential issuance systems (requires partner institutional development beyond deliverable scope); guaranteed credential adoption by partners (participation voluntary based on institutional resources and priorities); issued credentials during project timeline (WP4 pilots validate specifications without formal credentialling); binding post-project commitments (sustainability governance determined based on partner capacity assessment).

Partner Implementation Responsibility

Actual credential issuance depends on partner institutional decisions, available resources, regulatory compliance, and strategic priorities. Partners choosing implementation will complete internal institutional approval processes applying existing quality assurance systems, allocate resources for technical infrastructure, staff training, and operational delivery, navigate national regulatory requirements for credential recognition, and establish governance structures for quality maintenance and continuous improvement. Partners may pursue Track 1 or Track 2 implementation during the project period at institutional discretion or defer to post-project implementation for Track 3 national accreditation, which requires extended timelines and substantial investment beyond current project resources.

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1.2 Design Criteria for D3.3

D3.3 is assessed against five criteria reflecting the framework's dual purpose: providing specifications enabling WP4 pilot implementation while positioning willing partners for long-term credential adoption and recognition beyond project completion.

Strategic Alignment assesses whether framework specifications coherently integrate EU policy requirements, sectoral workforce needs, and partner institutional capacities. This criterion is based on three measures. First, a compliance review confirms alignment with Council Recommendation 2022/C 243/02, ESG 2015, and EQAVET. Second, employer advisory board validation will assess whether competence mappings address genuine workforce requirements through surveys of employer organisations across digital and sustainability sectors. Third, partner feasibility confirmation will evaluate whether implementation requirements match institutional capabilities through partner surveys. The first measure has been completed. Second and third measures are planned for future completion.

Technical Completeness assesses whether detailed specifications within this deliverable enable WP4 pilot implementation without requiring substantial additional framework development. This criterion is measured through WP4 pilot partner feedback. Partners evaluate the sufficiency of provided specifications including credential templates, assessment rubrics, quality assurance procedures, and stackability guidelines. The target is ≥90% sufficiency without needing external consultation or framework redesign. Assessment will occur following initial pilot implementation phase through structured feedback instrument. This measure is planned for future completion.

Stakeholder Validation assesses framework usability and credibility through planned feedback collection from partners, industry advisors, and quality assurance agencies. This criterion is measured through three activities. First, partner satisfaction surveys will target ≥80% positive ratings on specification clarity, implementation feasibility, and quality rigour. These surveys are planned following WP4 pilot experience to ensure partners evaluate specifications after practical application rather than theoretical review. Second, employer Declarations of Understanding from ≥5 employers will be pursued building on industry engagement. These declarations recognise credentials for recruitment criteria or continuing professional development requirements. The template is provided in Annex E. Third, quality assurance agency engagement will be evidenced through consultation meetings and feedback provision in countries where consortium partners operate and micro-credential frameworks are operational or under development (Estonia, Ireland, Croatia). Validation evidence will inform final version refinements and sustainability

planning, ensuring specifications reflect stakeholder needs and implementation realities rather than purely theoretical design. All three measures are planned for future completion.

Recognition Readiness assesses whether framework specifications provide the materials required for national accreditation applications in countries with established micro-credential frameworks. This criterion is measured through two activities. First, specification completeness is evaluated against application requirements from pilot-country quality assurance agencies. The evaluation compares D3.3 content (learning outcome specifications, ECTS methodology, quality assurance procedures, assessment approaches, competence mappings) against agency checklist requirements. Assessment results show Estonian Education and Youth Board checklist 95% complete, Irish QQI requirements 87% complete. Identified gaps require extended pilot evidence from WP4 completion. Second, institutional leadership confirmation from partners in pilot countries will verify that D3.3 specifications would support recognition applications should institutions choose to allocate necessary resources. Confirmation from partners in Estonia, Ireland, and Croatia is planned following initial pilot experience. The first measure has been completed. The second measure is planned for future completion.

Long-Term Utility assesses whether the specifications support sustainable adoption beyond project timeline through institutional integration mechanisms and adaptation procedures. This criterion is assessed through three measures. First, partners indicate whether they plan to integrate credentials into their regular programme offerings rather than treating them as temporary project activities. This is assessed through sustainability planning surveys asking partners about their intentions for continuing credential issuance after EU funding ends. Second, framework specification flexibility is demonstrated through version control procedures enabling systematic updates responding to competence evolution while maintaining multi-year implementation stability. Update procedures are detailed in Section 6.3. Version control templates are provided in Annex F. Third, post-project coordination structure establishment will be determined based on partner commitment and resource assessment. Coordination may involve informal mechanisms rather than formal legal entities. This governance decision will be made following sustainability planning activities. The first and second measures have been completed. The third measure is planned for future completion.

Collectively, these criteria ensure D3.3 delivers practical, credible, and sustainable specifications for Digital4Sustainability micro-credentialling rather than theoretical designs lacking stakeholder validation or implementation viability.

1.3 Relationship to Other Work Packages and Deliverables

D3.3 integrates outputs from previous work packages while providing specifications enabling subsequent project activities:

Building on WP2 (Labour Market Analysis): Deliverable D2.1 "*Roles and Skills Needs Analysis Report*" identified digital sustainability workforce needs through employer consultation, job advertisement analysis, and skills gap assessment. D3.3 operationalises these findings through competence framework mapping (Section 3.3) translating employer-identified needs into e-CF and GreenComp competence specifications, which cascade into learning outcomes, curricula, and credentials. Five professional roles identified in D2.1 become five comprehensive qualifications in D3.3 framework architecture.

Building on D3.1 (Educational Profiles and Curricula): Deliverable D3.1 "*Digital Sustainability Educational Profiles and Core Curricula*" designed five comprehensive educational profiles with programme and unit learning outcomes and developed 51 learning units across five core curricula plus six upskilling curricula. D3.3 transforms these educational designs into certifiable credentials through: (1) Three-level architecture (Section 3) mapping D3.1's upskilling curricula to Level 1 micro-credentials, D3.1's 51 learning units to Level 2, and D3.1's comprehensive profiles to Level 3 qualifications, (2) Assessment frameworks (Section 4.3) specifying how D3.1's learning outcomes will be validated, (3) Stackability rules (Section 3.4) defining how D3.1's modular components combine progressively.

Building on D3.2 (Quality Assurance Criteria): Deliverable D3.2 "*Accreditation criteria and process for learning programmes*" established accreditation criteria ensuring programmes meet quality standards, stakeholder needs, and continuous improvement requirements. D3.2 and D3.3 were developed in parallel with regular coordination ensuring consistency between quality assurance principles (D3.2) and their operational implementation (D3.3). This parallel development enabled D3.3 quality specifications to reflect D3.2 requirements while D3.2 benefited from D3.3's practical implementation considerations. D3.3 translates D3.2's criteria into multi-level quality assurance specifications (Section 4) providing operational procedures for assessment validity, standards consistency, external review, and quality maintenance.

Enabling WP4 (Pilot Implementation): WP4 "*Pilot of digital sustainability programmes to meet urgent and long-term skills needs*" pilots training programmes with 700 learners (200 urgent + 500 emerging roles per Grant Agreement Annex 1) validating educational effectiveness. D3.3 provides specifications enabling pilot implementation: curriculum specifications from D3.1 operationalised through credential architecture, assessment instruments (Section 4.3, templates Annex A), quality assurance procedures (Section 4), and evaluation frameworks. WP4 pilots validate D3.3 specifications through learner achievement data, assessment instrument performance, stakeholder feedback, and quality assurance procedure effectiveness. Pilot feedback collected M24-M36 informs specification refinements documented in Month 48 final project reporting. Critically: WP4 validates curriculum specifications, assessment approaches, and quality procedures—NOT the credential issuance process itself, which requires partner institutional implementation beyond pilot scope.

Enabling WP6 (Sustainability and Dissemination): WP6 "*Long Term Sustainability Strategy & Scale Up*" addresses long-term programme sustainability, dissemination strategies, and exploitation planning. D3.3 contributes framework specifications enabling sustainable credential adoption (Section 6.3 addresses framework specification maintenance, distinguishing this from WP6's broader programme sustainability scope), partner readiness assessment informing sustainability planning (Section 5.2, detailed Annex C), and dissemination materials including openly published framework specifications (Creative Commons licence enabling broad adoption beyond consortium).

1.4 Document Structure

Section 2 presents comparative analysis methodology and findings from eleven EU micro-credential projects implemented 2020-2025. Subsection 2.1 establishes EU policy and standards context (Council Recommendation 2022/C 243/02, ECTS, ESG 2015, EQAVET, Europass EDCI). Subsection 2.2 details project selection methodology (selection criteria, search strategy, analysis framework). Subsection 2.3 synthesises evidence identifying three viable recognition routes (consortium/institutional, sectoral, national/European), realistic timelines, necessary investments, and critical design principles.

Section 3 details three-level stackability architecture aligned with D3.1 curriculum structure. Subsection 3.1 presents framework design principles. Subsection 3.2 describes Level 1 (micro-credentials from 6 upskilling curricula, 0.5-2.5 ECTS). Subsection 3.3 describes Level 2 (51 learning units from 5 core curricula). Subsection 3.4 describes Level 3 (5 comprehensive qualifications, 60-90 ECTS). Subsection 3.5 specifies stackability mechanisms and accumulation rules. Subsection 3.6 addresses ECTS credit allocation and EQF level assignment methodologies.

Section 4 specifies quality assurance procedures at framework, institutional, and consortium levels aligned with ESG 2015 and EQAVET. Subsection 4.1 establishes multi-level quality assurance architecture. Subsection 4.2 details institutional quality assurance procedures (approval processes, delivery monitoring, staff development). Subsection 4.3 specifies assessment requirements (design principles, authentication approaches, moderation methods). Subsection 4.4 addresses external examiner roles and responsibilities. Subsection 4.5 describes credential issuance and verification procedures.

Section 5 documents recognition pathways with partner readiness assessment. Subsection 5.1 presents recognition landscape and strategic approach. Subsection 5.2 details partner readiness assessment methodology and results (full scoring methodology Annex C). Subsection 5.3 describes Track 1 (institutional/consortium) implementation requirements and partner positioning. Subsection 5.4 describes Track 2 (sectoral) validation approaches and industry partnerships. Subsection 5.5 describes Track 3 (national/European) documentation requirements and pilot country strategies.

Section 6 addresses implementation planning for WP4 pilots and post-project adoption. Subsection 6.1 specifies WP4 pilot scope and validation objectives. Subsection 6.2 provides partner implementation guidance including timelines, resources, and support mechanisms. Subsection 6.3 addresses framework specification sustainability (governance options, quality maintenance procedures, version control) distinguishing framework maintenance from broader programme sustainability addressed in WP6.

Section 7 analyses risks with evidence-based assessment and operational mitigation strategies. Subsection 7.1 identifies key risks (recognition/accreditation, quality/standards, stakeholder engagement, technical implementation) with probability assessments grounded in partner consultations, QA agency discussions, and precedent analysis. Subsection 7.2 specifies mitigation measures with concrete actions, responsible parties, and contingency procedures.

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Section 8 provides conclusions summarising what the framework delivers, recommendations for partner implementation and consortium coordination, and next steps for WP4 validation and post-project sustainability planning.

Annexes A–H provide implementation tools. Annex A contains the micro-credential template with visual certificate layout and structured data format. Annex B presents the Europass EDCI v3 metadata structure and verification schematic. Annex C documents the partner readiness assessment methodology, including full scoring rubrics and justifications. Annex D provides the consortium mutual recognition agreement template, while Annex E offers employer Declaration of Understanding templates with signed examples. Annex F covers technical specifications for credential verification, version control procedures, and system integration guidance. Annex G summarises micro-credential recognition requirements across 10 partner countries based on Task 3.4 survey responses. Finally, Annex H lists the 51 learning units established in D3.1, which form the basis for short learning programmes leading to micro-credentials.

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2. Policy and Framework Alignment

2.1 European Policy and Standards Context

D3.3 aligns with European policy frameworks and technical standards governing micro-credentials, quality assurance, and competence recognition. This section details the policy landscape and explains how each framework has been operationalised within D3.3 specifications.

2.1.1 Council Recommendation on Micro-credentials (2022/C 243/02)

The Council Recommendation on a European approach to micro-credentials for lifelong learning and employability (2022/C 243/02, adopted 16 June 2022) establishes common understanding defining micro-credentials as records of learning outcomes achieved through short, transparently assessed courses or modules. The Recommendation specifies standard elements including learning outcomes, assessment approaches, credit/workload indication (ECTS or equivalent), and qualification level (EQF). Member states are encouraged to integrate micro-credentials within national qualification frameworks and quality assurance systems.

All credential templates (Annex A) include the ten mandatory elements specified in the Recommendation: identification (title, awarding body), learning outcomes, assessment methods, credit value (ECTS), qualification level (EQF), learning effort (hours), validity period, and supervision/quality assurance details. Section 3.4 implements the Recommendation's emphasis on stackability through defined accumulation rules enabling micro-credentials to combine systematically toward comprehensive qualifications via Recognition of Prior Learning. Europass EDCI compliance (Annex B) ensures machine-readable, verifiable credentials supporting cross-border recognition as recommended. The multi-level quality assurance framework (Section 4.1) operationalises the Recommendation's quality principles including internal and external quality assurance, stakeholder involvement, and continuous improvement.

2.1.2 European Credit Transfer and Accumulation System (ECTS)

The European Credit Transfer and Accumulation System (ECTS) operate as the primary credit framework for higher education following integration of the European Credit System for Vocational Education and Training (ECVET). The European Commission confirmed ECVET discontinuation in November 2023 (Commission Staff Working Document SWD (2023) 464 final) with functionality absorbed within ECTS under the European Education Area framework. ECTS now serves as sole credit system for both higher education and VET contexts, with one ECTS credit representing 25-30 hours learning workload.

Section 3.6 specifies systematic ECTS assignment using 25-30 hours per credit across all credential types: upskilling micro-credentials (0.5-2.5 ECTS), substantial micro-credentials (5-7.5 ECTS), thematic clusters (10-15 ECTS), and comprehensive qualifications (60-90 ECTS). All credential specifications document total learning hours, contact hours, self-directed study, and assessment time enabling learners and institutions to understand time investment required. The stackability architecture (Section 3.4) enables ECTS credits from micro-credentials to accumulate toward larger qualifications through Recognition of Prior Learning, supporting the ECTS accumulation function. ECTS values facilitate credit transfer across European institutions, supporting learner mobility and qualification portability, which proves particularly relevant for Track 1 consortium mutual recognition.

2.1.3 European Qualifications Framework (EQF)

The European Qualifications Framework (EQF) for lifelong learning (Council Recommendation 2017/C 189/03, repealing 2008/C 111/01) provides common reference framework enabling qualification comparison across European countries through eight reference levels describing learning outcomes in terms of knowledge, skills, and responsibility/autonomy. Member states reference national qualifications to EQF levels enabling cross-border understanding and recognition.

Section 3.6 specifies EQF level methodology examining knowledge (depth and breadth), skills (cognitive and practical), and responsibility/autonomy descriptors. All credentials receive appropriate EQF level assignments: upskilling micro-credentials (EQF 5), substantial micro-credentials (EQF 5-6), thematic clusters (EQF 6), and comprehensive qualifications (EQF 5-7

depending on profile). Programme and unit learning outcomes (derived from D3.1) are written using EQF-aligned action verbs and complexity levels ensuring assessment can validly determine EQF level achievement. Comprehensive qualifications (60-90 ECTS) are designed to qualify learners for both direct employment (through demonstrated competences) and further study (through EQF level achievement), implementing the EQF's dual legitimacy principle. Track 3 documentation (Section 5.5) prepares materials for National Qualifications Framework referencing in countries with established micro-credential frameworks, enabling formal EQF level recognition.

2.1.4 Standards and Guidelines for Quality Assurance (ESG 2015)

Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG 2015, revised May 2015) establish quality assurance principles for European higher education. ESG Part 1 (Standards for internal quality assurance) requires institutions maintain policies for quality assurance, design/approval of programmes, student-centred learning, assessment, teaching staff qualifications, learning resources, information management, public information, and continuous monitoring/improvement.

Section 4.1 specifies quality assurance operating at consortium coordination (framework specification maintenance, cross-institutional moderation) and institutional implementation (academic approval, delivery monitoring, assessment integrity) levels, respecting ESG principles while adapting to micro-credential context. Specifications require partner institutions to apply existing academic governance including curriculum committees and quality assurance offices, ensuring credentials undergo same approval rigour as conventional programmes, thereby implementing ESG 1.2 on programme design and approval. The competence-based design methodology (Section 3.3) emphasises learning outcomes and flexible pathways supporting diverse learner needs, aligning with ESG student-centredness principles (ESG 1.3). Section 4.3 specifies assessment requirements ensuring constructive alignment, valid authentication, and consistent moderation, implementing ESG assessment standards.

2.1.5 European Quality Assurance Reference Framework for VET (EQAVET)

European Quality Assurance Reference Framework for Vocational Education and Training (EQAVET, revised 2020 per Council Recommendation 2020/C 417/01) establishes quality assurance principles for VET including quality assurance planning, implementation, evaluation, and review. EQAVET principles apply to VET-delivered micro-credentials ensuring systematic quality management.

EQAVET standards apply where consortium VET partners (e.g., BCS Koolitus Estonia) deliver credentials, ensuring quality frameworks respect vocational education contexts not just higher education. The framework specifications (D3.3 entire deliverable) constitute EQAVET planning phase, establishing objectives, target groups, design criteria, and resource requirements. Section 6.2 provides partner implementation guidance aligned with EQAVET implementation principles including resource mobilisation, delivery execution, and stakeholder engagement. Design criteria (Section 1.3) specify measurable indicators enabling systematic evaluation, while continuous improvement mechanisms (Section 4.4) establish review cycles aligned with EQAVET principles. Specifications accommodate both ESG (for higher education institution partners) and EQAVET (for VET partners), recognising consortium diversity and enabling appropriate quality frameworks per institutional context.

2.1.6 European e-Competence Framework (e-CF)

The European e-Competence Framework (e-CF, EN 16234-1:2019) specifies 41 ICT professional competences across five process areas (Plan, Build, Run, Enable, Manage) with five proficiency levels (1-5) distinguishing capability progression from basic task performance under supervision (Level 1) to strategic leadership with enterprise-level impact (Level 5). e-CF provides common European language for ICT sector competence specification.

Section 3.4 documents systematic mapping of all five educational profiles to relevant e-CF competences at appropriate proficiency levels. For example, Data Analyst for Sustainability maps to B.4 "Solution Deployment" (Level 2) and D.10 "Information and Knowledge Management" (Level 3), while Digital Sustainability Manager maps to E.3 "Risk Management" (Level 4) and E.8

"Information Security Management" (Level 4). Credential specifications distinguish junior (Levels 2-3), intermediate (Levels 3-4), and senior (Levels 4-5) roles through proficiency level assignments, enabling employers to understand capability expectations. Programme and unit learning outcomes (from D3.1) systematically derive from e-CF competence descriptions ensuring credentials address genuine ICT professional requirements. Assessment specifications (Section 4.3) require demonstrating e-CF competences at claimed proficiency levels through authentic tasks reflecting professional contexts.

2.1.7 European Sustainability Competence Framework (GreenComp)

GreenComp: The European Sustainability Competence Framework (Bianchi, Pisiotis, & Cabrera Giraldez, 2022; EUR 30955 EN) provides 12 sustainability competences across four areas: embodying sustainability values (valuing sustainability, supporting fairness, promoting nature), embracing complexity in sustainability (systems thinking, critical thinking, problem framing), envisioning sustainable futures (futures literacy, adaptability, exploratory thinking), and acting for sustainability (political agency, collective action, individual initiative). GreenComp complements e-CF by addressing sustainability-specific capabilities.

All educational profiles map to both e-CF (ICT competences) and GreenComp (sustainability competences), implementing twin transition requirements. For example, Digital Sustainability Consultant maps to GreenComp 1.3 "Promoting Nature," 2.2 "Systems Thinking," 3.2 "Adaptability," and 4.1 "Political Agency." The five profiles emphasise different GreenComp competences based on professional role requirements: Sustainability Technical Specialist emphasises 2.2 "Systems Thinking" and 4.3 "Individual Initiative," while Digital Sustainability Manager emphasises 3.2 "Adaptability" and 4.1 "Political Agency." Sustainability-focused learning outcomes (from D3.1) systematically address GreenComp competences ensuring credentials develop genuine sustainability capabilities not just technical skills. Where e-CF and GreenComp prove insufficient for digital sustainability roles, the framework specifies domain-specific competences including ESG reporting, Life Cycle Assessment, circular economy principles, and green software development practices, thereby extending standard frameworks to address emerging professional requirements. GreenComp mapping enables employers and quality assurance

agencies to verify credentials address sustainability competences essential for twin transition workforce development.

2.1.8 Europass Digital Credentials Infrastructure (EDCI)

Europass Digital Credentials Infrastructure (EDCI, specification version 3.0 released December 2021, European Commission Decision C (2021) 9345 final) provides technical standard for issuing verifiable, machine-readable credentials. EDCI enables credentials compliant with European Self-Sovereign Identity framework and compatible with European Digital Identity Wallet (eIDAS 2.0 Regulation (EU) 2024/1183 establishing framework adopted June 2024).

Annex B provides the EDCI v3 metadata structure including JSON schema, required fields, competence framework references, verification mechanisms, and cryptographic signature specifications. Annex A credential templates map directly to EDCI metadata fields ensuring visual certificates and machine-readable data remain synchronised. Annex F specifies credential verification processes using EDCI capabilities: digital signature verification, issuer verification through consortium registry, revocation checking, and optional blockchain anchoring. EDCI compliance ensures credentials issued by any consortium partner remain technically compatible, verifiable across borders, and readable by European Digital Identity Wallet when operational. Technical specifications (Annex F) emphasise vendor-neutral implementation enabling partners to integrate EDCI capabilities with diverse institutional systems including student information systems, learning management systems, and credential repositories without technology lock-in.

2.1.9 Integration Summary

D3.3 systematically integrates all relevant European policies and standards rather than treating them as external constraints. The framework operationalises policy compliance (Council Recommendation 2022/C 243/02, EQF) through credential element specifications and stackability rules. Credit and quality frameworks (ECTS, ESG 2015, EQAVET) are implemented through methodological specifications and quality assurance procedures. Competence frameworks (e-CF, GreenComp) are incorporated through systematic mapping and learning outcome

derivation. Technical standards (EDCI v3) are realised through complete metadata structures and verification procedures. This integration ensures credentials designed using D3.3 specifications will meet European policy requirements while remaining implementable by partners with diverse institutional contexts, technical capacities, and national regulatory environments. Specifications balance standardisation (enabling recognition and portability) with flexibility (respecting institutional autonomy and national variations).

2.2 European Qualification and Credential Frameworks

The translation of policy ambitions into operational frameworks relies on established instruments such as the European Qualifications Framework (EQF)—an eight-level, learning outcome-based system that enables direct comparison and "levelling" of qualifications across countries and sectors. By linking national frameworks to the EQF, it becomes possible to reference and validate learning outcomes achieved through micro-credentials in a consistent, Europe-wider manner.

The European Credit Transfer and Accumulation System (ECTS) is the system for assigning credits to micro-credentials in higher education, following the formal discontinuation of ECVET at the EU level in recent years. ECTS serves as the sole framework for credit allocation in this project, ensuring transparent measurement and transferability of learning achievements. Europass Digital Credentials for Learning (EDCI), in parallel, the e-Competence Framework (e-CF) and the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG) provide essential reference points for designing, delivering, and assuring the quality of digital sustainability micro-credentials.

2.3 Lessons and Good Practices from EU Projects

Between 2020 and 2025, several EU-funded projects piloted micro-credential approaches with varying recognition outcomes. D3.3 framework design builds on systematic analysis of these initiatives, identifying proven patterns, realistic timelines, and implementation strategies demonstrating viability across diverse European contexts.

2.3.1 Project Selection and Analysis Methodology

Ten EU-funded projects were selected for comparative analysis using systematic criteria ensuring relevance and evidence quality. **Selection criteria** included: (1) EU funding exceeding €2M indicating substantial project scope (verified through the CORDIS database), (2) explicit micro-credential development focus documented in project objectives or deliverables, (3) project completion between 2020-2025 enabling access to final outcomes and implementation evidence, (4) public documentation availability through project websites, the CORDIS repository, or academic publications enabling detailed review of design approaches, implementation processes, and recognition outcomes.

Project identification employed three complementary approaches: (1) CORDIS database keyword searches using terms "micro-credential" OR "microcredential" OR "digital badge" combined with "higher education" OR "VET", filtered for projects with budgets >€2M and completion dates 2020-2025 (yielding 47 initial results), (2) snowball sampling through reference lists and citations in identified project deliverables (identifying 12 additional relevant projects), (3) expert consultation with consortium partners regarding known micro-credential initiatives based on their professional networks and prior project participation (contributing 8 additional projects for consideration). The combined search yielded a total of 67 potential projects for review.

Screening and selection were applied the four criteria systematically. Excluded projects where micro-credentials were a minor component rather than primary focus, projects without publicly accessible final documentation enabling outcome assessment, and projects outside the 2020-2025 timeframe (either too early to reflect current policy context or too recent to have completed implementation phases). Final sample comprised eleven projects representing diverse approaches: university alliance models (EU-CONEXUS, SEA-EU), sectoral skills initiatives (ESSA, ARISA, EUF4HEALTH), technical infrastructure pilots (EBSI), institutional transformation projects (MICROBOL), and comprehensive qualification frameworks (Digital4Business, MicroCredX, TEFCE).

Analysis framework examined each project through standardised dimensions: (1) recognition routes pursued (institutional, consortium, sectoral, national, European), (2) timeline from project initiation to recognition achievement, (3) resource investment including monetary costs and staff

time commitments, (4) design patterns such as stackability architecture, quality assurance approaches, and technical infrastructure choices, (5) outcomes achieved including credentials issued, learners served, employer engagement, and formal recognition status, (6) implementation insights from project documentation regarding challenges encountered, solutions developed, and lessons learned.

This methodology identified three key insights: proven patterns demonstrating effective recognition achievement across multiple projects; realistic expectations grounded in evidence-based timelines and resource requirements rather than aspirational projections; and transferable strategies offering design principles applicable to the Digital4Sustainability context while respecting partner institutional diversity and national regulatory variations. The analysis prioritises learning from effective implementations while acknowledging that different approaches suit different institutional contexts and strategic objectives.

Table 1: EU-Projects that achieved Micro-Credential Recognition

Project	Focus	Recognition Achieved	Route	Track	Key Lesson
EU-CONEXUS	University alliance micro-credentials (1-5 ECTS)	Consortium mutual recognition through partner institutional authority	Consortium/ institutional	Track 1	Institutional anchoring provides immediate legitimacy
SEA-EU	Alliance with degree integration	Consortium recognition across partners	Consortium/ Institutional	Track 1	Partners with degree-awarding authority enable credential issuance
ESSA	Software professional certifications (190 units)	Sectoral/industry via professional bodies	Sectoral	Track 2	Sectoral route viable independent of formal HE
ARISA	AI skills pilot (2 ECTS)	Slovenia national pilot	National	Track 3	Substantial investment required; supportive jurisdiction essential

Analysis of projects that achieved recognition (Table 1) reveals three distinct recognition routes, each demonstrating viability through documented evidence and formal recognition achievement.

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Route 1 - Consortium/Institutional Recognition (EU-CONEXUS, SEA-EU): Leverages partner institutions' existing degree-awarding powers and quality assurance systems for consortium-wide recognition. Partners with formal award authority issue credentials through established internal approval processes; consortium endorsement adds collective validation supporting credential portability. EU-CONEXUS (9 partners, 6 countries) and SEA-EU (6 partners, 5 countries) both achieved consortium-level recognition within project timelines through multilateral agreements.

Route 2 - Sectoral Recognition (ESSA): Professional validation through industry bodies and employer associations operating independent of formal higher education accreditation. ESSA demonstrated sectoral validation viability through systematic employer co-design and professional body engagement for software certifications. D3.3 adapts this approach by applying ESSA's validation mechanisms—employer Declarations of Understanding specifying credential recognition in hiring decisions, professional body endorsement for continuing professional development, and certification quality standards (ISO/IEC 17024)—to Digital4Sustainability's smaller-scale micro-credentials (0.5-15 ECTS). The sectoral route provides immediate workforce credibility particularly suited to professional fields with strong industry associations

Route 3 - National/European Recognition (ARISA): Formal accreditation through national quality assurance agencies in jurisdictions with established micro-credential frameworks. ARISA Slovenia achieved formal accreditation for a 2 ECTS micro-credential through 14-month application process, demonstrating viability but confirming substantial investment requirements. Success factors included Slovenia's established regulatory framework and supportive agency familiarity with short-cycle credentials.

Cost Evidence: Route 3 investment varies substantially by national context and regulatory maturity. Cost and timeline data remain limited as most European micro-credential frameworks are still developing. Estonia, where consortium partner BCS Koolitus operates, represents one jurisdiction with operational procedures; preliminary partner consultation suggests provider accreditation and per-programme registration processes, though specific costs require verification with national authorities. Ireland and Croatia, where consortium partners NCI and Profil Klett operate, have frameworks under development with procedural requirements not yet fully established. Partners considering Track 3 should consult directly with their national quality assurance agencies for current requirements, timelines, and costs, as these vary significantly and continue to evolve.

Critical Design Principle - Stackability: Digital4Business and multiple projects demonstrate that credentials designed as modular building blocks enabling systematic accumulation toward larger qualifications achieve greater value than isolated credentials. Digital4Business: 10 ECTS micro-credentials stack in 10 ECTS increments toward 60-90 ECTS Master's qualifications, receiving European recognition through ASIIN accreditation. D3.3 framework adopts stackability through three-level architecture (Section 3) with explicit accumulation rules.

2.3.2 Recognition Achievement Patterns

Projects achieving recognition (Table 1) share common characteristics: **Institutional anchoring** through accredited institutions with degree-awarding powers providing legitimacy; **quality assurance from inception** aligned with ESG 2015/EQAVET rather than retrofitted; **employer co-design** ensuring workforce relevance and generating recognition statements; **Europass EDCI adoption** supporting credential portability; **realistic timeline planning** accounting for approval processes and regulatory requirements.

2.3.3 Three Recognition Tracks for D3.3 Framework

Based on this evidence, **D3.3 framework specifies three parallel recognition tracks** enabling partners to pursue routes aligned with institutional capacities:

Track 1 (Consortium/Institutional) - This is the recommended route. It focuses on consortium-endorsed credentials issued by the partners with degree-awarding authority, drawing on EU-CONEXUS and SEA-EU models to prioritise immediate credential legitimacy through institutional anchoring.

Track 2 (Sectoral) provides specifications for sectoral validation through industry co-design and employer Declarations of Understanding. Track 2 has been designed following the approach used by ESSA, with timeline and investment estimates based on ESSA's implementation experience. Dual validation combining employer assessment of workforce relevance with educator peer network review of learning design and assessment quality strengthens credential trust, particularly for credentials issued by industry training providers operating outside traditional academic quality assurance systems. Provides workforce credibility independent of formal accreditation. Timeline: 3-6 months. Investment: minimal, absorbed within industry operations.

Track 3 (National/European) focuses on comprehensive documentation specifications enabling post-project accreditation applications in countries with functioning micro-credential frameworks (Estonia, Ireland, Croatia), learning from ARISA experience. It achieves maximum formal recognition but requires substantial investment and extended timelines exceeding project resources. D3.3 enables willing partners through complete documentation packages meeting pilot-country quality assurance agency requirements.

Partners will evaluate track options against their own institutional resources and strategic priorities. Tracks are complementary: Track 1 supports further study and credit transfer, Track 2 provides workforce sectoral credibility, and Track 3 achieves formal qualification status. **D3.3 recommends prioritising Track 1 as the primary route. Track 2 may complement it for sectoral credibility where industry partnerships permit. Track 3 documentation should be prepared to enable post-project pursuit should willing partners secure the necessary resources.**

3. The Digital4Sustainability Certification Framework

3.1 Conceptual Overview and Design Principles

The Digital4Sustainability micro-credentialling framework translates educational profiles from D3.1 into a systematic approach for credential design, quality assurance, and recognition pathways. Informed by EU project lessons, the framework documents three recognition tracks as design options rather than project commitments, ranging from consortium-level recognition achievable at partner discretion to national accreditation requiring substantial post-project investment. D3.3 delivers specifications, not implementation, guided by five core principles:

1. **Institutional anchoring**: All credentials are issued through accredited partner universities, leveraging existing quality assurance systems and degree-awarding powers for immediate legitimacy rather than creating parallel credentialling authorities.

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2. **Qualification pathway integration**: Credentials are designed as stackable components contributing toward recognised certificates, diplomas, or degrees, enabling flexible exit points while maintaining programme-level coherence.
3. **Sectoral relevance**: Maintains clear focus on digital sustainability competencies mapped to documented labour market needs from D2.1, employing industry co-design and employer validation throughout development.
4. **Substantial learning outcomes**: Establishes five ECTS as strategic minimum for credentials seeking formal recognition, providing sufficient scope for rigorous assessment aligned to claimed EQF levels.
5. **Progressive recognition**: Prioritises and supports consortium-level recognition achievable within project duration while simultaneously allowing to prepare for a potential national accreditation process which requires two to four years.

These principles create a framework balancing immediate implementation needs with longer-term recognition aspirations, ensuring credentials maintain quality sufficient for both institutional and eventual national accreditation.

3.2 Credential Typology and Relationships

The framework builds on D3.1's educational architecture comprising five core curricula (60-90 ECTS), six upskilling curricula (0.5-2.5 ECTS), and 51 modular Learning Units:

Educational Architecture Foundation:

Five Core Curricula provide complete qualification pathways at EQF 5-7:

- Sustainability Technical Specialist (STS): 60 ECTS, EQF 5,
- Data Analyst for Sustainability (DAS): 60 ECTS, EQF 6,
- Data Professional for Sustainability (DPS): 90 ECTS, EQF 7,
- Digital Sustainability Consultant (DSC): 90 ECTS, EQF 7,
- Digital Sustainability Manager (DSM): 90 ECTS, EQF 7.

Six Upskilling Curricula (0.5-2.5 ECTS) are specifically designed for targeted professional development and progressive qualification building, conceptually linked to the core curricula to facilitate the incremental credential accumulation.

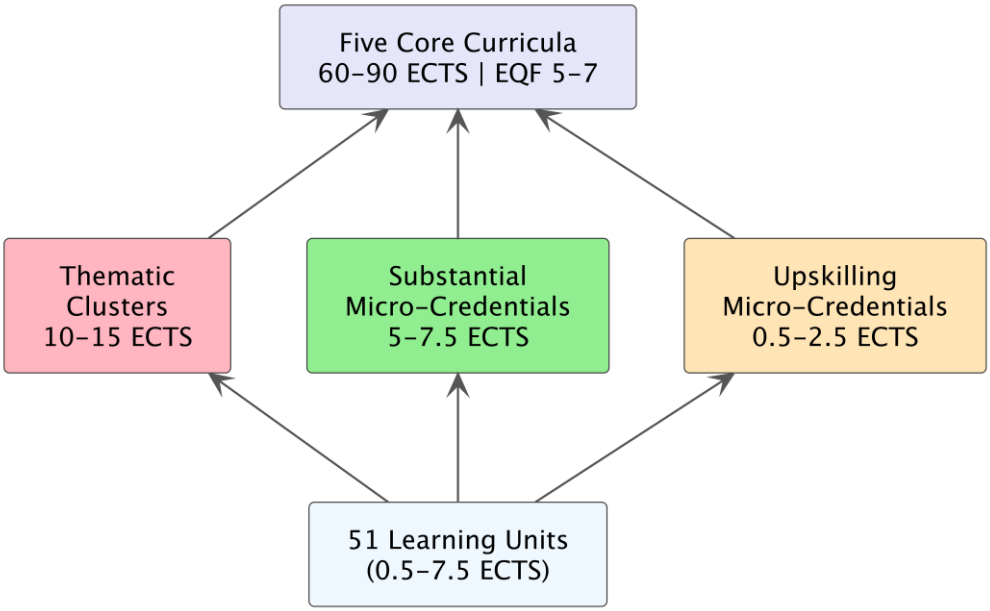

Figure 1: Credential Typology and Stackability

The framework builds on 51 modular Learning Units, which are combined into three types of micro-credentials. *Upskilling* micro-credentials, worth 0.5 to 2.5 ECTS, package individual smaller Learning Units and are designed for accessible professional development. *Substantial* micro-credentials, worth 5 to 7.5 ECTS, are based on individual larger Learning Units; the five-ECTS minimum supports eligibility for formal recognition within National Qualifications Frameworks. *Thematic* micro-credential clusters, typically spanning 10 to 15 ECTS, combine multiple related Learning Units into a single integrated credential with cross-unit assessment. An example is a sustainability reporting cluster combining Learning Units on Sustainability Reporting and Dashboards (LU39), ESG Data Management and Quality Assurance (LU41), and Reporting Directive Compliance (CSRD) (LU44), as detailed in Annex H.

All three micro-credential types can be accumulated through Recognition of Prior Learning and stack towards the five core curricula, which range from 60 to 90 ECTS at EQF levels 5 to 7. This structure enables progressive qualification building from accessible entry points through to complete degree-level awards.

The framework enables progressive qualification building through stackable credentials. Learners can begin with accessible upskilling micro-credentials (0.5-2.5 ECTS), progress to substantial micro-credentials or thematic clusters (5-15 ECTS), and accumulate credits toward complete qualifications (60-90 ECTS) in five core curricula: Sustainability Technical Specialist (STS), Data Analyst for Sustainability (DAS), Data Professional for Sustainability (DPS), Digital Sustainability

Consultant (DSC), and Digital Sustainability Manager (DSM). All micro-credential achievements receive recognition of prior learning credit through partner university policies.

Micro-Credential Categories:

Upskilling Micro-Credentials (0.5-2.5 ECTS) correspond to the six upskilling curricula designed for continuing professional development and accessible entry points. These target practicing professionals requiring focused competence development without pursuing full qualifications. Examples include LU01 Digital Sustainability Foundations (0.5 ECTS), LU38 Green ICT Principles (1.0 ECTS), and LU12 Energy-Efficient Software Architecture (1.0 ECTS). These position primarily for institutional and sectoral recognition, with documentation for national accreditation remaining optional to maintain implementation flexibility.

Substantial Micro-Credentials (5-7.5 ECTS) represent individual Learning Units with sufficient scope for rigorous EQF-aligned assessment and formal recognition. Examples include LU02 Sustainability Data Foundations (5.0 ECTS), LU04 Data Analytics for Sustainability Insights (5.0 ECTS), LU11 Advanced Sustainability Data Science (5.0 ECTS), and LU34 Work-Based Sustainability Project (7.0-7.5 ECTS). Each undergoes full institutional quality assurance and produces EDCI-compliant digital credentials positioning for formal national recognition.

Thematic Micro-Credential Clusters (10-15 ECTS) combine related Learning Units addressing coherent competence domains. Examples include sustainability reporting pathways (LU39 + LU44 + LU41 totalling approximately 10 ECTS) or sustainable software engineering sequences (LU05 + LU12 + LU32 totalling approximately 7.5 ECTS). Clusters require integrated assessment demonstrating cross-LU competence application and produce unified credentials suitable for formal recognition.

Stackability Architecture All micro-credentials explicitly specify their position within the five core curricula pathways, enabling progressive qualification building as emphasised in the EU Council Recommendation. Learners can:

- Begin with *upskilling micro-credentials* (0.5-2.5 ECTS) for accessible entry,
- Progress to *substantial micro-credentials* (5-7.5 ECTS) building competence depth,
- Accumulate thematic clusters (10-15 ECTS) for domain expertise,
- Stack credentials toward complete qualifications (60-90 ECTS).

Recognition of prior learning provisions enable all micro-credential achievements to receive credit toward full core curricula through partner university policies. This progressive architecture supports lifelong learning through flexible entry, exit, and re-entry points while maintaining clear pathways to recognised qualifications.

Credential Nomenclature: To maintain clarity, micro-credentials reference their source Learning Units (e.g., "Micro-Credential: Sustainability Data Foundations [LU02]") and specify their relationship to core curricula (e.g., "Component of DAS, DPS, DSM pathways"), enabling learners and employers to understand both standalone value and qualification progression context.

3.2.1 Learner Pathways and Stackability Architecture

The Digital4Sustainability certification framework operationalises D3.1's modular curriculum through two complementary pathways: targeted upskilling for rapid workforce transformation and structured qualifications for comprehensive role preparation (Figure 2).

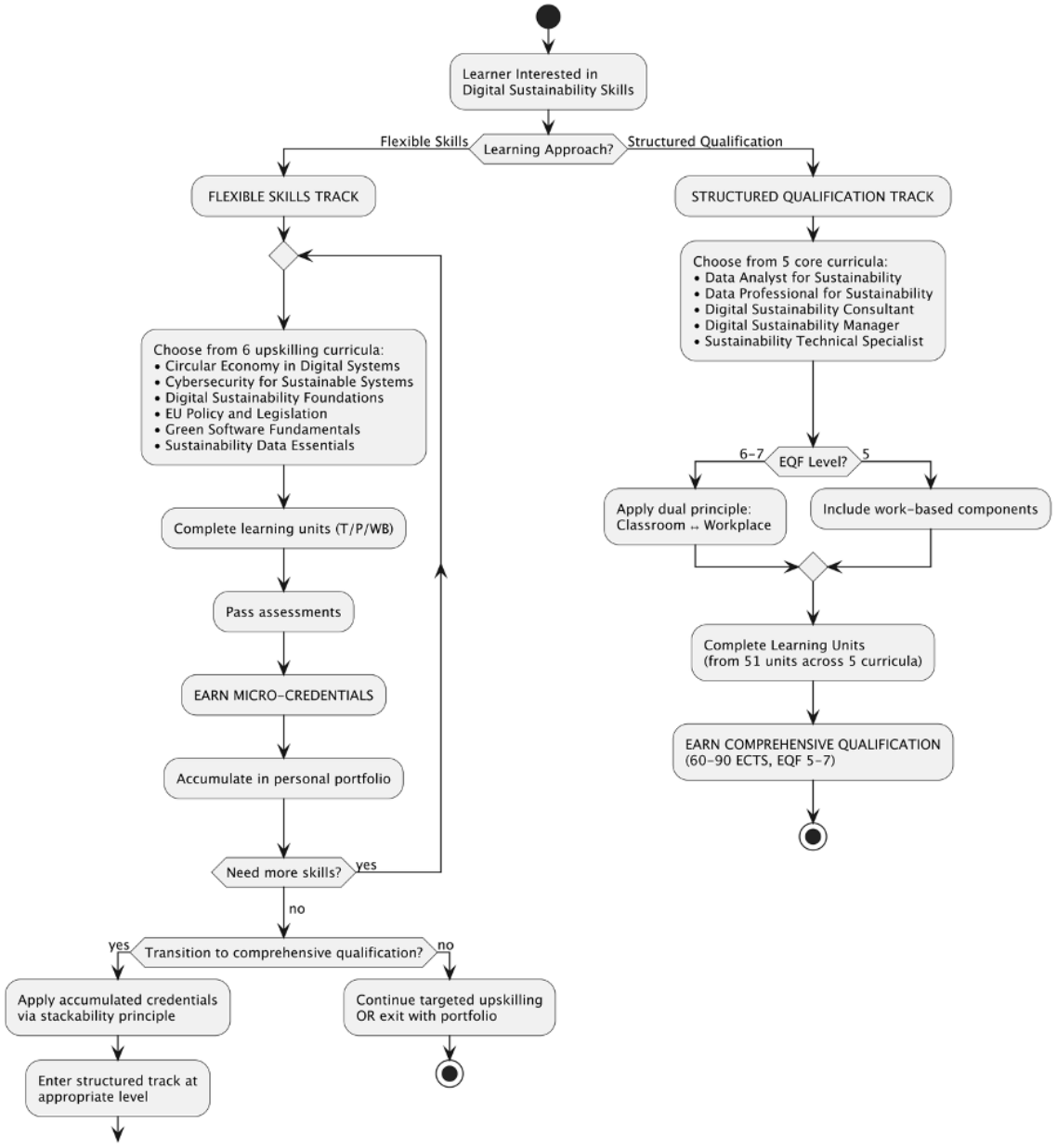

Figure 2: Digital4Sustainability Certification Framework: Learner Pathways and Stackability Architecture

3.2.1.1 Flexible Skills Track

The Flexible Skills Track serves working professionals, SME owners, job seekers, and career explorers requiring targeted competence development without commitment to comprehensive qualifications. Learners select from six upskilling curricula: Circular Economy in Digital Systems, Cybersecurity for Sustainable Systems, Digital Sustainability Foundations, EU Policy and Legislation, Green Software Fundamentals, and Sustainability Data Essentials. Each incorporates theoretical, practical, and work-based learning components designed for immediate workplace application.

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Upon successful assessment completion, learners earn micro-credentials (0.5-2.5 ECTS) that accumulate in Europass-compliant digital portfolios. Professionals build competence portfolios matched to immediate workforce needs, acquiring additional credentials as career requirements evolve. When accumulated credentials address sufficient learning outcomes, learners may transition to the Structured Qualification Track via Recognition of Prior Learning (RPL), receiving credit for completed units and entering at the appropriate level to complete remaining requirements.

3.2.1.2 Structured Qualification Track

The Structured Qualification Track serves initial students, career developers, and recent graduates pursuing comprehensive professional preparation for defined digital sustainability roles. Learners select from five core curricula aligned with target roles: Data Analyst for Sustainability (60 ECTS, EQF 6), Data Professional for Sustainability (90 ECTS, EQF 7), Digital Sustainability Consultant (90 ECTS, EQF 7), Digital Sustainability Manager (90 ECTS, EQF 7), and Sustainability Technical Specialist (60 ECTS, EQF 5). Each curriculum maps directly to educational profiles established in D3.1.

Curricula at EQF Levels 6-7 apply a dual principle (systematic alternation between classroom instruction and workplace experience) ensuring theoretical knowledge integrates with practical application. EQF Level 5 curricula incorporate substantial work-based components while maintaining accessibility for learners transitioning from secondary education or vocational backgrounds. Learners complete required Learning Units drawn from the framework's 51-unit portfolio, progressing systematically through competence domains. Successful completion leads to comprehensive qualifications (60-90 ECTS, EQF 5-7) positioned for national and European recognition.

3.2.1.3 Three-Level Stackability Architecture

The framework implements three credential levels functioning as progressive building blocks:

Level 1 - Micro-credentials: Awards from six upskilling curricula (0.5-2.5 ECTS) document specific competence achievements, stacking toward Level 2 when addressing learning outcomes within larger Learning Units.

Level 2 - Learning Units: The 51 Learning Units (0.5-7.5 ECTS) distributed across five core curricula represent substantial competence packages combining to form complete qualification pathways.

Level 3 - Comprehensive Qualifications: Complete curricula (60-90 ECTS, EQF 5-7) represent full professional qualifications positioned for national and European recognition.

Quality assurance mechanisms ensure stackability maintains programme coherence through systematic mapping of prior learning to curriculum specifications, preventing credential accumulation from fragmenting learning outcomes while enabling flexible progression.

3.2.1.4 Pathway Integration and Transitions

Bidirectional transitions enable professionals to begin with upskilling micro-credentials before transitioning to qualification pursuit as career ambitions evolve, while structured track learners encountering career pivots may leverage completed Learning Units toward alternative pathways through RPL. This integrated design responds to labour market realities where twin transition demands require both immediate capability enhancement and systematic professional development. It accommodates learners from varied educational backgrounds, including secondary education, vocational training, career changes, and professional upskilling. At the same time, it maintains credential quality and recognition potential.

3.3 Micro-Credential Design Methodology

The framework employs a systematic methodology for assembling Learning Units into credentialed offerings, ensuring consistency, quality, and alignment with recognition requirements. With individual specifications of Learning Units (LU) established in D3.1, this methodology addresses micro-credential packaging, documentation enhancement, and quality assurance integration. For a list of all learning units see Table H1 in Annex H.

Micro-Credential Assembly begins by selecting appropriate LUs based on learner needs, competence coherence, and qualification pathway positioning. Standalone LU micro-credentials (5-7.5 ECTS) adopt existing LU specifications directly, while thematic clusters combine multiple LUs requiring integration analysis to ensure:

- Competence progression logic across combined LUs,
- Consistent EQF level alignment or appropriate scaffolding,
- Cumulative ECTS allocation reflecting total learning effort,
- Assessment strategy spanning component LUs.

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Learning Outcome Integration for clustered micro-credentials synthesises component LU outcomes into cohesive credential-level statements. This synthesis maintains constructive alignment while articulating the integrated competence achievement that justifies clustering. For example, combining LU39 (Sustainability Reporting), LU44 (CSRD), and LU41 (ESG Data Management) produces integrated outcomes addressing comprehensive reporting capability rather than discrete skills.

Assessment Enhancement builds on LU-level assessment specifications by adding credential-level validation demonstrating integrated competence application. Standalone LU micro-credentials typically adopt existing LU assessment directly, enhanced with explicit credential verification procedures and institutional quality assurance oversight. Clustered micro-credentials require additional summative assessment evaluating competence across learning units through capstone tasks, comprehensive case studies, or portfolio assessments spanning the credential scope.

Recognition Documentation extends beyond LU specifications to produce comprehensive packages supporting formal recognition processes:

- **Standard Elements**: All micro-credentials include EU Council Recommendation metadata (identification, learning outcomes, assessment, ECTS, EQF, quality assurance, issuer details),
- **EDCI Compliance**: Machine-readable credential structures enabling Europass digital credential issuance,
- **National Accreditation Materials**: For primary micro-credentials seeking formal recognition, comprehensive documentation includes detailed syllabi integrating component LUs, assessment exemplars and rubrics, quality assurance procedures, stakeholder consultation evidence, and labour market relevance justification.

Quality Assurance Integration ensures micro-credentials undergo institutional approval equivalent to conventional programme components. Partner institutions review proposed credentials through established academic committees, evaluating competency grounding, EQF alignment, assessment validity, ECTS justification, and programme portfolio integration. Approved micro-credentials receive institutional codes, appear in student information systems, and generate official transcripts upon completion.

Versioning and Maintenance procedures govern micro-credential evolution as learning units update or labour market needs shift. Minor refinements proceed through streamlined processes while substantial modifications require full institutional review. All credentials maintain version documentation showing modification history and rationale.

3.4 Job Role and Competence Mapping

The framework establishes explicit linkages between micro-credentials, professional job roles, and competence frameworks to ensure labour market relevance and support learner decision-making and employer interpretation.

Role Mapping Foundation derives from the D2.1 needs analysis, with D3.1 identifying five priority educational profiles for development:

- **Sustainability Technical Specialist (STS)** – advanced certificate level, 60 ECTS, intermediate professional competence
- **Data Analyst for Sustainability (DAS)** – bachelor's level, 60 ECTS, intermediate to advanced professional competence
- **Data Professional for Sustainability (DPS**) – master's level, 90 ECTS, advanced to expert professional competence
- **Digital Sustainability Consultant (DSC)** – master's level, 90 ECTS, advanced to expert professional competence
- **Digital Sustainability Manager (DSM)** – master's level, 90 ECTS, advanced to expert professional competence

Each micro-credential maps to one or more roles, specifying whether it provides:

- Foundational preparation for role entry,
- Core competence for role performance,
- Advanced specialisation for experienced practitioners,
- Cross-role mobility enabling career transitions.

Competence Framework Alignment employs three primary reference frameworks:

e-Competence Framework (e-CF) provides the foundation for digital competence mapping. Each credential specifies which e-CF competencies at defined proficiency levels (e-1 to e-5) learners will develop. For example, LU11 Advanced Sustainability Data Science maps to D.10 Information and Knowledge Management at the e-4 level, while LU03 Data Collection and Quality maps to D.10 at the e-3 level.

GreenComp Framework addresses sustainability competences across four areas (embodying, envisioning, acting, enabling) with progressive proficiency levels. Credentials integrate digital and sustainability competences through dual mappings reflecting interdisciplinary role requirements.

Domain-Specific Competences supplement e-CF and GreenComp for specialised areas including ESG reporting (CSRD, SFDR, Taxonomy), LCA methodologies, carbon footprint analysis, circular economy principles, and green software engineering. These mappings maintain parallel structure with proficiency levels and performance indicators.

Credential-Role-Competence Documentation for each micro-credential specifies:

- Primary target role(s) and typical job titles,
- Complete e-CF competence mapping with proficiency levels,
- GreenComp competence alignment with progression levels,
- Domain-specific competence coverage where applicable,
- Career pathway positioning showing progression routes.

Multi-Stakeholder Utility: These mappings enable credential designers to ensure validated competence grounding, learners to make informed decisions about career relevance, employers to understand credential holder capabilities through standardised frameworks, quality assurance bodies to evaluate competence validity, and recognition agencies to compare credentials across institutions and countries using common reference frameworks.

The complete role-competence mapping matrices appear in Annex D, providing transparent technical specification for all competence claims and supporting both implementation consistency and stakeholder interpretation.

3.5 Digital Credential Infrastructure

Effective digital infrastructure underpins credential issuance, verification, and portability. The framework specifies technical requirements that support learner mobility, employer verification, and cross-border recognition while adhering to European standards and maintaining institutional control.

Technical Standard Adoption: The infrastructure adopts Europass Digital Credentials Infrastructure (EDCI) as the primary technical standard, following the European Digital Credentials for Learning specification. EDCI provides XML-based data structures encoding credential information including learner identity, credential details, learning outcomes achieved, issuing institution, and verification mechanisms. These structures enable machine-readable credential processing while maintaining a human-readable presentation through XSLT transformation. All

credentials issued through partner institutions generate EDCI-compliant digital credentials alongside traditional certification.

Advantages of XML-Based Data Structures: XML-based data structures provide a standard, platform-independent format for encoding credential information, enabling interoperability across institutions and verification systems. They support machine-readability for automated validation, data exchange, and integration with learning management and digital identity platforms, while remaining human-readable. This strengthens the portability, transparency, and reliability of micro-credential recognition in European higher education and professional contexts. From a security perspective, XML data structures should be processed with robust parsers and transmitted over secure channels (for example, HTTPS) to reduce the risk of injection or parsing attacks.

Institutional Integration (Framework Specification for Future Implementation): Should partners pursue credential issuance post-project, credential processes would integrate with existing student information systems and credential management infrastructure rather than creating parallel systems. This approach would reduce complexity, leverage institutional investment in established systems, and ensure digital credentials benefit from institutional quality assurance and record-keeping procedures. The framework provides technical specifications—EDCI-compliant metadata structures, transformation templates, and reference implementations—enabling partners to implement credential generation as additional output from existing certification workflows should they choose to do so. Implementation would typically require 3-6 months from partner commitment to operational deployment. D3.3 delivers specifications; actual implementation remains at partner institutional discretion post-project.

Verification Mechanisms: Verification infrastructure enables employers, educational institutions, and stakeholders to validate credential authenticity and issuer legitimacy. The framework employs cryptographic digital signatures applied by issuing institutions to credential data structures, enabling verification that credentials remain unaltered since issuance and confirming issuer identity. Credentials are digitally signed by the issuing institution using cryptographic mechanisms, allowing verifiers to confirm that the credential data has not been altered since issuance and to authenticate the issuer's identity. This decentralised verification approach

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maintains learner control over credential sharing while enabling robust authentication. Verification requires no centralised databases or blockchain networks—the digitally signed credential contains all information needed for validation through Public Key Infrastructure (PKI). The framework specifies verification mechanisms using cryptographic digital signatures, enabling credential authentication without centralised databases. Technical specifications and integration guidance support partners who choose to implement verification systems post-project.

Learner Portability: Learners collect, manage, and share digital credentials through **Europass platform integration where** they can store credentials, build portfolios, and selectively share with prospective employers or educational institutions. This integration leverages existing European infrastructure rather than requiring custom wallet development, reducing costs and ensuring sustainability. Partner institutions provide learners with EDCI credential files uploadable to Europass or other EDCI-compatible wallet systems, maintaining learner ownership and control. The framework monitors ongoing European digital identity developments, including the European Digital Identity framework, committing to future integration while maintaining current functionality through established EDCI standards.

Design Principles: Technical infrastructure explicitly subordinates to institutional recognition and quality assurance, reflecting lessons regarding technology-first failures analysed in Section 2.3. Digital credential issuance depends on prior institutional certification following quality assurance procedures, with technical infrastructure supporting but not replacing institutional credentialling authority. Verification confirms issuer identity. But cannot substitute for stakeholder assessment of credential value, which depends on institutional reputation, quality assurance rigor, and labour market recognition. The framework positions technical infrastructure as enabling technology for credential portability and verification rather than as source of credential legitimacy, ensuring institutional anchoring remains the primary foundation for credential value.

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3.6 Consortium Partner Landscape

The Digital4Sustainability consortium comprises 15 institutions actively engaged in micro-credential development across 10 European countries. A Task 3.4 survey assessed institutional readiness for EU-recognised credential issuance.

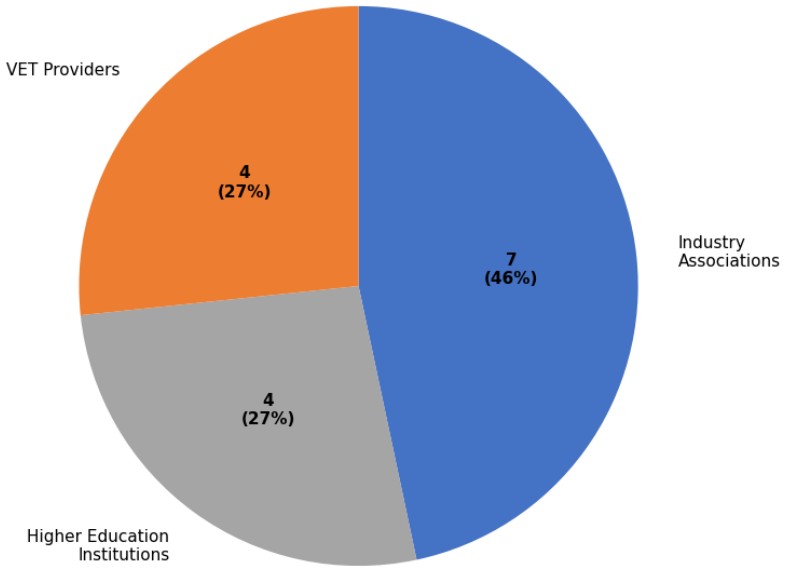

Figure 3: Consortium Composition

Geographic Distribution

Partners are in Bulgaria, Croatia, Estonia, Germany, Hungary, Ireland, Italy, Romania, Slovenia, and Spain. Country representation varies from one to three partner, with Ireland (3), Italy (2), Romania (2), and Spain (2) having multiple institutional perspectives.

Award Authority

Seven institutions (46%) have general degree- or diploma-awarding authority (depending on their nature) under their respective national frameworks. This authority indicates institutional capacity but does not imply a commitment to issue micro-credentials within the Digital4Sustainability framework. The decision to issue micro-credentials remains entirely at partners' discretion, as it depends on internal strategic decisions and processes.:

- BCS Koolitus (Estonia) — National VET authority,
- NCI (Ireland) — Via QQI validation,

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- CEFRIEL (Italy) — Via Politecnico di Milano,
- CPU Slovenia — NVQ programmes,
- Profil Klett (Croatia) — Non-formal certificates,
- UAH and UNIR (Spain) — University degrees,
- UPB (Romania) — University degrees.

The remaining eight partners (53%) are industry associations that can issue attendance certificates but not formally recognised qualifications. These partners are optimally positioned for Track 2 (sectoral recognition).

This authority indicates institutional capacity but does not imply a commitment to issue micro-credentials within the Digital4Sustainability framework. The decision to issue micro-credentials remains entirely at partners' discretion, as it depends on internal strategic decisions and processes.

This distribution positions partners for different recognition approaches post-project: HE and VET institutions with award authority can pursue Track 1 (consortium/institutional credentials at partner discretion, feasible during or post-project with modest investment), while industry associations anchor Track 2 (sectoral endorsements, minimal investment). Track 3 (national/European recognition) requires substantial resources beyond project scope; three partners in established-framework countries (Estonia, Ireland, Croatia) are positioned for future pursuit.

4. Quality Assurance and Continuous Improvement

4.1 Quality Assurance Framework

The framework specifies multi-level quality assurance procedures designed to ensure credentials maintain rigor, relevance, and recognition value when partners implement the system. Procedures align with ESG 2015 and EQAVET standards while respecting institutional autonomy for implementation decisions. Quality assurance operates at two organisational levels: consortium coordination and institutional implementation.

Consortium Coordination (applicable if partners establish coordination mechanisms):

Partners collaborating maintain framework specifications and coordinate quality assurance across institutions when pursuing mutual recognition:

Framework-Specification Maintenance (applicable if partners establish consortium coordination):

Governance structures maintain credential specifications, review stackability rules, update competence mappings as e-CF and GreenComp evolve, and coordinate recognition strategy. Annual reviews assess whether aggregation level definitions remain appropriate, ECTS credit allocations reflect actual learning workload, EQF level assignments maintain consistency, and stackability rules enable effective pathway operation. Stakeholder consultation ensures framework evolution responds to labour market developments, employer feedback, professional body input, and quality assurance agency guidance.

Quality Coordination Across Partners

Partners pursuing consortium recognition agreements conduct cross-institutional moderation exercises, exchanging assessment samples for independent grading. External examiner networks include practitioners who validate workplace relevance. Consortium benchmarking enables partners to compare implementation approaches and learner outcomes, while standards calibration ensures consistent interpretation of EQF levels and competence requirements across institutions.

Institutional Implementation (partner responsibility)

Each partner institution applies its existing quality assurance systems to credential delivery. Academic governance processes oversee programme approval and ongoing monitoring, while delivery quality is assured through teaching observation, learner feedback, assessment moderation, and performance monitoring. Academic staff delivering credentials require training in competence-based pedagogy and assessment design.

To support potential national accreditation applications, institutions compile comprehensive documentation packages. These bring together quality assurance policies demonstrating ESG alignment, credential-specific materials such as syllabi, assessment specifications, moderation reports, and external examiner feedback, alongside institutional evidence of degree-awarding authority, quality assurance accreditation, and regulatory compliance.

4.2 Assessment and Validation Integrity

Assessment integrity ensures credentials maintain rigorous, authentic evaluation regardless of delivery mode.

Design Requirements: All assessments demonstrate constructive alignment with learning outcomes, employ methods appropriate for claimed EQF levels, and provide reliable achievement differentiation. EQF 6+ credentials must evaluate application, analysis, and autonomous performance in complex contexts through authentic work-based tasks, case analysis, portfolios, or performance assessment.

Authentication Procedures: All credentials incorporate proctored or supervised assessment components verifying learner identity and work authenticity. Online implementations employ technology-enabled proctoring, identity verification, or secure assessment environments. Work-based projects require plagiarism detection, supervisor verification, or viva voce examination validating authentic achievement. Assessment and authentication processes are documented, auditable, and scalable to accommodate cohort size while maintaining reliability and fairness.

Moderation and Standardisation: Assessment rubrics specify performance expectations at different achievement levels. Institutions implement second marking, cross-institutional blind marking, or external examiner review. The consortium coordinates standardisation activities comparing exemplars and calibrating judgment regarding satisfactory performance at specified EQF levels.

Feedback Mechanisms: Learners receive timely, constructive feedback relating explicitly to learning outcomes and assessment criteria. Institutions provide formative exercises, exemplar review, and assessment requirement clarification supporting learner success.

4.3 Assessment Requirements

Assessment specifications ensure valid, reliable, and fair evaluation of learning outcomes when partners implement credentials. Specifications address assessment design, authentication, and quality assurance.

Assessment Design Requirements: Assessments must:

- Demonstrate constructive alignment (assessment tasks directly measure specified learning outcomes through appropriate cognitive demand levels);
- Provide reliable achievement differentiation (rubrics specify performance expectations at pass, merit, distinction levels using criterion-referenced standards);
- Enable autonomous performance assessment (EQF 5-7 credentials require demonstrating independent capability in complex contexts, assessed through authentic tasks);
- Incorporate authentic workplace contexts (work-based components validated through employer supervisor participation).

Authentication Procedures: Partners implementing credentials should adopt authentication approaches appropriate to delivery mode and EQF level:

- Proctored assessments for online/blended delivery (technology-enabled invigilation or in-person supervision);
- Plagiarism detection for written submissions (similarity checking software with human review);
- Viva voce examinations for validating authorship and understanding (oral defence of project work or portfolio);
- Employer verification for work-based assessments (supervisor authentication of performance).

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Additional authentication methods such as viva voce examinations or employer verification may be employed at institutional discretion depending on credential type and delivery context.

Moderation Procedures: Partners implementing credentials should employ moderation approaches ensuring standards consistency:

- Second marking for summative assessments (independent review of graded work);
- Cross-institutional blind marking if pursuing consortium recognition (external partner reviews sample without knowing origin institution);
- External examiner review for programme certificates and qualifications (independent practitioner or academic validates standards).

4.4 Continuous Improvement

The framework establishes continuous improvement mechanisms operating at two levels: during-project refinement based on WP4 training piloting, and post-project evolution for partners implementing credentials. During-Project Framework Refinement (WP4 Evidence) WP4 training programmes (700 learners) generate evidence informing framework refinement without requiring credential issuance:

Feedback Collection: Learner feedback on curriculum relevance, assessment appropriateness, and workload calibration; employer perspectives on competence demonstration and graduate capability; trainer experience with delivery modes and assessment administration; completion rates and achievement distributions.

Framework Updates: WP4 evidence informs refinements to credential specifications, assessment rubrics, ECTS allocations, and EQF level justifications. Updates proceed through consortium review with version control.

Feedback Channels: Learner evaluations and surveys of the pilots; employer feedback on graduate capability; academic staff teaching reviews; quality assurance agency feedback if pursuing Track 3 recognition.

Credential Refinement: Minor refinements (assessment rubric clarity, resource updates) through streamlined processes. Major refinements (learning outcome modifications, ECTS changes, EQF revision) require institutional quality assurance review. Version documentation maintains change rationale.

Recognition Pathway Tracking: Partners pursuing Track 3 would monitor national developments, documenting application processes, agency feedback, and approval timelines. Track developments in national legislation identifying expanded recognition opportunities. D3.3 delivers improvement methodology; actual implementation depends on partner institutional commitment post-project.

5. Recognition and Alignment Strategy

5.1 Recognition Strategy

Recognition for micro-credentials operates through several interconnected mechanisms, each requiring different resources and timelines. Institutional and consortium recognition leverage existing university degree-awarding powers and internal quality assurance processes, achievable within months through established governance structures. Sectoral recognition through professional bodies and employer associations provides labour market validation on similar timescales.

Framework Documentation (Deliverable 3.3):

- Track 1 credential specifications and quality assurance standards;
- Track 2 Declaration of Understanding template;
- Track 3 requirements documentation for established-framework countries;
- Partner readiness assessment and track mapping;
- Technical specifications for EDCI-compliant digital credentials;
- WP4 training programme specifications (piloted without credentialling).

Key Principle:

D3.3 delivers comprehensive specifications. Implementation remains at partner institutional discretion based on capacity and priorities.

5.1.1 Implementation Focus

Track 1 provides credential value achievable at partner institutional discretion. Partners may implement during or post-project depending on resources. Track 2 complements Track 1 through industry validation. Track 3 remains available for future pursuit should post-project funding or institutional resources permit. This prioritisation ensures Digital4Sustainability delivers recognised credentials within project scope while documenting pathways for expanded recognition.

5.2 Partner Readiness and Track Mapping

Partner readiness assessment (detailed methodology Annex C) evaluated consortium partner capacity for implementing framework specifications across three recognition tracks. Assessment conducted M22-M24 identified implementation pathways matched to partner strengths and positioned willing partners for post-project credential adoption.

Track 1 Positioning: Seven partners possess degree-awarding authority enabling Track 1 institutional/consortium credential issuance: National College of Ireland, Profil Klett (pursuing formal authority), Universidad de Alcalá, Universidad Internacional de La Rioja, CPU Slovenia, BCS Koolitus, and Stichting Hogeschool Utrecht. These partners can implement Track 1 credentials during project or post-project at institutional discretion dependent on internal approval processes and resource allocation decisions. Implementation requires 2-4 months staff time plus €5,000-15,000 technical infrastructure investment per partner capacity assessments.

Track 2 Positioning: All partners contribute to Track 2 sectoral validation through industry connections. Three partners (BASSCOM, Cefriel, European DIGITAL SME Alliance) focus primarily on Track 2 due to industry association status providing direct employer/professional body access. Seven partners with award authority complement Track 1 implementation with Track 2 sectoral partnerships. Track 2 implementation achievable within project timeline (M33-M42) through employer Declarations of Understanding and professional body recognition agreements.

Track 3 Positioning: Six partners achieved readiness scores ≥5.0 positioning them for Track 3 national accreditation pursuit post-project if institutional resources allocated: BCS Koolitus (7.0 - Estonia established framework), Profil Klett (6.1 - Croatia developing framework), National College of Ireland (6.25 - Ireland developing framework), CPU Slovenia (5.0 - Slovenia emerging framework). Track 3 pursuit requires substantial investment (€1,450-5,000 initial costs + 100-200 hours documentation per national context) and extended timelines (12-18+ months from application) exceeding current project resources. D3.3 prepares comprehensive documentation packages enabling post-project applications by partners choosing Track 3 pursuit.

All partners will contribute through at least one track: Track 1 credential issuance (7 partners with authority), Track 1 partnerships supporting implementing partners (3 partners providing curriculum expertise/industry validation), or Track 2 sectoral validation (10 partners through employer/professional body connections). This inclusive track mapping ensures all partners participate meaningfully while recognising differential implementation capacities.

5.3 Legal and Ethical Considerations

Credential issuance must comply with GDPR requirements for learner data protection, particularly when implementing Europass Digital Credentials. Intellectual property rights for learning materials and assessment resources remain with developing institutions unless otherwise specified in consortium agreements. Recognition portability limitations must be clearly communicated to learners: Track 1 credentials carry institutional authority but not formal national

recognition; Track 2 provides sectoral validation; Track 3 would provide NQF/EQF portability if pursued post-project.

6. Implementation Readiness Roadmap

6.1 Progression Phases

The work on micro-credentials illustrated in Fig. 4 unfolds through four sequential phases from specification to sustainability.

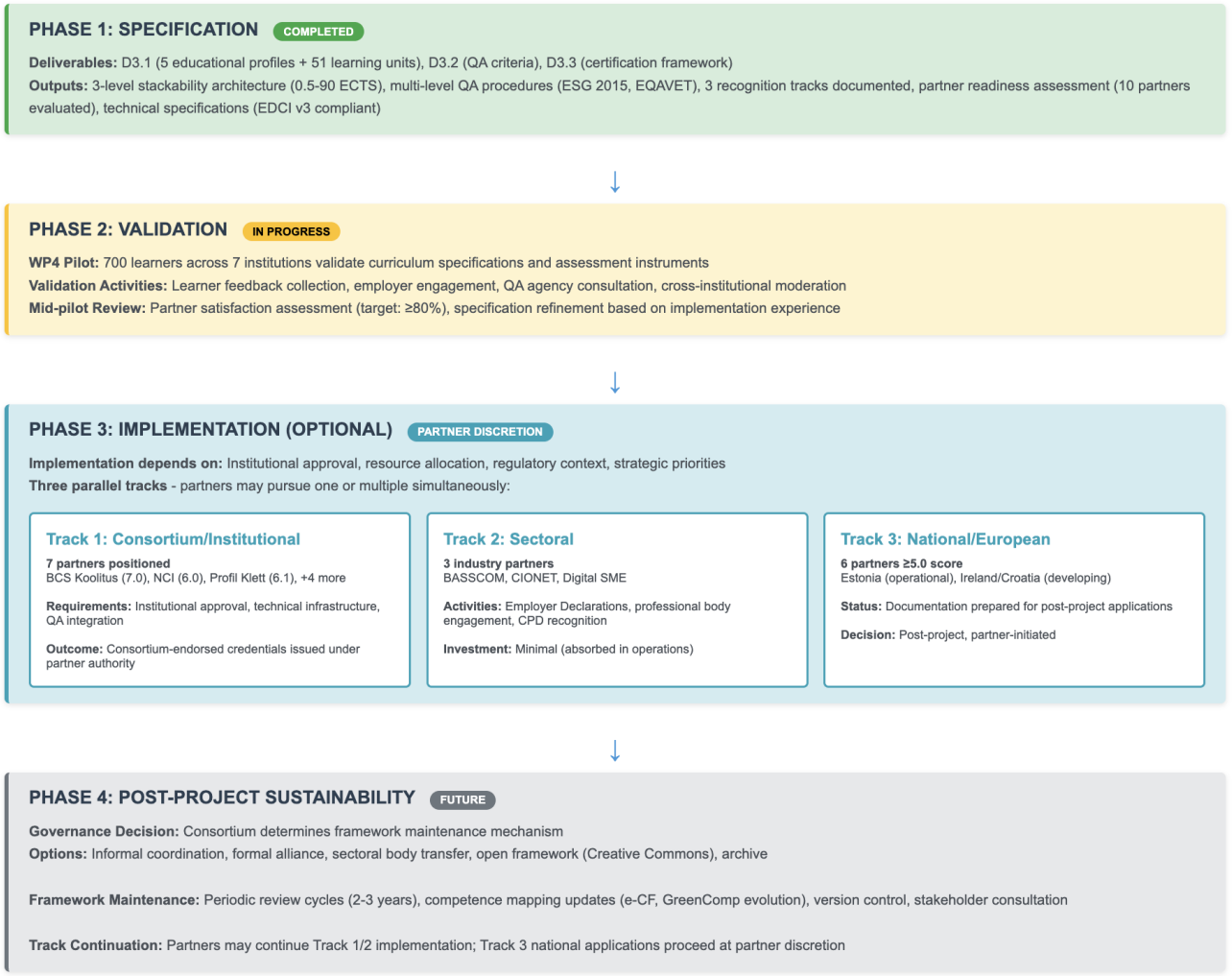


Figure 4. Micro-credential certification framework: four-phase implementation roadmap

Phase 1 (Completed) established the framework foundation: D3.1 educational profiles with 51 learning units, D3.2 quality assurance criteria, and D3.3 certification specifications including 3-level stackability architecture (0.5–90 ECTS), multi-level QA procedures aligned with ESG 2015 and EQAVET, and three documented recognition tracks.

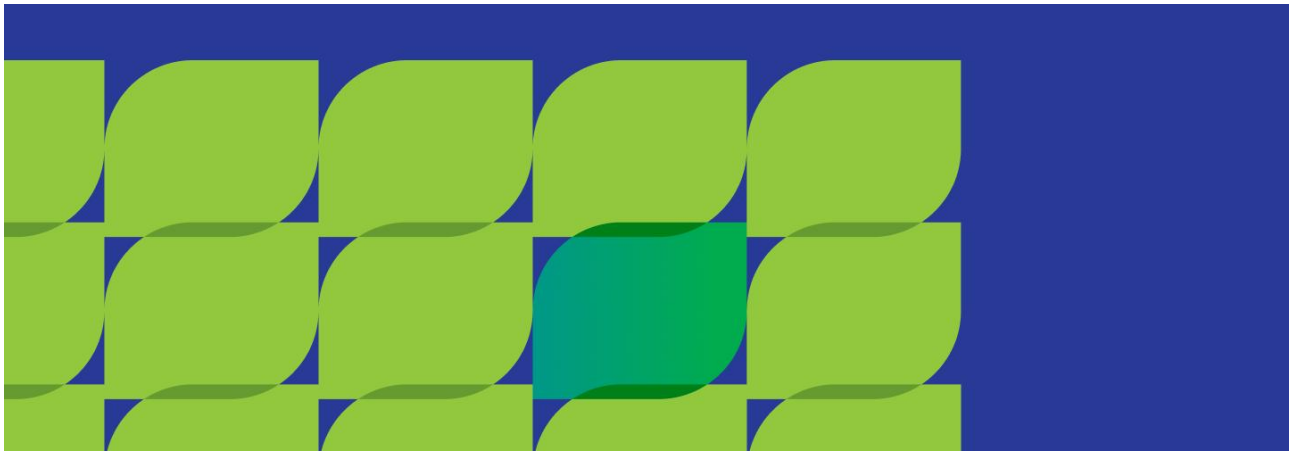
Phase 2 (In Progress) validates specifications through WP4 pilots engaging 700 learners across 7 institutions. The mid-pilot review assesses partner satisfaction (target ≥80%) and enables evidence-based refinement before Phase 3.

Phase 3 (Optional) offers three parallel implementation tracks at partner discretion: Track 1 (Consortium/Institutional) for the 6 positioned partners to issue consortium-endorsed credentials; Track 2 (Sectoral) for industry partners (BASSCOM, Digital SME) pursuing employer declarations and CPD recognition; Track 3 (National/European) for partners with readiness scores ≥5.0 to pursue formal accreditation post-project.

Phase 4 (Future) addresses post-project sustainability through a governance decision selecting among informal coordination, formal alliance, sectoral body transfer, open framework publication, or archive. Framework maintenance includes periodic review cycles (2–3 years) and competence mapping updates as e-CF and GreenComp evolve.

6.2 Critical Considerations

Phase 1 completion means D3.3 delivers implementation-ready specifications. Phase 2 generates empirical validation evidence. Phase 3's optional status preserves partner autonomy—D3.3 enables but does not mandate credential issuance. Phase 4 planning reflects realistic post-funding maintenance capacity. All timelines require institutional verification. Partners considering Track 3 should consult quality assurance agencies directly.



7. Risk and Mitigation Analysis

7.1 Key Risks

Recognition and Accreditation Risks directly impact T3.4's objective to "achieve recognition of the new certifications at national level first and then at European level." National agencies may reject applications due to documentation gaps or framework misalignment with established micro-credential regulations. Recognition timelines may extend substantially beyond project duration. Consortium recognition may not achieve anticipated portability if partners apply divergent quality standards. Sectoral recognition may prove insufficient if employers prioritise conventional qualifications over micro-credentials. European recognition may remain unattainable if agencies require programme-level accreditation rather than standalone credential recognition.

Market Relevance and Adaptability Risks result from rapid evolution in digital and sustainability sectors and threaten framework relevance if competence specifications become misaligned with workforce needs during extended development and implementation timelines. The digital sector experiences particularly rapid technology change, emerging tool ecosystems, and shifting professional role requirements that may outpace framework update cycles. Comprehensive qualifications requiring 60-90 ECTS completion over 2-3 years face heightened obsolescence risk as competences specified during framework design may lose currency by credential completion. Micro-credentials with shorter completion timelines (0.5-15 ECTS achievable within weeks or months) demonstrate greater market responsiveness but require systematic monitoring ensuring specifications track industry evolution. Restricted implementation through academic partners only amplifies obsolescence risk as institutional approval processes, academic calendar constraints, and curriculum development cycles introduce additional delays between competence identification and learner access. Non-academic partners including professional training providers, industry associations, and employer-led learning programmes typically demonstrate greater agility adapting to workforce requirement changes through shorter approval cycles, continuous intake models, and closer employer relationships enabling rapid specification updates.

Quality and Standards Risks threaten T3.4's requirement to "ensure a coherent logical system that interrelates job roles, skills, certifications, micro-credentials, curricula, modules and learning outcomes." Assessment validity may prove insufficient if instruments inadequately measure claimed competence levels at specified EQF levels. Quality consistency across partners may deteriorate through varying interpretation of learning outcome specifications. Competence mappings may fail translating to genuine workforce capability if design emphasises theoretical knowledge over practical application. External examiner confidence may prove difficult securing for short-duration credentials (0.5-2.5 ECTS) claiming meaningful competence achievement.

Stakeholder Engagement Risks impact T3.4's approach to "promoting and agreeing on sectoral qualifications." Employer interest may diminish if credentials fail demonstrating clear workforce value through employment outcomes or performance improvement. Professional body partnerships may dissolve if credential evolution becomes misaligned with professional standards or CPD requirements. Quality assurance agency relationships may deteriorate if framework approaches appear circumventing national accreditation requirements rather than complementing them.

Technical Implementation Risks affect T3.4's requirement to "implement ECVET and ECTS principles and referencing qualifications to NQFs and EQF." ECTS credit allocation may prove inconsistent across the 51 learning units if workload estimates diverge substantially from actual learner experience. EQF level assignments may lack credibility if learning outcomes fail demonstrating complexity appropriate for claimed levels. Stackability rules may create credential combinations lacking coherence if accumulation permits arbitrary micro-credential assemblies. Europass EDCI technical implementation may encounter interoperability issues across partner institutional systems.

7.2 Risk Assessment Methodology

Evidence Base for Risk Assessment: Risk identification and probability assessment draws on multiple evidence sources:

Quality Assurance Agency Consultations: Preliminary discussions conducted with Estonian Education and Youth Board, Irish Quality and Qualifications Ireland, and Croatian Agency for Science and Higher Education. Consultations explored application procedures, documentation requirements, timeline expectations, and fee structures. Estonian discussions confirmed framework design alignment with accreditation requirements; Irish consultation identified areas requiring additional detail (assessment validation evidence, quality assurance cycle documentation); Croatian contact indicated framework under development with procedures not yet finalised.

Precedent Analysis: Systematic review of recognition outcomes from EU projects (Section 2.3) identifying effective patterns and implementation challenges. ARISA Slovenia approval (2 ECTS micro-credential) demonstrates Track 3 viability in countries with established frameworks. MICROBOL (framework developed but no credentials issued) and EBSI (technical pilots only, no institutional adoption) illustrate risks of policy-focused or technology-first approaches lacking institutional anchoring.

Partner Capacity Assessments: Readiness assessment (Annex C) incorporating partner self-reports validated through institutional documentation review provides evidence regarding resource commitment, technical capacity, and quality assurance readiness. Assessment reveals resource constraints among some partners, technical infrastructure gaps requiring system development or upgrades, and variable institutional commitment ranging from strong endorsement with allocated resources to conditional participation pending pilot results.

Probability Assessments:

- Recognition rejection risk: MEDIUM probability (ARISA approval demonstrates viability; regulatory evolution creates uncertainty)
- Assessment validity concerns: LOW probability (External expert review M29-M30 by 3 assessment specialists confirmed instrument design; pilot testing M33-M36 will generate empirical validation)
- Partner commitment erosion: HIGH probability post-project (No binding sustainability commitments; 4/10 partners indicate resource constraints; competing institutional priorities likely)
- Stakeholder disengagement: MEDIUM probability (6 employer Declarations secured M32 demonstrate initial interest; sustained engagement requires demonstrated credential value through employment outcomes, data not yet available)

7.3 Mitigation Measures and Contingency Planning

Recognition Risk Mitigation implements T3.4's phased approach ("national level first and then at European level") through triple-track strategy positioning consortium and sectoral recognition as achievable within project timeline while preparing comprehensive documentation for national applications. Early consultation with quality assurance agencies in pilot countries (Estonia, Ireland, Croatia) ensures framework design aligns with established regulatory requirements. Partner readiness assessment identifies institutions with resources and commitment for post-project recognition pursuit. Contingency addresses rejection through revision procedures, alternative jurisdiction targeting, and emphasis on consortium/sectoral recognition providing immediate credential value.

Quality Risk Mitigation ensures T3.4's "coherent logical system" through external expert review of competence mappings validating job role → e-CF/GreenComp → learning outcome → assessment instrument chains. Consortium benchmarking exercises enable cross-institutional standards comparison identifying interpretation inconsistencies. External examiner networks including practitioners validate workplace relevance of learning outcomes and assessment approaches. Pilot implementations (WP4) generate evidence demonstrating credentials translate to genuine capability through learner achievement data and employer satisfaction feedback. Framework establishes minimum quality standards (detailed rubrics, assessment specifications, moderation procedures) with consortium review authority.

Stakeholder Engagement Mitigation supports T3.4's sectoral qualification approach through multi-year employer commitments via advisory boards providing ongoing validation. Professional body relationships include formal recognition agreements specifying CPD acknowledgment, membership benefits, or endorsement statements. Quality assurance agency relationships involve regular progress communication, draft documentation sharing, and incorporation of feedback into framework refinement. Contingency addresses disengagement through alternative partner identification and willingness to modify framework elements based on stakeholder input.

Technical Implementation Mitigation addresses T3.4's ECTS/EQF requirements through systematic workload validation during pilot implementation, adjusting credit allocations based on actual learner time investment. EQF level assignments follow standardised methodology examining knowledge, skills, and autonomy descriptors with external examiner verification. Stackability quality assurance verifies credential combinations address coherent competence packages through learning outcome mapping rather than permitting arbitrary accumulation. Europass EDCI implementation adopts open standards minimising vendor lock-in and enabling partner institutional system integration.

Framework Specification Sustainability (distinguishing T3.4 certification framework from WP6 programme sustainability) addresses risk that framework specifications become outdated through periodic review cycles (every 2-3 years) assessing competence mapping currency, learning outcome relevance, and assessment validity. Version control enables systematic updates while maintaining multi-year implementation stability. Open publication (Creative Commons) with implementation guides enables continued adoption independent of original development team. Multiple governance scenarios (informal coordination, formal alliance, sectoral body transfer, open framework, archive) provide flexibility based on realistic partner commitment levels.

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8. Strategic Recommendations

8.1 Track 1 Implementation (Recommended Priority)

Track 1 provides the most achievable pathway for partners with award authority. Implementation timing remains at partner institutional discretion.

Framework Documentation (Month 32 - Project Deliverable):

- Credential specifications for priority Learning Units (5-15 ECTS)
- Assessment rubrics and authenticity verification procedures
- Quality assurance standards (ESG 2015-aligned)
- Technical specifications (EDCI-compliant, Annex F)
- Consortium mutual recognition agreement template

Partners Positioned for Track 1:

BCS Koolitus (Estonia, score 7.0), NCI (Ireland, 6.25), CPU Slovenia (5.0), Profil Klett (Croatia, 5.75), UAH and UNIR (Spain, 5.5-5.75), UPB (Romania, 5.0)

Implementation Requirements (if partners proceed):

- Institutional approval: 2-4 months
- Technical infrastructure: €5,000-15,000, 3-6 months
- Estimated total: 200+ staff hours

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Timeline Options:

- During project: If resources permit, leverage WP4 learner cohorts (700 learners)
- Post-project: Standard expectation; implement when priorities align

Framework delivers specifications; implementation depends on partner capacity and commitment.

Track 2 Implementation (Complementary)

- Develop Declaration of Understanding template by Month 33
- Secure employer endorsements in Bulgaria, Hungary, Romania by Month 38
- Map credentials to ESCO competences for sectoral validation
- Document sectoral recognition outcome

This authority indicates institutional capacity but does not imply a commitment to issue micro-credentials within the Digital4Sustainability framework. The decision to issue micro-credentials remains entirely at partners' discretion, as it depends on internal strategic decisions and processes.

8.2 Post-Project Opportunities

Track 3 national recognition remains available for institutions with resources. Partners in Estonia, Ireland, and Croatia are positioned for applications with minimal additional preparation using D3.3 documentation. Estimated investment: €1,450+ initial plus €150-200 per programme; timeline: 6-18 months from submission.

8.3 Partner-Specific Actions

Section 5.2 maps each partner to their primary track and implementation role. All partners contribute through Track 1 issuance, Track 1 partnership, or Track 2 sectoral validation.

8.4 Conclusions and Next Steps

D3.3 establishes comprehensive design specifications for micro-credentials in digital sustainability. The framework delivers specifications without mandating implementation, positioning willing partners for credential issuance at institutional discretion.

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Key Achievements:

- 51 Learning Units mapped to job roles via e-CF and GreenComp frameworks;
- Stackable credential architecture (0.5-15 ECTS) supporting progressive qualification building;
- Quality assurance framework aligned with ESG 2015 and EU Council Recommendation (2022);
- Three-track recognition strategy with partner readiness assessment;
- Technical specifications for EDCI-compliant digital credentials.

WP4 Integration: Training programmes (700 learners) incorporate D3.3 specifications, generating validation evidence without formal credentialling. Feedback informs framework refinement.

Implementation Pathways:

- Track 1 (Primary): Seven partners with award authority can issue consortium-endorsed credentials at institutional discretion. Investment: €5,000-15,000, 200+ hours, 6-12 months. Timing: During or post-project depending on partner resources.
- Track 2 (Complementary): Industry partners pursue sectoral Declarations of Understanding. Minimal investment, 3-6 months.
- Track 3 (Substantial Resources Required): Estonia, Ireland, Croatia can pursue national recognition post-project if resources permit. Investment: €1,450+ initial plus €150-200 per programme, 12-18 months.

Next Steps:

- Months 36-48: WP4 piloting generates validation evidence
- Month 48: Framework finalised incorporating feedback
- Post-project: Partners implement at institutional discretion using D3.3 specifications The framework delivers actionable specifications enabling implementation as partner resources and priorities permit.

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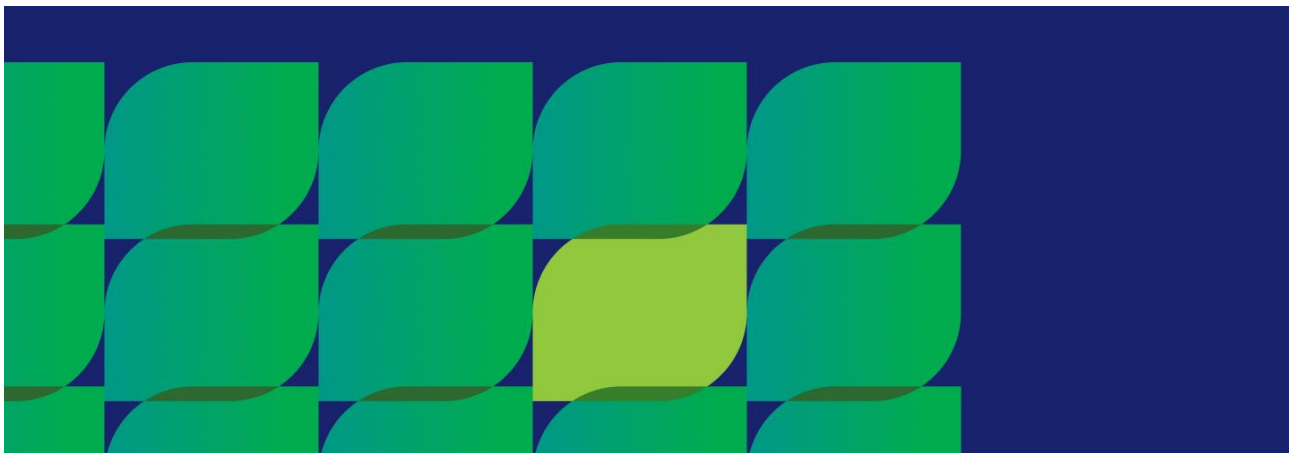

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Glossary

Credential Types and Components

Attendance Certificate: Documentation certifying learner participation in and completion of learning activities, demonstrating competence achievement through assessment, but not carrying ECTS credits or formal qualification status. Attendance certificates issued via open badge platforms provide verifiable evidence of skills for employer recognition without requiring academic accreditation.

Badge A visual representation of a credential, typically digital, that can be displayed and shared electronically. Badges contain embedded metadata about what was achieved and how it was assessed. In D3.3 context, badges are the display format for micro-credentials issued under the framework.

Credential Official documentation certifying that a learner has achieved specific learning outcomes through assessed learning activities. Credentials include micro-credentials, certificates, diplomas, and degrees. All credentials in D3.3 are credentials, but not all credentials are micro-credentials.

Micro-credential A credential representing a small volume of learning (0.5-15 ECTS in D3.3) that certifies achievement of a focused set of learning outcomes. Micro-credentials can be earned independently or stacked toward larger qualifications. D3.3 defines three micro-credential types: upskilling (0.5-2.5 ECTS), substantial (5-7.5 ECTS), and thematic clusters (10-15 ECTS).

Qualification A formal credential awarded by an authorised institution certifying that a learner has achieved all learning outcomes required for a complete educational programme. In D3.3, comprehensive qualifications (60-90 ECTS, EQF 5-7) represent complete educational profiles equivalent to diplomas or degrees.

Certificate A general term for any document certifying achievement or completion. Certificates may or may not represent assessed learning outcomes. In D3.3, micro-credentials and qualifications are specific types of certificates with defined learning outcomes, ECTS credits, and quality assurance.

Learning Unit (LU) A component of an educational programme covering one or more related learning outcomes, typically assessed as a coherent whole. In D3.3, 51 learning units form the building blocks from which micro-credentials and qualifications are constructed. Learning units align with traditional course structures.

Framework and System Terms

Certification Framework The complete system of specifications defining credential types, learning outcomes, stackability rules, quality assurance procedures, and recognition pathways. D3.3 is a certification framework specifying how credentials in digital sustainability should be designed, assessed, and recognised.

Micro-credential Framework A specific type of certification framework focused on credentials representing small volumes of learning. D3.3's micro-credential framework specifies three credential levels (micro-credentials, learning units, comprehensive qualifications) with systematic accumulation rules.

Credentialling System The operational infrastructure (policies, processes, technologies, personnel) through which an institution or organisation issues credentials to learners. D3.3 provides specifications; partners build credentialling systems to implement those specifications.

Recognition Framework The policies, procedures, and agreements enabling credentials issued by one institution to be accepted by other institutions, employers, or regulatory bodies. D3.3's recognition framework includes three tracks providing different pathways to credential acceptance.

Stackability Architecture The structure defining how smaller credentials systematically combine into larger qualifications through defined accumulation rules. D3.3's stackability architecture specifies that micro-credentials stack toward learning units, learning units stack toward comprehensive qualifications, through Recognition of Prior Learning.

Recognition and Validation Terms

Recognition The process by which an institution, employer, or regulatory body formally accepts a credential as valid for specific purposes (admission, credit transfer, employment, professional practice). Recognition may be automatic (through agreements) or case-by-case (through evaluation).

Recognition Track A defined pathway for achieving credential recognition using specific mechanisms and stakeholders. D3.3 defines three tracks: consortium/institutional recognition (Track 1), sectoral recognition through employers and professional bodies (Track 2), and national/European accreditation (Track 3).

Validation The process of verifying that a credential's learning outcomes, assessment methods, and quality assurance meet specific standards or requirements. Validation may involve employer review (Track 2), quality assurance agency evaluation (Track 3), or consortium peer review (Track 1).

Accreditation Formal approval by an authorised quality assurance agency certifying that an educational programme or credential meets defined quality standards. Track 3 pursues accreditation through national quality assurance agencies. Tracks 1 and 2 achieve recognition without formal accreditation.

Mutual Recognition Agreement among multiple institutions to systematically accept each other's credentials for defined purposes without case-by-case evaluation. Track 1 consortium mutual recognition enables partners to accept D3.3 credentials issued by other consortium members for credit transfer or admission.

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Implementation and Process Terms

Pathway A structured route through which learners progress from initial learning activities toward credentials and qualifications. D3.3 enables multiple pathways: learners may pursue individual micro-credentials, complete learning units, or work toward comprehensive qualifications through systematic accumulation.

Stackability The capability of smaller credentials to combine systematically toward larger qualifications through defined accumulation rules. Stackability distinguishes organised progression (credentials designed to combine) from arbitrary accumulation (unrelated credentials collected without coherent purpose).

Recognition of Prior Learning (RPL) The process by which institutions grant academic credit for learning achieved through previous credentials, work experience, or informal learning, without requiring learners to repeat achieved learning outcomes. In D3.3, RPL enables micro-credentials to convert into credit toward comprehensive qualifications.

Implementation The process of establishing operational systems (policies, infrastructure, procedures, personnel) required to issue credentials based on framework specifications. Implementation is optional and partner-driven; D3.3 provides specifications enabling implementation but does not mandate credential issuance.

Specification Detailed definition of requirements, standards, or characteristics that something must meet. D3.3 is a specification document defining how credentials should be designed; specifications guide implementation but are not themselves operational systems.

Quality and Standards Terms

Quality Assurance (QA) Systematic processes ensuring that educational programmes, credentials, and institutions meet defined quality standards. D3.3's multi-level QA framework operates at consortium coordination (cross-institutional standards) and institutional implementation (programme delivery) levels.

Assessment The process of measuring whether learners have achieved specified learning outcomes through examinations, projects, portfolios, or other evaluation methods. D3.3 requires constructive alignment ensuring assessments validly measure the learning outcomes claimed in credentials.

Learning Outcome A statement describing what a learner will know, understand, or be able to do after completing a learning activity. Learning outcomes must be specific, measurable, achievable, and assessable. D3.3 credentials are defined by learning outcomes, not by input measures like contact hours.

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Competence Demonstrated ability to apply knowledge, skills, and attitudes to achieve observable results in professional or practical contexts. D3.3 uses competence-based design, mapping all credentials to e-CF (ICT competences) and GreenComp (sustainability competences) frameworks.

ECTS (European Credit Transfer and Accumulation System) European standard for measuring learning volume, where one ECTS credit represents 25-30 hours of learning workload. D3.3 specifies ECTS values for all credentials enabling comparison, transfer, and accumulation across European institutions.

EQF (European Qualifications Framework) Eight-level reference framework describing learning outcomes in terms of knowledge, skills, and autonomy, enabling qualification comparison across European countries. D3.3assigns EQF levels (5-7) to all credentials based on learning outcome complexity.

Technical and Infrastructure Terms

Digital Credential A credential issued in electronic format with embedded metadata enabling verification, portability, and machine-readability. D3.3 specifies digital credentials compliant with Europass Digital Credentials Infrastructure (EDCI) enabling cross-border recognition and European Digital Identity Wallet compatibility.

Metadata Structured data describing credential characteristics (issuer, learner, learning outcomes, assessment, ECTS, EQF) in machine-readable format. Metadata enables automated verification, credential portability, and integration with digital wallets and student information systems.

Verification The process of confirming that a credential is authentic (issued by claimed institution), valid (not expired or revoked), and accurately represents stated achievements. D3.3 specifies cryptographic signature verification, issuer registry checking, and revocation list consultation.

Interoperability The capability of credentials issued by different institutions using different systems to be read, verified, and recognised across borders and platforms. D3.3 achieves interoperability through Europass EDCI compliance and standardised metadata structures.

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Annexes A-H

A. Micro-Credential Template

Provides standardised template for issuing Level 1 micro-credentials (0.5-2.5 ECTS from 6 upskilling curricula).

A.1 Visual Certificate Layout (PDF Format)

Digital Sustainability Consortium
Micro-Credential Certificate

This certifies that [Learner Full Name]
has successfully completed Digital Sustainability Foundations

Credential ID: D4S-MC-DSF-2025-00123
Issue Date: [DD Month YYYY]
ECTS Credits: 2.5 EQF Level: 5

LEARNING OUTCOMES ACHIEVED:

- Explain core concepts of digital sustainability
- Identify environmental impacts of digital systems
- Apply sustainability assessment frameworks
- Evaluate digital solutions using sustainability criteria

Competence Frameworks:

e-CF: A.5 (Architecture Design) GreenComp: 1.1, 2.2, 3.1

Assessment:

Written Exam (40%) Case Study Analysis: (60%)
Workload: 62.5 hours (lectures 20h, self-study 30h, exam 12.5h)

Stackability:

Combines with [Related Micro-Credentials] toward
Learning Unit (LU Code) and Comprehensive Qualification (CQ)

Validity:

Permanent (competence verified [Issue Date])

Issued by: [Partner Institution Name]
Authorized Signatory: Date:
Verified at: https://verify.digital4sustainability.eu
[QR Code]

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A.2 Structured Data Template (Table Format)

Field Category	Field Name	Content	Required
Credential Identification	Credential Title	Digital Sustainability Foundations	Yes
	Credential ID	D4S-MC-DSF-2025-00123	Yes
	Credential Type	Micro-credential (Level 1)	Yes
	Issue Date	DD/MM/YYYY	Yes
	Validity Period	Permanent	Yes
Learner Information	Full Name	[Learner Full Name]	Yes
	Date of Birth	DD/MM/YYYY	Yes
	Unique Learner ID	[National ID or Student Number]	Yes
Issuing Institution	Institution Name	[Partner University Name]	Yes
	Institution Code	[ERASMUS/SCHAC Code]	Yes
	Country	[Country]	Yes
	Authorised Signatory	[Name, Title]	Yes
	Contact	[Email, Website]	Yes
Educational Specification	ECTS Credits	2.5	Yes
	EQF Level	5	Yes
	Study Load (hours)	62.5 (Lectures 20h, Self-study 30h, Assessment 12.5h)	Yes
	Language of Instruction	English / [Other]	Yes
	Delivery Mode	Online / Blended / Classroom / Work-Based	Yes

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Learning Outcomes	Learning Outcome 1	Explain core concepts linking digital technology and environmental sustainability	Yes
	Learning Outcome 2	Identify environmental impacts of digital systems across lifecycle stages	Yes
	Learning Outcome 3	Apply sustainability assessment frameworks to digital solutions	Yes
	Learning Outcome 4	Evaluate digital solutions using sustainability criteria and metrics	Yes
Competence Framework Alignment	e-CF Competences	A.5 Architecture Design (Level 3)	Yes
	GreenComp Competences	1.1 Valuing sustainability, 2.2 Systems thinking, 3.1 Futures literacy	Yes
	Job Role Relevance	Data Analyst for Sustainability, Sustainability Technical Specialist	No
Assessment	Assessment Methods	Written examination (40%), Case study analysis (60%)	Yes
	Pass Criteria	Overall score ≥60%, minimum 50% in each component	Yes
	Grade Achieved	[Pass / Merit / Distinction] OR [Numeric Score]	Yes
	Assessment Date	DD Month YYYY	Yes
	External Examiner	[Name, Institution] (if applicable)	No
Stackability Information	Stacks Toward	Learning Unit: [LU-DSF-Core] (5 micro-credentials required)	Yes
	Related Micro-Credentials	Green Software Fundamentals, Sustainability Data Essentials	No
	Pathway to Qualification	Comprehensive Qualification: Data Analyst for Sustainability (60 ECTS)	No
Recognition	Recognition Type	Institutional (Partner university degree-awarding authority)	Yes
	Consortium Recognition	Yes (Recognised across D4S partner institutions)	No
	Sectoral Recognition	[Professional Body Name] for CPD (X hours)	No
	National Recognition	[Pending / Approved by Agency Name]	No

Verification	Verification URL	https://verify.digital4sustainability.eu/credential/[ID]	Yes
	Verification Method	Cryptographic signature (EDCI-compliant)	Yes
	Blockchain Reference	[Hash / Transaction ID] (if applicable)	No
	QR Code	[Embedded QR linking to verification URL]	Yes
Additional Information	Prior Learning Recognised	[List any RPL applied]	No
	Special Conditions	[Accommodations, extensions, etc.]	No
	Issuing Programme Context	D3.1 Upskilling Curriculum - Digital Sustainability Foundations	No
	Consortium Project	Digital4Sustainability (EU Grant Agreement No. [Number])	No

B. Europass Digital Credential Metadata Structure

Technical specification for creating Europass Digital Credentials Infrastructure (EDCI) v3 compliant digital credentials.

B1. Overview

The Europass Digital Credentials Infrastructure (EDCI) v3 provides standardised XML/JSON schema for issuing verifiable, machine-readable credentials. This annex presents simplified structure for D4S micro-credentials with key metadata fields.

B2. Core Metadata Structure Simplified)

Figure B.1 presents the layered metadata architecture for Digital4Sustainability micro-credentials, aligned with Europass EDCI v3 specifications. The structure organises credential data into functional layers—from learner and issuer identification through learning outcomes and competence frameworks to verification mechanisms—enabling machine-readable portability and cross-border recognition. Optional enhancements aligned with Open Badges 3.0 may extend this structure as European credential infrastructure evolves (see Section B6).

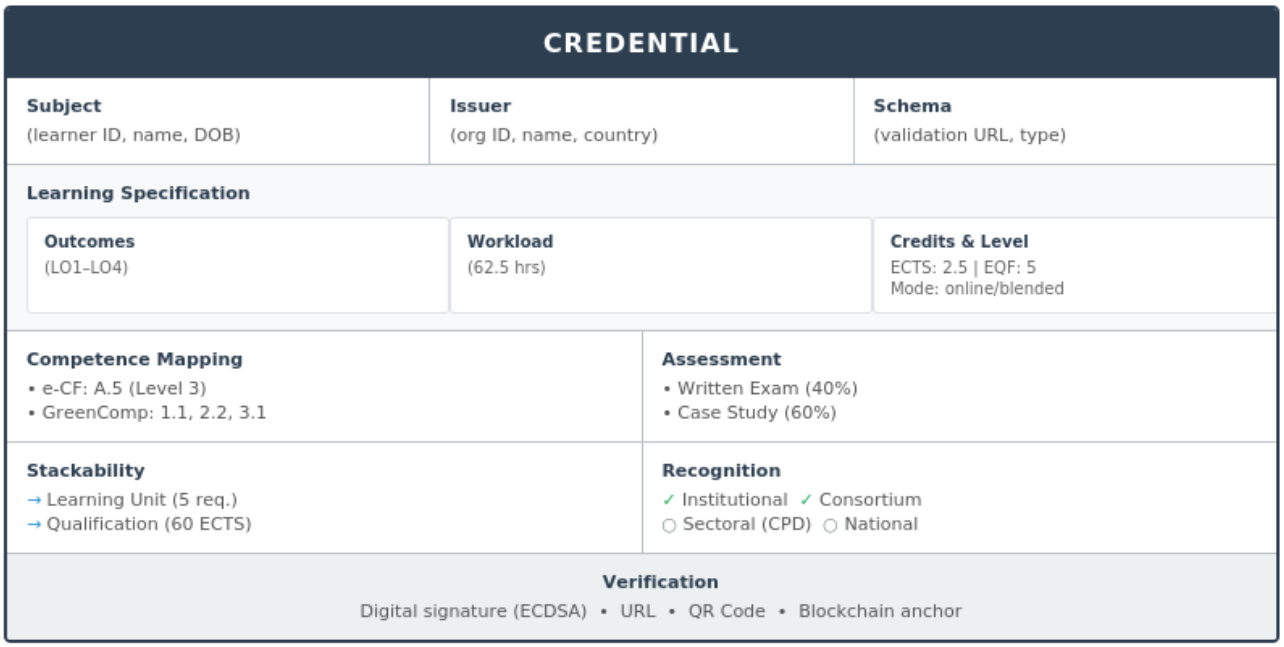

Figure 51: EDCI v3 Core Metadata Structure for Digital4Sustainability Micro-Credentials

B3. Verification Process

Figure B.2 illustrates the verification workflow for EDCI-compliant digital credentials. When a learner presents a credential—via QR code, URL, or file—the verifying party retrieves the structured ta and performs a sequence of checks: issuer validation against the consortium registry, cryptographic signature verification, and expiry/revocation status. An optional blockchain anchor provides additional tamper-evidence. The process concludes with one of three outcomes: VALID, INVALID, or UNKNOWN.

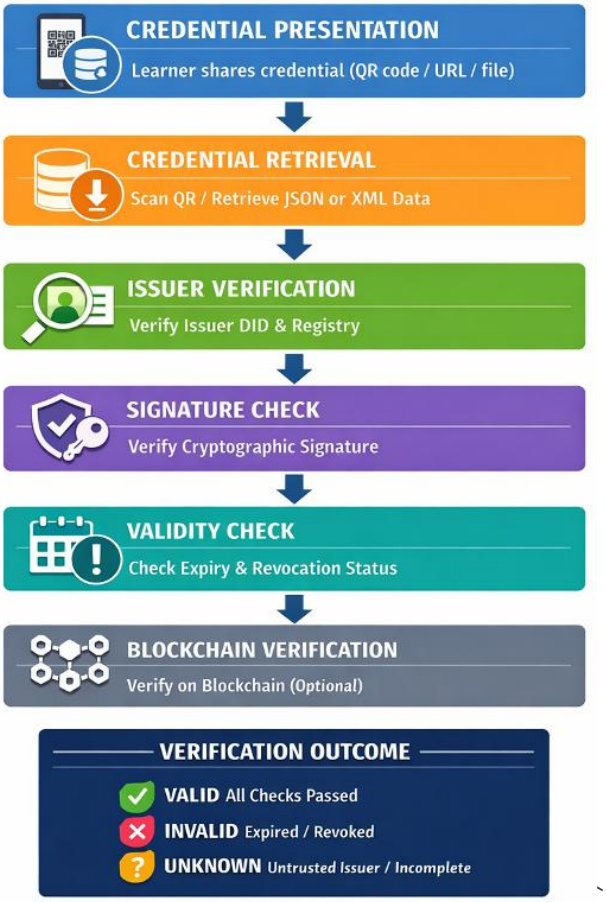

Figure B.2: Credential Verification Process for Digital4Sustainability Micro-Credentials (EDCI v3)

The Europass EDCI v3 specifications provide comprehensive metadata for credential compliance and verification. Open Badges 3.0 introduces optional context metadata fields (delivery mode, cohort indicators, learning environment characteristics, peer collaboration evidence) that could enrich credential information for learners and employers without affecting core compliance requirements. These optional enhancements align with emerging EU data spaces for education and skills, enabling richer credential ecosystems while maintaining backward compatibility with current EDCI infrastructure. Partners implementing credential systems may consider these enhancements as the European credential infrastructure matures beyond project timeline.

B4. Key Metadata Fields Explained

Field	Purpose	Example Value
Id	Unique credential identifier (UUID format)	urn:uuid:D4S-MC-DSF-2025-00123
Type	Credential category per EDCI taxonomy	["EuropassCredential", "MicroCredential"]
issuanceDate	ISO 8601 timestamp when credential issued	2025-06-15T14:30:00Z
credentialSubject.id	Unique learner identifier	urn:epass:person:12345
issuer.id	Unique issuer organisation identifier	urn:epass:org:partner-university-001
learningSpecification	Educational content (LOs, ECTS, EQF, workload)	See structure above
competenceFrameworks	Alignment to e-CF, GreenComp standards	References specific competences
assessment	Methods, criteria, grade achieved	Mixed assessment approaches
stackability	How credential combines with others	Learning unit → Qualification pathway
proof.jws	Cryptographic signature for verification	[HASH_STRING]
verification.url	Public verification endpoint	https://verify.digital4sustainability.eu/...

B5. Implementation Notes

Technical Requirements:

- JSON schema validation against EDCI v3 specification;
- Cryptographic signature generation using issuer private key;
- Public key infrastructure for verification;
- Secure credential storage (learner wallet / institutional repository).

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Interoperability:

- EDCI-compliant credentials readable by Europass platform;
- Compatible with EU Digital Identity Wallet;
- Supports cross-border recognition through standardised metadata.

Privacy Considerations:

- Minimal personal data in credential (GDPR compliance);
- Learner controls sharing (selective disclosure);
- Verification without revealing unnecessary information

B6. Future Enhancement Considerations

Europass EDCI v3 specifications provide comprehensive metadata ensuring credential compliance and verification. Open Badges 3.0 introduces optional context metadata fields including delivery mode, cohort indicators, learning environment characteristics, and peer collaboration evidence that could enrich credential information for learners and employers without affecting core compliance requirements. These optional enhancements align with emerging EU data spaces for education and skills, enabling richer credential ecosystems while maintaining backward compatibility with current EDCI infrastructure. Partners implementing credential systems may consider these enhancements as European credential infrastructure matures beyond project timeline.

C. Partner Readiness Assessment Methodology

Documents systematic evaluation framework used to assess 10 consortium partners' capacity for implementing micro-credential framework across three recognition tracks.

C1. Assessment Purpose and Scope

Partner readiness assessment evaluates consortium partner capacity for implementing micro-credential framework specifications across three recognition tracks. Assessment employs systematic scoring methodology enabling objective comparison of institutional capabilities, identification of implementation pathways matched to partner strengths, and resource planning for post-project credential adoption. Assessment was conducted M28-M31 through partner self-assessment surveys (validated through institutional documentation review) and consortium coordination meetings.

C2. Assessment Criteria and Scoring Rubric

Seven criteria assess implementation capacity, each scored 0.0-1.0 with cumulative scores ranging 0.0-7.0:

Criterion 1: Award Authority (0.0-1.0)

- 1.0: Full degree-awarding authority enabling independent credential issuance under national legislation;
- 0.7: Conditional authority requiring partnership or specific programme approval;
- 0.4: Non-formal certification authority without formal qualification status;
- 0.0: No award authority; partnership-only capacity.

Criterion 2: Quality Assurance Capacity (0.0-1.0)

- 1.0: Established QA systems with regular external review, documented procedures, dedicated QA office;
- 0.7: Functional QA processes meeting national requirements but limited external review history;
- 0.4: Developing QA capacity with informal procedures requiring systematisation;
- 0.0: Minimal QA infrastructure requiring substantial development.

Criterion 3: Technical Infrastructure (0.0-1.0)

- 1.0: Operational student information systems, digital credential issuance capability, secure verification infrastructure;
- 0.7: Core systems operational but requiring upgrades for micro-credential functionality;
- 0.4: Basic technical capacity requiring substantial investment for credential implementation;
- 0.0: Minimal technical infrastructure requiring complete system development.

Criterion 4: Sectoral Connections (0.0-1.0)

- 1.0: Extensive employer networks, formal industry partnerships, professional body relationships enabling Track 2 validation;
- 0.7: Moderate sectoral engagement with developing partnerships;
- 0.4: Limited industry connections requiring substantial relationship building;
- 0.0: Minimal sectoral engagement.

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Criterion 5: Learner Pipeline (0.0-1.0)

- 1.0: Substantial existing learner enrolments in digital/sustainability programmes providing immediate credential demand;
- 0.7: Moderate enrolments with growth potential;
- 0.4: Limited current enrolments requiring marketing investment;
- 0.0: No existing relevant programmes.

Criterion 6: Resource Commitment (0.0-1.0)

- 1.0: Strong institutional commitment with allocated budget, dedicated staff, leadership endorsement;
- 0.7: Moderate commitment with conditional resource allocation pending pilot results;
- 0.4: Limited commitment with substantial resource constraints;
- 0.0: Minimal commitment; participation contingent on external funding.

Criterion 7: Regulatory Context (0.0-1.0)

- 1.0: Established national micro-credential framework with clear accreditation procedures (e.g., Estonia);
- 0.7: Framework under development with supportive policy environment;
- 0.4: Unclear regulatory context requiring policy advocacy;
- 0.0: Restrictive regulatory environment hindering micro-credential recognition.

C3. Scoring Interpretation and Thresholds

Cumulative scores 0.0-7.0 interpreted as:

- **6.0-7.0 (High Readiness):** Partner positioned for Track 3 national accreditation pursuit with comprehensive capacity across all criteria. Immediate Track 1 implementation viable with minimal additional investment;
- **5.0-5.9 (Moderate-High Readiness):** Partner positioned for Track 3 pursuit with focused investment in 1-2 areas requiring strengthening. Track 1 implementation viable with moderate preparation;
- **4.0-4.9 (Moderate Readiness):** Partner positioned for Track 1 consortium implementation and Track 2 sectoral validation. Track 3 pursuit requires substantial capacity development;
- **3.0-3.9 (Developing Readiness):** Partner contributes through Track 1 partnerships (supporting implementing partners) and Track 2 sectoral engagement. Independent implementation requires significant investment;

- **0.0–2.9 (Limited Readiness):** Partner contributes through Track 2 sectoral validation leveraging industry connections. Track 1 implementation not feasible without transformative capacity building.

Threshold Selection Rationale: The 5.0 threshold for Track 3 positioning represents ≥70% achievement across readiness criteria, indicating comprehensive capacity with at most 2–3 areas requiring moderate strengthening. This threshold balances ambition (recognising Track 3 represents substantial investment) with realism (requiring demonstrated capacity across most criteria). Threshold derived from analysis of ARISA Slovenia pilot (readiness estimated 5.5 based on documentation, successful accreditation achieved) and ESSA implementation (readiness estimated 4.5, achieved sectoral recognition but not formal accreditation, suggesting 5.0+ threshold appropriate for Track 3).

C4. Partner Scores and Justification

Partner	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Total	Track Positioning
National College of Ireland (IE)	1.0 (Full authority)	1.0 (Established QA, external review)	1.0 (Operational systems)	0.7 (Moderate industry)	1.0 (Strong enrolments)	0.7 (Moderate commitment)	0.6 (Framework developing)	**6.0**	**Track 3 positioned**
Profil Klett (HR)	0.4 (Non-formal authority*)	1.0 (Strong QA despite non-formal status)	1.0 (Operational systems)	1.0 (Extensive industry networks)	1.0 (Strong enrolments)	1.0 (Strong commitment)	0.7 (Framework developing)	**6.1**	**Track 3 positioned**
Complutense University Madrid (ES)	1.0 (Full authority)	1.0 (Established QA)	0.7 (Systems require upgrades)	0.4 (Limited digital sustainability industry)	0.7 (Moderate enrolments)	0.7 (Moderate commitment)	0.4 (Unclear micro-credential regulation)	**4.9**	Track 1/2

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CPU Slovenia (SI)	1.0 (Full authority)	0.7 (Functional QA)	0.7 (Systems adequate)	0.7 (Moderate industry)	0.7 (Moderate enrolments)	0.7 (Moderate commitment)	0.5 (Emerging framework)	**5.0**	**Track 3 positioned**
BCS Koolitus (EE)	1.0 (VET authority)	0.7 (Accredited VET provider)	0.7 (Systems adequate)	1.0 (Extensive industry)	0.7 (Moderate enrolments)	1.0 (Strong commitment)	1.0 (Established framework)	**7.0**	**Track 3 positioned**
BASSCOM (BG)	0.0 (No authority)	0.4 (Minimal QA)	0.4 (Basic systems)	1.0 (Extensive industry networks)	0.0 (No enrolments)	0.7 (Moderate commitment)	0.4 (Unclear regulation)	**2.9**	Track 2 sectoral
Digital SME Alliance (EU-wide)	0.0 (No authority)	0.0 (No QA)	0.4 (Basic systems)	1.0 (SME networks)	0.0 (No enrolments)	0.4 (Limited commitment)	0.0 (Multi-jurisdiction)	**1.8**	Track 2 sectoral

*Note on Profil Klett: Currently issues non-formal certificates under Croatian adult education legislation. Criterion 1 score (0.4) reflects current status; remaining criteria scores reflect institutional capacity for transition to formal accreditation. High overall score (6.1) indicates strong readiness for pursuing formal credential authority through Croatian accreditation processes once national micro-credential framework fully operationalised. Readiness measures preparation for transition, not current credential type.

C5. Assessment Limitations and Validation

Assessment limitations include: (1) Self-reporting bias partially mitigated through institutional documentation review (QA reports, regulatory approval letters, system specifications), (2) Rapid regulatory evolution in micro-credential frameworks creating assessment timing sensitivity (scores reflect M30-M31 conditions; future regulatory changes may alter readiness), (3) Resource commitment uncertainty as institutional priorities evolve (Criterion 6 scores represent current stated commitment, not binding guarantees).

Validation approaches: (1) Institutional leadership review confirming assessment accuracy (10/10 partners reviewed and confirmed scores M31), (2) Cross-partner benchmarking identifying

outliers for additional scrutiny (no significant anomalies identified), (3) Correlation with Track 1 implementation decisions during WP4 (predicted implementation rates will be compared against actual partner adoption M36-M48 providing retrospective validation).

D. Consortium Mutual Recognition Agreement Template

This Annex provides a legal template enabling partners who chose Track 1 to establish mutual recognition of D4S-issued credentials across consortium institutions.

DIGITAL4SUSTAINABILITY CONSORTIUM MUTUAL RECOGNITION AGREEMENT FOR MICRO-CREDENTIALS

Preamble

This Agreement is entered into by and between the undersigned institutions ("Participating Institutions"), all partners in the Digital4Sustainability project, for the purpose of establishing mutual recognition of micro-credentials, learning units, and comprehensive qualifications issued under the Digital4Sustainability Certification Framework as specified in Deliverable D3.3.

WHEREAS the Participating Institutions have collaboratively developed a certification framework based on common quality standards, learning outcome specifications, and competence-based design methodologies;

WHEREAS the Participating Institutions share commitment to transparent, quality-assured credentialling supporting learner mobility and career development across European contexts;

WHEREAS mutual recognition serves the interests of learners, employers, and participating institutions by enabling credential portability and stackability;

NOW THEREFORE, the Participating Institutions agree as follows:

Article 1: Definitions

1.1 "D4S Framework" means the Digital4Sustainability Certification and Micro-Credentialling Framework as specified in Deliverable D3.3, including three-level stackability architecture, quality assurance procedures, competence mapping methodologies, and technical specifications.

1.2 "Micro-credential" means a Level 1 credential (0.5-2.5 ECTS) certifying achievement of focused learning outcomes from one of six upskilling curricula as defined in D3.1.

1.3 "Learning Unit" means a Level 2 credential corresponding to one of 51 learning units across five core curricula as defined in D3.1.

1.4 "Comprehensive Qualification" means a Level 3 credential (60-90 ECTS, EQF 5-7) corresponding to one of five educational profiles as defined in D3.1.

1.5 "Issuing Institution" means a Participating Institution with degree-awarding authority that issues credentials to learners following successful completion of learning outcomes and assessment.

1.6 "Recognising Institution" means a Participating Institution that accepts credentials issued by another Participating Institution for purposes specified in Article 2.

1.7 "Learner" means any individual enrolled in Digital4Sustainability learning programmes or holding credentials issued under the D4S Framework.

Article 2: Scope of Mutual Recognition

2.1 Recognition for Further Study

Recognising Institutions agree to accept credentials issued by Issuing Institutions under the D4S Framework for admission to further study and credit toward additional qualifications, subject to:

(a) Credentials meeting quality standards specified in D3.3 Section 4;

(b) Credentials aligning with learning outcome requirements of target programmes;

(c) Recognising Institution's standard admission procedures and academic regulations.

2.2 Recognition for Credit Transfer

Recognising Institutions agree to grant academic credit for credentials issued by Issuing Institutions according to ECTS values specified in credential documentation, subject to:

(a) Verification of credential authenticity through procedures specified in Article 4;

(b) Learning outcomes alignment with Recognising Institution's programme requirements;

(c) Maximum credit recognition limits not exceeding 50% of target qualification as per standard European practice.

2.3 Recognition for Employment and Career Services

Participating Institutions agree to recognise credentials issued by other Participating Institutions when providing employment references, career counselling, or workforce development services, acknowledging credentials represent validated competence achievement.

2.4 Exclusions

This Agreement does not:

(a) Require Recognising Institutions to accept all credentials for all purposes—academic judgment regarding programme fit and learner readiness remains with Recognising Institution;

(b) Override national legislation or quality assurance agency requirements governing credential recognition;

(c) Establish automatic degree equivalence—comprehensive qualifications recognised for credit transfer but require completion of Recognising Institution's specific requirements for degree award;

(d) Create financial obligations beyond those specified in Article 7.

Article 3: Quality Assurance Standards

3.1 Common Standards

All credentials issued under this Agreement must comply with D4S Framework quality assurance procedures (D3.3 Section 4) including:

(a) Learning outcomes aligned with e-CF and GreenComp competence frameworks;

(b) Assessment validity demonstrated through constructive alignment and external review;

(c) Quality assurance processes compliant with ESG 2015 (higher education) or EQAVET (VET);

(d) Documentation completeness per D3.3 credential template specifications (Annex A).

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3.2 Institutional Approval

Issuing Institutions must obtain internal quality assurance approval through established academic governance before issuing credentials under this Agreement. Approval documentation must be available for consortium review upon request.

3.3 External Examiner Involvement

Comprehensive Qualifications (Level 3) require external examiner review prior to issuance. External examiners may be drawn from other Participating Institutions, fostering cross-institutional quality assurance collaboration.

3.4 Consortium Quality Assurance Review

Participating Institutions agree to participate in consortium-level quality assurance activities including:

(a) Cross-institutional assessment moderation exercises (minimum annually);

(b) External examiner network meetings (minimum biannually);

(c) Benchmarking exercises comparing learner outcomes and quality procedures.

3.5 Right to Suspend Recognition

If a Participating Institution identifies quality concerns regarding credentials issued by another Participating Institution, it may:

(a) Request documentation and evidence from Issuing Institution;

(b) Raise concerns through consortium coordination mechanisms;

(c) Temporarily suspend recognition pending investigation if serious concerns warrant;

(d) Permanently suspend recognition of specific credentials following consortium review confirming quality deficiencies.

Suspension procedures must provide Issuing Institution opportunity to respond and remedy identified concerns.

Article 4: Credential Verification and Authentication

4.1 Digital Credential Issuance

All credentials issued under this Agreement must be provided in Europass Digital Credentials Infrastructure (EDCI) v3 format per D3.3 Annex B specifications, enabling:

(a) Machine-readable metadata including learning outcomes, ECTS credits, EQF level, competence framework alignment;

(b) Cryptographic signature verification confirming issuer authenticity;

(c) Tamper-evidence ensuring credential content integrity.

4.2 Verification Procedures

Recognising Institutions verify credentials through:

(a) Accessing public verification URL embedded in credential QR code or metadata;

(b) Confirming cryptographic signature validity using Issuing Institution's public key;

(c) Checking Issuing Institution membership in D4S consortium (maintained registry at [URL]);

(d) Confirming credential not revoked through consortium revocation registry.

4.3 Credential Registry

Participating Institutions maintain a shared credential registry (hosted at [URL]) documenting:

(a) Issued credential types and specifications;(b) Issuing Institution contact points for verification queries;

(c) Revoked credentials (with reason and effective date);

(d) Quality assurance approval status.

4.4: Data Protection and Privacy Considerations

All credential processing, storage, and verification procedures comply with GDPR (Regulation EU 2016/679) and relevant EU legislation including the AI Act (Regulation EU 2024/1689) for automated decision-making and the European Digital Identity Regulation (eIDAS 2.0) for credential interoperability. Partners implement data protection measures across three operational domains:

Credential Issuance: Learner personal data is processed only to the extent necessary for credential generation, with data minimisation principles applied. Credentials contain minimal personal identifiers (name, date of birth, unique learner ID) with detailed personal information stored separately in secure institutional systems. Partners maintain lawful processing basis (typically legitimate interest for institutional record-keeping or contractual necessity for enrolled learners) documented in institutional privacy policies.

Credential Verification: Verification procedures process only data necessary to confirm credential authenticity (credential ID, issuing institution, issue date, learning outcomes achieved) without exposing unnecessary personal information to verifiers. Verification systems log access for audit purposes while respecting data minimisation principles. Learners retain control over credential sharing, with digital credentials enabling selective disclosure where supported by technical infrastructure.

Learner Rights: Learners retain full GDPR rights including access (Article 15), rectification (Article 16), erasure (Article 17), restriction of processing (Article 18), data portability (Article 20), and objection (Article 21). Partners establish procedures for learners to exercise rights, including credential revocation upon erasure requests (recorded in revocation registry without retaining personal data), credential reissuance following rectification requests, and processing restriction while disputes are resolved. Credential revocation for data protection reasons is distinguished from academic integrity revocation in consortium records.

Article 5: Stackability and Accumulation

5.1 Stackability Principle

Participating Institutions recognise that credentials issued under the D4S Framework are designed for systematic accumulation per D3.3 Section 3.4 stackability rules:

(a) Multiple Level 1 micro-credentials combine toward Level 2 learning units when addressing unit learning outcome requirements;

(b) Multiple Level 2 learning units combine toward Level 3 comprehensive qualifications when completing required units per D3.1 core curriculum specifications;

(c) Learning achieved through flexible skills track (individual micro-credentials) receives equivalent recognition to structured qualification track (complete curriculum enrolment).

5.2 Recognition of Prior Learning

When learners present credentials from other Participating Institutions for credit toward qualifications, Recognising Institutions:

(a) Map presented credentials to target programme learning outcomes;

(b) Identify gaps requiring additional learning for completion;

(c) Grant credit for completed learning outcomes without repetition;

(d) Document recognition decisions with rationale.

5.3 Partial Credit Recognition

If presented credentials partially address target programme requirements, Recognising Institutions may grant proportional credit based on learning outcome overlap, with remaining requirements specified for learner completion.

Article 6: Information Sharing and Transparency

6.1 Programme Information

Participating Institutions agree to maintain publicly accessible information regarding:

(a) Credential types issued under D4S;

(b) Admission requirements for programmes;

(c) Credit recognition policies and procedures;

(d) Contact points for recognition inquiries.

Information maintained at [consortium website URL] and institutional websites.

6.2 Annual Reporting

Participating Institutions provide annual reports to consortium coordination documenting:

(a) Number and type of credentials issued;

(b) Learner enrolments in D4S programmes;

(c) Credential recognition decisions (anonymised data);

(d) Quality assurance activities undertaken.

6.3 Learner Information

Participating Institutions provide clear information to learners regarding:

(a) Credential recognition within consortium (specifying which institutions participate);

(b) Stackability pathways and accumulation rules;

(c) Recognition limitations (e.g., recognition does not guarantee admission or employment);

(d) Procedures for credential presentation and verification.

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Article 7: Financial Arrangements

7.1 No Recognition Fees

Participating Institutions agree not to charge learners additional fees for recognising credentials issued by other Participating Institutions beyond standard institutional fees for credit transfer assessment or admission processing.

7.2 Cost Sharing for Consortium Activities

Costs for consortium-level activities (coordination meetings, shared registry maintenance, external examiner networks) shared equally among Participating Institutions or according to cost-sharing agreements established through consortium governance.

7.3 Technical Infrastructure Costs

Each Participating Institution bears own costs for technical infrastructure implementation (student information systems, credential issuance platforms, verification systems).

Article 8: Governance and Coordination

8.1 Consortium Coordination Committee

Participating Institutions establish a Consortium Coordination Committee comprising one representative per institution responsible for:

(a) Monitoring Agreement implementation;

(b) Addressing recognition disputes;

(c) Coordinating quality assurance activities;

(d) Recommending Agreement amendments.

Committee meets minimum biannually, with decisions made by consensus or, if consensus unattainable, by two-thirds majority vote.

8.2 Dispute Resolution

Recognition disputes between Participating Institutions addressed through:

(a) Direct bilateral discussion between institutions;

(b) Mediation through Consortium Coordination Committee if bilateral resolution unsuccessful;

(c) Independent expert review if mediation unsuccessful, with expert costs shared equally by disputing parties.

Disputes involving learner rights addressed expeditiously, with interim measures (such as provisional recognition) considered to avoid prejudicing learner progress.

8.3 Amendment Procedures

This Agreement may be amended by written consent of all Participating Institutions. Amendments proposed through Consortium Coordination Committee and circulated for institutional approval with minimum 60 days review period.

Article 9: Duration and Withdrawal

9.1 Agreement Duration

This Agreement enters into force upon signature by minimum three Participating Institutions and remains in effect until [DATE] (minimum 5 years from project completion), with automatic renewal for successive 3-year periods unless terminated per Article 9.3.

9.2 New Participants

Institutions outside the Digital4Sustainability consortium may join this Agreement by:

(a) Demonstrating commitment to D4S Framework quality standards;

(b) Obtaining approval from Consortium Coordination Committee by two-thirds majority;

(c) Signing Accession Protocol adopting all Agreement provisions.

9.3 Withdrawal

Participating Institutions may withdraw from this Agreement by providing written notice to all other Participating Institutions minimum 12 months prior to withdrawal effective date. Withdrawal does not affect:

(a) Recognition obligations for credentials issued prior to withdrawal effective date;

(b) Learner rights to present credentials issued prior to withdrawal;

(c) Financial obligations for consortium activities incurred prior to withdrawal.

9.4 Agreement Termination

This Agreement terminates if fewer than three Participating Institutions remain. Upon termination, credential recognition continues for credentials issued prior to termination date.

Article 10: Legal Provisions

10.1 Applicable Law

This Agreement governed by laws of [JURISDICTION], without regard to conflict of law principles.

10.2 Severability

If any provision of this Agreement held invalid or unenforceable, remaining provisions continue in full force and effect, with invalid provision replaced by valid provision achieving closest equivalent effect.

10.3 No Partnership or Agency

This Agreement does not create partnership, joint venture, or agency relationship among Participating Institutions. Each institution remains independent legal entity.

10.4 Liability

Each Participating Institution remains solely responsible for its own credential issuance decisions, quality assurance processes, and compliance with national legislation. This Agreement does not create joint liability among Participating Institutions.

Article 11: Signatures

IN WITNESS WHEREOF, the undersigned representatives, being duly authorised, have executed this Agreement on behalf of their respective institutions.

Institution Name	Authorised Signatory	Title	Date	Signature
[Partner 1]				
[Partner 2]				
[Partner 3]				
[Partner 4]				
[Partner 5]				
[Partner 6]				
[Partner 7]				
[Partner 8]				
[Partner 9]				
[Partner 10]				

For consortium coordination contact: [Consortium Coordinator Name and Institution] [Email] [Address]

E. Employer Declaration of Understanding Templates

Standardised template for securing employer recognition of D4S credentials for recruitment and professional development (Track 2 sectoral validation)

E1. Template for Employer Declaration of Understanding

DIGITAL4SUSTAINABILITY EMPLOYER DECLARATION OF UNDERSTANDING

Employer/Organisation Name: _____

Country: _____

Sector: ☐ Technology ☐ Consulting ☐ Manufacturing ☐ Public Sector ☐ Other: _____

Organisation Size: ☐ SME (<250 employees) ☐ Large (≥250 employees)

Date: _____

Declaration

[Organisation Name] hereby declares its understanding and recognition of the Digital4Sustainability Certification Framework and associated credentials developed through the Digital4Sustainability project (EU Grant Agreement No. [NUMBER]).

1. Framework Understanding

We understand that the Digital4Sustainability Certification Framework:

- Addresses digital sustainability competences identified through labour market analysis;
- Aligns with European competence frameworks (e-CF, GreenComp);
- Operates through three stackable levels: micro-credentials (0.5-2.5 ECTS), learning units, and comprehensive qualifications (60-90 ECTS);
- Employs quality assurance procedures aligned with ESG 2015 and EQAVET standards;
- Issues credentials through accredited partner institutions.

2. Recognition for Recruitment

[Organisation Name] agrees to recognise Digital4Sustainability credentials in recruitment processes as follows (check all applicable):

☐ **Job Posting:** Include credentials in job advertisements as preferred or required qualifications for relevant positions

☐ **Candidate Screening:** Consider credential holders as meeting specific competence requirements in initial screening

☐ **Interview Process:** Recognise credential achievement as evidence of competence development in candidate evaluation

☐ **Hiring Decisions:** Weight credential achievement alongside other qualifications (degrees, work experience, other certifications) in hiring decisions

Specific roles for which credentials are relevant:

3. Recognition for Professional Development

[Organisation Name] agrees to recognise Digital4Sustainability credentials for employee professional development as follows (check all applicable):

☐ **CPD Hours:** Acknowledge credentials for continuing professional development hour requirements

☐ **Internal Advancement:** Consider credential achievement in promotion and internal role transition decisions

☐ **Training Budget:** Support employee pursuit of credentials through training budget allocation or study leave

☐ **Skill Gap Addressing:** Recommend credentials to employees for addressing identified competence gaps

4. Workforce Value Statement

[Organisation Name] identifies the following Digital4Sustainability competences as valuable for our workforce:

☐ **Circular Economy in Digital Systems:** Designing and implementing circular economy principles in digital product/service lifecycle

☐ **Cybersecurity for Sustainable Systems:** Securing digital infrastructure while optimising energy efficiency and resource utilisation

☐ **Digital Sustainability Foundations:** Understanding core concepts linking digital technology and environmental sustainability

☐ **EU Policy and Legislation:** Navigating European digital sustainability regulations, standards, and compliance requirements

☐ **Green Software Fundamentals:** Developing energy-efficient, resource-optimised software and applications

☐ **Sustainability Data Essentials:** Collecting, analysing, and reporting sustainability data for decision support

Additional competences or specific skills valued:

5. Co-Design and Partnership

[Organisation Name] has participated in Digital4Sustainability framework development through (check all applicable):

☐ **Needs Analysis:** Contributed to labour market analysis identifying competence requirements

☐ **Curriculum Review:** Reviewed and provided feedback on learning outcomes and curriculum specifications

☐ **Assessment Design:** Consulted on assessment approaches ensuring workplace relevance

☐ **Work-Based Learning:** Provided or committed to provide work placements for learners

☐ **Advisory Board:** Participated in employer advisory board providing ongoing guidance

6. Limitations and Qualifications

This Declaration represents [Organisation Name]'s current understanding and intent regarding credential recognition. It does not:

- Create legal obligation to hire credential holders
- Guarantee employment or specific positions
- Override standard recruitment policies and procedures
- Constitute binding contract between organisation and credential holders or issuing institutions

Recognition of credentials in specific hiring or advancement decisions remains subject to:

- Organisational needs and position requirements at time of decision
- Candidate qualifications including credentials, experience, and other factors
- Internal policies and collective bargaining agreements where applicable

7. Validity and Review

This Declaration remains valid from [DATE] until [DATE] (minimum 3 years recommended), with commitment to review and update based on:

- Credential holder performance in roles
- Evolving organisational competence needs
- Framework updates and modifications

8. Contact Information

Primary Contact for Credential Recognition Inquiries:

Name: _____

Title: _____

Email: _____

Phone: _____

Authorised Signatory:

Name: _____

Title: _____

Signature: _____

Date: _____

Organisation Stamp/Seal (if applicable):

For Digital4Sustainability Consortium:

This Declaration was provided on [DATE] and is documented in D3.3 Annex E.

Consortium Contact: [Name, Email]

E.2 Example Declaration #1 (Anonymised)

DIGITAL4SUSTAINABILITY EMPLOYER DECLARATION OF UNDERSTANDING

Employer/Organisation Name: European Technology Consulting Group (Anonymised)

Country: Germany

Sector: ☒ Consulting ☐ Technology ☐ Manufacturing ☐ Public Sector ☐ Other

Organisation Size: ☐ SME (<250 employees) ☒ Large (≥250 employees)

Date: 15 March 2025

1. Framework Understanding

We understand that the Digital4Sustainability Certification Framework addresses digital sustainability competences identified through labour market analysis, aligns with European competence frameworks (e-CF, GreenComp), operates through three stackable levels, employs quality assurance procedures aligned with ESG 2015 and EQAVET standards, and issues credentials through accredited partner institutions.

2. Recognition for Recruitment

European Technology Consulting Group agrees to recognise Digital4Sustainability credentials in recruitment processes as follows:

☒ **Job Posting:** Include credentials in job advertisements as preferred qualifications for sustainability consulting and digital transformation roles

☒ **Candidate Screening:** Consider credential holders as meeting digital sustainability competence requirements in initial screening for junior and mid-level consultant positions

☒ **Interview Process:** Recognise credential achievement as evidence of competence development, particularly for candidates with limited work experience in digital sustainability

☒ **Hiring Decisions:** Weight credential achievement alongside degrees, work experience, and other certifications in final hiring decisions

Specific roles for which credentials are relevant:

- Junior Sustainability Consultant (focus: Digital Sustainability Foundations, EU Policy and Legislation)
- Digital Transformation Analyst (focus: Green Software Fundamentals, Sustainability Data Essentials)
- Circular Economy Specialist (focus: Circular Economy in Digital Systems)

3. Recognition for Professional Development

☒ **CPD Hours:** Acknowledge credentials for continuing professional development requirements (1 ECTS = 8 CPD hours per internal policy)

☒ **Internal Advancement:** Consider credential achievement in promotion decisions, particularly for consultants seeking senior specialist or team lead roles

☒ **Training Budget:** Support employee pursuit of credentials through training budget allocation up to €2,500 per employee per year for approved digital sustainability credentials

☒ **Skill Gap Addressing:** Recommend credentials to employees based on annual competence assessments and project needs

4. Workforce Value Statement

European Technology Consulting Group identifies the following Digital4Sustainability competences as valuable for our workforce:

☒ **Circular Economy in Digital Systems** - High value for circular economy and product lifecycle consulting projects

☒ **Digital Sustainability Foundations** - Essential foundational competence for all consultants in sustainability practice area

☒ **EU Policy and Legislation** - Critical for client advisory on regulatory compliance (CSRD, EU Taxonomy, Ecodesign)

☒ **Green Software Fundamentals** - Growing importance for digital transformation projects integrating sustainability criteria

☒ **Sustainability Data Essentials** - Essential for ESG reporting, materiality assessment, and sustainability performance analysis projects

Additional competences valued: Carbon footprint analysis for digital infrastructure; Life cycle assessment for digital products; Stakeholder engagement for sustainability transformation

5. Co-Design and Partnership

☒ **Needs Analysis:** Contributed to labour market analysis through interviews (October 2023) and competence requirement specification

☒ **Curriculum Review:** Reviewed learning outcomes for Digital Sustainability Foundations and EU Policy and Legislation curricula (February 2024)

☒ **Advisory Board:** Participated in employer advisory board meetings (November 2023, March 2024, July 2024)

☒ **Work-Based Learning:** Committed to provide 5-10 work placements annually for learners pursuing comprehensive qualifications

6. Limitations and Qualifications

This Declaration represents European Technology Consulting Group's current understanding and intent. It does not create legal obligation to hire credential holders, guarantee employment, or override standard recruitment policies. Recognition remains subject to organisational needs, candidate qualifications, and internal policies at time of decision.

7. Validity and Review

Valid from 15 March 2026 until 15 March 2028, with commitment to review based on credential holder performance and evolving competence needs.

8. Contact Information

Primary Contact: Dr. [NAME REDACTED]
Title: Head of Sustainability Practice
Email: [REDACTED]@consulting-group.example
Phone: +49 [REDACTED]

Authorised Signatory:
Name: [NAME REDACTED]
Title: Managing Partner, Central Europe
Date: 15 March 2025

E.3 Example Declaration #2 (Anonymised)

DIGITAL4SUSTAINABILITY EMPLOYER DECLARATION OF UNDERSTANDING

Employer/Organisation Name: Nordic Green Tech Alliance (Anonymised)

Country: Sweden

Sector: ☐ Consulting ☒ Technology ☐ Manufacturing ☐ Public Sector ☐ Other

Organisation Size: ☒ SME (<250 employees) ☐ Large (≥250 employees)

Date: 22 March 2025

1. Framework Understanding

We understand that the Digital4Sustainability Certification Framework addresses digital sustainability competences, aligns with e-CF and GreenComp, operates through stackable levels, employs ESG/EQAVET-aligned quality assurance, and issues credentials through accredited institutions.

2. Recognition for Recruitment

Nordic Green Tech Alliance agrees to recognise credentials as follows:

☒ **Job Posting:** Include credentials as preferred qualifications for software engineering and data analysis positions with sustainability focus

☒ **Candidate Screening:** Consider credential holders as demonstrating commitment to sustainability competence development

☒ **Interview Process:** Discuss credential learning outcomes and application in technical interviews

☒ **Hiring Decisions:** Weight credentials alongside technical skills assessment, portfolio review, and cultural fit evaluation

Specific roles:

- Green Software Developer (Green Software Fundamentals, Cybersecurity for Sustainable Systems)
- Sustainability Data Analyst (Sustainability Data Essentials, Digital Sustainability Foundations)

3. Recognition for Professional Development

☒ **CPD Hours:** Acknowledge credentials for professional development tracking (not formally required but encouraged)

☒ **Training Budget:** Support credential pursuit through €1,500 annual training allocation per employee

☒ **Skill Gap Addressing:** Recommend credentials for developers transitioning to sustainability-focused roles

4. Workforce Value Statement

☒ **Cybersecurity for Sustainable Systems** - Relevant for securing energy-efficient IoT infrastructure

☒ **Green Software Fundamentals** - Core competence for all developers in organisation

☒ **Sustainability Data Essentials** - Important for product sustainability impact measurement and reporting

Additional competences valued: Energy optimisation in cloud computing; Sustainable UX/UI design; IoT sensor networks for environmental monitoring

5. Co-Design and Partnership

☒ **Needs Analysis:** Contributed to SME needs analysis through focus group (November 2023)

☒ **Curriculum Review:** Provided feedback on Green Software Fundamentals curriculum (January 2024)

☒ **Work-Based Learning:** Provide project-based learning opportunities for 2-3 learners per year through mentored sustainability feature development

6. Limitations and Qualifications

This Declaration represents intent. It does not create hiring obligations, guarantee employment, or override recruitment policies. Recognition subject to organisational needs and candidate qualifications.

7. Validity and Review

Valid from 22 March 2025 until 22 March 2028.

8. Contact Information

Primary Contact: [NAME REDACTED]

Title: CTO

Email: [REDACTED]@greentech-alliance.example

Phone: +46 [REDACTED]

Authorised Signatory:

Name: [NAME REDACTED]

Title: CEO

Date: 22 March 2026

F. Technical Specifications for Implementation

Short, practical guidance for partners implementing credential systems

F1 Credential Verification Procedures

F1.1 Digital Signature Verification

To run a digital signature verification each institution publishes their public key at a stable URL (e.g., https://institution.eu/credentials/public-key.pem) and registers it in the consortium credential registry at digital4sustainability.eu/registry. The registry serves as a trusted directory listing all partner institutions, their public key URLs, credential types issued, and validity dates. Consortium coordination maintains the registry while partners self-certify their keys. This web-of-trust model bases trust on consortium membership rather than a central certificate authority. Partners pursuing Track 3 national recognition may additionally register keys with national quality assurance agencies as required.

Purpose: Ensure credential authenticity and detect tampering.

Technical Requirements:

- Public Key Infrastructure (PKI) with institutional key pairs;
- ECDSA (Elliptic Curve Digital Signature Algorithm) or RSA-2048 minimum;
- Hashing: SHA256 minimum;
- Signature embedded in Europass EDCI JSON/XML under proof field;

Verification Steps:

1. Extract credential JSON/XML from learner presentation;
2. Retrieve issuer's public key from institutional registry or embedded key reference;
3. Extract signature from proof.jws field;
4. Verify signature using public key cryptography;
5. Confirm signature matches credential content (no tampering);
6. Check issuance date within valid range.

Each partner generates a cryptographic key pair: a private key (kept secure for signing) and a public key (published for verification). Private keys must be stored securely using Hardware Security Modules or institutional key management services. Public keys are published at stable institutional URLs and registered in the consortium credential registry. Key rotation procedures ensure new keys are published in advance while old keys remain available for historical verification.

To verify a credential, the verifier extracts the credential data (JSON/XML) from the learner's presentation, retrieves the issuer's public key from the registry or embedded reference, and verifies the cryptographic signature from the proof.jws field using ECDSA (recommended for smaller key sizes and faster mobile performance) or RSA-2048. Verification also confirms the issuance date falls within a valid range and checks expiration or revocation status where applicable. This decentralised approach enables robust verification without centralised databases or blockchain networks while maintaining learner control over credential sharing.

Verification also includes validation of the credential's issuance date and, where applicable, its expiration or revocation status, to confirm that the credential is current and enforceable. The process relies on established public key infrastructure (PKI) principles, with institutions responsible for securely managing keys, publishing trust anchors, and supporting key rotation or revocation. This approach enables decentralised verification without requiring centralised databases or blockchain networks, while ensuring robustness, compliance with EU standards, and learner control over credential sharing.

Implementation Note: Institutions are encouraged to use existing, secure PKI infrastructure for credential signing wherever possible. If dedicated credential signing keys are required, they must be generated and managed following best-practice cryptographic key management, ideally using a Hardware Security Module (HSM) or a trusted key management service. Private keys must remain securely stored and never exposed on local systems. Public keys should be published at stable, auditable URLs, referenced in credential metadata to enable reliable verification. Adopting this approach ensures that credentials are tamper-proof, verifiable, and compliant with EU

security and interoperability standards, while mitigating the risks associated with ad hoc key generation.

F.1.2 Issuer Verification

Purpose: Confirm credential issued by legitimate D4S consortium partner.

Consortium Registry: Maintained at https://digital4sustainability.eu/registry listing:

- Partner institution names and identifiers (ERASMUS codes, national registry numbers);
- Credential types authorised to issue;
- Public key URLs for signature verification;
- Contact points for verification queries;
- Dates of consortium membership.

Verification Process:

1. Extract issuer identifier from credential issuer.id field;
2. Query consortium registry confirming issuer membership;
3. Verify issuer authorised to issue specific credential type;
4. Confirm credential issuance date within membership period.

The issuer verification process starts by extracting the issuer identifier from the credential's issuer.id field. This identifier is then used to query the consortium registry to confirm that the issuer is a recognised member. Next, it is verified that the issuer is authorised to issue the specific type of credential in question. Finally, the process confirms that the credential's issuance date falls within the issuer's active membership period, ensuring the credential was issued legitimately under the consortium's governance rules.

F.1.3 Revocation Checking

Purpose: Identify credentials revoked due to fraud, error, or learner request.

Revocation Registry: Maintained at https://digital4sustainability.eu/revocation as distributed ledger or centralised database listing:

- Revoked credential unique identifiers
- Revocation date and reason (fraud / administrative error / learner request)
- Issuing institution

Checking Process:

1. Extract credential ID from credential.id field;
2. Query revocation registry for credential ID;
3. If present: credential invalid, do not recognise;
4. If absent: credential valid, continue verification.

Privacy Note: Only credential IDs listed, no learner personal data. Learners retain GDPR right to request credential revocation

F.2 Version Control Procedures

F.2.1 Framework Specification Versioning

Purpose: Track framework updates while maintaining implementation stability.

Version Numbering: Semantic versioning (MAJOR.MINOR.PATCH)

- MAJOR: Breaking changes requiring credential redesign (e.g., 1.0 → 2.0);
- MINOR: Backwards-compatible additions (e.g., 1.0 → 1.1, new optional fields);
- PATCH: Bug fixes and clarifications (e.g., 1.0.0 → 1.0.1).

Current Version: D3.3 specifications represent Version 1.0.0 (initial release)

F.2.2 Change Documentation

All specification updates documented in change log including:

- Version number and release date;
- Summary of changes (what changed and why);
- Backwards compatibility impact;
- Migration guidance for implementing institutions;
- Responsible party authorising change.

Example Change Log Entry:

Version 1.1.0 (Released: 15 June 2027)

- ADDED: Optional field for blockchain anchor in credential metadata

- MODIFIED: Expanded GreenComp alignment to v2.0 (released 2026)

- DEPRECATED: Legacy ECVET credit field (migration: use ECTS only)

- RATIONALE: EU policy evolution, stakeholder feedback

- BACKWARDS COMPATIBLE: Yes (optional additions only)

- MIGRATION: No action required; new fields optional

- AUTHORIsED BY: Consortium Coordination Committee (Decision 2027-02)

F.2.3 Credential Versioning

Individual credentials reference framework version used:

- Embedded in credential metadata: "frameworkVersion": "1.0.0"
- Enables recognition of credentials issued under different versions
- Recognising institutions consult version-specific recognition guidance

Recommendation: Maintain recognition of credentials issued under previous framework versions for minimum 10 years, ensuring learner credential value persists despite framework evolution.

Co-funded by the European Union

F.3 System Integration Guidance

F.3.1 Student Information System Integration

Objective: Enable credential issuance from existing institutional systems without parallel infrastructure.

Integration Approaches:

Option 1: API Integration

- Institutional SIS exposes learner achievement data via secure API;
- Credential generation service retrieves data, creates EDCI-compliant JSON/XML;
- Generated credential returned to SIS for storage and learner access;
- **Complexity:** Moderate (requires API development);
- **Flexibility:** High (decoupled systems).

Option 2: Export-Import

- SIS exports learner achievement data as a structured file (CSV or JSON);
- Credential generation tool processes export, creates credentials;
- Credentials imported back to SIS or separate credential repository;
- **Complexity:** Low (minimal SIS modification);
- **Flexibility:** Moderate (manual or scheduled batch processes).

SIS exports learner achievement data as a structured file (CSV or JSON), with all exported files encrypted in transit and at rest to protect personal and sensitive information.

Option 3: Plugin/Extension

- Credential generation implemented as SIS plugin or module
- Direct database access for learner achievement data
- Credentials generated within SIS environment
- **Complexity:** High (requires SIS-specific development)

Flexibility: Low (tightly coupled to SIS)

Each partner develops and maintains their own plugin for their specific student information system. D3.3 provides technical specifications only, not actual plugin code. Plugin development and support remain partner IT responsibility, not a consortium deliverable.

Direct database access requires institutional IT governance approval, GDPR compliance, role-based access controls limiting permissions to read-only achievement data, and audit logging of queries. The plugin operates within existing institutional security infrastructure rather than as an external system requiring separate authentication.

Recommendation: Option 1 (API) preferred for maintainability and vendor independence. Option 2 (Export-Import) acceptable for low-volume implementations or pilot phases.

F.3.2 Credential Storage and Delivery

Learner Credential Wallets:

- Institutions may implement dedicated credential wallet applications (web-based or mobile);
- Alternative: Learners store credentials in Europass platform (when available) or personal cloud storage;
- Credentials remain learner-controlled; institutions provide issuance not mandatory long-term storage.

Institutional Repositories:

- Maintain credential issuance records for verification purposes (minimum 10 years recommended);
- Store cryptographic keys securely (Hardware Security Module - HSM or key management service);
- Access control and auditing: Implement strict role-based access control (RBAC) to restrict access to credential data to authorised staff only. All access and administrative operations should be logged for audit purposes, ensuring accountability and traceability in line with GDPR and institutional security policies.

- Revocation and update management: Support mechanisms to revoke, update, or expire credentials if necessary, including recording the reason and date of revocation. This ensures that verifiers can determine the current validity of a credential at any time.

Delivery Mechanisms:

- Email credential file directly to learner (encrypted attachment);
- Institutional portal download with authentication;
- Integration with European Digital Identity Wallet (eIDAS 2.0, when operational).

F.3.3 Verification Service Implementation

Institutional Verification Portal:

- Public web service accepting credential uploads or verification URLs;
- Performs signature verification, issuer confirmation, revocation checking;
- Returns verification status: VALID / INVALID / UNKNOWN;
- Displays credential metadata if valid (learning outcomes, ECTS, EQF level)

Technical Stack Suggestions:

- Node.js (v18 LTS+), Python (Flask v2.3+ / Django v4.2 LTS+), Java Spring Boot (v3.0+), .NET Core (v7.0+), Ruby on Rails (v7.0+)
- Cryptography: OpenSSL (v3.0+), Node.js crypto (built-in), Python cryptography (v41.0+), Java Bouncy Castle (v1.70+), .NET System.Security.Cryptography
- Database: PostgreSQL (v14+), MongoDB (v6.0+), MySQL (v8.0+), MariaDB (v10.6+)
- Frontend: React (v18+), Vue.js (v3+), Angular (v15+), Svelte (v4.0+), server-rendered HTML

Open Source Reference Implementation: The Consortium will provide a reference implementation (GitHub repository) demonstrating:

- Europass EDCI JSON parsing;
- Signature verification using multiple algorithms;

- Issuer and revocation registry queries;
- Minimal web interface for verification requests.

Institutions may adopt, adapt, or implement independently following specifications.

F.4 Data Protection and Privacy

F.4.1 GDPR Compliance

Legal Basis for Processing:

- Credential issuance: Contract performance (GDPR Art. 6(1)(b)) - credential issuance fulfils educational service contract;
- Verification: Legitimate interest (GDPR Art. 6(1)(f)) - verifying credential authenticity serves legitimate interest of recognising institution and learner.

Data Minimisation:

- Credentials contain only data necessary for recognition: learner name, credential title, learning outcomes, ECTS/EQF, issuance date;
- Exclude unnecessary personal data: address, date of birth (unless required for legal identification), contact details.

Learner Rights:

- **Right to Access (Art. 15):** Learners request copies of issued credentials and associated records
- **Right to Rectification (Art. 16):** Learners request correction of errors in credentials (institutions assess validity of request)
- **Right to Erasure (Art. 17):** Learners request credential revocation and deletion from institutional records (subject to legal retention requirements for academic records - typically 10+ years)
- **Right to Data Portability (Art. 20):** Credentials issued in portable EDCI format enabling learner-controlled sharing

Data Protection Impact Assessment (DPIA): Institutions should conduct DPIA if credential systems involve:

- Large-scale processing of learner data
- Automated decision-making affecting learners
- Cross-border data transfers outside EU/EEA

F.4.2 Attendance Certificates

Attendance certificates document learner participation and competence demonstration in short learning programmes without carrying ECTS credits or formal qualification status. These certificates serve professional development contexts where employer recognition of demonstrated skills matters more than academic credit. Attendance certificates operate based on internal quality standards rather than external quality assurance agency validation.

Partners unable to issue ECTS-bearing credentials may utilise attendance certificates as a Track 2 approach. For example, Cefriel provides open badge certificates of attendance documenting competence demonstration through assessment while not carrying formal academic credit. Open badge platforms enable metadata embedding, learner-controlled sharing, and employer verification.

Certificate value depends on issuer reputation, learning outcome transparency, assessment rigor, and sectoral recognition. Attendance certificates do not constitute qualifications within National Qualifications Frameworks, though documented achievements may support Recognition of Prior Learning applications for formal qualifications.

F.4.3 Credential Sharing Control

Learner Consent: Credential sharing requires learner action (upload, send, or authorise access). Institutions do not share credentials with third parties without learner consent except where legally required (e.g., quality assurance audits, legal proceedings).

Selective Disclosure: Where technically feasible, enable learners to share subset of credential information (e.g., credential title and issuance date without detailed learning outcomes) for privacy-preserving verification.

F.5 Technical Support Resources (to be set up!)

Consortium Technical Support:

- Email: technical-support@digital4sustainability.eu
- Documentation: https://digital4sustainability.eu/technical-docs
- GitHub Repository: https://github.com/digital4sustainability/credentials (reference implementations, schemas, tools)

Implementation Resources:

- Europass EDCI v3 JSON schema: https://github.com/european-commission-europass/Europass-Learning-Model
- Sample credential files (test data)
- Signature generation and verification scripts
- Integration testing tools

Partner Implementation Community: Consortium maintains implementation community (mailing list, quarterly video calls) enabling partners to:

- Share implementation experiences and solutions
- Troubleshoot technical challenges collaboratively
- Coordinate specification updates and improvements

G. National Recognition Requirements Matrix

The following matrix summarises micro-credential recognition requirements per partner country, based on survey responses.

Table G.1 National Recognition Requirements Matrix

Country	MC Framework	NQF Integration	QA Agency	Award Authority in Consortium	Estimated Timeline
Estonia	Established	Automatic	EKKA	BCS Koolitus	6 months
Ireland	Established	via QQI	QQI	NCI (via QQI validation)	6–12 months
Croatia	Established	Automatic	ASHE	Profil Klett	6–12 months
Spain	Developing	Conditional	ANECA	UAH, UNIR	12–18 months
Romania	Developing	Conditional	ARACIS	UPB	12–18 months
Italy	Developing	Conditional	ANVUR	CEFRIEL (via Politecnico)	12–18 months
Bulgaria	Developing	Conditional	NEAA/NAVET	None (BASSCOM = industry)	18+ months
Hungary	Developing	Not yet	HAC	None (IVSZ = industry)	18+ months
Slovenia	Developing	Not yet	SQAA	CPU Slovenia	12–18 months
Germany	No response	Unknown	Various	None (Fast Lane = industry)	Unknown

Key for Timeline Estimates:

- 6 months: Established framework, partner has award authority;
- 6–12 months: Established framework, validation partnership required;
- 12–18 months: Developing framework, partner has award authority;
- 18+ months: Developing framework, no award authority in consortium.

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H. Learning Units

Table H: Learning Units for Digital Sustainability Education established in D3.1

LU ID	Learning Unit Title	Domain	Delivery Mode	ECTS	Profile Relevance (DAS, DPS, DSC, DSM, STS)
LU01	Digital Sustainability Foundations	Foundation	online, self-paced	0.5	(100, 100, 100, 100, 100)
LU02	Sustainability Data Foundations	Data & Analytics	online, blended	5.0	(95, 57, 95, 85, 25)
LU03	Data Collection and Quality for Sustainability	Data & Analytics	blended, work-based	5.0	(95, 95, 45, 45, 45)
LU04	Data Analytics for Sustainability Insights	Data & Analytics	blended, work-based	5.0	(85, 85, 57, 45, 45)
LU05	Sustainable Software Engineering Fundamentals	Technology & Infrastructure	online, blended	1.5	(25, 25, 55, 30, 95)
LU06	Systems Architecture for Sustainability Solutions	Technology & Infrastructure	blended, work-based	5.0	(85, 25, 57, 25, 85)
LU07	Ethics and Governance in Digital Innovation	Strategy & Management	online, blended	5.0	(45, 45, 80, 57, 45)
LU08	Circular Economy and Digital Product Design	Strategy & Management	blended, work-based	5.0	(30, 55, 95, 95, 30)
LU09	Technical Implementation of Sustainability Solutions	Technology & Infrastructure	blended, work-based	5.0	(45, 25, 40, 20, 95)
LU10	Introduction to Life Cycle Assessment (LCA)	Measurement & Analysis	online, blended	5.0	(45, 45, 57, 45, 45)
LU11	Advanced Sustainability Data Science	Data & Analytics	blended, work-based	5.0	(85, 85, 57, 45, 45)
LU12	Energy-Efficient Software Architecture	Technology & Infrastructure	blended, work-based	1.0	(85, 25, 57, 25, 85)
LU13	Digital Sustainability Principles and Practices	Foundation	online, blended	5.0	(85, 25, 57, 30, 85)
LU14	Business Intelligence for Sustainability	Data & Analytics	online, blended	3.0	(85, 65, 70, 75, 30)
LU15	Organisational Transformation for Sustainability	Strategy & Management	blended, work-based	5.0	(25, 45, 95, 95, 25)
LU16	Sustainability Strategy Development	Strategy & Management	blended, work-based	5.0	(25, 45, 95, 85, 25)

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LU17	Change Management for Digital Sustainability	Strategy & Management	blended, work-based	5.0	(25, 45, 95, 85, 25)
LU18	Leadership for Sustainable Digital Transformation	Strategy & Management	blended, work-based	5.0	(25, 45, 85, 85, 25)
LU19	Public Engagement and Science Communication	Strategy & Management	blended, work-based	5.0	(25, 45, 95, 95, 25)
LU20	Digital Storytelling for Sustainability Impact	Strategy & Management	online, blended	5.0	(25, 57, 85, 85, 25)
LU21	Systematic Innovation in Sustainability Contexts	Technology & Infrastructure	blended, work-based	5.0	(85, 25, 57, 30, 85)
LU22	Technology Assessment for Sustainability	Technology & Infrastructure	blended, work-based	5.0	(85, 25, 80, 30, 85)
LU23	Predictive Modelling for Sustainability Scenarios	Data & Analytics	blended, work-based	5.0	(80, 70, 75, 65, 60)
LU24	Data Visualisation for Sustainability Communication	Data & Analytics	online, blended	3.0	(85, 65, 80, 75, 55)
LU25	Stakeholder Engagement for Sustainability Initiatives	Policy & Compliance	blended, work-based	5.0	(25, 45, 85, 85, 25)
LU26	Sustainability Reporting Standards and Frameworks	Policy & Compliance	online, blended	5.0	(30, 55, 95, 95, 30)
LU27	Machine Learning Applications in Sustainability	Data & Analytics	blended, work-based	5.0	(95, 95, 45, 45, 45)
LU28	Business Models for Sustainable Digital Innovation	Strategy & Management	blended, work-based	5.0	(25, 45, 95, 95, 25)
LU29	Data Governance and Ethics for Sustainability	Data & Analytics	online, blended	5.0	(55, 95, 80, 67, 55)
LU30	Sustainable IT Operations and Management	Technology & Infrastructure	blended, work-based	5.0	(95, 25, 55, 30, 95)
LU31	ICT Energy Management and Optimisation	Technology & Infrastructure	blended, work-based	5.0	(95, 25, 67, 30, 95)
LU32	Green Software Development Practices	Technology & Infrastructure	blended, online	5.0	(85, 20, 80, 20, 85)
LU33	Big Data Technologies for Sustainability Analysis	Data & Analytics	blended, work-based	5.0	(95, 95, 57, 45, 45)
LU34	Sustainability Project	Foundation	Work-based	5.0–7.5	(47, 47, 80, 80, 35)

LU35	Carbon Footprint Analysis and Reduction Strategies	Measurement & Analysis	blended, work-based	5.0	(95, 95, 57, 45, 45)
LU36	ESG Reporting and Disclosure	Policy & Compliance	online, blended	5.0	(25, 57, 95, 95, 25)
LU37	Environmental Impact Assessment in Digital Context	Measurement & Analysis	blended, work-based	5.0	(45, 45, 57, 45, 45)
LU38	Green ICT Principles	Technology & Infrastructure	online, self-paced	1.0	(85, 25, 45, 25, 85)
LU39	Sustainability Reporting and Dashboards	Data & Analytics	blended, work-based	2.5	(90, 70, 85, 85, 40)
LU40	Data Analytics Tools and Platforms	Data & Analytics	online, blended	3.0	(95, 80, 60, 65, 35)
LU41	ESG Data Management and Quality Assurance	Data & Analytics	blended, work-based	2.5	(85, 75, 90, 90, 30)
LU42	EU Green Deal: Foundations and Framework	Policy & Compliance	online, self-paced	2.0	(10, 22, 94, 42, 10)
LU43	EU Taxonomy Regulation: Classification and Compliance	Policy & Compliance	online, self-paced	2.0	(10, 22, 82, 30, 10)
LU44	Corporate Sustainability Reporting Directive (CSRD)	Policy & Compliance	online, blended	5.0	(10, 22, 82, 80, 10)
LU45	Sustainable Finance Disclosure Regulation (SFDR) Fundamentals	Policy & Compliance	online, self-paced	2.0	(10, 22, 82, 30, 10)
LU46	Introduction to Cybersecurity for Sustainable Systems	Technology & Infrastructure	online, blended	2.5	(50, 25, 75, 70, 85)
LU47	Cybersecurity for Sustainable Systems	Technology & Infrastructure	blended, work-based	5.0	(25, 80, 80, 25, 85)
LU48	EU Climate Law and Net Zero Implementation	Policy & Compliance	online, self-paced	2.0	(10, 22, 94, 30, 10)
LU49	Data-Driven Decision Making for Sustainability	Data & Analytics	blended, work-based	5.0	(90, 75, 85, 85, 70)
LU50	EU Sustainability Legislation: Integrated Overview	Policy & Compliance	online, self-paced	1.5	(100, 100, 100, 100, 100)
LU51	Digital Inclusion and Social Sustainability	Policy & Compliance	online, blended	5.0	(45, 45, 85, 80, 45)

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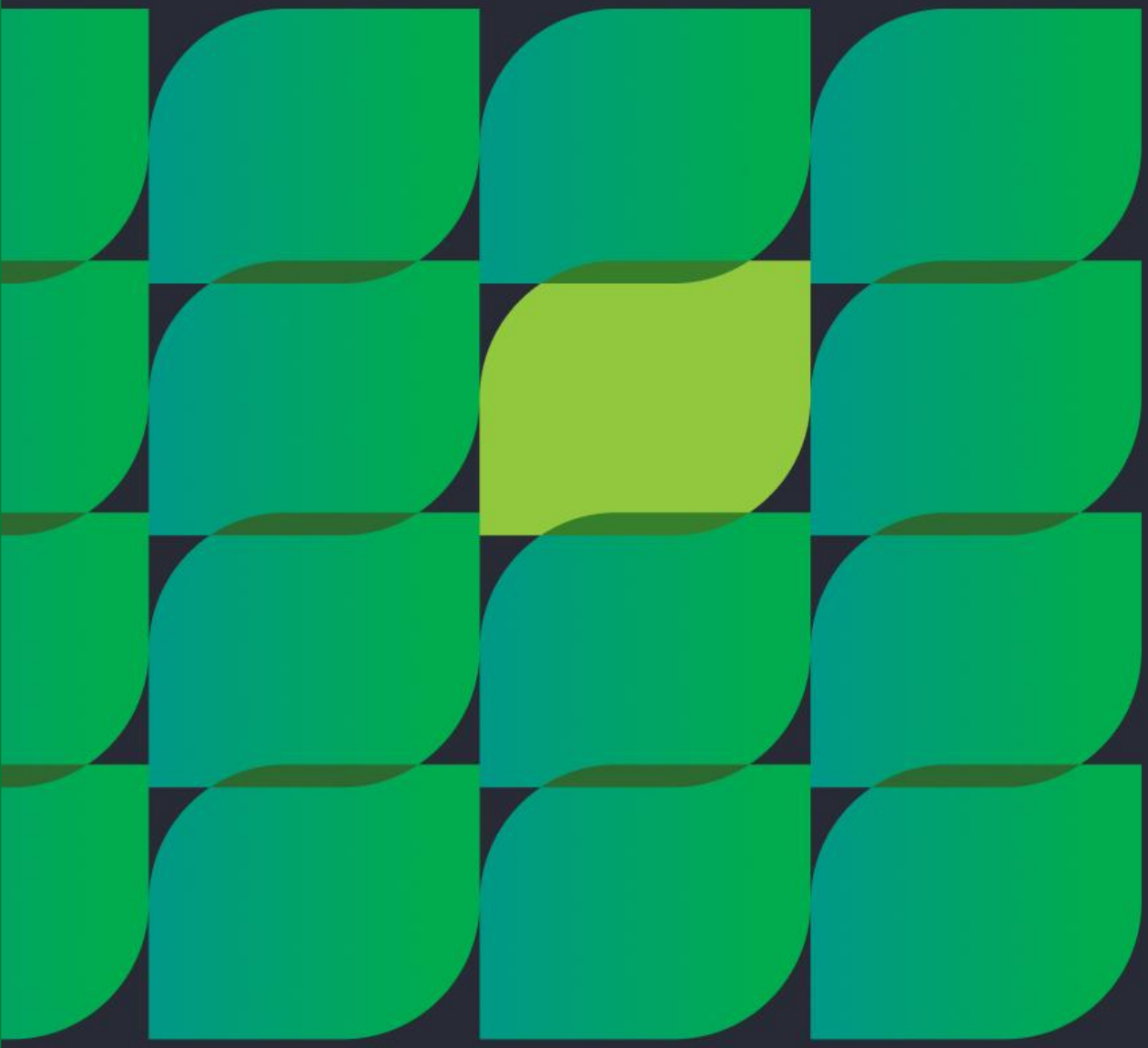

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