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EXCEL4HOUSING4.0

Project Number: 101194



D.2.2 – Rapport sur l'analyse de l'état de l'art

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1. Synthèse

L'Analyse de l'État de l'Art D2.2 sert de recherche fondamentale pour le projet EXCEL4Housing 4.0, cartographiant les tendances actuelles, les pressions réglementaires et les déficiences systémiques en matière de compétences au sein du secteur européen du bâtiment. La conclusion centrale est que si l'Union européenne a établi un cadre législatif solide pour la Transition Verte (Refonte de la DEPB, Taxonomie de l'UE, CSRD), la capacité du secteur à exécuter cette transition — la Capacité de Mise en Œuvre — est considérablement limitée par un déficit de compétences multiples et en accélération.

Note méthodologique sur les données ukrainiennes: Alors que les métriques pour les États membres de l'UE suivent principalement Eurostat et les Plans Énergétiques Nationaux, les données pour l'Ukraine sont dérivées des statistiques nationales récentes (2024-2025) et des rapports de reconstruction internationaux. Ces chiffres reflètent le volume des travaux achevés et les besoins urgents de redressement, qui peuvent différer par nature cyclique des taux de rénovation typiquement observés dans l'UE-27.

Conclusions clés par section

Tendances du marché (Réf. Chapitre 3) : le marché évolue d'un modèle traditionnel de construction neuve, cyclique, vers une priorité accordée à la rénovation lourde, rendue obligatoire et portée par les politiques publiques. Alors que l'activité de nouvelle construction a ralenti dans les économies matures (par exemple, l'Allemagne et la Suède) en raison de facteurs macroéconomiques, la demande de rénovation est robuste et non cyclique, soutenue par les Plans de Relance et de Résilience (PRR) dans des pays comme l'Espagne et le Portugal.

Un cas unique au sein du consortium est **l'Ukraine**, où le marché est défini par un effort massif de « Relance Verte » suite à des dommages de guerre à grande échelle. Contrairement aux marchés matures de l'UE confrontés à une chute des nouvelles constructions, l'Ukraine a signalé une augmentation significative de **23,5 %** de l'activité de construction en 2024. Cette vague est tirée par la reconstruction urgente des infrastructures résidentielles et d'ingénierie, qui est progressivement alignée sur les normes d'efficacité énergétique et climatiques de l'UE pour assurer une durabilité à long terme.

Cadre réglementaire et risque (Réf. Chapitre 4) : la conformité n'est pas négociable, avec des pénalités allant du risque réglementaire aux risques financiers significatifs de « décote marron ». La principale menace pour l'atteinte des objectifs n'est pas l'absence de législation, mais le manque de personnel qualifié. La Suède est déjà en tête de ce changement en rendant obligatoires les déclarations de Carbone de Vie Entière (WLC), forçant les concepteurs à intégrer immédiatement l'ACV dans leur pratique.

Lacunes en compétences et connaissances (Réf. Chapitre 5) : le déficit de compétences est systémique, impactant à la fois les rôles techniques et managériaux :

- **Lacunes techniques (Niveau EFP):** la lacune la plus critique est le manque de précision dans l'étanchéité à l'air et l'installation de systèmes énergétiques intégrés. Cette défaillance technique est la cause directe de l'écart de performance observé sur site dans les rapports de la Grèce, de la Croatie et de l'Ukraine, où le rythme rapide de la reconstruction résidentielle intensifie encore le besoin d'installateurs spécialisés d'enveloppes thermiques à haute efficacité.
- **Lacunes stratégiques (Niveau ES/Managérial):** Il existe un manque profond de compétence dans l'application de l'Analyse du Cycle de Vie (ACV) à la conception, et un déficit critique de compétences liées à l'ESG et à la gouvernance des données de la Taxonomie de l'UE. Cette compétence numérique-financière est essentielle pour les gestionnaires d'actifs dans des pays comme l'Italie et l'Allemagne qui doivent préparer des données vérifiables pour le reporting CSRD, ainsi que pour les chefs de projet en Ukraine qui alignent les projets de reconstruction sur les normes internationales de financement vert.

Numérisation et économie circulaire (Réf. Chapitre 6) : bien que le BIM soit un outil nécessaire (s'étendant à la rénovation en Espagne et en Finlande), son plein potentiel pour la modélisation de la durabilité et l'utilisation des données (Jumeaux Numériques) reste largement inexploité. L'Économie Circulaire est entravée par des barrières logistiques et techniques, soulignant le besoin de compétences en logistique inverse et en certification des matériaux (un domaine d'intérêt en Belgique).

Recommandations stratégiques pour le WP4 (Réf. Chapitre 7)

Pour combler le déficit de compétences observé, le programme EXCEL4Housing 4.0 (WP4) doit adopter une approche axée sur des compétences ciblées et vérifiables :

1. **Formation à l'intégration systémique:** prioriser les modules de formation axés sur les interfaces entre les différents systèmes (par exemple, CVC et enveloppe du bâtiment), ciblant directement l'écart de performance.
2. **Micro-certifications accréditées:** développer des unités de formation flexibles et de courte durée pour les compétences à haut risque et à fort impact (par exemple, Techniques d'Étanchéité à l'Air) afin de faciliter le perfectionnement rapide dans les contraintes de temps et de coûts des PME.
3. **Conformité numérique:** rendre obligatoire la formation à l'utilisation du BIM/Jumeaux Numériques pour l'extraction de données et le calcul du WLC, créant de nouveaux profils pour les Gestionnaires de Conformité Axés sur les Données.
4. **Formation des formateurs:** mettre immédiatement en œuvre un programme dédié pour perfectionner les instructeurs d'EFP, qui représentent le goulot d'étranglement le plus critique pour l'intensification du nouveau programme. Dans ce contexte, l'initiative ukrainienne « #100 Ateliers » sert de référence stratégique pour la modernisation rapide des infrastructures de formation et de la capacité des instructeurs dans des environnements sous haute pression.
5. **Modèles d'EFP résilients aux crises:** tirer parti de l'initiative ukrainienne '**#100 Ateliers**' comme référence pour la modernisation rapide des infrastructures de formation afin de répondre aux demandes urgentes de rénovation éco-énergétique dans des environnements sous haute

pression.

La mise en œuvre réussie de ces recommandations est essentielle pour garantir que la main-d'œuvre européenne possède la compétence requise pour atteindre l'objectif de Bâtiment à Émission Zéro d'ici 2050.

2. Introduction & Méthodologie

Ce chapitre présente le contexte fondamental du projet EXCEL4HOUSING4.0 et établit la méthodologie utilisée pour compiler ce rapport d'Analyse de l'État de l'Art (D2.2).

Il détaille les objectifs spécifiques du projet et de la tâche 2.2, qui se concentre sur la cartographie des tendances du marché et l'identification des meilleures pratiques. De plus, il décrit l'approche de recherche systématique utilisée, qui combine une recherche documentaire structurée au niveau européen avec la synthèse des données nationales compilées par les partenaires du consortium. Ceci assure une base de preuves robuste et géographiquement diversifiée pour éclairer l'élaboration du programme du projet.

2.1. Contexte du Projet

Ce rapport, D2.2 État de l'Art dans le secteur de l'efficacité énergétique et du logement durable, est le livrable fondateur du lot de travail 2 (WP2) du projet EXCEL4HOUSING 4.0. En tant que Partenariat pour l'Excellence Erasmus+ (N° de projet 101194014), le projet aborde directement le déficit de compétences dans le secteur européen du bâtiment, nécessaire pour atteindre les objectifs de Bâtiment à Émission Zéro (ZEB) fixés par la refonte de la DEPB et la stratégie plus large de la Vague de Rénovation.

EXCEL4HOUSING4.0 est un centre transnational d'excellence professionnelle Erasmus+ axé sur l'autonomisation des secteurs de la construction et du logement pour répondre aux transitions verte et numérique. Le projet crée un réseau solide de prestataires d'EFP, d'universités, d'industries et d'autorités publiques pour co-développer des solutions répondant aux nouvelles demandes de compétences en matière d'efficacité énergétique, de technologies de construction verte et de logement durable. Avec une approche multi-cluster, le projet vise à favoriser l'innovation transfrontalière, à développer des programmes de formation pertinents pour l'industrie, à renforcer la coopération entre les entreprises et l'éducation et à assurer la durabilité à long terme grâce à des mécanismes de gouvernance et de financement. L'initiative soutient la mise en œuvre du pacte vert pour l'Europe et des stratégies de double transition dans le secteur de l'environnement bâti.

Les objectifs spécifiques sont les suivants :

- Développer des programmes transfrontaliers de formation et de renforcement des capacités
 - → Co-crée des programmes de formation innovants axés sur les compétences vertes, numériques et circulaires pour le logement durable et l'efficacité énergétique.
- Établir des partenariats stratégiques EFP-Universités-Industrie
 - → Promouvoir la collaboration entre les établissements d'enseignement, les PME et les leaders de l'industrie pour assurer la pertinence et l'applicabilité des programmes de formation.
- Développer les compétences en construction intelligente et verte
 - → Équiper les apprenants, les travailleurs et les éducateurs avec les connaissances et les outils nécessaires à la décarbonisation et à la numérisation du secteur du logement.
- Promouvoir des parcours de perfectionnement/reconversion inclusifs et flexibles
 - → Adapter les opportunités d'apprentissage pour les jeunes, les adultes et les groupes

sous-représentés, conformément aux objectifs de l'apprentissage tout au long de la vie.

- Créer un modèle de financement et de gouvernance durable
 - → Assurer la durabilité à long terme et l'alignement politique de l'excellence de l'EFP en matière de financement de l'efficacité énergétique et de construction verte.
- Contribuer aux objectifs du Pacte Vert de l'UE et de l'Économie Circulaire
 - → Aligner les résultats de la formation sur les objectifs environnementaux et sociaux de l'UE par le biais d'une transformation professionnelle systémique.

Le WP2, intitulé “Cartographie du marché du travail, évaluation des besoins en compétences et analyse de l'état de l'art en efficacité énergétique et logement durable est conçu pour établir une base de référence solide et factuelle. Cette base est essentielle pour garantir que les programmes d'Enseignement et de Formation Professionnels (EFP) développés dans le WP4 sont véritablement axés sur la demande, pertinents pour l'agenda Logement 4.0 (économie numérique et circulaire) et capables d'atténuer les risques de conformité détaillés au chapitre 4.

Ceci est réalisé en cartographiant les tendances du marché du travail (T2.1), en analysant l'état de l'art et en collectant les meilleures pratiques (T2.2), et en définissant les besoins d'apprentissage et les profils d'emploi (T2.3).

2.2. Objectifs de la Tâche 2.2

La tâche 2.2, intitulée « État de l'art dans le secteur de l'efficacité énergétique et du logement durable et identification des meilleures pratiques d'EFP (enseignement, méthodologies et outils) », est dirigée par le CEEC.

L'objectif principal de la T2.2 est de **fournir une base solide et factuelle** qui soutient l'élaboration de programmes de formation prospectifs et axés sur la demande dans le WP4.

Ceci est accompli par deux principaux livrables :

- **Le rapport d'état de l'art** (D2.2), pour consolider les tendances nationales, les impacts réglementaires et les qualifications d'EFP existantes dans un aperçu européen synthétisé. L'objectif principal est d'identifier les lacunes en compétences et en connaissances les plus aiguës et systémiques qui empêchent une conformité efficace.
- **Le compendium des meilleures pratiques** (D2.3), pour identifier et présenter des méthodologies, outils et programmes d'enseignement d'EFP innovants qui comblent avec succès les lacunes en compétences identifiées, fournissant des modèles pour la mise en œuvre du WP4.

2.3. Aperçu de la Méthodologie

Le rapport D2.2 est le résultat d'une approche méthodologique structurée en deux phases, mise en œuvre par l'ensemble du consortium, assurant la cohérence et la traçabilité transnationale.

Phase 1 : recherche documentaire & collecte initiale de données

Cette phase a impliqué la collecte de données primaires par les partenaires nationaux, guidée par un cadre méthodologique strict et une liste de vérification d'éligibilité:

- Contributions nationales : le rapport synthétise les données de 11 rapports nationaux d'état de l'art soumis par les partenaires et pays suivants : Belgique, Croatie, Finlande, Allemagne, Grèce, Italie, Pologne, Portugal, Espagne, Suède et Ukraine.
- Accent sur les données : chaque rapport national devait contenir des points d'analyse spécifiques sur cinq axes principaux : tendances du marché, mise en œuvre réglementaire (DEPB, CSRD), statut de l'EFP, numérisation et économie circulaire, garantissant que tous les domaines thématiques clés étaient couverts pour la consolidation.
- Crédibilité des sources : tous les rapports nationaux ont été compilés en utilisant un minimum de dix sources récentes (2018+), pertinentes et crédibles, y compris des statistiques nationales, des documents politiques et des publications faisant autorité de l'UE. Ceci garantit que la synthèse présentée au Chapitre 3 et au Chapitre 4 est fondée sur des données vérifiées et spécifiques à chaque pays.

Phase 2 : Validation interne et synthèse

Les rapports nationaux ont servi d'entrée brute pour l'activité de synthèse centrale menée par le CEEC. Cette phase a assuré la qualité et la cohérence:

- Examen interne : tous les rapports nationaux ont fait l'objet d'un processus d'examen par les pairs au sein du consortium pour valider les conclusions et assurer l'alignement avec la portée globale du projet.
- La portée géographique couvre un éventail diversifié de marchés : des économies matures avec des plans de rénovation établis (par exemple, l'Allemagne et la Suède) aux contextes d'Europe du Sud (Grèce et Portugal) et aux **environnements de reconstruction d'Europe de l'Est (Ukraine)**. Cette diversité permet une analyse transnationale de la manière dont les différents moteurs réglementaires et économiques influencent la demande de compétences vertes.
- Consolidation : l'étape finale a impliqué une analyse comparative dans les 11 pays pour identifier les déficits de compétences systémiques et uniques (voir Chapitre 5). Des références directes à des contextes nationaux spécifiques (par exemple, le mandat suédois WLC ou l'accent grec sur les programmes de subvention) sont maintenues tout au long du document pour assurer une traçabilité élevée entre la conclusion européenne consolidée et sa source nationale.

La structure de ce rapport est basée sur le plan indicatif et synthétise les données compilées par 24 partenaires dans 11 pays.

Pour assurer la comparabilité, la méthodologie aligne les données nationales sur les normes de l'UE (telles que la DEPB et la DEE) dans la mesure du possible. Dans le cas de l'Ukraine, bien qu'elle soit en cours d'harmonisation réglementaire complète avec l'UE, l'analyse intègre les données des plans nationaux de redressement et des rapports d'infrastructure récents (2024), offrant une perspective prospective sur son intégration dans le cadre européen du logement durable.

3. Analyse des Tendances et des Moteurs du Marché

3.1. Activité de construction actuelle: synthèse des taux de rénovation et des tendances de la nouvelle construction dans les pays participants.

Le secteur européen de la construction, bien que fondamental pour la transition verte, présente un tableau très hétérogène en ce qui concerne l'activité actuelle, largement dicté par les politiques économiques nationales et les facteurs macroéconomiques.

Dans les pays du consortium, l'activité reste fortement bifurquée : le segment de la rénovation est généralement stable ou en croissance (tiré par des incitations soutenues par l'État), tandis que le segment des nouvelles constructions est confronté à des vents contraires importants.

Le secteur de la construction dans les pays partenaires présente un paysage mitigé. Alors que les marchés matures comme l'Allemagne et la Suède ont connu un ralentissement des permis résidentiels en raison de pressions économiques, d'autres comme la Grèce, le Portugal et l'Ukraine maintiennent une trajectoire plus active. Dans ces derniers, l'accent est de plus en plus mis sur la reconstruction et la restauration des unités de logement, souvent tirées par des plans de redressement nationaux qui donnent la priorité aux besoins résidentiels immédiats parallèlement à la durabilité à long terme.

Tendances dans la nouvelle construction: plusieurs marchés européens clés, dont l'Allemagne, la Suède et la Finlande, signalent un ralentissement ou un fléchissement anticipé de la **nouvelle construction résidentielle** pour 2024 et 2025. Ce ralentissement est principalement attribué à l'inflation élevée, à l'augmentation des coûts de l'énergie et des matériaux, et aux taux d'intérêt élevés, qui ont gravement affecté les modèles de financement des promoteurs et la demande des consommateurs. Inversement, des pays comme la Pologne et l'Italie ont signalé une résilience ou une croissance récente, souvent soutenues par de fortes mesures de relance publiques qui ont temporairement compensé le refroidissement du marché.

L'impératif de la rénovation: le cœur de l'activité actuelle dans tous les pays participants de la Croatie (tirée par la reconstruction post-séisme et les objectifs d'efficacité énergétique) au Portugal et à l'Espagne (tirant parti des plans de redressement nationaux) est le besoin de rénovation des bâtiments.

- La **Vague de Rénovation** et la directive refondue sur la Performance Énergétique des Bâtiments (DEPB) servent d'ancrages critiques au marché. Les programmes nationaux (par exemple, Exoikonomo en Grèce, Renolution dans les régions de Belgique) se concentrent fortement sur les améliorations profondes ou échelonnées de l'efficacité énergétique, faisant évoluer le stock existant vers les normes de Bâtiment à Énergie Quasi-Nulle (NZEB) ou de Bâtiment à Émission Zéro (ZEB).
- En **Croatie**, l'accent est double : atteindre les normes de performance énergétique obligatoires et intégrer la résilience sismique dans les pratiques de rénovation.
- En **Italie**, bien que le volume ait été considérablement stimulé par le Superbonus, le marché évolue maintenant vers des économies d'énergie à long terme et vérifiables, alignées sur la Taxonomie de l'UE.

Conclusion sur l'activité: alors que le climat économique actuel présente des défis immédiats, en particulier un ralentissement notable des nouveaux projets de construction en raison de facteurs macroéconomiques à court terme tels que la hausse des taux d'intérêt et l'inflation, la perspective à long terme pour les services spécialisés de rénovation profonde reste exceptionnellement forte et non cyclique.

Cette demande robuste est principalement tirée par deux forces critiques et interdépendantes qui transcendent les cycles économiques typiques:

1. **Impératifs de politique publique:** les politiques publiques nationales et régionales se concentrent de plus en plus sur l'efficacité énergétique, la décarbonation et la résilience du parc immobilier en tant que composantes essentielles de la croissance durable. Les incitations financières et le financement public ciblé créent un flux constant de projets.
2. **Pression réglementaire de Bruxelles:** le cadre législatif de l'Union Européenne, en particulier les directives liées à la Performance Énergétique des Bâtiments (DEPB) et aux objectifs globaux de neutralité climatique (Fit for 55), impose des exigences obligatoires claires et croissantes pour la modernisation et l'amélioration énergétique des bâtiments existants. Cet environnement réglementaire agit comme un catalyseur puissant et inéluctable pour l'investissement dans la rénovation profonde.

Par conséquent, l'ensemble du consortium, qui se spécialise dans des solutions complètes de rénovation profonde, est bien placé pour bénéficier d'une demande structurelle, soutenue et réglementée qui est largement isolée des fluctuations temporaires affectant le secteur de la nouvelle construction. Ce positionnement stratégique assure une prévision commerciale stable et valide l'accent mis sur les améliorations spécialisées et éco-énergétiques des bâtiments.

3.2. Principaux moteurs du marché : Analyse des forces communes qui animent (ou freinent) la transition verte (par exemple, financement public, pression économique, demande de NZEB/ZEB).

Le passage au « Logement 4.0 » est tiré par une puissante confluence de mandats réglementaires et de dynamiques de marché en évolution.

La poussée réglementaire (descendante) : dans tous les rapports nationaux, les moteurs les plus importants sont les initiatives législatives de l'UE. Celles-ci imposent le changement en fixant des seuils de performance et en définissant l'investissement durable:

- **Refonte de la DEPB et normes ZEB:** c'est le moteur le plus direct pour la main-d'œuvre technique. Le passage au ZEB pour les nouvelles constructions et l'exigence de Normes Minimales de Performance Énergétique (MEPS) pour le parc existant forcent un changement rapide dans les pratiques de conception et de construction (cité par l'Allemagne, la Belgique et la Suède).
- **Taxonomie de l'UE pour la finance durable:** cette réglementation influence les décisions d'investissement, rendant les actifs « verts » (ceux qui répondent à des critères techniques de sélection) financièrement préférentiels. Ce facteur est particulièrement important pour les grands promoteurs et les investisseurs institutionnels sur les marchés matures (par exemple, la Suède et l'Italie).
- **Directive sur le reporting extra-financier (CSRD) et ETS2:** il s'agit là de facteurs émergents qui vont considérablement accroître la demande en données et en performances vérifiables. Les

grandes entreprises de construction et les fournisseurs de logements devront bientôt rendre compte de leur impact environnemental, ce qui nécessitera des outils numériques et des compétences hautement spécialisées en matière de reporting.

L'attrait financier et économique (approche ascendante): alors que les réglementations fixent les objectifs, les mécanismes financiers fournissent la stimulation immédiate pour le volume:

- **Plans nationaux de financement et de relance:** les programmes financés par les plans nationaux de relance et de résilience (RRP) sont le principal moteur à court terme du volume de rénovation (Portugal, Espagne, Grèce). Ces subventions créent un pipeline stable pour **les prestataires de formation professionnelle**.
- **Demande de décarbonisation:** sur les marchés avancés, notamment en **Suède** et en **Allemagne**, les clients privés, les entités publiques et les investisseurs sont de plus en plus demandeurs de bâtiments certifiés, à faibles émissions de carbone ou à zéro émission, ce qui stimule l'innovation dans le domaine des matériaux et des technologies.
- **Adoption de la numérisation:** la nécessité d'améliorer la coordination des projets, le contrôle qualité et les données relatives au cycle de vie favorise l'adoption de la modélisation des informations du bâtiment (BIM) et des jumeaux numériques (Finlande, Croatie, Espagne). Cette transition numérique devient un moteur implicite du marché en termes de compétences.

La transition vers le 'Housing 4.0' est portée par une double dynamique forte. Cette force, qui combine des réglementations imposées par le haut et des pressions financières et consuméristes venues de la base (comme les cadres de relance verte en Ukraine), protège le secteur de la rénovation en profondeur de l'instabilité économique à court terme qui affecte la construction neuve.

Au cœur de cette initiative descendante se trouvent les initiatives législatives de l'UE : la refonte de la directive sur la performance énergétique des bâtiments (EPBD), qui fixe des objectifs non négociables pour les bâtiments à zéro émission (ZEB) et les normes minimales de performance énergétique (MEPS) ; et la taxonomie de l'UE pour la finance durable, qui oriente activement les capitaux vers des actifs verts vérifiés, faisant de la durabilité une condition financière préalable plutôt qu'une option technique.

Cet environnement réglementaire transforme rapidement la non-conformité en un risque financier important (le « Brown Discount »). Parallèlement, la dynamique ascendante est alimentée par des stimuli financiers et économiques essentiels, principalement les plans nationaux de financement et de relance (RRP), qui fournissent un flux constant de projets de rénovation profonde subventionnés dans les pays du consortium (par exemple, en Espagne, au Portugal, en Grèce et en Ukraine).

De plus, sur les marchés avancés comme la Suède et l'Allemagne, la demande croissante des investisseurs publics et privés pour des bâtiments certifiés à faibles émissions de carbone et à zéro émission accélère l'innovation dans les matériaux et la conception.

Enfin, la nécessité d'améliorer le contrôle qualité et la vérification des données, motivée par les exigences imminentes de la CSRD en matière de reporting, fait de l'adoption d'outils numériques, en particulier le BIM pour l'énergie et l'analyse du cycle de vie (ACV), un moteur implicite et incontournable du marché pour le développement des compétences tout au long de la chaîne de valeur.

4. Cadre Réglementaire et Risques de Conformité

4.1. Le Cadre législatif de l'UE : aperçu des directives clés ayant un impact sur le secteur (EPBD, Vague de rénovation, ETS2, Éco-conception).

Le paysage de l'activité de construction nationale est fondamentalement façonné et régi par un trio de réglementations européennes interdépendantes et influentes.

Ces actes législatifs—la **directive sur la performance énergétique des bâtiments** (PEB) Refonte, la **taxonomie de l'UE pour la finance durable** et la **directive sur la publication d'informations en matière de durabilité par les entreprises** (CSRD)—établissent les normes minimales absolues non négociables et les exigences en matière de rapports.

Directive sur la performance énergétique des bâtiments (DPEB) refonte

La refonte de la DEPBB (Directive sur la Performance Énergétique des Bâtiments) est la réglementation fondamentale axée explicitement sur l'efficacité énergétique du parc immobilier de l'UE. Son objectif principal est d'atteindre un parc immobilier hautement économe en énergie et décarboné d'ici 2050, en facilitant la transformation rentable des bâtiments existants en Bâtiments à Énergie Quasi-Nulle (NZEB) et, à terme, en Bâtiments à Émission Zéro (ZEB).

- **Dispositions clés:** elle impose des stratégies nationales de rénovation à long terme, fixe des normes minimales de performance énergétique (MEPS) pour les bâtiments non résidentiels et, de plus en plus, résidentiels, et encourage le déploiement de systèmes d'automatisation et de contrôle des bâtiments.
- **Impact sur la construction:** cette directive a un impact direct sur les spécifications de conception, le choix des matériaux (par exemple, isolation, vitrage), les exigences des systèmes de chauffage et de refroidissement, et l'adoption de technologies d'énergie renouvelable sur site. La conformité est essentielle pour obtenir les permis de construire et assurer la commercialisation.

Taxonomie de l'UE pour une finance durable

La taxonomie de l'UE est un système de classification qui établit une liste d'activités économiques considérées comme durables sur le plan environnemental. Elle fournit aux entreprises, aux investisseurs et aux décideurs politiques une définition robuste et scientifique de ce qui est considéré comme « vert », visant spécifiquement à intensifier l'investissement durable et à prévenir l'écoblanchiment.

- **Pertinence pour la construction:** Les activités du secteur de la construction, telles que la construction de nouveaux bâtiments, la rénovation et l'installation d'équipements d'énergie renouvelable, doivent contribuer de manière démontrable et substantielle à l'un des six objectifs environnementaux (par exemple, l'atténuation/l'adaptation au changement climatique) sans nuire de manière significative aux autres (principe de non-préjudice significatif ou Do No Significant Harm - DNSH).

- **Impact sur le financement:** pour qu'un projet de construction soit labellisé « durable » et attire un financement vert, il doit s'aligner sur les critères d'examen technique détaillés établis dans la Taxonomie, influençant tout, du choix du site et de l'approvisionnement en matériaux à la performance énergétique.

Directive sur la publication d'informations en matière de durabilité par les entreprises (CSRD)

La CSRD renforce considérablement les règles concernant les informations sociales et environnementales que les grandes entreprises doivent communiquer. Elle remplace la **Directive sur la publication d'informations non financières** (NFRD) et vise à garantir que les entreprises divulguent publiquement des informations adéquates sur les risques et opportunités en matière de durabilité auxquels elles sont confrontées, ainsi que sur les impacts qu'elles ont sur les personnes et l'environnement.

- **Pertinence pour les entreprises de construction:** les entreprises de construction, les promoteurs et les institutions financières associées relevant du champ d'application de la CSRD sont tenus de rendre compte en détail de leur performance en matière de durabilité, en utilisant les Normes européennes d'information en matière de durabilité (European Sustainability Reporting Standards - ESRS).
- **Impact sur les opérations et la chaîne d'approvisionnement:** cette obligation de reporting contraint le secteur de la construction à suivre et à divulguer méticuleusement les indicateurs liés à la consommation d'énergie, aux émissions de GES (Scopes 1, 2 et 3, incluant de manière critique le carbone intrinsèque des matériaux), à la production de déchets et au devoir de diligence de la chaîne d'approvisionnement. La directive intègre les exigences de l'EPBD et de la Taxonomie de l'UE dans la divulgation obligatoire des entreprises, liant directement l'activité de construction à la responsabilité financière et à la transparence du marché.

Ces trois réglementations fonctionnent donc de concert: l'EPBD fixe les objectifs de performance technique, la Taxonomie de l'UE définit ce qui est considéré comme un investissement durable, et la CSRD exige le reporting et la transparence qui intègrent la performance en matière de durabilité dans la stratégie d'entreprise et les marchés financiers.

Ensemble, elles forment le cadre réglementaire incontournable par lequel toutes les activités de construction nouvelles et rénovées dans les États membres de l'UE doivent être mesurées et exécutées.

Directives sur l'écoconception et l'étiquetage énergétique

Ces directives sont essentielles pour garantir que les composants techniques installés dans un bâtiment s'alignent sur les objectifs globaux d'efficacité énergétique fixés par l'EPBD.

La directive sur l'écoconception établit des normes de performance minimales obligatoires pour les produits liés à l'énergie (par exemple, chaudières, pompes à chaleur, systèmes de ventilation, chauffe-eau) mis sur le marché de l'UE, éliminant ainsi les produits les moins efficaces.

Parallèlement, la directive sur l'étiquetage énergétique fournit des informations claires et comparables aux consommateurs et aux professionnels concernant la consommation d'énergie de ces produits. Leur effet combiné est de pousser les fabricants vers l'innovation, garantissant que les systèmes utilisés dans la rénovation et les nouvelles constructions—en particulier ceux couverts par l'accent mis sur les systèmes intégrés dans ce rapport.

4.2. Déclinaison nationale & impact : analyse consolidée de la manière dont les pays mettent en œuvre la législation et des risques réglementaires spécifiques de non-conformité au niveau national.

La transposition de la législation de l'UE en droit national révèle des niveaux d'ambition et de complexité variables au sein du consortium. L'objectif principal pour tous les partenaires est la **mise en œuvre de la refonte de la DEPB (Directive sur la performance énergétique des bâtiments)**, en particulier le passage aux Bâtiments à Émission Zéro (ZEB) et l'application des Normes Minimales de Performance Énergétique (MEPS).

La transposition de la législation de l'UE en droit national présente un paysage complexe et varié chez les partenaires du consortium, reflétant des différences dans les cadres réglementaires existants et les priorités nationales.

L'objectif le plus critique et universel pour tous les partenaires est la **mise en œuvre diligente de la refonte de la Directive sur la performance énergétique des bâtiments (DEPB)**, spécifiquement le passage ambitieux vers les Bâtiments à Émission Zéro (ZEB) et l'application pratique des Normes Minimales de Performance Énergétique (MEPS).

Cette mise en œuvre implique des défis législatifs et techniques substantiels, notamment la mise à jour des codes nationaux du bâtiment, le développement de nouvelles méthodologies de calcul de la performance énergétique et l'établissement de mécanismes d'application solides. De plus, la transposition doit aborder l'intégration des sources d'énergie renouvelable, les exigences pour les passeports de rénovation des bâtiments et l'élimination progressive des combustibles fossiles dans les systèmes de chauffage et de refroidissement pour s'aligner sur les objectifs de neutralité climatique de l'UE.

Les variations observées au sein du consortium concernent le rythme d'adoption, les seuils spécifiques fixés pour les ZEB et les MEPS, et les mécanismes de soutien déployés pour aider le secteur du bâtiment dans cette transition.

Pays	Instrument réglementaire Clé	Principal objectif et statut de la conformité
Allemagne	Loi sur l'Énergie des Bâtiments (GEG)	La GEG consolide l'efficacité énergétique. Fort accent sur l'élimination progressive du chauffage au mazout/gaz et l'intégration des énergies renouvelables. Le défi réside dans la coordination des artisans qualifiés pour répondre aux normes de qualité requises.
Suède	Loi Nationale sur la Déclaration Climatique	Normes déjà élevées. L'accent est mis sur les Déclarations de Carbone sur l'Ensemble du Cycle de Vie (WLC) (obligatoires depuis 2022 pour les nouveaux bâtiments). La pression réglementaire est désormais centrée sur la circularité et l'analyse du cycle de vie (ACV).
Belgique	Cadres Hautement Régionalisés	La conformité est gérée différemment à travers la Flandre, la Wallonie et Bruxelles. Bruxelles vise à ce que toutes les maisons aient un CPE d'ici 2030, ce qui exerce une pression sur la rénovation progressive à grande échelle.

Espagne	Code Technique du Bâtiment (CTE) & PRR	Utilisation du Plan de Relance et de Résilience (PRR) pour des programmes de rénovation à grande échelle. L'accent réglementaire est mis sur l'assurance d'une exécution de haute qualité de ces travaux subventionnés et l'alignement des compétences techniques.
Croatie	Stratégie Nationale de Rénovation	Fort accent sur la reconstruction après les tremblements de terre et l'utilisation des fonds de l'UE pour la rénovation énergétique profonde. La conformité est étroitement surveillée via les projets financés par des fonds publics.
Grèce	Plan d'Action National (Electra, Exoikonomo)	La conformité est induite par des incitations financières publiques (subventions) qui appliquent les normes NZEB. Un défi clé est d'assurer une gestion de la qualité cohérente sur le site.
Pologne	Normes ZEB Nationales	L'objectif principal est d'appliquer les normes ZEB pour toutes les nouvelles constructions et de fixer des objectifs nationaux de rénovation profonde dans le parc immobilier existant.
Finlande	Directive de l'UE sur l'Efficacité Énergétique (EU/2023/1791)	Ceci sert de base à la Finlande pour préparer une mise à jour des réglementations nationales actuelles et des exigences pour le calcul de l'efficacité énergétique dans les nouveaux bâtiments et les rénovations.
Portugal	Plan National Énergie et Climat 2021–2030 (PNEC 2030)	Aligné sur le Pacte Vert Européen et le Plan d'Action pour l'Économie Circulaire (CEAP). Le marché consolide sa position, avec plus de 30 % des nouveaux projets de logement autorisés en 2024 conçus avec la durabilité et l'efficacité énergétique comme facteurs clés (Confidencial Imobiliário, 2025).
Italie	Criteri Ambientali Minimi, CAM	Le secteur est guidé par un cadre complet aux niveaux européen et national, fixant des objectifs ambitieux pour la durabilité, l'efficacité énergétique et la numérisation. Ce sont des exigences nationales obligatoires de durabilité et de circularité dans les projets de marchés publics.
Ukraine	Loi sur l'Efficacité Énergétique ; Plan National de Relance	Alignement sur le Pacte Vert de l'UE et les normes de performance énergétique pour la reconstruction.

Table 1. Liste des instruments réglementaires clés par pays

Le Risque de conformité principal: Le consensus dans tous les rapports nationaux est que le risque principal pour atteindre la conformité réglementaire n'est pas la capacité législative, mais la capacité d'exécution. La rapidité et le volume requis par la Vague de Rénovation combinés à la complexité technique des normes ZEB exposent une déficience critique dans le **volume et la compétence de la main-d'œuvre qualifiée** (par exemple, installateurs, chefs de chantier, concepteurs spécialisés). Cela a un impact direct sur la capacité à respecter les délais et les métriques de performance vérifiables

Comme exemple spécifique, la **structure fédérale de la Belgique** conduit à des voies de mise en œuvre

divergentes mais complémentaires à travers les trois régions:

- **Wallonie:** a progressivement renforcé sa transposition de la DEPB et aligné toutes les nouvelles constructions sur les normes de bâtiment à énergie quasi-nulle (NZEB) depuis 2021.
- **Flandre:** met en œuvre une « obligation de rénovation » exigeant des acheteurs de bâtiments résidentiels peu performants (EPC E/F) de rénover jusqu'à un label D dans les cinq ans.
- **Région de Bruxelles-Capitale:** mène sa stratégie RENOLUTION (2021–2030), qui fournit des primes financières et une assistance technique pour atteindre les objectifs énergétiques et circulaires.

Implications et défis clés

- **Fragmentation:** le modèle décentralisé, tout en permettant une adaptation régionale, crée des défis pour la coordination nationale et le développement de normes de formation cohérentes pour la main-d'œuvre de la construction.
- **Taux de Rénovation:** les objectifs alignés sur la DEPB exigent que le taux de rénovation de la Belgique quadruple pour atteindre les normes énergétiques de 2050, faisant de la rénovation le « foyer de croissance » décisif du secteur.
- **Goulot d'Étranglement des Compétences:** le rapport souligne qu'une pénurie de compétences (en particulier dans le BIM/ACV numérique et les compétences circulaires) est la « contrainte contraignante » qui doit être abordée pour garantir que la demande induite par la politique ne dépasse pas la capacité de livraison.

4.3. Rapports financiers (Taxonomie & CSRD) : synthèse de l'état actuel concernant les exigences de reporting et leur impact sur la finance et la valeur des actifs (la « Décote Marron »).

L'introduction de la Taxonomie de l'UE et les exigences imminentes de la CSRD redéfinissent les exigences en matière de gestion des données et de reporting, exerçant une pression significative sur les rôles managériaux et financiers au sein du secteur de la construction et du logement.

- **Taxonomie de l'UE comme norme d'investissement:** la Taxonomie est devenue la référence en matière de finance verte en Europe. Les partenaires signalent que les grands promoteurs et les institutions financières dépendent de plus en plus d'experts techniques capables de prouver que les projets de rénovation ou de nouvelle construction répondent aux Critères d'Examen Technique (par exemple, performance énergétique vérifiée, calcul WLC) pour accéder à des prêts préférentiels ou attirer des investissements.
- **Exigence de données de la CSRD:** la CSRD imposera aux grandes entreprises de rendre compte de leur performance en matière de durabilité, y compris des indicateurs vérifiables sur la consommation d'énergie, les émissions de carbone et la consommation de ressources. Cela crée une nouvelle demande critique de compétences dans les domaines suivants:
 - **Collecte et gestion des données:** mise en œuvre de systèmes numériques (BIM, Jumeaux Numériques, compteurs intelligents) pour suivre, vérifier et auditer avec précision les données de performance tout au long du cycle de vie de l'actif.
 - **Reporting intégré:** capacité à lier les données de performance environnementale technique aux systèmes de reporting financier.

Ce changement confirme que le déficit de compétences ne se limite plus aux métiers techniques, mais s'étend profondément aux rôles de gestion, de finance et d'information numérique.

La future directive sur la publication d'informations en matière de durabilité par les entreprises (CSRD) représente un changement radical dans la responsabilité et la transparence des entreprises, en particulier pour les grandes entreprises opérant dans le champ d'application de l'UE. Cette réglementation exigera un nouveau niveau de détail et de rigueur dans le reporting de la performance en matière de durabilité, dépassant les divulgations volontaires pour atteindre des métriques standardisées et exécutoires.

Au cœur de cette transformation se trouve une demande critique et sans précédent de données vérifiables et de haute qualité dans de nombreux domaines environnementaux, sociaux et de gouvernance (ESG).

Cette directive exige spécifiquement que les entreprises rendent compte d'un ensemble complet d'indicateurs quantifiables et vérifiables, avec un accent particulier sur les indicateurs de performance environnementale tels que:

- **Consommation d'énergie:** des ventilations détaillées de la consommation d'énergie par source (renouvelable ou non renouvelable) et par activité ou installation, nécessitant une gestion et une agrégation sophistiquées des données de compteurs.
- **Émissions de carbone:** un reporting complet pour les trois Scopes (Scope 1 : émissions directes ; Scope 2 : émissions indirectes liées à l'énergie achetée ; et Scope 3 : toutes les autres émissions indirectes tout au long de la chaîne de valeur), nécessitant des méthodologies complexes de collecte et de calcul des données de la chaîne d'approvisionnement.
- **Consommation de ressources:** des données vérifiables sur l'utilisation des ressources critiques, y compris l'eau (prélèvement, consommation et rejet) et les matériaux, ainsi que sur la production de déchets et les taux de recyclage, soulignant la nécessité de systèmes de gestion environnementale robustes.

Ce cadre de reporting rigoureux crée une nouvelle demande critique de compétences capables de faire le pont entre les opérations techniques, le reporting financier et la stratégie de durabilité. Les ensembles de compétences requis sont hautement spécialisés et transversaux, et se concentrent sur:

1. **Gestion et gouvernance des données ESG:** expertise dans la conception, la mise en œuvre et la maintenance de l'infrastructure informatique, des bases de données et des cadres de gouvernance nécessaires pour collecter, valider et sécuriser de vastes quantités de données non financières.
2. **Comptabilité et assurance de la durabilité:** professionnels capables d'appliquer la rigueur de la comptabilité financière aux métriques de durabilité, garantissant que les données sont vérifiables, cohérentes et conformes aux Normes européennes d'information en matière de durabilité (ESRS), et se préparant à l'assurance externe obligatoire.
3. **Modélisation et analyse des risques climatiques:** compétences pour interpréter les risques physiques et de transition liés au climat, les intégrer dans la planification financière de l'entreprise et utiliser les données pour modéliser divers scénarios climatiques (par exemple, recommandations du TCFD).
4. **Cartographie de la chaîne de valeur et collecte de données Scope 3:** capacité à tracer et à quantifier les émissions et les impacts à travers des chaînes d'approvisionnement complexes et mondiales, nécessitant souvent une collaboration approfondie avec les fournisseurs et l'application d'analyses avancées.

5. Écosystème actuel des compétences et lacunes

Ce chapitre, composante essentielle du livrable D2.2, fournit une synthèse et une analyse complètes du paysage actuel dans les domaines couverts par le projet, à travers l'ensemble des pays du consortium. Le cœur de cette analyse repose sur les résultats détaillés des rapports nationaux sur l'état de l'art soumis par chaque partenaire.

Les objectifs principaux de cette synthèse sont triples :

1. **Revue des cadres de qualification existants:** examiner et comparer de manière systématique les cadres nationaux de qualification, les programmes éducatifs et les dispositifs de certification professionnelle actuellement en place dans le secteur de l'énergie au sein des pays du consortium, y compris les processus d'alignement en cours dans des pays partenaires tels que l'Ukraine. Cette analyse comparative vise à identifier les structures communes, les spécificités nationales et les zones potentielles de convergence ou de divergence.
2. **Identification des lacunes en compétences et en connaissances:** identifier les déficits de compétences et de connaissances les plus critiques qui entravent actuellement l'innovation, la croissance et la transition efficace de la main-d'œuvre dans les marchés nationaux de l'énergie. Cela inclut les compétences techniques, transversales (soft skills) et réglementaires essentielles à la transition énergétique.
3. **Identification des principaux obstacles à la montée en compétences:** diagnostiquer et documenter les barrières systémiques, institutionnelles et pratiques qui empêchent l'adoption efficace et à grande échelle des initiatives de perfectionnement et de reconversion professionnelle. Ces obstacles peuvent inclure l'insuffisance des infrastructures de formation, le manque de financements, des programmes obsolètes ou une résistance au changement.

Les éléments probants consolidés et les conclusions robustes présentés dans ce chapitre constituent la base factuelle essentielle et non négociable qui **orientera directement le développement stratégique** des contenus de formation dans le cadre du Lot de travaux 4 (WP4) : **Développement des curricula et des formations.**

5.1. Qualifications existantes : synthèse des programmes actuels d'EFP et d'enseignement supérieur liés à l'efficacité énergétique

Le paysage éducatif actuel en Europe est fortement fragmenté, reflétant des niveaux variables d'intégration entre les systèmes d'enseignement et de formation professionnels (EFP) et d'enseignement supérieur (ES). Bien que la plupart des pays disposent de qualifications fondamentales dans le secteur de la construction, l'intégration systématique des compétences vertes et numériques spécialisées demeure inégale.

Cette fragmentation résulte directement des différences de collaboration et de coordination entre les systèmes EFP et ES selon les États membres.

Le manque d'harmonisation entraîne des incohérences dans la reconnaissance et la transférabilité des qualifications, affectant la mobilité de la main-d'œuvre et l'uniformité des normes professionnelles à l'échelle européenne.

Dans le secteur de la construction en particulier, bien que les qualifications traditionnelles soient généralement bien établies et reconnues dans la majorité des pays européens, y compris en Ukraine, une lacune majeure subsiste concernant l'intégration systématique des compétences spécialisées indispensables à une industrie moderne, durable et numérisée. L'intégration des compétences vertes telles que l'efficacité énergétique, la gestion durable des matériaux, l'analyse du cycle de vie (ACV) et les techniques de bâtiments à consommation énergétique quasi nulle (NZE) reste très inégale.

De même, l'intégration des compétences numériques, notamment le BIM, les technologies de construction intelligente, l'analyse de données et l'automatisation, varie considérablement en profondeur et en portée d'un programme national à l'autre. Cette disparité empêche la montée en compétences rapide de la main-d'œuvre nécessaire pour atteindre les objectifs environnementaux et technologiques ambitieux fixés par l'Union européenne, notamment dans le cadre du Pacte vert européen et de la transition vers la Construction 4.0.

- **Résilience du système EFP:** les établissements d'EFP demeurent la principale source de compétences techniques opérationnelles. Toutefois, la rapidité d'actualisation des programmes est souvent inférieure au rythme d'adoption des nouvelles technologies et aux exigences strictes des normes EPBD et ZEB.
- **Orientation de l'enseignement supérieur:** les universités offrent généralement de solides bases théoriques en conception durable, performance énergétique et analyse du cycle de vie (ACV). Le défi réside dans la traduction de ces connaissances théoriques en compétences pratiques applicables sur chantier.
- **Besoin de compétences transdisciplinaires:** tous les pays signalent la nécessité de qualifications capables de dépasser les silos traditionnels, en combinant efficacité énergétique, outils numériques (BIM, monitoring intelligent) et principes de circularité. Les qualifications existantes sont souvent trop spécialisées ou obsolètes.

5.2. Identification des lacunes critiques en compétences : résultats consolidés par profil professionnel

La persistance et l'ampleur des lacunes en compétences constituent un défi systémique qui affecte l'ensemble de la chaîne de valeur du bâtiment, depuis la conception et la planification jusqu'à la construction, l'exploitation, la maintenance et, in fine, la déconstruction ou la rénovation.

Cette déficience critique ne se limite pas à un métier ou à une discipline professionnelle spécifique, mais touche une multitude d'acteurs, notamment les architectes, les ingénieurs, les ouvriers du bâtiment, les gestionnaires d'installations et les décideurs publics.

Les rapports sectoriels et analyses industrielles identifient de manière récurrente des déficits précis et mesurables dans les connaissances, l'expertise et l'expérience pratique de la main-d'œuvre actuelle. Ces lacunes entravent directement la capacité des pays et des régions **des États membres de l'UE aux contextes de reconstruction tels que l'Ukraine** à atteindre les objectifs ambitieux de bâtiments à zéro émission (ZEB) et de carbone sur l'ensemble du cycle de vie (WLC).

Parmi les déficiences les plus répandues figurent le manque de maîtrise de la modélisation énergétique avancée, des stratégies de conception passive, de l'intégration des énergies renouvelables (telles que le photovoltaïque et les pompes à chaleur), ainsi que des exigences strictes en matière d'étanchéité à l'air et de traitement des ponts thermiques.

De plus, les compétences nécessaires pour calculer, minimiser et gérer avec précision le carbone intrinsèque tout au long du cycle de vie d'un bâtiment ce qui est essentiel pour atteindre les objectifs du Coût du Cycle de Vie (WLC) sont souvent sous-développées, voire totalement absentes, chez les principaux décideurs et responsables de la mise en œuvre. Sans une stratégie concertée et efficace pour combler ce déficit de compétences systémique, la transition vers un environnement bâti véritablement durable et décarboné restera fortement entravée.

Lacunes par segment professionnel:

- **Travailleurs de chantier et installateurs (niveau EFP):**
 - **Étanchéité à l'air et ponts thermiques:** lacune universelle et critique. Le manque de précision dans l'installation de l'isolation, des fenêtres et des systèmes de ventilation conduit directement à des écarts de performance et à la non-conformité aux normes NZEB.
 - **Systèmes intégrés:** les installateurs manquent souvent de compétences pour installer et mettre en service des systèmes intégrés de chauffage, de ventilation et d'énergies renouvelables reposant sur des contrôles numériques.
 - **Gestion de la qualité:** déficit de compétences pratiques et mesurables liées à la vérification sur site et aux procédures de réception des travaux.
- **Ingénieurs, architectes et concepteurs (niveau ES):**
 - **Analyse du cycle de vie (ACV):** bien que connue sur le plan théorique, son application pratique dans les décisions de conception et le calcul des coûts du cycle de vie (LCC) reste insuffisante. L'accent demeure excessivement mis sur l'énergie opérationnelle au détriment du carbone incorporé.
 - **BIM pour la durabilité:** l'utilisation du BIM pour la modélisation énergétique, la détection des conflits et la spécification durable des matériaux, au-delà de la simple modélisation géométrique, fait défaut.
 - **Planification de rénovations profondes:** manque d'expertise dans la planification de rénovations complexes et phasées, conciliant structures existantes et confort des occupants.
- **Fonctions managériales, financières et liées aux données:**
 - **Reporting ESG et taxonomie:** les professionnels de la finance, de l'immobilier et de la gestion d'actifs manquent de compréhension technique pour évaluer correctement les actifs selon les critères de la Taxonomie européenne et préparer des données vérifiables pour le reporting CSRD.
 - **Gestion des données:** insuffisance des compétences nécessaires pour gérer et exploiter les données de performance des bâtiments issues des compteurs intelligents, capteurs et jumeaux numériques à des fins de maintenance prédictive et de conformité vérifiable.

5.3. Obstacles à la montée en compétences : analyse des freins communs à une formation efficace.

Même lorsque des programmes de formation existent, plusieurs obstacles systémiques entravent une montée en compétences efficace et à grande échelle:

- **Disponibilité et pertinence de la formation:** Un défi commun est que les programmes d'EEP existants sont trop longs, trop théoriques ou utilisent des méthodologies dépassées (par exemple, manquant d'Apprentissage en Milieu de Travail ou de laboratoires numériques).
- **Coûts et contraintes de temps:** pour les PME — qui dominent le secteur de la construction —, le coût de l'absence des travailleurs en formation et le manque de temps pendant les projets actifs constituent des freins majeurs. En Ukraine, cette contrainte est aggravée par l'urgence de la reconstruction du parc résidentiel endommagé.
- **Capacité des formateurs:** un goulet d'étranglement critique réside dans le manque de formateurs qualifiés maîtrisant les technologies ZEB avancées, les outils BIM et les principes de circularité. Les formateurs eux-mêmes nécessitent une requalification substantielle.
- **Manque de certification et de standardisation:** l'absence de certifications standardisées et facilement reconnaissables pour les compétences vertes et numériques (telles que les micro-certifications) complique la reconnaissance des résultats de formation par les employeurs et leur valorisation salariale.

La mise en œuvre réussie de ces recommandations est essentielle pour garantir que la main-d'œuvre européenne possède les compétences requises pour atteindre l'objectif de Bâtiment à Émission Zéro d'ici 2050, traduisant efficacement l'ambition réglementaire en une performance vérifiable sur site.

Cette analyse D2.2 sert ainsi de fondement essentiel, basé sur des preuves, pour le projet EXCEL4Housing 4.0, validant l'importance stratégique du développement ultérieur du programme d'EEP dans le WP4 pour assurer un avenir durable au secteur.

6. Intégration de la numérisation et de l'économie circulaire

La transition verte est indissociable de la transition numérique. L'atteinte des objectifs de logements à zéro émission nette nécessite des changements fondamentaux non seulement en matière de matériaux et de systèmes énergétiques, mais également dans la gestion des données, la conception et les processus de construction. Ce chapitre évalue l'état actuel de la numérisation (Housing 4.0) et de l'adoption des principes de l'économie circulaire (EC) dans les pays partenaires.

6.1. État de la transition numérique : évaluation des taux d'adoption des principaux outils numériques dans les pays du consortium

La numérisation est universellement reconnue comme un levier clé pour garantir une performance énergétique vérifiable et rationaliser des processus de rénovation complexes. Toutefois, le degré de maturité de sa mise en œuvre varie considérablement au sein du consortium.

A. Adoption du Building Information Modelling (BIM)

Le BIM constitue l'outil numérique le plus établi pour favoriser l'intégration et le partage de données, bien que son utilisation reste souvent limitée à la modélisation géométrique, au détriment de fonctions avancées liées à la durabilité. Dans le contexte ukrainien, le BIM est de plus en plus reconnu comme un outil essentiel pour la gestion transparente et efficace de la reconstruction à grande échelle du logement, en facilitant le suivi des matériaux et de la performance énergétique dès la phase de conception.

- **Marchés matures:** des pays tels que la Finlande et la Suède affichent un niveau de maturité plus élevé, le BIM y étant de plus en plus obligatoire pour les projets publics et utilisé pour la coordination de projets complexes.
- **Adoption émergente:** dans des pays comme l'Espagne, l'utilisation du BIM s'étend au-delà de la construction neuve pour inclure les projets de rénovation, où il est spécifiquement employé pour la modélisation énergétique, la détection des conflits et la validation des exigences de performance.
- **Lacune de capacités:** malgré l'impulsion donnée à l'adoption du BIM, la Croatie souligne que son utilisation généralisée et compétente demeure à un stade précoce, en raison du manque de personnel qualifié capable d'exploiter le BIM pour la simulation énergétique et la spécification durable.

B. Jumeaux numériques et gestion des données

Le concept de jumeaux numériques répliques virtuelles de bâtiments alimentées par des données en temps réel est reconnu comme l'avenir de la gestion des actifs et de la vérification de la conformité, mais reste principalement au stade de l'innovation plutôt que de la pratique courante.

- **Initiatives stratégiques:** en Allemagne, le gouvernement a mis en place une feuille de route pour la conception et la construction numériques, positionnant la numérisation comme une stratégie centrale pour gérer la complexité et améliorer le contrôle qualité dans le cadre de la vague de rénovation. De même, l'Italie met en avant des partenariats stratégiques avec le secteur privé qui accélèrent l'adoption des jumeaux numériques afin de soutenir l'efficacité et le reporting en matière de durabilité.
- **Lacune en matière de données de performance:** une déficience majeure, observée dans

presque tous les pays, concerne le manque de compétences en **gouvernance des données**, c'est-à-dire la capacité à collecter, gérer et exploiter les données de performance issues des compteurs intelligents et des capteurs afin de combler l'écart entre la performance énergétique conçue et la performance réelle. Cette compétence est cruciale pour répondre aux exigences de reporting de la CSRD et de la Taxonomie européenne.

6.2. Pratiques d'économie circulaire : synthèse de la mise en œuvre de l'ACV, de l'utilisation des passeports matériaux et des principes de conception pour le démontage

La transition d'un modèle économique linéaire conventionnel fondé sur une logique « extraire–produire–jeter »— vers un modèle fondamentalement circulaire ne constitue plus une option, mais une nécessité stratégique majeure pour le secteur moderne de la construction.

Cette transition, qui met l'accent sur la réutilisation des matériaux, l'efficacité des ressources, la réduction des déchets et l'analyse rigoureuse du cycle de vie (ACV), représente la réponse la plus efficace pour atténuer l'empreinte environnementale considérable du secteur.

L'impact environnemental de l'industrie de la construction est particulièrement élevé, principalement en raison de deux facteurs majeurs:

1. **Production de déchets:** le secteur figure parmi les plus grands producteurs de déchets au niveau mondial, notamment les gravats de démolition, les matériaux inutilisés et les emballages. Ces volumes exercent une pression importante sur les capacités de mise en décharge et représentent une perte considérable d'énergie grise et de ressources valorisables.
2. **Carbone incorporé:** la production, le transport et la transformation des matériaux de construction (tels que le ciment, l'acier et les granulats) sont fortement énergivores et émettent d'importantes quantités de gaz à effet de serre. Ce carbone incorporé représente une part significative de l'impact climatique total du secteur.

Un modèle circulaire permet de répondre directement à ces défis en intégrant des principes visant à prolonger la durée de vie des matériaux et à fermer les boucles de ressources. En favorisant la réutilisation de composants récupérés — pratique particulièrement pertinente en Ukraine dans le cadre du recyclage des débris issus des bâtiments endommagés par la guerre —, en promouvant l'utilisation de contenus recyclés et en concevant des bâtiments pour le démontage plutôt que pour la démolition, le secteur peut réduire drastiquement sa dépendance aux matières premières vierges tout en limitant la production de déchets.

Par ailleurs, l'adoption d'outils d'analyse du cycle de vie (ACV) permet aux parties prenantes d'évaluer de manière holistique la performance environnementale des matériaux et des conceptions de bâtiments sur l'ensemble de leur durée de vie, de la « berceau à la tombe » ou, idéalement, de la « berceau au berceau », garantissant ainsi une prise de décision réellement orientée vers la durabilité.

A. Carbone sur l'ensemble du cycle de vie (WLC) et ACV

Le carbone sur l'ensemble du cycle de vie (WLC) émerge comme l'indicateur de référence ultime, élargissant l'analyse au-delà de l'énergie opérationnelle pour inclure le carbone incorporé dans les matériaux et les processus de construction.

- **Leadership réglementaire:** la Suède fait figure de pionnière, la Loi nationale sur la déclaration climatique rendant obligatoires les déclarations de carbone sur l'ensemble du cycle de vie pour les nouveaux bâtiments depuis 2022. Cette exigence réglementaire contraint immédiatement les concepteurs à intégrer des outils d'ACV dès les premières phases de conception, influençant directement le choix des matériaux et les décisions d'approvisionnement.
- **Sensibilisation croissante:** d'autres pays, notamment le Portugal et l'Espagne, observent une intégration accrue de l'ACV dans les débats politiques et les projets pilotes, souvent en lien avec les marchés publics écologiques et les stratégies nationales d'économie circulaire.

B. Réutilisation des matériaux et gestion des déchets

La transition vers la réutilisation des matériaux et la conception pour le démontage (DfD) demeure l'aspect le plus complexe sur le plan logistique, car elle nécessite des transformations profondes des chaînes d'approvisionnement et des cadres juridiques.

- **Initiatives pilotes:** en Belgique, les autorités régionales soutiennent activement la transition circulaire. Par exemple, la Région de Bruxelles-Capitale fait référence à l'utilisation d'instruments tels que l'outil **TOTEM** pour évaluer l'impact environnemental des matériaux, et promeut la circulation des éléments de construction récupérés à travers des projets comme FCRBE. La plateforme TOTEM (Tool for Optimising the Total Environmental impact of Materials) fonctionne comme l'environnement de référence belge d'aide à la décision en matière d'ACV, développé grâce à une collaboration interrégionale et fédérale. TOTEM intègre des déclarations environnementales de produits (DEP) et des ensembles de données génériques sélectionnés pour permettre des choix de conception comparatifs au niveau du bâtiment et des composants ; il est de plus en plus référencé dans les marchés publics et les offres de formation (FCRBE, 2021). La base d'utilisateurs – environ 4 400 utilisateurs enregistrés, dont environ 600 architectes formés – indique une professionnalisation croissante de la pratique de l'ACV, même si l'adoption reste loin d'être universelle (FCRBE, 2021).
- **Ukraine:** les efforts actuels se concentrent sur le développement de pôles régionaux dédiés au traitement des déchets minéraux de construction, avec pour objectif de réintégrer des granulats recyclés dans la production de nouveaux éléments de construction pour les immeubles résidentiels.
- **Solutions spécifiques:** la **Pologne** illustre des avancées techniques ciblées, notamment dans le domaine de la gestion durable de l'eau, en mettant l'accent sur la récupération des eaux de pluie et les systèmes de réutilisation des eaux grises afin de réduire la consommation de ressources en phase d'exploitation.
- **Italie:** le rapport national souligne l'importance croissante des matériaux durables et à faible empreinte carbone, en particulier le bois, comme pilier de la feuille de route circulaire du pays.
- **Lacune:** le déficit critique de compétences le plus important concerne la logistique inverse, la vérification de la qualité des matériaux et la mise en place de cadres juridiques (contrats) facilitant le transfert et la réutilisation de matériaux récupérés certifiés.

Dans le cas de la **Pologne**, il est important d'élaborer un plan qui prenne en compte la rentabilité des projets. L'eau réutilisée est souvent utilisée pour l'irrigation, et en Pologne, la demande moyenne en eau d'irrigation est relativement faible par rapport au reste de l'Europe.

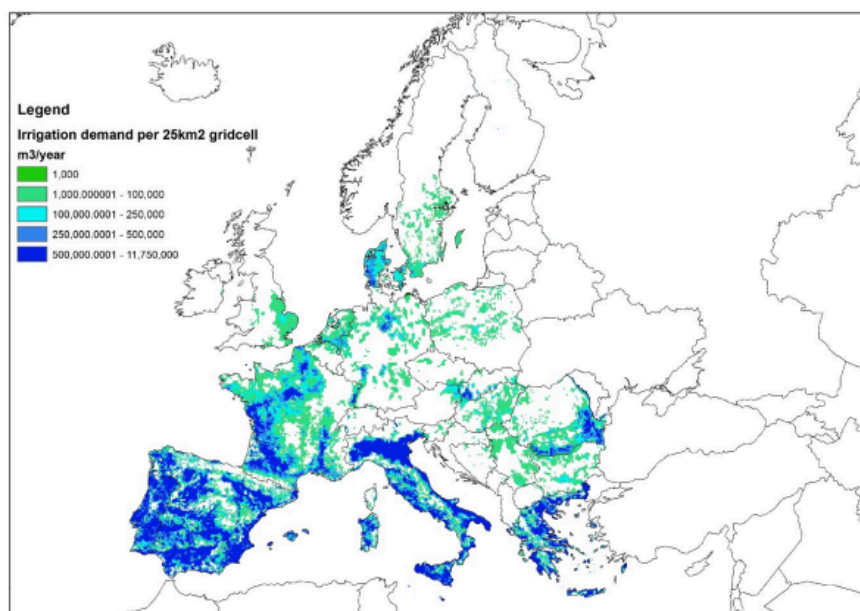


Figure 1. Demande moyenne en eau pour l'irrigation, calculée à l'aide du modèle EPIC¹

Compte tenu de ces éléments, le 22 juin 2023, le Ministre des Infrastructures a adopté une décision visant à exclure le territoire national de l'application du Règlement (UE) 2020/741 du Parlement européen et du Conseil du 25 mai 2020, relatif aux exigences minimales applicables à la réutilisation de l'eau.

Conformément à cette décision, la réutilisation de l'eau à des fins d'irrigation agricole ne sera pas appliquée dans les zones correspondant à **neuf bassins hydrographiques en Pologne**. Cette décision repose sur un **critère de rentabilité**, tenant compte de l'ensemble des coûts — environnementaux et liés aux ressources — démontrant que, dans ce contexte spécifique, des solutions alternatives s'avèrent plus optimales.²

Le rapport italien, comme mentionné dans la section des solutions spécifiques, souligne l'importance croissante des matériaux durables et à faible émission de carbone, avec un accent particulier sur le bois, en mettant en évidence les points clés suivants:

- **Le bois comme matériau circulaire central:** le bois est décrit comme un « matériau circulaire par excellence », car il est naturellement renouvelable, 100 % recyclable et capable de stocker du dioxyde de carbone, ce qui est crucial pour atténuer le changement climatique.
- **Utilisation croissante du bois d'ingénierie:** Il existe une tendance croissante à l'adoption de systèmes de construction en bois tels que le bois lamellé-croisé (CLT) et le bois de placage stratifié (LVL) dans les pratiques de construction durable.
- **Position sur le marché:** L'Italie est classée comme le troisième producteur européen de maisons en bois (avec 3 602 nouveaux logements construits en 2022), ce qui indique une croissance constante tirée par la sensibilisation à la durabilité.

¹ Pistocchi, A., Aloe, A., Dorati, C., Sanz, L. A., Bouraoui, F., Gawlik, B., Grizzetti, B., Pastori, M., Vigiak, O. (2017) *The potential of water reuse for agricultural irrigation in the EU: a hydro-economic analysis*, Publications Office of the European Union, Luxembourg, Join Research Centre, EUR 28980 EN <https://publications.jrc.ec.europa.eu/repository/handle/JRC109870>

² Decision of the Minister of Infrastructure of June 22, 2023, on excluding the country from the application of Regulation (EU) 2020/741 of the European Parliament and of the Council of May 25, 2020, on minimum requirements for water reuse

- **Certification et qualité:** des systèmes de certification comme ARCA (Architettura Comfort Ambiente) et ReMade in Italy® jouent un rôle crucial dans l'établissement de normes de qualité, de durabilité et de respect de l'environnement, soutenant le développement d'un marché structuré pour la construction à base de bois.
- **Projets phares:** des exemples concrets d'excellence dans la construction en bois, tels que le quartier « Ex Marangoni » à Rovereto (un bâtiment de 9 étages en CLT avec une efficacité énergétique et une circularité élevées) et le « Trentino Social Housing Building » à Trente (un bâtiment en bois certifié ARCA), démontrent l'application de ces matériaux dans des projets à grande échelle et à haute performance.

7. Conclusions et recommandations

L'analyse de l'état de l'art menée dans l'ensemble des pays du consortium y compris le contexte unique de reconstruction de l'Ukraine révèle un consensus quasi universel : **le secteur européen du bâtiment se situe à un point d'inflexion décisif, caractérisé par une forte ambition réglementaire et d'importants défis de mise en œuvre profondément enracinés.** Cette double réalité définit l'environnement opérationnel actuel.

D'une part, les fondements de la Transition verte sont solidement établis par un cadre législatif robuste de l'Union européenne. Des instruments clés tels que la Directive sur la performance énergétique des bâtiments (EPBD), la taxonomie de l'UE et la Directive relative à la publication d'informations en matière de durabilité par les entreprises (CSRD) fournissent conjointement l'impulsion nécessaire, en fixant des objectifs ambitieux en matière d'efficacité énergétique, de décarbonation et de transparence des investissements durables. Ces réglementations sont conçues pour orienter les investissements, accélérer les vagues de rénovation et impulser un changement systémique tout au long de la chaîne de valeur, rendant obligatoire la transition d'un environnement bâti linéaire vers un environnement circulaire et neutre en carbone.

D'autre part, la capacité actuelle du secteur à mettre en œuvre cette transition essentielle est manifestement entravée par une crise généralisée et systémique des compétences et des capacités. Ce déficit est multifacette : il comprend une pénurie de personnel qualifié tout au long du cycle de vie du bâtiment — des architectes et ingénieurs spécialisés dans la rénovation profonde aux installateurs certifiés et aux ouvriers de chantier formés aux technologies modernes hautement efficaces. En outre, la crise dépasse la simple pénurie de main-d'œuvre et inclut un déficit de compétences numériques, de capacités de gestion intégrée de la chaîne d'approvisionnement, ainsi que de capacité financière et administrative au sein des entités publiques et privées nécessaire pour naviguer dans des exigences réglementaires complexes et sécuriser des financements à grande échelle. Sans une intervention urgente et coordonnée pour remédier à ces contraintes de capacité, les objectifs ambitieux fixés par le cadre de l'UE risquent de devenir inatteignables, créant un écart significatif entre l'intention politique et la réalité sur le terrain.

7.1. Synthèse clé : conclusion finale résumant les principaux défis et les déficiences systémiques en compétences observés.

La conclusion principale de ce rapport D2.2 est le décalage entre les exigences réglementaires de haut niveau et la capacité de mise en œuvre sur le terrain.

A. Moteurs réglementaires non négociables

Le marché n'est plus uniquement guidé par les coûts ou la demande des consommateurs ; il est désormais orienté par des obligations législatives non négociables :

- a. **Normes de Bâtiment à Zéro Émission (ZEB)** : ces normes exigent une approche globale de la performance des bâtiments, imposant des systèmes intégrés et une étanchéité à l'air vérifiable, en particulier sur des marchés comme l'Allemagne, la Pologne et l'Ukraine, où l'alignement sur les standards ZEB devient une pierre angulaire des plans nationaux de relance. Le Plan national allemand de rénovation des bâtiments (NBRP) définit des

objectifs détaillés et des mesures politiques visant à soutenir la transition vers un parc immobilier à zéro émission d'ici 2050.

- b. **Conformité financière** : la taxonomie de l'UE et la CSRD ont réussi à faire passer la durabilité d'une question technique à un risque financier. Cela impose un nouvel ensemble de compétences en matière de reporting d'entreprise et de gestion de données vérifiables pour les propriétaires d'actifs et les financeurs, notamment dans des marchés dotés de secteurs financiers solides comme la Suède et l'Italie.

B. Le goulot d'étranglement systémique des compétences

L'analyse confirme un déficit critique et généralisé de compétences, qui se décline en deux volets :

1. **Écart de précision technique** : la carence technique la plus urgente concerne le manque de compétences dans l'installation et la mise en service de systèmes intégrés, ainsi que dans l'atteinte de normes élevées d'étanchéité à l'air et de réduction des ponts thermiques. Les défaillances dans ces domaines provoquent directement l'écart de performance (différence entre la consommation énergétique prévue et réelle), compromettant la conformité ZEB dans des pays comme la Grèce, la Croatie et l'Ukraine, où l'ampleur des projets de reconstruction rend cet écart encore plus critique pour la résilience urbaine à long terme.
2. **Écart stratégique numérique/circulaire** : les compétences nécessaires pour gérer la transition font défaut tout au long de la chaîne de valeur. Cela inclut l'utilisation maîtrisée du BIM pour les calculs ACV (LCA) et le coût du cycle de vie (WLC), essentielle en Suède ainsi que la capacité à gérer une logistique inverse complexe et la certification des matériaux requises pour un modèle d'économie circulaire.

C. Obstacles à la montée en compétences rapide

La transition est freinée par une inertie éducative : les programmes actuels de formation professionnelle (VET) sont souvent trop lents à être actualisés, et les formations sont peu accessibles à une main-d'œuvre dominée par les PME en raison de contraintes de coût et de temps (comme signalé au Portugal et en Allemagne). La capacité limitée des formateurs dans des domaines modernes et interdisciplinaires constitue un goulot d'étranglement critique pour l'augmentation des compétences à grande échelle.

La conclusion principale de ce rapport est l'existence d'un écart profond et préoccupant entre les mandats législatifs ambitieux de l'UE en faveur d'une transition verte et numérique portés par l'EPBD, la Taxonomie de l'UE et la CSRD et la capacité systémique largement insuffisante du secteur de la construction à mettre en œuvre ces exigences sur le terrain.

Ce déficit de mise en œuvre s'explique par un double goulot d'étranglement en matière de compétences : premièrement, un écart critique de **précision technique** chez les professionnels de niveau VET dans les systèmes énergétiques intégrés, l'étanchéité à l'air et les ponts thermiques, qui entraîne directement l'écart de performance énergétique ; deuxièmement, un **écart stratégique numérique/circulaire** chez les profils de l'enseignement supérieur et de gestion, caractérisé par un manque de maîtrise des outils numériques (BIM/ACV) pour le calcul du carbone sur l'ensemble du cycle de vie (WLC) et la préparation de

données de performance vérifiables pour le reporting financier obligatoire.

Le défi est aggravé par l'inertie éducative, notamment des programmes VET obsolètes et une pénurie critique de formateurs qualifiés, ce qui entrave la montée en compétences rapide nécessaire pour respecter des échéances réglementaires non négociables.

7.2. Recommandations pour le WP4 : recommandations concrètes pour orienter le développement du nouveau programme de formation professionnelle (VET).

Sur la base de la synthèse des tendances du marché, des pressions réglementaires et des déficits critiques de compétences, les recommandations suivantes sont proposées pour la conception et la mise en œuvre du nouveau programme de formation professionnelle (VET) dans le cadre du WP4 :

En s'appuyant sur une synthèse complète et une analyse rigoureuse des tendances actuelles du marché dans les secteurs de l'énergie et de la durabilité, des pressions réglementaires prévalentes et des déficits critiques de compétences identifiés au sein de la main-d'œuvre existante, les recommandations stratégiques détaillées suivantes sont présentées.

Ces recommandations sont conçues pour informer et guider le développement, la structuration et la mise en œuvre du nouveau programme de formation professionnelle (VET), qui constituera une livrable clé du Work Package 4 (WP4).

Recommandation 1: prioriser les compétences intégrées au niveau systémique

Le programme doit passer de la formation de travailleurs spécialisés isolés à la formation de professionnels capables d'intégrer des systèmes.

- **Focus :** la formation doit se concentrer sur les interfaces entre les systèmes (par exemple, l'intégration de l'isolation avec la ventilation mécanique et les énergies renouvelables).
- **Cible:** les installateurs, chefs de chantier et réviseurs de conception doivent être formés à l'impact de leur travail sur la performance globale du bâtiment (par exemple, le lien direct entre un joint défectueux et la note EPC).

Recommandation 2 : intégrer la numérisation pour la conformité et l'utilisation des données

La maîtrise du numérique doit être obligatoire, en déplaçant l'accent de « BIM pour le dessin » vers « BIM pour la conformité ».

- **Action :** développer des modules sur le BIM pour l'énergie et les simulations ACV (LCA) afin d'éclairer les décisions de conception..
- **Nouveau profil :** créer une trajectoire d'apprentissage claire pour les gestionnaires de données ESG/Taxonomie — des professionnels capables de relier les données de performance technique des jumeaux numériques aux besoins légaux et financiers du CSRD.

Recommandation 3 : développer des micro-certifications pour la montée en compétences urgente

Pour surmonter les obstacles liés au temps et au coût, le projet doit produire des unités de formation courtes, flexibles et certifiées.

- **Focus** : concentrer les micro-certifications sur les tâches à haut risque et fort impact, telles que : tests d'étanchéité et techniques de scellement, installation et mise en service de pompes à chaleur, et approvisionnement en matériaux pour le calcul du carbone sur le cycle de vie (WLC).
- **Modèle** : utiliser une approche d'apprentissage modulaire et flexible permettant aux travailleurs d'obtenir une certification rapidement sans engagement à long terme (par exemple, la structure « Learning Unit » mentionnée dans le rapport de Belgique).

Recommandation 4 : initier un programme de « formation des formateurs »

Le goulot d'étranglement le plus immédiat est la capacité des formateurs. Le programme WP4 doit être piloté et déployé en formant d'abord les formateurs qui dispenseront le contenu au niveau national.

- **Groupe cible 1** : formateurs VET dans le domaine de l'énergie et de la construction.
- **Groupe cible 2** : instructeurs issus de clusters industriels et d'associations professionnelles (par exemple, ceux travaillant avec la Fundación Laboral de la Construcción en Espagne ou les réseaux professionnels impliqués dans l'initiative « #100 Workshops » en Ukraine).

Recommandation 5 : utiliser des living labs et l'Apprentissage en Milieu de Travail (WBL)

L'efficacité de la formation dans des domaines complexes (comme la rénovation profonde) est faible si elle est dispensée uniquement de manière théorique.

- **Méthodologie** : la formation doit être pratique, en utilisant des environnements de type « Living Lab » ou des sites démonstrateurs (par exemple, comme cité dans l'approche de la Finlande et les centres de formation spécialisés en cours de modernisation en Ukraine) qui simulent les conditions réelles du chantier pour le contrôle qualité et l'installation de systèmes intégrés.
- **Certification** : la certification doit se baser sur la démonstration pratique des compétences dans un contexte WBL, plutôt que sur des examens purement théoriques.

8. Bibliographie

La bibliographie ci-dessous inclut une sélection de sources autoritaires citées tout au long du rapport D2.2, s'appuyant sur des documents de politique de l'UE, la législation nationale et des rapports fiables provenant des partenaires du consortium, d'organismes professionnels et d'institutions de recherche.

Citation : Commission Européenne (CE)

Titre : Directive (UE) 2018/844 du Parlement européen et du Conseil du 30 mai 2018 modifiant la Directive 2010/31/UE sur la performance énergétique des bâtiments et la Directive 2012/27/UE sur l'efficacité énergétique.

Source/Éditeur : Journal officiel de l'Union européenne

Date : 2018

Citation : Commission Européenne (CE)

Titre : Proposition de directive du Parlement européen et du Conseil sur la performance énergétique des bâtiments (refonte) (EPBD Recast).

Source/Éditeur : Commission Européenne, COM/2021/802 final

Date : 2021

Citation : Commission Européenne (CE)

Titre : Règlement Taxonomie (Règlement (UE) 2020/852) et actes délégués sur l'atténuation et l'adaptation au changement climatique.

Source/Éditeur : Journal officiel de l'Union européenne

Date : 2020/2021

Citation : Parlement Européen et Conseil

Titre : Directive sur le reporting de durabilité des entreprises (CSRD) (Directive (UE) 2022/2464).

Source/Éditeur : Journal officiel de l'Union européenne

Date : 2022

Citation : DG Énergie (CE)

Titre : La vague de rénovation pour l'Europe – Verdir nos bâtiments, créer des emplois, améliorer la vie.

Source/Éditeur : Commission Européenne, COM/2020/662 final

Date : 2020

Citation : Eurostat

Titre : Performance énergétique des bâtiments : activité de construction et taux de rénovation

Source/Éditeur : Rapports statistiques

Date : En cours (données les plus récentes disponibles pour 2024/2025)

Citation : FCRBE (Facilitating the Circulation of Reclaimed Building Elements)

Titre : Analyse des passeports matériaux et des outils de circularité (Référence de l'outil TOTEM).

Source/Éditeur : Documentation du projet FCRBE (Interreg NWE)

Date : 2021

Citation : Confidencial Imobiliário (Portugal)

Titre : Analyse du marché : durabilité et efficacité énergétique dans les projets de logements neufs (T1 2025).

Source/Éditeur : Rapport sectoriel (cité par le partenaire portugais)

Date : 2025

Citation : Conseil national suédois du logement, de la construction et de la planification (Boverket)

Titre : Mise en œuvre et guide de la Loi nationale sur la déclaration climatique.

Source/Éditeur : Cadre réglementaire et lignes directrices pour la mise en œuvre

Date : 2022

Citation : DG Recherche & Innovation (JRC)

Titre : Compétences pour la transition verte : défis et opportunités dans le secteur de la construction.

Source/Éditeur : Commission Européenne, Centre commun de recherche (JRC)

Date : 2023

Citation : Rapports nationaux (partenaires du consortium)

Titre : Rapports nationaux d'état de l'art pour EXCEL4HOUSING 4.0 (Compilation de 11 rapports nationaux : Belgique, Croatie, Finlande, Allemagne, Grèce, Italie, Pologne, Portugal, Espagne et Suède).

Source/Éditeur : Livrables internes du projet EXCEL4HOUSING 4.0

Date : 2025

9. Annexes

Annex 1: State-of-the-Art National Report - Belgium



REPORT ON THE STATE OF THE ART

Belgium

• Introduction

This report delivers a state-of-the-art analysis of Belgium's construction sector with a focus on energy-efficient housing, sustainable construction, digitalisation (Housing 4.0), and the circular economy, and examines the resulting qualification needs, evolving skill requirements, and emerging job profiles. The analysis is designed to inform WP4 by identifying implications for VET curricula, upskilling pathways, and credentialing.

Methodologically, the study follows the EXCEL4HOUSING4.0 desk-research guidelines, applying an eligibility checklist to ensure that sources are recent (2018+), relevant (sustainability, digitalisation, VET innovation, labour market trends), credible (peer-reviewed work, national statistics, or authoritative policy documents), and accessible for dissemination. At least ten national sources were included (see Annex), complemented by up-to-date EU legislation and recognised statistical and policy publications.

The inquiry is organised as follows. First, we situate Belgium within the European transition context shaped by the recast Energy Performance of Buildings Directive (EPBD, 2024), the Renovation Wave, and the EU Taxonomy (European Commission, 2020; European Commission, 2024; European Union, 2024). Second, we unpack Belgium's multi-level regulatory architecture, noting the interaction between federal responsibilities and regional frameworks in Flanders, Wallonia, and the Brussels-Capital Region (Public Service of the Walloon Region, 2024; Brussels Environment, 2025). Third, we assess market dynamics, contrasting pressures in new-build with opportunities in renovation and infrastructure (FIEC, 2025; ING Economics, 2024). Fourth, we synthesise the skills and employment implications of the green and digital transitions (FPS Health et al., 2023). Finally, we develop VET-oriented recommendations around digital and circular competencies, procurement levers, and living-lab partnerships (BBRI & BIM4D, 2024; FCRBE, 2021; Vlaamse Overheid, n.d.).

• Analysis summary

European policy frame. Buildings account for roughly 40% of EU final energy use and 36% of GHG emissions, positioning the built environment at the centre of the EU's 2050 climate-neutrality objective (European Commission, 2024). The EPBD (2024 recast) requires national renovation plans, minimum energy-performance standards, and large-scale skills measures; together with the Renovation Wave and EU Taxonomy, this creates a coherent regulatory-financial architecture that cascades into national and regional programmes (European Commission, 2020; European Union, 2024).

Belgian regulatory landscape. Belgium's federal-regional governance yields divergent but complementary implementation pathways. Wallonia tightened EPB rules (2013/2017/2019) and aligned new-build with NZEB since 2021 (Public Service of the Walloon Region, 2024). Flanders couples obligations with market signals via the renovation obligation (post-purchase EPC E/F → to D within five years) for residential—and analogous rules for non-residential (Vlaamse Overheid, n.d.). Brussels-Capital Region advances the RENOLUTION agenda, combining energy/circular targets with financial premiums and technical support (Brussels Environment, 2025; Urban.brussels, 2022). Fragmentation allows policy tailoring but complicates national skills harmonisation and procurement alignment (FPS Health et al., 2023).

Market dynamics. The sector employs 600k+ workers and mobilised ~€41 bn in 2024 (FIEC, 2025). New residential construction contracted amid higher interest rates and input costs; renovation and infrastructure expanded, pulled by policy incentives and high energy prices (FIEC, 2025; ING Economics, 2024). With ~85% of dwellings below 2050 standards, renovation rates must roughly quadruple, implying sustained demand for energy-efficiency services and delivery capacity (ING Economics, 2024).

Digitalisation (Housing 4.0). BIM adoption is voluntary and concentrated in larger clients/projects; SME uptake is slowed by cost, standards, and ROI uncertainties (BBRI & BIM4D, 2024). TOTEM anchors LCA practice in Belgium and is increasingly referenced in procurement and training; targeted micro-incentives (e.g., Brussels' TOTEM premium) can unlock adoption (FCRBE, 2021; Renolution.brussels, n.d.). The shift from document-centric to data-centric delivery elevates demand for BIM/LCA fluency across roles (BBRI & BIM4D, 2024).

Circular economy. Circular Flanders and Circular Wallonia institutionalise pilots, learning networks, and value-chain interventions (Confederation of the Construction Industry & OVAM, 2021; Walloon Government, 2021). Practices such as design-for-disassembly, selective deconstruction, reuse logistics, and materials passports are maturing, with FCRBE translating reuse into impact assessment workflows in line with EN 15804/EN 15978 (FCRBE, 2021). Market frictions persist (standards, liability, reverse logistics), but price volatility since 2022 strengthens the business case for reuse (ING Economics, 2024; FIEC, 2025).

Employment and skills. Net job effects to 2030 are modestly positive (≈ 1 –1.7%), yet highly uneven across occupations (FPS Health et al., 2023). Demand grows for hybrid roles—e.g., Retrofit Coordinators (BIM-LCA), BIM Managers, LCA specialists, deconstruction planners—while traditional roles require digital and circular upskilling (BBRI & BIM4D, 2024; FPS Health et al., 2023). The binding constraint is workforce capability rather than headline job counts.

Cross-cutting opportunity. The BIM–LCA–procurement nexus is the most powerful lever: BIM objects enriched with EPD/circularity attributes and TOTEM thresholds can steer low-carbon, circular choices and create a traceability loop for EU-Taxonomy-grade reporting (BBRI & BIM4D, 2024; European Commission, 2020; FCRBE, 2021).

Implications for WP4. Priority actions include:

- embedding BIM-LCA literacy as a baseline across VET;
- building stackable micro-credentials for NZEB retrofit/heat pumps/BIPV/automation;
- operationalising living labs with Green Deal and RENOLUTION pilots;
- harmonising competence frameworks inter-regionally; and
- using public procurement to reward verifiable digital/circular competencies (BBRI & BIM4D, 2024; Vlaamse Overheid, n.d.; Brussels Environment, 2025; FPS Health et al., 2023).

1. Introduction

This report presents a state-of-the-art analysis of Belgium's construction sector, with a focus on energy-efficient housing, sustainable construction, digitalisation, and the circular economy. It also **considers** the evolving landscape of qualifications, skill requirements, and emerging job profiles.

The analysis employs a structured desk-research methodology following the *EXCEL4HOUSING4.0* guidelines, relying on an eligibility criteria checklist to ensure that sources are:

- Recent (2018 or later);
- Relevant (covering sustainability, digitalisation, innovation in vocational education and training (VET), labour market trends, and job profiles);
- Credible (peer-reviewed studies, national statistics, or authoritative policy documents); and
- Accessible for dissemination within WP4 of the project.

At least ten national sources were selected (see Annex), and findings were synthesised into a narrative exploring the regulatory framework, market dynamics, technological innovations, circular economy initiatives, and cross-cutting opportunities for VET modernisation.

2. General Context: The European Construction Sector & Energy Transition

Buildings account for approximately 40% of the European Union's (EU) energy consumption and 36% of greenhouse gas (GHG) emissions (European Commission, 2024). Consequently, the EU has prioritised building decarbonisation as a cornerstone of its climate-neutrality goal for 2050.

The revised Energy Performance of Buildings Directive (EPBD, 2024) introduces significant changes, obliging Member States to adopt national renovation plans, implement minimum energy performance standards, and ensure large-scale training of skilled workers (European Commission, 2024). These reforms are embedded within the European Green Deal (2019), the Renovation Wave strategy (2020), and the EU Taxonomy on Sustainable Finance (2021), which together provide a coherent regulatory and financial framework for a greener built environment (European Commission, 2021).

For Belgium, the implications are particularly complex given its federal governance structure, with Flanders, Wallonia, and the Brussels-Capital Region each responsible for implementing EPBD transposition and related building codes (Public Service of the Walloon Region, 2020).

3. Policy and Regulatory Landscape in Belgium

Belgium's regulatory framework for sustainable construction is shaped not only by the European Union's climate and energy policies but also by the country's federal governance structure, which allocates substantial responsibility for energy and construction policies to its three regions: Flanders, Wallonia, and the Brussels-Capital Region. This decentralised model results in a fragmented regulatory landscape, where regional governments interpret and transpose EU directives into their own distinct building codes and support schemes.

The Walloon Region has progressively revised its transposition of the Energy Performance of Buildings Directive (EPBD) in 2013, 2017, and 2019, gradually tightening energy performance requirements for both public and private buildings (Public Service of the Walloon Region, 2020). These revisions introduced obligations for building permits to include initial and final energy performance statements, while accredited experts were required to complete training and pass examinations to maintain professional certification. The 2019 reinforcement for public buildings and the 2021 update applying to all new

constructions aligned Wallonia with the EU's nearly-zero-energy building (NZEB) standards, marking a decisive shift towards higher performance thresholds (Public Service of the Walloon Region, 2020).

Flanders has pursued a somewhat more ambitious trajectory, linking regulatory obligations to financial incentives for renovation. The “renovation obligation” introduced in 2022 requires purchasers of poorly performing residential buildings (Energy Performance Certificate category E or F) to undertake energy renovation within five years, thus directly mobilising the housing market for climate objectives (Flemish Government, 2022). The Brussels-Capital Region, meanwhile, has adopted a framework centred on its Renovation Strategy (2021–2030), which seeks to renovate 100,000 buildings by 2030 and provides financial premiums and technical assistance to both households and SMEs (Brussels Environment, 2021).

These regulatory divergences highlight both the strength and weakness of Belgium's federal model. On the one hand, regions can tailor measures to their socio-economic and housing contexts. On the other, fragmentation creates challenges for national coordination, particularly in developing coherent training standards for the construction workforce (FPS Health & Partners, 2023).

At the European level, Belgium's regional frameworks are embedded within broader EU policies, notably the Renovation Wave strategy, which aims to double the annual renovation rate by 2030, and the EU Taxonomy Regulation, which mandates sustainability disclosures from large companies and financial institutions (European Commission, 2021). These instruments serve as drivers of green financing, life-cycle assessment integration, and workforce upskilling investments, reinforcing regional obligations and aligning Belgium with the EU's 2050 decarbonisation pathway.

4. Market Dynamics and Key Trends in Belgium

The construction sector in Belgium represents a cornerstone of the national economy, employing over 600,000 workers and mobilising approximately €41 billion in investments in 2024 (FIEC, 2025). Yet, the sector faces a paradigm shift, driven by the combined pressures of macroeconomic instability, climate obligations, and demographic housing needs.

On the demand side, new residential construction has entered a period of contraction. Rising interest rates, increased construction costs, and persistent inflation in raw materials (notably cement, bricks, and steel) have contributed to a slowdown in building permits and a decline of around 7% in new housing activity in 2023 (FIEC, 2025). Simultaneously, bankruptcies in the sector have reached record levels, reflecting the vulnerability of SMEs that dominate the Belgian construction ecosystem (ING, 2024).

By contrast, renovation and infrastructure segments are expanding. This growth is largely attributable to policy instruments such as the Flemish renovation obligation and financial support under Brussels' Renovation Strategy, which stimulate household investment in energy-efficient upgrades (Flemish Government, 2022; Brussels Environment, 2021). Moreover, high energy prices following the energy crisis of 2022–2023 created strong incentives for homeowners to reduce consumption through insulation, heat pumps, and solar PV installations (ING, 2024).

The long-term structural challenge is formidable: approximately 85% of Belgian homes do not meet the 2050 energy standards, implying that the current renovation rate must quadruple if Belgium is to comply

with EU targets (ING, 2024). This figure underscores not only the scale of technical transformation required but also the labour and skills bottlenecks the sector will face in scaling up renovation capacity.

In addition, Belgium's construction market is experiencing contradictory trends: while demand for renovation rises, financial and operational barriers persist. Contractors are confronted with higher input prices, limited availability of sustainable materials, and increasing complexity in project delivery due to digital and circular requirements (FIEC, 2025). Thus, the sector stands at a crossroads, where policy-driven demand collides with market-based constraints, shaping a volatile but opportunity-rich environment.

5. Impact of Green and Digital Transitions on Employment

The dual transitions—the green transition towards climate neutrality and the digital transition driven by Housing 4.0 technologies—are exerting profound impacts on the Belgian labour market for construction.

The Federal Climate-Neutral Transition Report projects modest net employment gains of 1–1.7% by 2030, equivalent to approximately 13,000–22,000 jobs (FPS Health & Partners, 2023). However, this aggregate figure conceals substantial sectoral and occupational disparities. The report distinguishes three categories of labour market effects:

- Emerging roles: New occupations directly linked to the energy transition are arising, including deep energy renovation coordinators, BIM managers, and life-cycle assessment specialists. These roles are knowledge-intensive and demand hybrid expertise at the intersection of technical, digital, and environmental skills (FPS Health & Partners, 2023).
- Existing jobs requiring new green skills: Traditional construction roles, such as architects, engineers, electricians, and HVAC technicians, are undergoing skill transformation. These professionals must integrate energy-efficiency standards, digital modelling, and circular economy practices into their workflows, requiring both initial training reform and continuous professional development (BBRI & BIM4D, 2024).
- Jobs largely unaffected: A segment of the labour market—such as administrative and non-technical support roles—remains relatively insulated from transition pressures, though digitalisation may still influence job organisation and efficiency (FPS Health & Partners, 2023).

The overarching challenge is not the quantity of jobs, but the quality and content of work. The convergence of green and digital megatrends is accelerating job polarisation: high-skilled professionals benefit from demand for expertise, while middle-skilled workers risk displacement unless supported by life-long learning and upskilling pathways (FPS Health & Partners, 2023).

This transformation has significant implications for Belgium's VET and higher education systems. To avoid bottlenecks, Belgium must develop flexible, modular curricula that allow rapid requalification, particularly in renovation techniques, BIM-based design, energy storage integration, and selective deconstruction. Without these reforms, the labour market risks failing to meet the quadrupled renovation demand by 2050, creating not only an economic shortfall but also a regulatory compliance gap with EU climate targets (ING, 2024; European Commission, 2024).

6. Thematic Analysis of State-of-the-Art

6.1 Digitalisation in Construction (Housing 4.0)

Key technologies and infrastructures

Digitalisation in Belgium coalesces around Building Information Modelling (BIM), life-cycle assessment (LCA) ecosystems (notably TOTEM), and a widening constellation of smart design and asset-management platforms (BBRI & BIM4D, 2024; FCRBE, 2021). BIM remains voluntary and is most prevalent in large and complex projects—public facilities, infrastructure, and multi-lot developments—where coordination, clash detection, and cost control yield clear returns on investment (BBRI & BIM4D, 2024). Public clients occasionally require BIM at tender stage, but in the absence of national mandates, standards, or subsidies, diffusion into SMEs is uneven and slow (BBRI & BIM4D, 2024).

The TOTEM platform (Tool for Optimising the Total Environmental impact of Materials) functions as Belgium's reference LCA decision-support environment, developed through inter-regional and federal collaboration. TOTEM integrates environmental product declarations (EPDs) and curated generic datasets to enable comparative design choices at building and component level; it is increasingly referenced in public procurement and training offers (FCRBE, 2021). The user base—~4,400 registered users, including ~600 trained architects—indicates growing professionalisation of LCA practice, even if adoption remains far from universal (FCRBE, 2021).

A complementary digital layer is emerging around compliance tooling (e.g., EPB/EPB-like software), materials databases, and procurement checkers that translate policy targets (NZEB, circularity criteria) into measurable design constraints. When these tools interoperate with BIM environments (IFC-based exchanges) and with TOTEM's impact models, they form a proto-“digital thread” that spans planning → design → procurement → construction → operation → end-of-life (BBRI & BIM4D, 2024; FCRBE, 2021).

Adoption patterns, barriers, and enabling conditions

Belgian diffusion of digital construction technologies exhibits a dual market:

- Leaders—large contractors, multi-disciplinary engineering practices, and public owners—use BIM for 4D/5D scheduling, cost control, and risk management, and they increasingly interface with LCA workflows for low-carbon design (BBRI & BIM4D, 2024).
- Followers—SMEs and specialty trades—cite cost of software and training, uncertain client demand, fragmented standards, and opaque ROI as adoption barriers (BBRI & BIM4D, 2024).

Policy micro-incentives (e.g., the Brussels TOTEM premium of up to €200 per housing unit in renovation design studies) show that targeted signals can stimulate uptake where capital constraints are binding (VB Interreg, 2021). However, absent mandates, diffusion remains contingent on client requirements, supply-chain coordination, and availability of qualified staff (BBRI & BIM4D, 2024).

Labour market and professional profiles

Digitalisation is re-shaping occupational taxonomies. Demand is rising for BIM coordinators, BIM managers, digital construction managers, information authors/checkers, LCA specialists, and digital-twin engineers who can bridge data modelling, building physics, and procurement (BBRI & BIM4D, 2024). In parallel, traditional roles (architects, site managers, quantity surveyors) increasingly require data literacy, model interrogation, and LCA interpretation skills (FPS Health & Partners, 2023; BBRI & BIM4D, 2024). The

net effect is a shift from document-centric to data-centric project delivery, with implications for competence frameworks, CPD pathways, and assessment modalities in VET and higher education (FPS Health & Partners, 2023).

Systemic gaps

Three structural gaps persist:

- Standards and interoperability: Non-mandatory BIM and heterogeneous data schemas impede model reuse across project phases and regions (BBRI & BIM4D, 2024).
- Evidence of ROI for SMEs: Limited Belgium-specific cost–benefit evidence for small firms slows investment (BBRI & BIM4D, 2024).
- Talent pipeline: Shortages in BIM/LCA educators and workplace mentors constrain scaling of digital skills (FPS Health & Partners, 2023).

6.2 Circular Economy and Sustainable Construction Materials

Policy frameworks and collective action

Belgium stands out as an EU frontrunner in circular construction through Circular Flanders and Circular Wallonia, each combining strategic agendas with practice-based coalitions (Confederation of the Construction Industry & OVAM, 2021; Walloon Government, 2021).

- Circular Flanders coordinates a strategic agenda to 2061 anchored in ten working paths and rolling action programmes that enrol firms, municipalities, and knowledge institutions (Confederation of the Construction Industry & OVAM, 2021). The Green Deal Circular Construction convenes 300+ signatories to run pilots, exchange data, and mainstream circular practices (Vlaamse Overheid, 2022).
- Circular Wallonia (2021) designates construction as a priority value chain, deploying calls for projects (e.g., €600k in 2021) and taskforces that support industrial symbiosis, selective deconstruction, and re-manufacturing (Walloon Government, 2021).

Practices, tools, and standards

Circular practices increasingly include design-for-disassembly, selective deconstruction, component reuse, materials passports, and high-value recycling, with TOTEM providing the LCA backbone for comparative assessment of design variants and materials (FCRBE, 2021). The FCRBE project has been pivotal in operationalising reuse, documenting market actors for reclaimed components, and mapping how circularity indicators can be integrated into impact tools in line with EN 15804 and EN 15978 (FCRBE, 2021).

Market formation and bottlenecks

Belgium's circular construction market is thickening through public procurement pilots, regional premiums, and knowledge networks, but frictions persist: fit-for-purpose standards for reclaimed

elements, liability and warranty frameworks, quality grading, and logistics for reverse flows (Confederation of the Construction Industry & OVAM, 2021). Cost pressures and supply-chain disruptions since 2022 have paradoxically strengthened the business case for reuse—as price volatility makes material circularity a risk-hedging strategy (ING, 2024; FIEC, 2025).

Skills and professionalisation

Circularity accelerates demand for reuse logisticians, materials auditors, circular procurement managers, deconstruction planners, and LCA/circular design consultants (FPS Health & Partners, 2023). Site teams need competences in selective dismantling, contamination assessment, and documentation for passports, while designers must integrate reversible detailing and inventory-led design (FPS Health & Partners, 2023; FCRBE, 2021).

7. Cross-Cutting Analysis & Opportunities

Digital–circular convergence

The most promising frontier is the coupling of BIM and LCA—with TOTEM as the impact engine—to enable design-for-disassembly, materials passports, and circular procurement at scale (BBRI & BIM4D, 2024; FCRBE, 2021). BIM objects enriched with EPD attributes, reusability flags, and end-of-life scenarios can be federated into project-level impact dashboards that steer low-carbon, circular choices during design and tendering (BBRI & BIM4D, 2024). This creates a traceability loop across the asset life cycle, facilitating quality assurance and finance-grade reporting under the EU Taxonomy (European Commission, 2021).

Persistent barriers

- Regulatory fragmentation across regions complicates national alignment of digital/circular requirements and qualification standards (FPS Health & Partners, 2023).
- Weak price signals: Externalities (carbon, waste) are still insufficiently priced, so green premiums remain a hurdle without targeted incentives (FIEC, 2025).
- Skills scarcity in BIM/LCA/circular competencies is the binding constraint for delivery capacity (FPS Health & Partners, 2023).
- SME finance and evidence gaps: Many smaller firms lack capex, time, and proof-of-payback for digital and circular investments (BBRI & BIM4D, 2024).

Opportunity levers

Priority levers include outcome-based public procurement (embed BIM/LCA deliverables, reuse targets, and TOTEM thresholds), micro-incentives for SMEs (vouchers for software, training, and coaching), and inter-regional competence frameworks that normalise skills recognition across Belgium (VB Interreg, 2021; FPS Health & Partners, 2023). In parallel, pilot-to-policy pipelines—formal mechanisms that translate Green Deal pilots into codified standards and guidance—can shorten the evidence-to-adoption loop (Vlaamse Overheid, 2022; Confederation of the Construction Industry & OVAM, 2021).

Macro headwinds

High interest rates, elevated material prices, and input cost volatility continue to pressure margins, particularly in new-build, while renovation remains the growth locus (ING, 2024; FIEC, 2025). Without skills scaling and procurement reform, there is a risk that policy-induced demand outpaces delivery capacity, undermining EPBD-aligned renovation trajectories (FPS Health & Partners, 2023).

8. Innovation Opportunities in VET for Sustainable Construction

Curriculum architecture and pedagogy

- **Digital core (BIM-LCA literacy)**
Make data literacy and model-based collaboration baseline outcomes across construction VET. Tier learning as: Foundations (2D→3D literacy, IFC basics, reading/interrogating models), Practice (model coordination, quantity take-off, 4D/5D basics), and Impact (LCA with TOTEM, EPD interpretation, design trade-offs) (BBRI & BIM4D, 2024; FCRBE, 2021).
- **Circular competencies**
Integrate selective deconstruction, reversible detailing, materials passports, reuse logistics, and circular procurement into modules that pair studio-based design with field exercises (audit of existing buildings, component recovery planning) (FCRBE, 2021; Confederation of the Construction Industry & OVAM, 2021).
- **Energy-renovation specialisms**
Develop stackable micro-credentials for NZEB retrofit, BIPV, heat pumps, building automation, airtightness and insulation protocols, and commissioning—aligned with the quadrupling of renovation rates projected to meet 2050 targets (ING, 2024; FPS Health & Partners, 2023).
- **Interdisciplinary “hybrid” profiles**
Create pathways for Digital Construction Manager (Circular), Retrofit Coordinator (BIM-LCA), and Site Superintendent (Selective Deconstruction) that blend technical, digital, and environmental outcomes and include work-based learning with mentored reflective practice (FPS Health & Partners, 2023).

Delivery models and system enablers

- Living labs & pilots: Formalise partnerships with Green Deal Circular Construction and Circular Wallonia so learners can instrument real projects, gather LCA data, and test reuse workflows under supervision (Vlaamse Overheid, 2022; Walloon Government, 2021).
- SME-first incentives: Provide training vouchers, on-the-job coaching, and loaner software seats tied to measurable adoption milestones (VB Interreg, 2021).
- Assessment and recognition: Align competence frameworks across regions; recognise BIM/LCA micro-credentials in public procurement pre-qualification to reinforce labour-market value (FPS Health & Partners, 2023).

- Trainer capacity: Fund train-the-trainer programmes for BIM/LCA/circular topics; co-develop open instructional assets (datasets, sample models, EPD libraries) with Buildwise/BBRI and regional agencies (BBRI & BIM4D, 2024; FCRBE, 2021).

9. Conclusions & Recommendations for WP4

Belgium's construction sector is navigating a dual transformation: decarbonisation via large-scale renovation and innovation via digital and circular methods. The growth centre of gravity is shifting decisively from new-build to renovation, propelled by regional obligations and EU policy (FIEC, 2025; ING, 2024). BIM remains voluntary and uneven in SMEs, but TOTEM is consolidating as the national LCA reference, increasingly embedded in procurement and training (BBRI & BIM4D, 2024; FCRBE, 2021). Circular economy strategies in Flanders and Wallonia show durable momentum, institutionalising pilot-to-practice pathways (Confederation of the Construction Industry & OVAM, 2021; Walloon Government, 2021). The binding constraint is skills—particularly digital (BIM/LCA) and circular—which must scale rapidly to meet EPBD-aligned renovation (FPS Health & Partners, 2023).

Strategic implications for WP4 (curriculum and programme design)

- a. Make digital and environmental literacy foundational: Treat BIM-LCA fluency and EPD/TOTEM literacy as core outcomes across all construction programmes (BBRI & BIM4D, 2024; FCRBE, 2021).
- b. Build modular, stackable pathways for hybrid roles (e.g., Retrofit Coordinator (BIM-LCA)), enabling rapid re-qualification and CPD (FPS Health & Partners, 2023).
- c. Embed living labs: Tie VET delivery to Green Deal and Circular Wallonia pilots, with learning contracts that specify data capture and reflection (Vlaamse Overheid, 2022; Walloon Government, 2021).
- d. Harmonise qualifications inter-regionally: Co-develop shared competence standards and micro-credential taxonomies to reduce fragmentation and aid labour mobility (FPS Health & Partners, 2023).
- e. Use procurement to pull skills: Encourage contracting authorities to reward BIM/LCA competencies (pre-quals, award criteria), creating clear market signals for training uptake (European Commission, 2021; BBRI & BIM4D, 2024).
- f. Support SMEs directly: Pair curricula with vouchers, coaching, and tool access; measure outcomes (e.g., first BIM coordination delivered, first TOTEM study completed) (VB Interreg, 2021).

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Annex 2: State-of-the-Art National Report - Croatia



REPORT ON THE STATE OF THE ART

CROATIA

● Introduction

The purpose of this report is to provide a state-of-the-art analysis of the energy efficiency and sustainable housing sector in Croatia, focusing on how green and digital transitions are transforming the construction industry and related vocational education and training (VET) systems.

Specifically, this national contribution aims to:

- Identify current practices, policies, and innovations in sustainable housing, with particular emphasis on digitalisation (Housing 4.0) and circular economy principles;
- Map how these innovations intersect with education and training, especially within VET and lifelong learning;
- Highlight labour market trends and skill requirements resulting from the twin transitions;
- Provide evidence-based insights and recommendations that will feed into the curriculum and upskilling framework developed under WP4 of the EXCEL4HOUSING4.0 project.

The analysis follows the EXCEL4HOUSING4.0 desk research methodology and applies the eligibility criteria checklist to ensure that sources are:

- Recent (published in 2018 or later);
- Relevant, addressing sustainability, digitalisation, innovation, VET, and labour market trends;
- Credible, including policy documents, national strategies, EU publications, academic studies, or statistical reports;
- Accessible and suitable for dissemination within the project framework.

At least ten national and European sources have been consulted, complemented by expert insights and data from ongoing public and EU-funded initiatives in Croatia.

The report is structured as follows:

- The general context describes the European and Croatian policy and regulatory framework, market dynamics, and the impact of the twin transitions.
- The thematic analysis explores digitalisation (Housing 4.0), circular economy, and emerging professional profiles.
- The final section provides conclusions and recommendations for vocational education and training, offering input for curriculum design and future capacity-building activities in WP4.

● Analysis summary

The Croatian construction sector is undergoing a gradual but decisive transformation shaped by the twin green and digital transitions. As in the rest of the European Union, buildings in Croatia account for around 40 % of total energy use and over 35 % of greenhouse gas emissions, positioning the built environment at the core of national decarbonisation efforts.

In alignment with the European Green Deal, the Renovation Wave, and the recast Energy Performance of Buildings Directive (EPBD, 2024), Croatia has adopted a comprehensive regulatory and strategic framework that targets large-scale renovation, decarbonisation, and resilience of the national building stock. The National Energy and Climate Plan (NECP 2021–2030) and the Long-Term Strategy for the Renovation of Buildings (2020) set ambitious goals to increase the rate of deep renovations, promote

nearly zero-energy buildings (nZEB), and expand the use of renewable energy in housing.

Several complementary programmes support these objectives, including the Programme for Energy Renovation of Public Sector Buildings (2021–2030) and the National Recovery and Resilience Plan (NRRP), which channels significant EU funding into energy-efficient refurbishment, green infrastructure, and sustainable housing. Post-earthquake reconstruction efforts in Zagreb and the Sisak–Moslavina region have further accelerated investment in resilient and energy-efficient construction.

At the same time, Croatia's Circular Economy Strategy (2022–2030) promotes the reuse of construction and demolition waste and supports pilot initiatives for circular construction. Combined with the upcoming BIM implementation roadmap, these policies signal the country's gradual shift towards Housing 4.0 - a construction model that integrates sustainability, digitalisation, and innovation.

Despite progress, several structural challenges persist. Renovation rates remain below the EU average, and the building stock of which over 80 % was built before 1990 requires significant upgrades to meet the 2050 climate targets. The labour market faces acute shortages of skilled workers, particularly technicians and site workers trained in energy renovation, digital tools, and sustainable materials. Although the demand for such profiles is increasing, VET programmes are only partially aligned with emerging needs. Continuous professional training, modular short courses, and micro-credentials are therefore essential to bridge the gap between policy ambition and workforce capacity.

Croatia's innovation landscape in construction is still emerging but shows encouraging signs. Universities, professional chambers, and agencies are piloting BIM-based energy modelling, digital renovation tracking, and circular material management in public projects. These examples demonstrate the potential for linking digital tools with sustainability outcomes, thereby informing future curricula and professional standards.

Overall, Croatia's state-of-the-art reflects a sector in transition: policy frameworks are largely in place, investment is increasing, and awareness of green and digital skills is growing. The remaining barriers - fragmented implementation, limited data integration, and insufficient training infrastructure - underscore the need for stronger coordination between government bodies, educational institutions, and industry.

For the EXCEL4HOUSING4.0 project, Croatia's experience highlights both the potential and the urgency of developing a new generation of construction professionals equipped for digitalised, circular, and energy-efficient building practices.

● Indicative outline

3.1 Introduction

This section presents the analytical framework and main themes explored in the Croatian state-of-the-art report, following the methodology defined under Task 2.2 of the EXCEL4HOUSING4.0 project.

The analysis aims to describe the current situation, key trends, and innovation patterns within the Croatian construction sector, focusing on energy efficiency, sustainable housing, and Vocational Education and Training (VET).

The research combines desk review, policy mapping, and stakeholder insights, using sources published after 2018 and validated against the project's Eligibility Criteria Checklist. Particular attention has been given to:

- a. The alignment of Croatia's construction and housing sector with EU-level strategies (EPBD, European Green Deal, Renovation Wave, EU Taxonomy);

- b. The intersection of digitalisation and circular economy principles in construction practices;
- c. The evolution of skills, qualifications, and job profiles driven by the twin transitions; and
- d. The identification of opportunities for innovation in VET, in line with future green and digital competence frameworks.

3.2 General Context: European Construction Sector & Energy Transition

3.2.1 Policy and Regulatory Landscape

The European policy framework for the construction sector is shaped by the European Green Deal (2019), the Renovation Wave Strategy (2020), the EU Taxonomy for Sustainable Finance (2021), and the recast Energy Performance of Buildings Directive (EPBD, 2024). Together, these instruments establish the legislative and financial backbone for achieving a climate-neutral building stock by 2050. They oblige Member States to prepare National Building Renovation Plans, introduce minimum energy performance standards, and ensure large-scale workforce upskilling in green and digital skills.

Croatia's national regulatory and strategic framework is fully aligned with these EU priorities and includes several key instruments:

- National Energy and Climate Plan (NECP 2021–2030) - sets national targets for reducing greenhouse gas emissions by 36-41 % by 2030 and achieving a 32 % share of renewables, with the building sector recognised as a priority area for decarbonisation and energy savings.
- Long-Term Strategy for the Renovation of the National Building Stock (2020) - defines a pathway for deep renovation and the transition to nearly zero-energy buildings (nZEB), with milestones for 2030, 2040, and 2050.
- Programme for Energy Renovation of Public Sector Buildings (2021-2030) -promotes systematic refurbishment of public facilities through grants and technical assistance provided by the Environmental Protection and Energy Efficiency Fund (FZOEU).
- National Recovery and Resilience Plan (NRRP, 2021-2026) - finances large-scale renovation projects, renewable energy integration, and digital transformation of construction processes, with over €200 million allocated to building-related measures.
- Circular Economy Development Strategy for Croatia (2022-2030) - promotes waste prevention, recycling of construction and demolition waste, and the introduction of circular principles in building design and materials management.
- Post-Earthquake Reconstruction Programme - integrates seismic strengthening with energy-efficiency and renewable-energy upgrades, illustrating how resilience and sustainability objectives can converge in practice.

These frameworks collectively demonstrate Croatia's strong political commitment to decarbonising its building stock and improving resource efficiency. However, implementation remains fragmented: local authorities often face administrative and technical barriers, and there is still limited use of digital tools (e.g. BIM, LCA, material passports) in public procurement and construction oversight.

3.2.2 Overall Market Dynamics and Key Trends in Construction

The Croatian construction sector contributes around 5 % to national GDP and employs approximately 120,000 people. Over the last decade, the sector has recovered steadily following the 2008 crisis, with growth fuelled by EU-funded renovation programmes and post-earthquake reconstruction.

Key trends shaping the market include:

- Increasing demand for renovation - driven by EU targets, high energy prices, and ageing building stock (over 80 % built before 1990).
- Investment in green and smart buildings - commercial and residential developers are progressively incorporating nZEB standards, energy management systems, and smart controls.
- Rising interest in sustainable materials and circular design - projects exploring recycled aggregates, timber structures, and modular prefabrication are emerging through EU cooperation (e.g. Interreg and Horizon projects).
- Growth of digitalisation - BIM adoption is still in its early stages but expanding in public tenders and engineering firms; universities and chambers of engineers actively promote BIM education.
- Skills shortage - employers face persistent challenges in recruiting skilled workers, particularly retrofit specialists, energy auditors, and technicians trained in digital tools.

Despite positive investment trends, the sector faces barriers related to high material costs, slow permitting, and insufficient digital capacity among SMEs. These factors limit renovation speed and the scalability of green construction methods.

3.2.3 Impact of Green and Digital Transitions on the Broader Construction Sector

The green transition is reshaping the sector's value chain by prioritising deep energy renovation, renewable-energy integration, and low-carbon materials. Financial support through the NRRP and FZOEU has accelerated investments in solar photovoltaic systems, heat pumps, and building envelope improvements, while also stimulating innovation in building energy management and performance monitoring.

In parallel, the digital transition, often referred to as Housing 4.0, is introducing BIM, digital twins, and IoT-enabled energy-monitoring systems. These technologies are gradually transforming project management, cost estimation, and facility operation. Universities, REGEA, and the Faculty of Architecture are actively testing BIM workflows for renovation planning, and pilot projects are emerging in public-sector procurement.

Together, these transitions are generating new occupational profiles and altering skill demands. Roles such as BIM coordinators, energy-renovation supervisors, and sustainability consultants are increasingly required. The sector's future competitiveness will depend on how rapidly VET and higher-education systems integrate digital and green competence frameworks (such as ESCO, GreenComp, and DigComp) into training pathways.

3.3.1 Digitalisation in Construction (Housing 4.0)

Key Digital Technologies

Digitalisation in the Croatian construction sector is developing progressively, driven by the need to improve productivity, reduce costs, and align with EU requirements for energy-efficient and transparent project delivery. The key digital technologies entering the market include:

- Building Information Modelling (BIM) – increasingly adopted by large engineering and design companies for project coordination, 3D modelling, and cost estimation. Although not yet mandatory in public procurement, several institutions, including the Faculty of Architecture and the Croatian Chamber of Civil Engineers, actively promote its integration through training and pilot projects.
- Digital Twins and Smart Building Systems - still at an early stage, mostly demonstrated in research or pilot renovation projects; these systems allow real-time monitoring of energy performance and predictive maintenance.
- Internet of Things (IoT) and AI applications - being tested in energy management for public buildings and residential retrofits, enabling data-based decision-making and automation of HVAC systems.
- Life-Cycle Assessment (LCA) and Material Passports - emerging tools in sustainability assessments, used by universities and regional energy agencies to evaluate environmental impacts of renovation scenarios.

Adoption and Impact in Construction Processes and Building Operation

While large-scale adoption of BIM and digital tools is still limited, early adopters have demonstrated tangible benefits in project coordination, quality control, and cost transparency. BIM integration into renovation projects allows improved material quantification, energy simulation, and scenario comparison. The use of digital tools is also transforming the operational phase of buildings: public facilities renovated through EU-funded programmes are beginning to incorporate monitoring systems for energy consumption and indoor comfort. Over time, these datasets are expected to inform renovation planning and maintenance strategies at the municipal and national levels.

However, barriers remain significant. SMEs, which dominate Croatia's construction sector, often lack the financial and human capacity to invest in software, training, and data management systems. The absence of a national BIM mandate or standardised guidelines limits interoperability and slows diffusion. Moreover, digitalisation is still perceived as an optional efficiency tool rather than a strategic necessity.

Current Qualifications and Emerging Job Profiles

New professional roles are gradually emerging, reflecting the growing convergence between construction, IT, and energy management. The most in-demand profiles include:

- BIM Coordinator / BIM Manager - responsible for integrating design data, ensuring model accuracy, and managing collaboration across disciplines.
- Energy and Building Performance Specialist - skilled in data analysis, simulation tools, and optimisation of HVAC and renewable systems.
- Digital Construction Technician - combining knowledge of CAD/BIM tools, surveying technologies, and on-site digital workflows.
- Facility Energy Manager - responsible for monitoring and optimising building performance through IoT and data-driven control.

Croatia's VET and higher education institutions are beginning to address these trends, but the offer of practical, interdisciplinary training remains limited. Upskilling initiatives led by professional associations and regional energy agencies play an important complementary role.

Relevant Market Trends

The digitalisation of construction in Croatia is closely linked to EU funding requirements and the growing demand for traceable, measurable, and sustainable project outcomes. The public sector is expected to lead adoption through pilot tenders that include BIM deliverables and energy-performance tracking.

As investment in green and smart buildings expands, digital competencies will become essential across all professional levels, from planners and contractors to site managers and maintenance staff.

3.3.2 Circular Economy & Sustainable Construction Materials

Principles and Practices

The circular economy has gained strategic relevance in Croatia through the Circular Economy Development Strategy (2022–2030) and its Action Plan, which identify construction and demolition waste as a priority value chain. The key principles guiding the sector include:

- Design for disassembly and reuse – promoting modular systems and components that can be dismantled and reused;
- Material substitution – replacing high-carbon materials (cement, steel) with bio-based and low-carbon alternatives such as timber, recycled aggregates, and eco-insulation;
- Selective demolition and waste management – increasing recovery rates of construction and demolition waste through better sorting, recycling, and certification of secondary materials;
- Life-Cycle Thinking (LCA) – integrating environmental impact assessment across the entire building life cycle.

Regional and local initiatives are demonstrating how circular design can be embedded in practice. Municipalities, especially Zagreb and Karlovac, have launched awareness campaigns and feasibility studies on circular construction and reuse of demolition materials.

Sustainable Materials and their Application in Buildings

In Croatia, the use of recycled and sustainable materials is slowly expanding. Notable examples include:

- The use of recycled aggregates in road construction and public infrastructure projects, supported by the Ministry of Economy and Sustainable Development.
- Pilot applications of cross-laminated timber (CLT) and other bio-based materials in public buildings.
- Demonstration of prefabricated façade systems combining insulation and ventilation modules for rapid, low-impact retrofits.
- Projects evaluating the carbon footprint and embodied energy of materials used in renovation.

However, scaling these practices faces challenges: a lack of national standards for secondary materials, limited recycling infrastructure, and conservative procurement practices. Certification systems for circular products are under development but not yet widely adopted.

Current Qualifications and Emerging Job Profiles

The shift towards circular construction introduces new competencies, such as:

- Deconstruction Supervisor/Reuse Coordinator - managing selective dismantling and material recovery;
- Circular Design Engineer - integrating material passports and life-cycle analysis into design;
- Sustainable Materials Specialist - evaluating material performance and environmental indicators;
- Circular Procurement Officer - responsible for integrating circularity criteria into public tenders.

These roles are largely new to the Croatian context and currently exist only as pilot profiles within research or EU-funded projects. Incorporating them into national qualification frameworks will be essential for mainstream adoption.

Relevant Market Trends

Circular construction in Croatia is primarily driven by EU-funded pilot projects and public tenders that include sustainability criteria. Growing construction costs and material shortages since 2022 have increased interest in reuse, modularity, and local material sourcing.

Nevertheless, market uptake remains slow due to the limited financial incentives, lack of awareness among SMEs, and insufficient VET integration of circular-economy topics. Strengthening collaboration between policymakers, VET institutions, and the private sector will be crucial to bridge this gap.

3.4 Cross-Cutting Analysis & Opportunities

The Croatian construction sector is experiencing an accelerating convergence between digital transformation and circular economy practices, forming the basis for a systemic shift toward sustainable, data-driven, and resource-efficient building processes. While these two areas are often addressed separately, their integration represents a key opportunity to unlock higher performance, transparency, and innovation within both policy and practice.

Interlinkages and Synergies between the Thematic Areas

The intersection of BIM, LCA, and circular construction holds particular potential for Croatia.

- BIM-based design workflows can embed environmental and material data, enabling life-cycle performance assessment and supporting green public procurement.
- LCA integration provides a measurable basis for decision-making, allowing project designers to compare embodied energy, carbon footprint, and material reuse potential.
- Material passports, although still at pilot stage, can link digital design tools with waste management systems, facilitating traceability of materials across the building life cycle.

- The integration of IoT technologies with circular principles can further enable smart monitoring of energy use and material flows, closing the loop between design, operation, and reuse.

Such synergies create opportunities not only for environmental gains but also for new business models, including service-based construction, leasing of materials, and digital platforms for secondary materials exchange. Croatian regional energy agencies, universities, and local governments are well positioned to demonstrate these approaches through pilot initiatives combining digitalisation, energy renovation, and circular economy principles.

Common Challenges and Barriers

Despite strong policy alignment with EU frameworks, Croatia faces several structural challenges that limit the full potential of digital and circular transition in construction:

- Regulatory fragmentation - Circular construction and digitalisation are addressed in separate strategies, with limited coordination between ministries and regional authorities.
- Insufficient standardisation - Lack of national BIM standards and unclear certification procedures for secondary materials hinder market confidence and interoperability.
- Skills and capacity gaps - The workforce lacks integrated digital and green competencies; VET curricula often treat sustainability and technology as separate domains.
- Financial and technical barriers for SMEs - Smaller companies struggle to access financing for software, training, and new equipment, and often lack qualified personnel to manage digital processes.
- Low awareness and cultural resistance - Construction firms remain risk-averse, prioritising short-term cost savings over long-term innovation benefits.

These challenges underscore the importance of establishing coherent frameworks for competence recognition, cross-sector collaboration, and continuous professional development.

Innovation Opportunities in VET for Sustainable Construction

The transition toward sustainable and digitalised construction in Croatia presents a strong case for reforming vocational education and training (VET). The following opportunities emerge as particularly relevant:

- g. Integration of digital and environmental modules - embedding BIM, LCA, and circular economy topics within construction, architecture, and technical VET programmes.
- h. Modular micro-credentials - developing short, stackable learning units that provide flexible upskilling pathways for both students and professionals.

- i. Work-based learning and living labs - promoting partnerships between schools, local authorities, and industry, allowing learners to gain hands-on experience in real renovation and digital monitoring projects.
- j. Cross-disciplinary teaching - combining technical, digital, and sustainability skills, with teachers trained to deliver hybrid learning outcomes.
- k. Recognition and standardisation of new profiles - such as BIM Coordinator, Digital Construction Technician, Circular Design Engineer, or Energy Renovation Supervisor, ensuring alignment with the Croatian Qualifications Framework (CROQF).
- l. Public procurement as a driver for skills demand - incorporating BIM and circularity requirements in tenders to stimulate demand for trained professionals and foster collaboration between training providers and employers.

In summary, Croatia's cross-cutting opportunity lies in connecting policy ambitions with practical education reform. Establishing clear competence frameworks, expanding digital and circular training opportunities, and strengthening collaboration between the public and private sectors will be decisive for building a skilled workforce capable of delivering the country's green and digital transition.

3.5 Conclusions and Recommendations for WP4

The Croatian state-of-the-art analysis confirms that the country's construction sector is at a critical stage of transformation, where policy alignment, investment momentum, and emerging innovation provide a strong foundation for advancing both the green and digital transitions. However, the full potential of these reforms depends on building a qualified, adaptable, and digitally literate workforce.

Key Findings Summary

- Policy and regulatory alignment - Croatia has developed a robust policy framework in line with EU objectives (Green Deal, EPBD, Renovation Wave, Circular Economy Strategy), but practical implementation and inter-ministerial coordination require further strengthening.
- Market and investment trends - Renovation and reconstruction activities, supported by the NRRP and FZOEU programmes, are driving demand for sustainable construction solutions. Yet, high material prices, limited recycling infrastructure, and administrative bottlenecks continue to hinder faster progress.
- Digitalisation and innovation - BIM and related technologies are gaining traction through pilot projects, but their diffusion remains limited among SMEs. The absence of national standards and structured training pathways delays large-scale adoption.
- Circular construction - Awareness of circular principles is growing, yet their application in practice is constrained by low market demand, limited technical expertise, and lack of certified secondary materials.

- Skills and labour market gaps - The shortage of skilled workers, particularly those with integrated digital and green competences, is one of the most pressing barriers to achieving renovation and decarbonisation targets.

Strategic Insights for Curriculum and Training Programme Design (WP4)

The findings highlight the need for a systemic, future-oriented approach to VET modernisation in Croatia, where digitalisation, sustainability, and innovation are embedded across all training levels. The following strategic directions are proposed for WP4:

- Integrate green and digital literacy as core outcomes
Introduce BIM, LCA, and circular-economy modules as standard components of construction-related VET curricula, ensuring alignment with EU competence frameworks (ESCO, GreenComp, DigComp).
- Develop modular and stackable training pathways
Design short, flexible courses and micro-credentials that allow rapid upskilling for professionals involved in renovation, energy management, and sustainable materials.
- Promote living labs and real-world learning environments
Connect schools, universities, and local governments with ongoing renovation projects, enabling students to gain hands-on experience with BIM tools, digital monitoring, and circular construction techniques.
- Strengthen teacher and trainer capacity
Establish “train-the-trainer” programmes in cooperation with universities, professional chambers, and energy agencies to ensure consistent delivery of green and digital skills training.
- Enhance cooperation with industry and public authorities
Foster partnerships between VET institutions, municipalities, and private companies through joint pilot projects and internships, aligning training outcomes with market needs.
- Leverage public procurement as a policy tool
Encourage contracting authorities to include competence-based criteria (BIM usage, sustainability indicators, LCA reporting) in tenders, thereby creating direct demand for newly trained professionals.

In conclusion, Croatia’s construction sector holds substantial potential to become a national showcase for sustainable, circular, and digitalised building practices. The transition now depends less on new policies and more on the human capital able to deliver them. By embedding innovation-oriented learning into vocational education and training, Croatia can build a resilient workforce that supports both national climate goals and the broader European objectives of the EXCEL4HOUSING4.0 initiative.

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Annexes

Annex 1 – National Bibliography

The following list includes all national and regional sources consulted during the preparation of the Croatian state-of-the-art analysis. Each document was reviewed and validated according to the Eligibility Criteria Checklist provided in the T2.2 methodology. The selected references represent Croatia's key policy, regulatory, statistical, and research frameworks relevant to energy efficiency, sustainable housing, digitalisation, circular economy, and skills development in the construction sector.

- 1 Long-Term Strategy for the Renovation of the National Building Stock of the Republic of Croatia by 2050 (2020) – Ministry of Physical Planning, Construction and State Assets (MPGI).
This strategy defines Croatia's roadmap for deep renovation and transition to nearly zero-energy buildings (nZEB), setting milestones for 2030, 2040, and 2050.
- 2 National Energy and Climate Plan (NECP) 2021–2030 (2021) – Ministry of Economy and Sustainable Development (MINGOR).
Establishes national targets for greenhouse gas reduction and renewable energy use, highlighting the building sector as a priority for energy savings and emissions reduction.
- 3 Programme for Energy Renovation of Public Sector Buildings 2021–2030 (2021) – MPGI and Environmental Protection and Energy Efficiency Fund (FZOEU).
Provides implementation measures and funding mechanisms for the systematic renovation of public buildings.
- 4 National Recovery and Resilience Plan (NRRP) 2021–2026 (2021) – Government of the Republic of Croatia.
Channels EU funds into energy-efficient renovation, seismic strengthening, renewable integration, and digitalisation of the construction sector.
- 5 Circular Economy Development Strategy 2022–2030 (2022) – Ministry of Economy and Sustainable Development (MINGOR).
Introduces principles for waste prevention, reuse, and recycling in construction, defining construction and demolition waste as a priority material stream.
- 6 Annual Report on Energy Renovation Programmes in Croatia 2022–2023 (2023) – Environmental Protection and Energy Efficiency Fund (FZOEU).
Summarises results of national and EU-funded renovation programmes, energy savings achieved, and lessons learned.
- 7 Construction Statistics: Building Permits, Employment, and Investment in the Construction Sector, 2023 Report(2024) – Croatian Bureau of Statistics (CBS).
Provides the latest data on sector performance, employment, and investment trends.
- 8 BIM Implementation and Digitalisation in the Croatian Construction Sector – Policy Brief (2023) – Croatian Chamber of Civil Engineers (HKIG).

- Analyses the current level of BIM adoption and the challenges of digital transformation in the Croatian construction industry.
- 9 Energy Efficiency and Digitalisation in Building Renovation: Pilot Activities and Lessons Learned (2024) – Regional Energy Agency North-West Croatia (REGEA).
Demonstrates pilot cases linking digitalisation and energy renovation processes in public buildings.
 - 10 Innovative Approaches to Sustainable Housing and Education in Croatia (2023) – Faculty of Architecture, University of Zagreb.
Presents academic perspectives and practical models for integrating sustainability and innovation into education and housing design.

Annex 2 – Templates and Methodological Tools Used

The preparation of the Croatian state-of-the-art report followed the methodology developed under Task 2.2 of the EXCEL4HOUSING4.0 project, coordinated by CEEC. The following templates and tools were used to ensure consistency, comparability, and quality across partner contributions.

1. Eligibility Criteria Checklist (State-of-the-Art)

All national and EU-level sources were validated against the following criteria:

- Published in or after 2018;
- Relevant to at least one of the project themes: energy efficiency, sustainable housing, VET innovation, digitalisation, or circular economy;
- Issued by a credible and verifiable source such as a government body, research institute, EU institution, or professional association;
- Containing data or analysis directly applicable to Croatia's construction and VET sectors;
- Cited in compliance with APA referencing standards.

2. Desk Research and Compilation Process

The desk research phase included:

- Systematic identification of national and EU-level sources relevant to Croatia;
- Review of policy frameworks, statistical data, and pilot projects;
- Extraction of key findings into a structured list summarising main insights, relevance, and implications for WP4;
- Verification and cross-referencing of data between official publications and recent project reports;
- Synthesis of findings into thematic sections (digitalisation, circular economy, market trends, and skills).

3. Tools and Templates Applied

The following tools and templates were used during the process:

- Eligibility Criteria Checklist – T2.2 (State-of-the-Art)

- Desk Research List Compilation Template (Excel)
- State-of-the-Art National Compilation Template (Word)
- EXCEL4HOUSING4.0 Task 2.2 Methodology Document (CEEC, 2025)

4. Validation and Quality Assurance

The draft report was internally reviewed by REGEA and the Faculty of Architecture, University of Zagreb, before submission to the WP2 Lead. All findings were cross-checked for relevance, accuracy, and consistency with the European framework and the project's objectives.

End of the National Contribution – Croatia

This national report has been prepared jointly by the North-West Croatia Regional Energy and Climate Agency (REGEA) and the Faculty of Architecture, University of Zagreb, as part of Task 2.2 – State-of-the-Art Analysis and Collection of Best Practices under the EXCEL4HOUSING4.0 project.

The contribution reflects Croatia's current status, challenges, and opportunities in advancing energy efficiency, sustainable housing, digitalisation, and circular construction within the national VET and labour market context. It provides evidence-based insights that will directly inform the development of curricula, training modules, and capacity-building actions under Work Package 4 (WP4).

All information has been compiled in accordance with the T2.2 methodological guidelines and validated against the project's eligibility and quality assurance criteria.

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Annex 3: State-of-the-Art National Report - Finland



REPORT ON THE STATE OF THE ART

FINLAND

● Introduction

This report is mapping the Finland's construction sector's policy drivers, market dynamics, and technological trends, and examines their implications for skills, jobs, and vocational training. The purpose is to understand how the green and digital transitions can happen in practice. Using structured desk research the analysis combined with detailed case studies of Swedish and Finnish smart and sustainable cities, highlighting its leadership in digitalisation and circular construction practices. The findings were then translated into concrete opportunities for VET, with a focus on curriculum design, micro-credentials, and living-lab approaches. In doing so, the analysis bridges European regulatory and market developments with national best practices and identifies how vocational education and training can equip the workforce with the competence needed to deliver on the climate and digital ambitions of the sector.

● Analysis summary

There are several initiatives both in VET-providers and cities to work in a cross-disciplinary way to address the challenges and barriers of sustainable, energy efficient housing. Cities can take leadership in this transition to overcome the barriers and challenges. The report gives practical examples how different cities have done this.

● Indicative outline

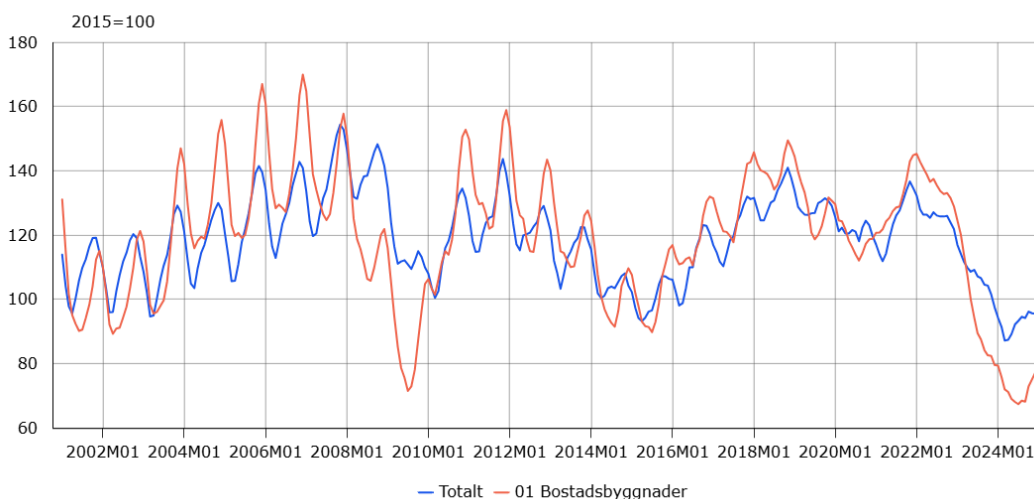
Introduction

This analysis of the Start-of-the-Art aims at providing an understanding of the vocational and professional situation regarding qualifications in circular economy, digitalisation and sustainability, with a forward-looking focus on innovation and market trends. The report is based on desk research, with analysis of legislation and research reports on sustainability issues and development as well as practical examples from smart and sustainable cities in Sweden and Finland which have introduced innovative processes for enhancing sustainable housing in the three thematic areas.

General Context: Finnish Construction Sector & Energy Transition

- Based on the EU directive on energy efficiency (EU/2023/1791), Finland is preparing an update of current regulations (and requirements regarding calculations of energy efficiency in both new buildings and in renovations (Ministry of the Environment n.d.).
- The new Building Act (751/2023) includes requirements for competences for designers and site managers, digitalization of administration of building permits (Lag om datasystemet för den byggda miljön 431/2023), as well as calculation of carbon footprint for all larger new buildings.
- The overall market dynamics are weak, with a 3 year period of decline in construction and housing new builds (Rakennusteollisuus 2025). See also graphic below.

Volymindex för nybyggnad (2015=100) 2001M01-2024M12
Indextal



Källa: Statistikcentralen, byggnads- och bostadsproduktion

- o The NATSPEC report 2025 states HE:s currently provide BIM education for students, in different disciplines.
- o Construction in wood has long been on the agenda in Finland, but in recent years the focus has shifted towards high rise buildings and CLT as means of promoting a climate-friendly construction method. Despite promotion it has not reached any large impact. Partly due to the recession in the construction markets. Education has been strengthened and there is today a better understanding of problems and solutions (Heino 2011).

Thematic Analysis of State-of-the-Art

Digitalisation in Construction (Housing 4.0)

- Buildings information modeling (**BIM**) is adapted by most large developers, contractors as well as architect and engineering offices (NATSPEC 2025). Building Smart Finland (BsF) is currently rewriting the existing BIM recommendations (YTV2012) from 2012 aiming at standardizing use cases (BuildingSmartFinland n.d.), in cooperation with corporations and BuildingSmart International. BuildingSmart Finland (BsF) is preparing a pre-study regarding a qualification setup for BIM competences in relation to international certification models for practitioners (BuildingSmart Finland, n.d.).
- **AI for energy & operations** – Finnish and Swedish cities have been actively supporting and testing the use of AI to optimise energy use, reduce costs and increase indoor air quality. One of the first public building owners to introduce this technology was SISAB in Stockholm as it in 2020 introduced SOLIDA. SISAB is fully owned by the City of Stockholm and owns and operates all public schools and daycares in Stockholm. SISAB partnered with a large company (Scneider Electric) and small companies such as Init and Myrspoven. SOLIDA uses real-time data and predictive algorithms to continuously fine-tune indoor climate and energy use. Thousands of temperature and CO₂-sensors feed into the system, enabling 24/7 intelligent control. From SISAB's control tower, experts now monitor more than 600 schools, manage 200 alarms daily and support

maintenance teams citywide. The problem with this type of system is that it is a vendor lock-in, if the building owner wants to change the building automation system to another vendor, the data will be lost. Another obstacle is that all building automation systems must be upgraded first, before AI can be introduced. To address these problems the City of Jakobstad used innovative new technology which avoided both the lock-in and the upgrading problematic. The company Nobody Engineering installed its IOT-robots in existing buildings with automation systems from different manufacturers and eras (from late 1980' to 2020's). The IOT-robot collects the data 24/7 and it is stored into an independent data layer. All data is owned by the city and it can decide which companies can provide AI-based added-value services for the city. In Jakobstad's case the company Lassila & Tikanoja provided the same type of service as Inet and Myrspöven in Stockholm. The large differences between the SISAB and Jakobstad cases were:

- the deployment time in Jakobstad was very short
 - the investment costs are very much lower
 - the payback time was very short
 - the city owns all data and can very easily change the service provider without any loss of historical data
- **Digital twins from district to building scale** – Metropolia University of Applied Sciences in Helsinki has launched a new multi-year cooperation project called Smart Buildings in Smart Communities, which aims to develop and expand the expertise in smart electricity use and building technology from properties to the block level – combining the opportunities of artificial intelligence, digitalisation and collaborative learning. The project continues the results of the Real Estate Information and IoT Solutions Management project carried out in 2020–2024, and it receives its funding from STEK ry. The goal is to develop Myllypuro's Smart Campus into an even more versatile RDI and learning environment and to develop new solutions for building interfaces, energy efficiency and data utilisation together with companies and research networks. The Smart Building Gold certified Myllypuro campus is being developed into a generic RDI and learning platform for data-based smart solutions in buildings. The campus has already proven its potential as a learning environment, and in ongoing projects and future projects, its solutions will be applied in residential, hotel and hospital environments. The project focuses on the development of AI-based solutions for electrical and building technology, digital twins of buildings and data visualization, technology transfer through education and learning solutions, and cooperation with companies, educational institutions and international networks.

Circular Economy & Sustainable Construction Materials

- The built environment in Finland is of recent date, with only about 4 % of the structures being built before 1920, and on average approx. 40 % is built about 50 years ago (Finlands officiella statistik 2024). According to Huuhka & Lahdensivu (2014) about 80 % of all demolished buildings were less than 60 years old.

- Since 1994 the legislation for construction and building includes a requirement for sustainability. Building activities should create: “preconditions for a favourable living environment and promote ecologically, economically, socially and culturally sustainable development” (Lag om ändring av byggnadslagen 1994).
- In 2022 the Ministry of the Environment initiated a study about the promotion of circular economy and lifespans of buildings, and with the aim of systematizing life cycle qualities in the construction processes (Hakaste, H., Häkkinen, T., Lahdensivu, J. and Saarimaa, S. 2024). There is no legislative outcome yet from this process.
- A recent process innovation in Finland is the concept of *project alliances* (Allianssimalli) (Hietajärvi 2017; RT 103239 and RT 103199, 2020). Instead of a process of step-by-step where each phase is limited and all phases are based on bidding and competition, the projects are initiated as integrative endeavors, where time is spent on searching for optimal solutions and streamlining design and construction (Saarinen 2020). This allows more space for evaluation of solutions and creates a holistic approach, instead of each party optimizing their efforts towards the goals of the client. It is said to promote holistic problem solving and innovation (Hietajärvi 2017; Ahlbäck 2020). This model is used for large projects, where smooth use of digital cooperation is important and all parties are involved in the setting of goals and targets, among others also sustainability (Ibid.).
- The cities of Stockholm and Vaasa has initiated processes, methodologies to steer and support construction companies towards constructing low-carbon buildings. In both cities the starting point is to calculate the carbon footprint of a standard building and then find possibilities to lower the footprint. Interestingly the calculation of a plus-energy multi-storey building showed a higher carbon footprint than a standard multi-storey building. The reason was that a lot of PV:s was installed both on the roof and walls of the building. All these PV:s were produced with coal-based energy plants abroad. In Vaasa the tool one-click LCA was defined as the method with which the building carbon footprint would be evaluated. The city set a goal that all new buildings in a green field area of ravilaakso would need to have 40% lower carbon footprint compared to standard buildings in Finland. For this purpose, construction companies received the possibility to participate in a series of lectures both on the use of the calculation tool, but also different ways of reducing the carbon footprint of a new building.
- In the project GrowSmarter (see best practice) a refurbished 13 story building was compared to a similar new building and the calculations showed that the refurbished and modernised had a 70% lower carbon footprint than an equal new building.
- VET education has curricula from government+ GreenComp 2022
- The Rector’s Conference of Finnish Universities of Applied Sciences (Arene ry) together with the organisation for VET providers (AMKE ry) have initiated a process to become carbon neutral by 2030 (Arene ry 2021).

- **Cross-Cutting Analysis & Opportunities**

- There are many initiatives in Swedish and Finnish cities to steer and support the construction of more sustainable and energy-efficient buildings. These initiatives include the implementation of IOT-platforms and AI to reduce the energy use, costs and improve the indoor climate.
- The initiative of Jakobstad in Finland to collect and store real-time data from its buildings into an independent data layer and share this data with a separate agreement to the University of Vaasa gives researchers an opportunity to get access to big data without a data collection cost.
- The practical cases and initiatives in Stockholm, Vaasa and Jakobstad shows interlinkages and synergies between the three thematic areas.
- Many of the challenges and barriers first-mover cities such as Stockholm have faced are common across diverse European regions (e.g., policy, financial, skills-related).
- There are a lot of innovation opportunities if cities open their buildings data for universities and start-up companies, where the barrier is: a) access to real-time data and b) high costs for installing own tools for data collection. In Jakobstad start-up companies as well as established companies got limited access to data from the independent data layer for the purpose of developing and testing new services to reduce both costs and energy use of existing buildings. ‘
- BIM is widely taught in higher education, but current AI development seems to indicate fast changes in work practices and need for reskilling both in the education of youth and by means of continuing education for those already with working life experiences.

- **Conclusions and Recommendations for WP4**

- Cities aiming for carbon neutrality can have an important role in supporting the construction of sustainable buildings:
 - by collecting real-time data from its buildings into an independent data layer, where it can be shared with agreement to external actors (schools, research institutes, public organizations, start-ups etc.)
 - by developing methodologies to calculate the carbon footprint of buildings
 - by providing training for construction companies regarding sustainable technologies, data collection, tools for calculating carbon footprints etc.
 - by testing and demonstrating both refurbished and new buildings where innovative solutions have been implemented to reduce the energy use and climate impact (see best practice GrowSmarter)
- Based on an assumption that AI will transform ways of working, it seems appropriate to rethink teaching and learning. The crucial changes seem to be an increasing need to monitor results, AI-tool fluency and management in a multi-disciplinary context and less work in routine tasks and detailing. The focus of skills development has to shift from the current university education complemented with initial on-the-job trainee positions for longer periods, to creating a preparedness for managing and understanding processes, risks and interrelated multi-disciplinary production.

- o A *generative design studio* could be an adequate learning environment for architect and engineering design students, as a training context for senior students providing training to master projects. This can be seen as a rearrangement of the Finnish example of Best Practice in digitalization.
- o For site management one can think of a similar generative studio, but with a *game-like setting*, providing the training model illustrating the progress of a construction process, as a simulation.
- o In both instances it is possible to *integrate sustainability issues*, and *vocational training* alongside that of architect and engineering students. This can be seen in relation to the Finnish Best Practice *Teknikhuset* as a hands-on environment, allowing for both simulations and adaption and refitting according to new emerging technology.

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Annex 4: State-of-the-Art National Report - Germany



REPORT ON THE STATE OF THE ART

Germany

● Introduction

This report provides a comprehensive overview of the state of the art in Germany's construction sector, focusing on the energy transition, digitalisation, circular economy, and sustainable construction materials. The methodology combines desk research, analysis of policy documents, market reports, and academic literature to synthesize current trends, challenges, and opportunities relevant to vocational education and training (VET) and the EXCEL4HOUSING4.0 project.

● Analysis summary

Within the broader European policy framework, the construction sector is influenced by a range of initiatives aimed at achieving climate neutrality and energy efficiency. The European Green Deal sets the overarching goal of making Europe the first climate-neutral continent by 2050, with the Renovation Wave strategy specifically targeting the improvement of energy performance in buildings across member states. The EU Taxonomy further encourages sustainable investment by defining criteria for environmentally sustainable economic activities. These measures are complemented by the revised Energy Performance of Buildings Directive (EPBD, 2024), which establishes ambitious standards for zero-emission buildings and the gradual phase-out of fossil fuels.

In Germany, the regulatory landscape is shaped by the Buildings Energy Act (GEG), which consolidates energy efficiency and renewable energy requirements for new and existing buildings. Recent amendments ensure alignment with EU targets, reinforcing the commitment to decarbonisation in the built environment. The National Building Renovation Plan (NBRP) outlines detailed milestones for 2030, 2040, and 2050, including policy measures and investment needs to support the transition to a zero-emission building stock. These frameworks collectively drive innovation, investment, and adaptation within the German construction sector, positioning it at the forefront of sustainable development in Europe.

● Indicative outline

General Context: European Construction Sector & Energy Transition

Policy and Regulatory Landscape

- Germany is implementing the revised Energy Performance of Buildings Directive (EPBD, 2024), which mandates zero-emission standards for new buildings by 2030 and a phase-out of fossil fuels by 2040. The national Buildings Energy Act (GEG) integrates energy efficiency and renewable energy requirements, with recent amendments to align with EU targets.
- The European Green Deal, Renovation Wave, and EU Taxonomy are driving investment and regulatory changes, with a focus on decarbonising the building stock and promoting sustainable finance.
- Germany's National Building Renovation Plan (NBRP) sets detailed targets for 2030, 2040, and 2050, including policies, measures, and investment needs to achieve a zero-emission building stock.

Overall Market Dynamics and Key Trends in Construction

- The German construction market was valued at USD 267.7 billion in 2024 and is projected to reach USD 458.3 billion by 2034, with a CAGR of 5.6%. Growth is driven by public infrastructure investment, housing demand, and sustainability initiatives.
- Renovation and retrofitting dominate activity, as owners upgrade buildings to meet EU energy rules. Modular construction and digitalisation are gaining traction as responses to labor shortages and cost pressures
- The sector is increasingly focused on energy-efficient buildings, eco-friendly materials, and innovative construction techniques, with strong private sector involvement.

Impact of Green and Digital Transitions on the Broader Construction Sector

- The green transition is accelerating demand for energy-efficient retrofits, sustainable materials, and circular practices. The digital transition is reshaping design, planning, and construction through technologies like BIM, AI, and IoT.
- Both transitions are creating new job profiles and upskilling needs, while also presenting challenges related to regulatory complexity, investment, and workforce adaptation.

Thematic Analysis of State-of-the-Art

Digitalisation in Construction (Housing 4.0)

– **Key Digital Technologies:**

- Building Information Modelling (BIM) is now standard in public procurement and widely adopted for planning, coordination, and lifecycle management.
- Digital Twins, AI, and IoT are increasingly used for real-time monitoring, predictive maintenance, and energy management.

– **Adoption and Impact:**

- Digitalisation improves productivity, reduces errors, and enables new business models. However, barriers include high upfront costs, lack of standardisation, and skills shortages.
- The German government has launched a Road Map for Digital Design and Construction to establish BIM as the nationwide standard.

– **Current Qualifications and Emerging Job Profiles:**

- Demand is rising for BIM managers, digital construction coordinators, data analysts, and specialists in AI and IoT for buildings.
- VET curricula are being updated to include digital competencies, but gaps remain in advanced digital skills.

– **Market Trends:**

- Digital transformation is a key driver of competitiveness and sustainability in the sector. Cloud-based BIM, digital twins, and AI are expected to become mainstream by 2030.

- o The EPBD³ (2024 recast) requires national renovation plans, minimum energy-performance standards, and large-scale skills measures; together with the Renovation Wave and EU Taxonomy, this creates a coherent regulatory-financial architecture that cascades into national and regional programmes.
- o Germany's National Building Renovation Plan (NBRP) outlines detailed targets for 2030, 2040, and 2050, including policy measures and investment needs to support the transition to a zero-emission building stock.
- o Renovation rates must roughly quadruple to meet EU targets, implying sustained demand for energy-efficiency services and delivery capacity.
- o The sector employs over 2.6 million workers and mobilised approximately €400 billion in 2024, with renovation and infrastructure segments expanding due to policy incentives and high energy prices.
- o Net job effects to 2030 are modestly positive, yet highly uneven across occupations. Demand grows for hybrid roles such as Retrofit Coordinators and BIM Managers, while traditional roles require digital and circular upskilling.
- o The binding constraint is workforce capability rather than headline job counts.
- o BIM adoption is increasingly standard in public procurement, but SME uptake is slowed by cost, standards, and ROI uncertainties.
- o The shift from document-centric to data-centric delivery elevates demand for BIM/LCA fluency across roles, requiring modular curricula and stackable micro-credentials.
- o Germany's circular construction market is thickening through public procurement pilots, regional premiums, and knowledge networks, but frictions persist: fit-for-purpose standards for reclaimed elements, liability and warranty frameworks, and logistics for reverse flows.
- o Circularity accelerates demand for reuse logisticians, materials auditors, circular procurement managers, and deconstruction planners.

Circular Economy & Sustainable Construction Materials

– Principles and Practices:

- o Germany's National Circular Economy Strategy (NCES) promotes reuse, recycling, and waste minimisation across the construction value chain.
- o The sector recycles about 90% of construction and demolition waste, but much is downcycled rather than reused in high-value applications.
- o Modular construction, material passports, and digital tools (e.g., BIM) support circularity.

– Sustainable Materials:

³ **Energy Performance of Buildings Directive.** In German language: **Richtlinie über die Gesamtenergieeffizienz von Gebäuden.**

- o Increasing use of recycled concrete, wood, and bio-based materials. Urban mining and cradle-to-cradle approaches are gaining ground.
- **Current Qualifications and Emerging Job Profiles:**
 - o New roles include circular construction managers, material flow analysts, and sustainability consultants.
 - o VET and higher education are integrating circular economy concepts, but further curriculum development is needed.
- **Market Trends:**
 - o Regulatory and market pressures are driving adoption of circular practices. Digitalisation is enabling better tracking and reuse of materials.

Cross-Cutting Analysis & Opportunities

- **Interlinkages and Synergies:**
 - o Digitalisation and circular economy are mutually reinforcing: digital tools enable material tracking, lifecycle analysis, and efficient resource use.
 - o Both areas require upskilling and new qualifications, especially in digital and green skills.
- **Common Challenges and Barriers:**
 - o Priority levers include outcome-oriented public procurement, micro-incentives for SMEs, and interregional competence frameworks that standardize the recognition of qualifications.
 - o Skills shortages, especially in digital and green competencies.
 - o Regulatory complexity and fragmented standards.
 - o High upfront investment costs and slow adoption of innovation, especially among SMEs.
 - o Need for better collaboration between VET providers, industry, and policymakers.
- **Innovation Opportunities in VET for Sustainable Construction:**
 - o Living labs and pilot projects that inform policy can shorten the path from evidence to adoption and support curriculum innovation.
 - o Expansion of modular, digital, and green skills in VET curricula.
 - o Greater use of digital platforms for training and upskilling.
 - o Partnerships between VET, industry, and research to pilot new approaches (e.g., InnoVET, BuildSkills Academy).

Conclusions and Recommendations for WP4

Key Findings Summary

- Germany's construction sector is at the forefront of the green and digital transitions, but faces significant challenges in workforce skills, regulatory adaptation, and innovation uptake.

- Digitalisation (BIM, digital twins, AI) and circular economy practices are reshaping job profiles and training needs.
- There is a strong policy and investment push for sustainable, energy-efficient, and circular construction, but implementation gaps remain, especially in VET.

Strategic Insights for Curriculum and Training Programme Design

- Update VET curricula to integrate digital and green skills, including BIM, AI, IoT, and circular economy principles.
- Foster partnerships between VET providers, industry, and research to ensure curricula reflect current and future skills needs.
- Promote modular and flexible training formats, including online and blended learning.
- Support upskilling and reskilling for existing workers, with a focus on SMEs and older employees.
- Encourage innovation in teaching methods, including the use of digital platforms and real-world project-based learning.

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Annex 5: State-of-the-Art National Report - Greece



REPORT ON THE STATE OF THE ART

Greece

● Introduction

This report delivers a state-of-the-art analysis of Greece's construction sector with a focus on energy-efficient housing, sustainable construction, digitalization (Housing 4.0), and the circular economy, and examines the resulting qualification needs, evolving skill requirements, and emerging job profiles.

Methodologically, the study follows the EXCEL4HOUSING4.0 desk-research guidelines, applying an eligibility checklist to ensure that sources are recent (2018+), relevant (sustainability, digitalization, VET innovation, labor market trends), credible (peer-reviewed work, national statistics, authoritative policy documents), and accessible for dissemination.

The report is structured as follows:

- The general context describes the European and Croatian policy and regulatory framework, market dynamics, and the impact of the twin transitions.
- The thematic analysis explores digitalization (Housing 4.0), circular economy, and emerging professional profiles.
- The final section provides conclusions and recommendations for vocational education and training, offering input for curriculum design and future capacity-building activities in WP4.

● Analysis summary

The Greek construction sector is rapidly evolving due to digitalization and the green transition. Energy efficiency, sustainable buildings, and circular economy principles are now key policies and market priorities. Public programs like Electra, Exoikonomo, and EU-funded initiatives are accelerating energy-efficient renovations and digital adoption, presenting both opportunities and workforce skills challenges.

Construction sector contributed approximately 2.6% of Greece's GDP in 2024, supported by over €14 billion in public and private investment. Employment in construction reached 210,000 workers in 2024, reflecting an 8.8% increase from 2023, although medium-skilled labor shortages remain critical (IOBE, 2025).

National strategies focus on the reutilization and recycling of waste generated from construction and demolition. Employment opportunities in circular construction, energy-efficiency retrofitting, and life cycle assessment (LCA) analysis are anticipated to grow. Occupations that require medium qualifications are especially impacted by the transitions towards digital technologies and green practices. There is an immediate demand for hands-on, modular vocational education and training (VET) programs that address BIM, circular design, energy efficiency, and the operation of smart buildings. Small and medium-sized enterprises (SMEs) and smaller construction companies need support to access training and implement innovative methods.

Greece is aligned with European Union initiatives such as the Renovation Wave, the Energy Performance of Buildings Directive (EPBD), and the EU Taxonomy, which incorporate sustainability, digitalization, and energy efficiency into regulatory standards.

National initiatives such as National Resilience and Recovery Plan aim to enhance building renovations, the integration of renewable energy, and the development of energy-efficient public infrastructure.

● Indicative outline

Introduction

This task aims to provide an overview of current practices and innovations in sustainable, digitalization and energy-efficient construction in Greece, focusing on their integration into training, qualifications, and innovation frameworks. Specifically, the report seeks to:

1. Explore sustainable practices and innovations in the construction sector, with emphasis on digitalization (Housing 4.0) and circular economy approaches.
2. Analyze the relationship between these innovations and education and training, especially in vocational education and training (VET) and lifelong learning.
3. Identify emerging market and policy trends that are influencing the need for new skills and qualifications.
4. Emphasize how government-funded initiatives foster connections between sustainability, digital transformation, and workforce development.

The analysis was conducted through desk research, combining literature review, case study analysis, and comparative framework review to capture the current landscape and relevant needs of construction professionals, policymakers, VET institutions, and end-users.

General Context: European Construction Sector & Energy Transition

The European construction sector is entering a period of profound structural transformation between 2025 and 2026, driven by the twin green and digital transitions. Following a moderate recovery from previous years' slowdown, the projected annual growth of 2.1% is underpinned by public investment focused on energy-efficient renovation, affordable housing, and resilient infrastructure.

Energy efficiency is emerging as a strategic priority, with a strong emphasis on retrofitting the existing building stock to reduce consumption and combat energy poverty, which continues to affect millions of vulnerable households. These interventions not only enhance the thermal performance of buildings but also strengthen social cohesion and urban resilience.

However, the green transition faces structural barriers, most notably the shortage of skilled labor. Despite financial momentum from European funds and national policies, the sector struggles to attract and retain technical professionals specialized in energy efficiency, industrialized construction, and digitalization. This shortage threatens to delay the implementation of key projects and highlights the urgent need for vocational training programs and improved working conditions. In parallel, technological innovation, such

as modular construction, low-impact materials, and digital solutions, is emerging as a critical lever to boost productivity and meet the EU's climate targets.

Employment in Construction in Greece reached 210 thousand workers in 2024, up by 8.8% compared to 2023 (+17 thousand workers), covering part of the sector's increased labor needs. In the Architecture and Engineering activities, employment reached 90,000 persons in 2024, showing a significant increase from 2020 (+21%). According to the ELSTAT Labor Force Survey, the majority of workers in Construction are employed in specialized construction activities (106,000 persons in 2024).

Policy and Regulatory Landscape (e.g., EPBD, European Green Deal, Renovation Wave, EU Taxonomy relevant to construction)

The Renovation Wave Strategy, launched in October 2020, outlines a comprehensive set of measures designed to more than double the annual rate of energy renovations across the European Union by 2030. This initiative is a central pillar of the EU's broader efforts to achieve climate neutrality and promote a just and sustainable energy transition.

A key component of the strategy is the revision of the Energy Performance of Buildings Directive (EPBD), which represents a fundamental step in updating the existing regulatory framework. The revised directive seeks to align building policies with the EU's higher climate ambitions and increasing social needs, while also providing Member States with the flexibility required to address the diverse characteristics of national building stocks across Europe. Through these measures, the Renovation Wave aims not only to enhance energy efficiency and reduce greenhouse gas emissions, but also to tackle energy poverty, improve indoor comfort, and stimulate economic activity in the construction and renovation sectors (CRES, 2023). In addition, Level(s) is a voluntary reporting framework to improve the sustainability of buildings. It provides a common EU approach to assess environmental performance in the built environment.

Greece's national regulatory and strategic framework is fully aligned with these EU priorities and includes several key instruments:

Greece's national climate law: adopted in May 2022, sets a climate neutrality target for 2050, as well as intermediate targets of a 55 % reduction of net GHG emissions by 2030 and an 80 % reduction by 2040. It introduces sectoral objectives and measures, and requires the government committee on climate neutrality to prepare sectoral carbon budgets. The law requires the adoption of a national climate adaptation strategy, regional adaptation plans, and municipal emissions reduction plans.

National Energy and Climate Plan (NECP 2021–2030) : Greece's NECP sets economy-wide 2030 targets (GHG reductions, renewables, energy efficiency) and treats the buildings sector as a priority for decarbonization and savings. The NECP is the national roadmap that coordinates how Greece contributes to EU-level climate & energy targets and investments toward renewables, energy efficiency and grid resilience.

Long-Term Renovation Strategy for the National Building Stock (2021): Greece's long-term renovation strategy (Ministerial decision published 2021) defines a pathway to transform the national building stock toward nZEB / near-zero emissions by 2050, setting intermediate milestones (2030/2040/2050) and mobilising public and private finance for deep and staged renovations.

Programmes for energy renovation of public buildings (ELECTRA 2021–2030) — Greece runs targeted public-building renovation programs (e.g., the ELECTRA program and specific NRRP investments) that combine grants, technical assistance and eligibility rules to upgrade public facilities to higher energy classes and to reduce energy consumption in the public estate.

National Recovery & Resilience Plan — “Greece 2.0” (NRRP, 2021–2026 and REPowerEU update): Greece's NRRP allocates large funding to building upgrades, public building renovations, energy infrastructure and licensing reforms for renewables. TGreece 2.0 includes 105 investments and 75 reforms, structured around five pillars:

- Green Transition
- Digital Transformation
- Employment-Skills-Social Cohesion
- Private Investments and Transformation of the Economy
- REPowerEU

Circular Economy & Waste / Construction & Demolition Waste policy (national strategy / action plans 2020–2030): Greece's national circular economy action plan and related legislative instruments (national waste management plans and sectoral measures) include objectives for construction and demolition waste (prevention, source separation, recycling, re-use) and encourage circular design and materials management in building works. This links construction practices directly to EU circularity objectives.

Overall Market Dynamics and Key Trends in Construction (e.g., investment, growth drivers, consumer demand for sustainable housing)

The Greek construction sector has entered a period of steady recovery and structural transformation, following a decade of economic recession and the subsequent rebound supported by EU funds. In 2024, construction contributed approximately 2.6% of Greece's GDP, with over €14 billion in total investment across public and private projects (ELSTAT, 2024).

The number of enterprises in the broad construction sector in Greece stood at 120,734 in 2020, representing a decrease of 32.3% since 2010. This was due to declines in the number of enterprises in the manufacturing (51.7%), the narrow construction (34.8%) and the architectural and engineering activities (29.8%) sub-sectors, offsetting an increase in the real estate activities sub-sector (+42.4%), over the 2010–2020 period.

In parallel, the volume index of production in the broad construction sector witnessed a decline of 36.6% over the 2015–2020 period. This was due to declines in the volume index of construction of buildings (37.8%) and the construction of civil engineering (35.9%) over the same period. Similarly, the total turnover of the broad construction sector reached EUR 17.1 billion in 2018, representing a 25.3% decline

compared to 2010. Furthermore, in 2020 it increased to EUR 17.8 billion, representing 4.2% increment from 2018, but 22.2% decline from 2010 (ECO,2020). Moreover, according to ELSTAT, 2025 the Production Index in Construction (IPC) in the 2nd quarter 2025 recorded an increase of 7.2% compared with the 2nd quarter 2024. The IPC in 2nd quarter 2024 increased by 15.5% compared with the corresponding index in the 2nd quarter 2023. The Production Index in Construction (IPC) in the 2 nd quarter 2025 recorded an increase of 44.0% compared with the 1st quarter 2025. In the 2nd quarter 2024, the IPC increased by 29.3% compared with the corresponding index in the 1st quarter 2024. The seasonally adjusted Production Index in Construction in the 2 nd quarter of 2025 recorded an increase of 9.8% compared with the 1st quarter 2025.

In terms of employment, there were 271,497 persons employed in the broad construction sector in 2020, representing a 28.2% decrease since 2010. This was due to declines in the manufacturing (42.4%), the narrow construction (33.8%) and the architectural and engineering activities (15.3%) sub-sectors, offsetting an increase in the real estate activities sub-sector (+73.5%), over the 2010 2020 period.

The number of households in Greece in 2020 reached 4.4 million units, representing a 0.8% growth from 2010 levels.

Additionally, the continuously declining mortgage interest rates since 2011 (reaching 2.0% in 2020), coupled with the increasing urbanization rate and rising household income, contributed to a strong housing demand, which drove the housing prices up in 2020. According to Bank of Greece, house prices in Greece's urban areas rose by 3.4% during the year to the third quarter of 2020. However, this is comparatively lower than the previous year (8.5%). The annual slowdown in housing prices can be attributed to the imposition of strict lockdown measures across the country in order to contain the COVID-19 pandemic. Foreign demand, which had been the driver of the Greek housing market. As a result, the property market accounted for a 25.3% share of total foreign direct investments (FDI) in Greece, down from 32.3% in the previous year. In order to uplift the housing market and the construction sector, the government introduced the Reduction of the Single Property Tax (ENFIA) measure to help reduce the tax burden.⁴

Greece's National Recovery and Resilience Plan (NRRP), aiming to deploy funds amounting to EUR 30.5 billion in grants and loans, includes urban regeneration, investment projects and renovation plans for upgrading the energy efficiency of residential buildings. The plan includes providing support for the green transition through investments of EUR 1.3 billion in the energy-efficient renovation of more than 100,000 residences, including for low-income households. The country will invest EUR 160.0 million for the development of 5G networks, EUR 1.3 billion in the digital transformation of the public sector and another EUR 375.0 million for the digitalization of businesses, promoting the integration of digital technologies in SMEs. Furthermore, as per the plan, the country will invest more than EUR 500.0 million to promote the

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https://single-market-economy.ec.europa.eu/sectors/construction/european-construction-observatory-eco/country-fact-sheets/greece_en

digital transformation of the education and health system, while nearly EUR 750.0 million will be invested in digital upskilling⁵.

With regards to non-residential construction and infrastructure, there are 118 projects in progress, but not yet funded, in Greece's infrastructure pipeline. These projects are collectively valued at EUR 43.4 billion. They comprise energy projects, railways and motorways, tourist infrastructure and waste management projects.

Impact of Green and Digital Transitions on the Broader Construction Sector

Energy poverty and energy efficiency are the main goals of building sector initiatives. Up to 2030, Greece intends to extend current initiatives by renovating 68,000 residential buildings. The Electra program supports energy efficiency improvements of public buildings. To reduce energy consumption and combat energy poverty, Greece promotes energy-efficient solutions, such as solar thermal water heaters. The country aims to phase out fossil fuel boilers by 2040.

Demand for new skills to implement the green and digital transitions is growing and could be an opportunity for the future sustainable competitiveness of Construction.

Thematic Analysis of State-of-the-Art Digitalisation in Construction (Housing 4.0)

Key digital technologies

Key digital technologies entering the Greek market include:

Building Information Modelling (BIM) – the cornerstone of Greece's digital transformation in construction. The Ministry of Infrastructure and Transport has launched the National BIM Strategy and Roadmap (2024–2029). While BIM is not yet mandatory in public procurement, its integration in pilot projects and public infrastructure design is expanding, supported by universities and professional chambers.

Digital twins are being introduced through pilot projects and research initiatives in energy renovation and public infrastructure. These virtual replicas of buildings allow real-time performance monitoring, predictive maintenance, and data-driven decision-making throughout the building lifecycle. Digital twin technologies support Greece's energy transition and renovation wave, enabling performance

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https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/country-pages/greeces-recovery-and-resilience-plan_en

tracking for buildings upgraded under NRRP programmes like ELECTRA and Energy Efficiency at Household.

e-Permitting & Digital Building Identity: Building permits are issued exclusively online via TEE's e-ΑΦΕΙΕΣ; the Electronic/Digital Building Identity (E-ID) creates a digital logbook of each building (blueprints, EPC, cadastral ID), underpinning asset data for digital twins.

Artificial Intelligence (AI) and Data Analytics for Energy Management: AI algorithms are increasingly applied to optimize HVAC systems, lighting, and renewable-energy integration in both new constructions and retrofitted buildings. Municipalities such as Athens, Thessaloniki, and Trikala are testing AI-driven energy management in smart-city contexts, with funding from EU digital innovation programs.

Internet of Things (IoT) in Buildings: IoT-based monitoring systems are increasingly integrated into public buildings renovated through NRRP and ELECTRA initiatives, supporting Greece's broader shift toward smart and efficient building operation.

Life-Cycle Assessment (LCA) and Digital Material Passport: To align with the EU Circular Economy Action Plan and the revised Energy Performance of Buildings Directive (EPBD), LCA tools and material passports are gaining traction in Greece. Research institutions (e.g., NTUA, CRES) and regional energy agencies are testing digital tools to evaluate embodied carbon, assess renovation options, and promote sustainable materials management.

Adoption and Impact in Construction Processes and Building Operation

The National BIM Strategy (2024–2029) is a major step forward, While BIM is not mandatory, starts to increasingly being used by large design and engineering firms, particularly in infrastructure, energy renovation, and public-building projects. Universities and professional bodies such as the Technical Chamber of Greece (TEE) and PEDMEDE are expanding BIM-related education and training. However, the majority of Greek construction firms, especially SMEs, still rely on traditional 2D CAD workflows, with limited data sharing and no integrated project management platforms,

Digital tools such as BIM, energy simulation software, and LCA models are being tested in building-renovation projects under NRRP programs like Electra and Exoikonomo ("Save Energy at Home"), mainly for energy audits.

Some municipalities (Athens, Trikala, Thessaloniki, Ioannina) and public bodies have introduced IoT-based energy monitoring in public buildings, mostly through EU projects or partnerships with research institutions. Data from smart meters and sensors is used to track electricity, heating, and water consumption, supporting energy-efficiency reporting.

Current qualifications & emerging job profiles

Greece's construction workforce is highly experienced but ageing, with many professionals trained under conventional methods of design and project delivery. The sector is still dominated by small-scale operations, with limited exposure to advanced digital tools such as BIM or digital twins. A major skills gap exists between what is required for digital transformation and the current technical capacity of the workforce, particularly among SMEs.

Increasing digitalization and moving towards a more service-oriented economy, including within manufacturing, will lead to a greater use of higher-level occupations. At the other end of the spectrum, lower-level occupations supporting production and the service sector seem to be decreasing as well as some intermediate occupations. The strength of most intermediate occupations, with a strong intermediate qualification level in Greece, limits the overall effect on medium-qualified occupations. Building and related trade workers, as well as industry-based Metal, machinery, and related trade workers, are expected to decrease, most likely due to increases in automation within the sectors (CEDEFOP, 2025).

Emerging job profiles are mostly related to smart building operation and automation technologies including the use of sensors, control systems, and building management systems (BMS) for real-time monitoring and optimisation of energy performance. : BIM coordinator/manager, digital construction technician (CDE admin), building data modeler, energy-data analyst, IoT technician, renovation-passport advisor. EU skills guidance (CEDEFOP/UNESCO-UNEVOC) highlights micro-credentials, upskilling and apprenticeships for green/digital transition.

Relevant market trends shaping the demand and supply

Based on the responses of construction companies to the Business and Consumer Surveys carried out monthly by the IOBE on behalf of the European Commission, labor shortages are highlighted as the main obstacle to growth in 2023. In Greece, the supply of low- and medium-skill workers is expected to be below what is required by demand by 2035, while the supply of high-skill workers is expected to broadly meet the demand for those qualifications. Labor shortages are therefore the main concern for construction companies in the current period, having even risen sharply since 2022, coupled with the demand for new skills to implement the green and digital transitions is growing

Circular Economy & Sustainable Construction Materials

Principles and Practices (e.g., reuse, recycling, waste management strategies)

Greece's Governmental Economic Policy Council endorsed a National Action Plan on Circular Economy (CE) in early 2018 to set the country on a path towards the long-term adoption of CE principles. This supports Greece's economic strategy in its key quest to green the economy in a way that creates jobs, especially for women and youth, and long-term equitable and inclusive growth based on resource efficiency, promotion of SMEs, innovation and investment in new technologies, and boosting of the "social economy" potential.

Moreover, the Greece's "National Energy and Climate Plan" (NECP) is as a Strategic Plan for climate and energy issues, presenting a detailed roadmap for achieving specific Energy and Climate targets by 2030. It outlines and analyses the priorities and necessary policy measures across a broad spectrum of

development and economic activities, benefiting Greek society, establishing it as a reference document for the next decade. The Long-Term Strategy (LTS) for the year 2050 is a roadmap for the country's climate and energy policies, aiming to achieve climate neutrality by 2050. This strategy begins from 2030 and incorporates the objectives of the NECP, proposing technological solutions applicable to the domestic market. It also aims for flexibility in energy policy to adapt to technological advancements and fluctuations in energy consumption across economic sectors post 2030. According to the NECP, the national target for the share of renewable energy sources (RES) in the final energy consumption is at least 35%, exceeding the European target of 32%.

The National Waste Management Plan (2020–2030), both of which prioritize construction and demolition (C&D) materials as key value chains for resource efficiency and waste reduction. The National Circular Economy Strategy (2022–2030) identify construction and demolition waste (CDW) as a priority value chain for achieving resource efficiency, waste reduction, and low-carbon growth. The transition is further supported by the National Waste Management Plan (2020–2030) and the National Recovery and Resilience Plan (Greece 2.0), which promote sustainable building materials, selective demolition, and digital monitoring of material flows. The Region of Attica and the Municipality of Athens are piloting selective demolition and material reuse schemes within urban regeneration projects, in collaboration with research institutions.

Sustainable Materials and their Application in Buildings

Energy-efficiency programmes such as “Exoikonomo” and “Electra” promote the use of environmentally certified insulation products.

Several pilot projects under the Circular Economy Action Plan (2021-2030) promote the reuse of construction and demolition waste (CDW) in road construction and non-structural concrete applications.

Greek research institutions such as the National Technical University of Athens (NTUA) and CERTH are developing nano-enhanced materials that improve surface durability, self-cleaning properties, and UV resistance. These technologies are being tested in energy-efficient building retrofits under Horizon Europe and NRRP-funded projects.

Greek companies like FIBRAN, ALUMIL, and Isomat are introducing eco-insulation products, EPS-recycling systems, and aluminium systems with recycled content, aligned with EU taxonomy and EPD certification standards. These support the transition toward Nearly Zero-Energy Buildings (nZEB) performance requirements.

Pilot initiatives in Attica, Thessaloniki, and Crete promote material recovery platforms where demolition materials, metal components, and tiles are reused or resold. The National Recovery and Resilience Plan (NRRP) includes funding for “Green Building Clusters”, integrating material recovery with local circular economy practices.

Greek manufacturers are beginning to align with European sustainability criteria, although innovation is still concentrated among a few major players and research consortia:

- HERACLES Group (LafargeHolcim) – producing EcoPlanet low-carbon cements and investing in alternative fuels and recycled aggregates.

- FIBRAN – developing insulation products made with recycled materials and improved thermal efficiency.
- ALUMIL – applying circular aluminium production with over 60% recycled content and Environmental Product Declarations (EPDs) for façade systems..

Nevertheless, the combination of traditional Mediterranean materials (stone, lime plaster, wood) with modern bio-based composites presents a growing opportunity for sustainable regional architecture.

Current qualifications & emerging job profiles

Emerging training needs by 2030 in the fields of renewable Energy and energy efficiency. The majority of technicians and skilled workers employed in the Greek building construction sector consider it highly important to develop competencies related to:

- Energy-efficiency upgrades and renewable energy integration – particularly in the installation of insulation systems, energy-efficient windows, heat pumps, photovoltaic systems, and solar thermal solutions in both residential and public buildings.
- Carbon footprint assessment and life-cycle thinking – understanding the embodied carbon and environmental impact of materials and systems throughout their life cycle, as required by emerging EU sustainability regulations.
- Circular construction and resource efficiency – skills related to the reuse, recycling, and recovery of building materials, as well as the application of circular design principles in new construction and renovation projects.
- Deep renovation and modular/industrialized construction solutions – the ability to implement comprehensive renovation projects using prefabricated and modular components, improving both construction speed and energy performance.

Relevant market trends shaping demand & supply

The revision of KENAK (Energy Performance Regulation) and alignment with the EU Taxonomy are tightening energy and environmental standards, creating growing demand for eco-insulation, low-carbon cement, and recycled materials. Over 55% of buildings in Greece were built before 1980; EU-funded renovation programs (e.g., “Exoikonomo”) support large-scale upgrades and drive demand for energy-efficient materials and modular retrofit systems.

At the same time, rising prices of traditional construction materials, prices of traditional materials (cement, steel) increased by 4–6% in 2024–2025 (ELSTAT, 2025) encouraging the adoption of lower-cost, sustainable, and locally sourced alternatives. On the supply side, domestic producers such as TITAN and HERACLES are innovating with low-carbon cements, clinker substitution, and carbon capture technologies, expanding the availability of sustainable materials in line with EU standards. The number of LEED and BREEAM certified projects growing significantly in recent years, strengthening demand for certified eco-materials.

Cross-Cutting Analysis & Opportunities

Interlinkages and Synergies between the Thematic Areas

Digitalization, circular economy principles, and sustainable materials are increasingly interconnected pillars of Greece's construction transition. Together, they support a shift towards low-carbon, resource-efficient, and data-driven building practices aligned with the EU Green Deal and Greece's Circular Economy Strategy. The combined use of BIM, material passports, and LCA tools can substantially improve resource efficiency, waste prevention, and carbon performance across the building life cycle.

Common Challenges and Barriers across Diverse European Regions (e.g., policy, financial, skills-related)

Broader challenges for the sector remain, these include, among others, issues related to human resources and financing of the sector's enterprises, the outlook for Construction after the completion of the Recovery and Resilience Facility in 2026, the institutional framework of the public works production system and the national infrastructure planning, the integration of technology and the digitalization of Construction in order to enhance the sector's productivity, the adaptation of the sector to climate change and, finally, the adoption of ESG standards by construction companies. In particular, labor shortages are highlighted as the main obstacle to growth in 2024 and financing difficulties have also had an impact on construction activity. The estimated growth in domestic construction activity in the next few years will create additional labor needs of various skills. According to the study's estimates, total construction employment could increase in the period 2025-2026 to about 236 thousand workers, a level that is 26 thousand workers higher compared to total construction employment in 2024 (210 thousand workers) (IOBE, 2025)

The most critical barriers that equally limit their access to training programs include the cost of education, the lack of available time for participating in training programs, the inadequate institutional framework, the lack of suitable educational programs, the end-users' ignorance about qualification certification which results in no added perceived value.

Innovation Opportunities in VET for Sustainable Construction (identifying promising areas for intervention)

Innovation opportunities lie in integrated training programs that combine:

- Digital construction tools (e.g., BIM, digital twins, drones for site monitoring);

- Energy performance and circular design principles;
- Practical application of sustainable materials
- Focus on selective demolition, material recovery, waste sorting
- Modular VET programs that link practical construction skills with energy transition technologies
- SMEs and workers often lack training in LCA, eco-material applications, and waste management, highlighting the need for VET innovation and certification schemes.

Conclusions and Recommendations for WP4

Key Findings Summary (synthesis of the most important insights)

There is significant potential in up-skilling and re-skilling the labour force, especially in terms of digital skills. CEDEFOP highlights that medium-qualified occupations in Greece are particularly affected by the digital and green transitions, with gaps emerging in the use of BIM, digital twins, IoT systems, and energy performance monitoring. Labor shortages in both low- and medium-skilled positions are projected to continue up to 2035, making targeted training essential for sector growth and competitiveness.

Strategic Insights for Curriculum and Training Programme Design (direct recommendations for WP4)

Training programs in Greece should expand modules on selective demolition, CDW sorting, secondary materials specification, lifecycle/material-traceability tools, and circular procurement.

Most technicians in the building construction sector consider it essential to acquire skills for implementing measures to improve energy efficiency and integrate renewable energy technologies/systems in buildings. Following closely in importance are the skills related to the smart operation of buildings (explicitly referring to sensors, control systems, and building management systems), the carbon footprint during the life cycle of a material/system, the circular construction, and the efficient use of resources, as well as the skills related to the comprehensive renovation of buildings, including among others, through modular and industrial solutions.

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Annex 6: State-of-the-Art National Report - Italy



REPORT ON THE STATE OF THE ART

ITALY

● Introduction

This task aims to provide an overview of current practices and innovations in sustainable and energy-efficient construction in Italy, focusing on their integration into training, qualifications, and innovation frameworks. Specifically, the report seeks to:

- Explore sustainable housing practices and innovations, with emphasis on digitalisation (Housing 4.0) and circular economy approaches.
- Examine how these innovations intersect with education and training, particularly in VET and lifelong learning.
- Identify market and policy trends shaping the demand for new skills and qualifications.
- Highlight how publicly funded projects promote synergies between sustainability, digital transition, and workforce development.

The analysis was conducted through desk research, combining literature review, case study analysis, comparative framework review, and stakeholder mapping to capture the current landscape and relevant needs of construction professionals, policymakers, VET institutions, and end-users.

– General Context: Italian Construction Sector & Energy Transition

This section provides a concise overview of the Italian construction sector in the context of the energy, sustainability and digital transitions. It reviews policy and regulatory landscape, the overall market dynamics and the key trends in construction and, finally, the impact of the green and digital transitions on the broader construction sector.

2.1. Policy and Regulatory Landscape

As for the other EU member States, the Italian construction sector is guided by a comprehensive framework of European and national policies and regulations promoting sustainability, energy efficiency, and digitalisation. At the European level, key initiatives include the **Energy Performance of Buildings Directive (EPBD)**, the **European Green Deal**, the **Renovation Wave**, the **EU Circularity Action Plan** and the **EU Taxonomy for sustainable construction**, which collectively set ambitious targets for climate neutrality, energy efficiency, and circular economy adoption.

- **National policy incentives, initiatives and strategies:**
 - **Superbonus 110% & Ecobonus:** Fiscal incentives for residential energy-efficient renovations, driving market uptake of energy and sustainability improvements. Launched in 2021, Superbonus was a 110% tax deduction until 2023, whereas it dropped to lower percentage until the end of 2025. It is estimated to improve approx. 500,000 buildings in

total (5.8% of Italy's housing stock), mostly multi-apartment and single-family buildings (FIEC, 2025).

- **Digitalisation and circularity initiatives:** Promotion of Building Information Modelling (BIM), digital hubs, and circular material practices to increase efficiency and sustainability. These topics are dealt with recent legislative review, definition of updated strategies and roadmaps, bottom-up actions fostered by the construction ecosystem.
- **Regulatory Measures:**
 - **Minimum Environmental Criteria (Criteri Ambientali Minimi, CAM):** National mandatory sustainability and circularity requirements in public procurement projects, introduced in 2017 and updated with mandatory regulations by the Ministerial Decree 256/2022.
 - **National Recovery and Resilience Plan (Piano Nazionale di Ripresa e Resilienza, PNRR):** The central strategic instrument – co-funded by the EU during the Covid-19 crisis - shaping public investment until 2026. Beyond a funding mechanism, the PNRR is a comprehensive reform agenda that prioritises urban regeneration, digitalisation, and green innovation, with a substantial share of resources allocated to construction-related activities (Grestone, 2023).
 - **Reform of the Public Contracts Code (Legislative Decree 36/2023):** Legislative overhaul aimed at streamlining procurement procedures and facilitating investment in green technologies, research, and innovation. This reform directly impacts the construction sector by modernising rules for its largest client: the public sector (Grestone, 2023). Among its main novelties, from January 2025 the reformed Code introduced the **mandatory use of BIM** for the design and construction of new public buildings, and for the renovation of heritage buildings – under certain economic thresholds.
 - **National Circular Economy Strategy:** Identifies construction as a priority sector for circular economy practices. It strengthens regulatory tools such as the “End of Waste” criteria and the CAM, encouraging more circular approaches across the industry (Construction.gov.it, 2022).
 - An additional relevant instrument is the **PNIEC – National Integrated Energy and Climate Plan** (updated 2024), which outlines the national strategy to 2030, including emission reduction targets and renewable energy goals. The latest version of the plan is available from the Ministry of Environment and Energy Security. The PNIEC 2024 also links to Italy's obligations under EU climate and energy governance, including objectives on energy efficiency, decarbonization, and the integration of renewables.

Despite these opportunities, several challenges remain. The financial sustainability of incentives, especially the Superbonus, limited absorption of PNRR funds, uneven digital and circular economy skills among SMEs, and gaps between VET supply and market demand constrain full sectoral transformation. These dynamics are reshaping professional profiles, highlighting the need for **green and digital skills** and innovative VET pathways, including micro-credentials, work-based learning, and digital labs (European Construction Sector Observatory, 2020).

The Superbonus incentive represents an exemplary case from this perspective. The 2021 Budget Law allocated **EUR 69.8 billion**, of which **EUR 29.6 billion** was dedicated to energy efficiency and building renovation (European Construction Sector Observatory, 2021). However, despite strong demand and a relevant employment increase in the sector, as long as the incentive was full in place (2023), recruiting qualified personnel remains a challenge in the long term, underscoring the importance of targeted training and upskilling initiatives (CRESME, 2021).

2.2. Overall Market Dynamics and Key Trends in Italy

The construction sector is one of the cornerstones of the Italian economy, directly accounting for around **5–6% of GDP** and up to **20% when considering the full supply chain** (materials, services, professional activities) (Randstad Research, 2023). Its systemic importance is further underlined by the **3.1 million workers** employed directly or indirectly in the industry. In the post-pandemic period, construction acted as a primary engine of recovery, driving one-third of national GDP growth and generating a total production value of **€624 billion in 2023** (BigMat, 2023).

Yet, the sector's recent growth has shown a pronounced **dependency on fiscal incentives**, such as the **Superbonus, Ecobonus, and other building-related tax measures**, which significantly stimulated construction activity (BuildNews, 2023). With the gradual phase-out of these measures, forecasts indicate a contraction of **–5.3% to –7.4%** for 2024–2025, highlighting a boom–bust cycle largely influenced by government policy (Repubblica Finanza, 2024).

The market shows a **clear divergence between segments**. **Residential renovation**, once the main beneficiary of the Superbonus, is now facing a forecast **27% decline** due to the withdrawal of fiscal support. Yet, with **73% of Italy's 12.2 million buildings** in the lowest energy classes (E–G), long-term demand for energy upgrades remains structurally strong, especially in light of the EU's EPBD directive (ANCE, 2024). Nonetheless, “the wind-down of Superbonus building tax credit triggers a larger and more persistent contraction in housing investment, which has been a key source of growth over 2021–23” (OECD: 187, 2024).

By contrast, **public works and infrastructure** continue to expand — **+18% in 2023 and +20% expected in 2024** — driven by PNRR and EU funds, effectively stabilising the sector amid private market contraction (ANCE, 2024). **New housing and non-residential construction** show moderate growth, influenced by rising costs and financing constraints, but increasingly shaped by demand for sustainable, energy-efficient buildings.

In sum, while the Italian construction market has recently been shaped by **policy-driven volatility**, its **structural fundamentals—aging building stock, EU decarbonisation targets, and massive public investment pipelines—continue to ensure long-term transformation and resilience**.

Beyond market dynamics, the Italian construction sector faces crucial social challenges that directly impact workforce availability. Key issues include:

- **An aging workforce:** a significant portion of workers is approaching retirement age, making generational turnover urgent.

- **A gender gap and low attractiveness for young people:** the sector is perceived as unattractive, especially by women and new generations, due to cultural stereotypes and perceived harsh working conditions.

In line with the project's cross-cutting objectives, EXCEL4HOUSING4.0 intends to address these challenges by promoting **equity, inclusion, and diversity as levers for an effective social dimension** in the sector. Through targeted campaigns to enhance the attractiveness of VET (including those for gender balance) and the creation of modern training pathways, the project aims to make the construction sector a valid and appealing career choice for a broader and more diverse audience.

2.3. Impact of Green and Digital Transitions on the Italian Construction Sector

Green Transition

The *Piano Nazionale di Ripresa e Resilienza (PNRR)* stands as the main driver until 2026, directing investment toward urban regeneration, sustainable renovation, and green infrastructure (Grestone, n.d.-a). Complementing this, the reform of the *Public Contracts Code* has simplified procurement and embedded sustainability criteria, while the *National Circular Economy Strategy* reinforces tools such as *End of Waste* criteria and *Minimum Environmental Criteria (CAM)* to promote resource efficiency and circular practices (Consultazione.gov.it, n.d.).

The abovementioned National Strategy for Circular Economy (SEC), adopted in 2022, provides a comprehensive framework to transition. The strategy outlines actions and objectives to promote the use of secondary raw materials, enhance waste traceability, and implement eco-design principles across various sectors, including construction. It identifies several economic instruments to support the circular shift in the sector, including tax incentives, regulatory reforms, and support for SMEs to adopt circular practices.

Digital transition

On the digital side, the PNRR directly links public funding to innovation, accelerating the adoption of BIM, Building Energy Modelling (BEM) and Digital Infrastructure Management (DIM) in both public and private projects (Grestone, n.d.-a). Alongside this, technologies such as IoT, robotics, automation, and VR/AR are reshaping design and execution, while industrialised methods like prefabrication enhance efficiency and reduce waste (Corti, Roiatti, & Sala, 2025). Regional analyses, particularly in Lombardy, show how these dynamics are reshaping labour demand, with hybrid green-digital competences becoming increasingly essential (Corti et al., 2025).

The convergence of green and digital is most evident in the application of BIM to energy-efficient renovation, the use of digital traceability to ensure compliance with CAM standards and circular practices, and the gradual integration of sustainability and digital skills in training initiatives—confirming a structural shift in Italy's construction sector.

This twofold transition, while representing a huge opportunity, is also creating a **significant gap between the skills demanded by the market and the current VET training offer** in Italy. The adult participation rate in education and training in the construction sector has historically been low, rising only from 2.6% in 2010

to 3.3% in 2020, a figure considerably lower than the EU average of 7.4%. Indeed, companies report growing difficulty in finding both **specialized operators (EQF levels 3-5)**, capable of installing new technologies and applying sustainable building techniques, and **highly qualified professionals (EQF levels 6-8)**, such as construction managers, architects, and engineers with hybrid technical and managerial skills. The EXCEL4HOUSING4.0 project fits into this context with the aim of filling this gap by developing innovative and transnational training programs for both qualification levels.

– Thematic Analysis of State of the Art

3.1 Digitalisation in Construction

3.1.1. Key digital technologies: (e.g., Building Information Modeling (BIM), Digital Twins, Artificial Intelligence (AI) for energy management, Internet of Things (IoT) in buildings)

The Italian construction sector is undergoing a gradual digital transformation, driven by the need to enhance efficiency, sustainability, and competitiveness. However, the adoption of advanced digital technologies remains uneven, with small and medium-sized enterprises (SMEs) facing significant challenges due to limited financial resources, specialized human capital, and economies of scale. This disparity has resulted in a "digital divide" within the industry, as highlighted by ANCE's Observatory reports, which emphasize the necessity for a national digital platform for construction and a digital infrastructure that can easily connect and communicate with systems across Europe, ensuring compatibility with EU standards and facilitating cross-border collaboration (ANCE, 2022; ANCE, 2024).

Key digital technologies shaping this transformation include **Building Information Modeling (BIM)**, **Digital Twins**, **Internet of Things (IoT)**, and **Artificial Intelligence (AI)** for energy management. BIM is increasingly recognized not merely as a 3D modelling tool but as a collaborative methodology for managing information throughout the entire lifecycle of construction assets (ANCE, 2025). The adoption of BIM is being accelerated by national regulations, as said earlier, including the reform of the Public Contracts Code and the requirements under the National Recovery and Resilience Plan, which make BIM a standard for public projects and create strong incentives for SMEs to invest in digital capabilities (DIHCUBE, n.d.).

These tools, as Digital Twins, are employed to enhance energy efficiency and resource management, with partnerships such as Harpaceas & Ekore demonstrating the application of AI and digital twins to optimize building performance and reduce energy consumption (Harpaceas & Ekore, 2025). Despite initiatives like DIHCUBE, a national hub for unlocking digital innovation at the SME-level, and support for European projects such as DigiPLACE, (DigiPlace, n.d.), digitalisation remains a challenge for many SMEs. ANCE reports indicate that the majority of firms are still far from fully adopting advanced digital technologies, highlighting the need for further interventions to close the digital gap and enhance efficiency, productivity, and sustainability (ANCE, 2024; ANCE, 2025).

In summary, while Italy is making progress in the digitalisation of the construction sector, greater dissemination of digital technologies among SMEs is necessary to bridge the gap and fully leverage the potential offered by digital transformation.

With this regard, DIHCUBE represents a pivotal opportunity for SMEs to upskill and improve their knowledge about existing and emerging digital technologies in the sector. Co-funded by the PNRR and coordinated by ANCE - the National Association of Italian Constructors - DIHCUBE brings together universities, research centres and consultancies to train enterprises and experiment directly digital technologies. The funding coverage is proportional to the business dimension, thus increasing the opportunity for the smallest ones.

3.1.2. Adoption and impact in construction processes and building operation

Digital technologies are gradually transforming Italian construction, but adoption remains uneven due to the sector's fragmentation and prevalence of micro-enterprises (ANCE, 2022; DIHCUBE, n.d.).

In **design and procurement**, BIM is increasingly used in public projects and large private developments to coordinate disciplines, quantify materials, and link design to procurement workflows (ANCE, 2025). SMEs lag behind, often using only basic digital tools, while initiatives like DIHCUBE support their integration of advanced solutions (DIHCUBE, n.d.).

In **construction and materials**, prefabrication, off-site production, and digital quality control reduce errors and waste, while digital tools support circular construction and Life Cycle Assessment (LCA), aligned with CAM and Italy's Circular Economy Strategy (Consultazione.gov.it, 2025). Timber and hybrid wood constructions benefit from digital design to optimize prefabrication and energy performance (ANCE, 2025).

In **operation**, buildings with digital twins, IoT, and BMS show improvements in energy efficiency, predictive maintenance, and occupant comfort (Harpaceas & Ekore, 2025).

Impacts and barriers: Digitalisation enhances quality, efficiency, and carbon performance, but SMEs face challenges including limited skills, heterogeneous data, and investment needs. This creates a "digital divide" where digitally mature firms achieve higher efficiency and profitability (ANCE, 2022; DIHCUBE, n.d.; Harpaceas & Ekore, 2025).

i. Current qualifications and emerging job profiles

Emerging job profiles are increasingly shaped by the twin green and digital transition. The adoption of technologies such as BIM (Building Information Modelling), BEM (Building Energy Modelling), DIM (District Information Modelling), IoT, robotics, automation, virtual and augmented reality, and industrialized construction methods (e.g., prefabrication) is transforming the skills required of construction professionals (Excelsior Unioncamere, 2024; ANCE, 2025). Workers are expected to combine traditional technical competencies with new capabilities in digital tools, energy efficiency, sustainable materials, and circular construction processes.

These shifts highlight an urgent need and plan for targeted upskilling and reskilling initiatives. The following section presents innovative professional profiles highlighted by the RES2 project (*Resilient System for Recognition of Energy Skills*), which conducted an in-depth analysis of the Italian context and regional qualification frameworks (Repertori Regionali delle Qualifiche Professionali) to identify emerging roles and evolving trends in the construction sector (RES2, n.d.). By means of this mapping effort, the

project identified evolving professional profiles – mixing traditional and innovative skills – and more innovative ones, resulting in the following list related to the digital domain:

m. **BIM Technician**

Responsible for developing and managing building information models, integrating traditional drafting and technical competencies with BIM processes. This role may also include tasks traditionally held by building drafting and architectural construction technicians or engineers.

n. **Construction Process Digitalization Technician**

Supports decision-making processes by processing and structuring project information. Performs complex tasks related to project development, calculations, and data management to optimize construction processes.

o. **Home Automation Systems Technician**

Specializes in designing, installing, and optimizing building automation systems, integrating digital and technical skills to improve efficiency and control of smart home technologies.

p. **3D Design and Printing Technician**

Manages 3D modeling and printing for construction applications, producing digital prototypes, components, and technical models, often requiring autonomous decision-making and handling complex design tasks.

q. **Drone Operator**

Conducts drone operations for surveying, volumetric calculations, or photogrammetry. May also analyze and process collected data to support technical and operational decisions on construction sites.

▪ **Relevant market trends shaping the demand and supply**

The Italian construction sector continues to experience significant workforce dynamics, driven by a combination of **replacement needs**, **expansion of activity**, and the increasing adoption of advanced construction technologies. Between 2024 and 2028, it is estimated that **245,000–280,000 positions will need to be filled to replace retiring workers** (replacement demand), while an additional **405,000–832,000 positions are expected due to sector growth** (expansion demand) (Excelsior Unioncamere, 2024). This implies a total projected increase of **30,000–64,000 workers** over the five-year period, highlighting the ongoing expansion of the sector.

The demand is particularly pronounced for **highly skilled roles**, accounting for approximately 39% of total demand (~1.3–1.4 million positions), including managers, specialists, and technical professionals (ANCE, 2025). **Skilled construction workers**, responsible for building, maintenance, and finishing, are expected to number **136,000–156,000**. Supporting roles in metalworking and machinery operations are also significant. Assemblers and machinery maintenance workers (58,000–63,000), welders and metalwork installers (31,000–36,000), earth-moving and lifting equipment operators (20,000–22,000), and drivers of motorized vehicles, mainly heavy machinery (74,000–82,000) play a key role in ensuring smooth construction processes.

This combination of replacement needs, sector expansion, and adoption of digital and green technologies emphasizes the critical importance of equipping the workforce with the necessary skills to leverage BIM,

digital twins, IoT, green construction methods, and industrialized processes. This ensures sustainable growth and competitiveness for the Italian construction sector.

o Circular Economy & Sustainable Construction Materials

3.2.1. Principles and Practices

Italy has placed the circular economy (CE) at the core of its environmental policy framework with the adoption of the **National Circular Economy Strategy (2022)** and the **National Waste Management Programme 2022–2028 (PNGR)**. These strategies set macro-objectives including: developing secondary raw material markets, strengthening Extended Producer Responsibility, introducing taxation to promote CE, enhancing eco-design and product life extension, improving waste stream traceability, and fostering CE-related skills across sectors (ETC-CE, 2024).

In the construction sector, circularity principles translate into **different scales and practices**. At the urban scale, *urban mining* considers cities as reservoirs of reusable materials, while at the building scale, the *building as material bank* approach recognizes the stored value of construction products and components. At the product level, emphasis is placed on **reuse, recycling, and design for circularity**—including adaptability of spaces, reparability, and the producer's responsibility throughout the lifecycle of products (GBC Italia, 2019).

Current practices in Italy reflect both **end-of-life strategies** and **design-stage approaches**:

- **End-of-life approaches:** selective demolition, advanced waste management systems, and prioritization of refurbishment over demolition.
- **Design approaches:** *design for disassembly* and *design for durability/flexibility*, ensuring that new buildings can be adapted, dismantled, and materials reused.

To ensure transparency and compliance with green public procurement, certification systems are increasingly adopted. Among these, **ReMade in Italy®** has emerged as a key certification scheme, verifying recycled content in materials and aligning with the Italian Public Procurement Code and *Criteri Ambientali Minimi* (CAM). This certification is recognized as valid proof whenever CAM requires the use of recycled-content products (Grestone, 2023).

Altogether, these frameworks and practices illustrate how Italy is embedding CE principles into construction, moving from policy commitments to practical applications across design, construction, and end-of-life phases.

3.2.2. Sustainable Materials and their Application in Buildings

Among sustainable materials, **wood stands out as a circular material for excellence**. Naturally renewable, 100% recyclable, and capable of storing carbon dioxide, wood plays a crucial role in mitigating climate change. Its long lifecycle allows for multiple reuses: after its first application, it can be collected, recycled, and transformed into new products, thus extending its environmental and economic value.

Italy is a European leader in wood recycling, with **64.5% of packaging recycled**, far exceeding the EU target of 30% by 2030. For instance, over the past 25 years, **Rilegno** has built a circular system that recycles

nearly **2 million tons of wood annually**, regenerates more than **70 million pallets**, and saves approximately **1.9 million tons of CO₂ emissions each year** (Rilegno, n.d.; Ingenio-Web, 2024).

At the same time, wood is increasingly used in **sustainable building practices**, particularly through the adoption of **timber construction systems** such as cross-laminated timber (CLT) and laminated veneer lumber (LVL). According to the **VIII Annual Report by FederlegnoArredo**, Italy ranks as the **third-largest European producer of wooden houses**, with **3,602 new housing units built in 2022** and a turnover of **€2.3 billion**. This sector is experiencing steady growth, driven by rising awareness of sustainability and supported by a concentration of specialized companies, particularly in northern regions such as **Trentino-Alto Adige, Lombardy, and Veneto** (FederlegnoArredo, 2023).

The combination of high recycling performance and growing use of engineered timber in construction positions wood as a **key enabler of the circular and sustainable transition in the building sector**.

3.2.3. Current qualifications and emerging job profiles

The Italian construction sector is experiencing a rapid transformation, requiring new professional profiles and updated qualifications. According to the *Skills Intelligence Forecast* by ART-ER and Clust-ER BUILD (2024), the most in-demand profiles to some extent linked to the circular skills, include:

- **Environmental and energy efficiency technician** → faces shortages due to a limited pool of candidates and inadequate training.
- **Construction site technician** → a hybrid figure positioned between design work and on-site operations, often affected by cultural and gender biases. Despite existing training paths at both university and post-diploma level (ITS – *Istituti Tecnici Superiori*, Higher Technical Institutes, and IFTS – *Istruzione e Formazione Tecnica Superiore*, Higher Technical Education and Training), there is still a lack of suitable candidates for this role.
- **Project manager assistant** → increasingly relevant for managing complex building processes.
- **BIM-related profiles (BIM Manager, BIM Coordinator, BIM Specialist)** → crucial for digitalization and integration of design, construction, and building operation.
- **Diagnostic technician** → limited by the absence of certification programs on diagnostic tools and data management, even if historical knowledge of existing materials remains solid.
- **Territorial monitoring technician** → currently linked mainly to waste management, but with the potential to evolve towards analyzing landslides, extreme weather events, and their integration into urban planning and mitigation strategies. The lack of training paths remains a barrier.
- **Data scientist** → increasingly needed in construction to process and interpret large datasets. However, the absence of targeted educational pathways and limited awareness among companies hinder recruitment.

This mapping highlights both the **growing demand for specialized and hybrid profiles** and the persistent **training gaps**, underlining the need for updated educational strategies to support circular economy practices, digitalization, and climate adaptation.

3.2.4 Relevant market trends shaping the demand and supply

Overall, the interplay of **sustainability imperatives, innovation in building technologies, and market consolidation through certification systems** is reshaping both demand and supply in Italy's **sustainable and circular construction sector**. A notable share of the sector is increasingly oriented towards **timber construction**, driven by the material's environmental performance, recyclability, and growing market acceptance. In this context, certification schemes such as **ARCA (Architettura Comfort Ambiente)** play a crucial role in establishing **quality, durability, and sustainability standards**, providing a benchmark for certified timber buildings and supporting the development of a structured market for wood-based construction (ARCA, n.d.; FederlegnoArredo, 2023).

Concrete examples of these trends and the excellence achieved in Italy's timber construction sector are the flagship projects cited in the EXCEL4HOUSING4.0 proposal, such as the **"Ex Marangoni" district in Rovereto** and the **"Trentino Social Housing Building" in Trento**. The former represents a benchmark for sustainability, being a 9-story building made of Cross Laminated Timber (CLT) with very high energy efficiency (A+ class) and an advanced level of circularity, built largely with wood recovered from the "Vaia" storm. The latter is an example of a certified wooden building ("ARCA certification") that combines high anti-seismic and fire safety requirements with excellent energy performance (Class A/A+).

These projects are not just technological showcases but true **"living labs"**: their analysis allows for the identification of the specific skills—both at the technical-operational and design-managerial levels—needed to replicate such models on a large scale, thus providing a fundamental knowledge base for designing the project's training programs.

3.3 Conclusions and Recommendations for WP4

Policy & Market Drivers: Italian construction relies on incentives (Superbonus, Ecobonus) and EU/National policies for sustainability, energy efficiency, and digitalisation; public works and PNRR-funded projects stabilize the sector amid residential slowdown.

Green & Digital Transformation: Adoption of circular economy practices, energy-efficient renovation, and digital tools (BIM, IoT, AI) is reshaping design, construction, and operations, though SMEs face adoption challenges.

Sustainable Materials & Timber: Wood is central to circular and sustainable construction—100% recyclable, carbon-storing, and widely used in engineered timber buildings; certifications like **ARCA** create a structured market and ensure quality.

Skills & Workforce Needs: High demand for specialized and hybrid profiles (BIM specialists, energy technicians, construction site technicians, data scientists) highlights urgent need for training and upskilling to align workforce with green and digital transitions.

Integration of European initiatives: build on Erasmus+ **Centres of Vocational Excellence (CoVE)** to reinforce the link between training provision and innovation in sustainable housing.

SME-focused approach: ensure targeted support for SMEs through modular training and mentoring schemes, reducing structural skill gaps and enabling adoption of digital and green practices.

Micro-credentials for new profiles: promote short and flexible credentials that certify competences in emerging roles (e.g., BIM specialists, circular construction technicians, green building assessors), aligning training with real labour market demand.

3.3.1 Strategic Insights for Curriculum and Training Programme Design (direct recommendations for WP4)

Modular and tailored learning paths: develop short, flexible training modules that can be combined to build progressively higher qualifications. Modules could cover areas such as energy-efficient buildings, sustainable materials, circular construction, smart building technologies, BIM, and digital twins.

Hands-on and applied learning: integrate practical placements, living labs, and demonstrations at real construction sites.

Trainer development and mentoring: scale up train-the-trainer initiatives to ensure instructors are proficient in both digital tools and circular economy principles. Mentoring, study visits, and coaching should support continuous professional development.

Career pathways for emerging profiles: define clear competency maps for new roles such as BIM Manager, Digital Twin Engineer, Material Passport Specialist, and circular construction technician. Link training modules to these profiles to support career development and meet market demand for specialized skills.

Integration of soft and technical skills: combine digital, sustainability, and technical competencies with project management, teamwork, and problem-solving skills to prepare learners for complex, hybrid roles in the construction sector.

Leverage the expertise of Italian partners: Utilize the specific skills of the Italian consortium partners to enrich the training programs. For example, integrate the experience of **University of Perugia** in the field of "Digital Techniques for the Sustainable Management of Buildings" into the digitalization modules, and structure the content of the **European ESG Academy** based on **Habitech's** expertise in sustainability certifications (e.g., LEED, BREEAM, ARCA).

Focus SME training on concrete tools: The capacity-building program for SMEs on the circular economy should concentrate on the practical application of the **Minimum Environmental Criteria (CAM)** and the use of certifications like **ReMade in Italy®**, which are crucial regulatory tools but often difficult for small and medium-sized enterprises to adopt.

Integrate mobility as a learning tool: In line with **TUCEP's** role as an accredited mobility agency, the training paths should actively provide for and promote opportunities for internships, job shadowing, and transnational exchanges as an integral part of the curriculum to accelerate the acquisition of practical and intercultural skills.

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Annex 7: State-of-the-Art National Report - Poland



REPORT ON THE STATE OF THE ART

POLAND

● Introduction

The purpose of this report is to present the current state of knowledge (“state of the art”) in the field of energy efficiency and sustainable housing practices in Poland, with particular emphasis on the European context. The analysis covers both technological and market issues, as well as aspects related to vocational education and training (VET), innovation, and digital and ecological transformation processes.

Housing construction is one of the key sectors for achieving the European Union's climate and energy goals. As the largest energy consumer in the EU, it accounts for around 40% of final energy consumption and 36% of greenhouse gas emissions. As a result, this sector is a priority in policies such as the European Green Deal, the Renovation Wave, and the EPBD directive on the energy performance of buildings.

The report covers:

- the political and regulatory context,
- market analysis and trends in the housing sector,
- the implementation of technological and process innovations (digitalization, sustainable materials, circular economy),
- current and future skills needs and their impact on the vocational education system,
- links between digital and green transformation and the resulting opportunities for education and the labor market.

The document was prepared on the basis of a review of scientific literature, reports from EU and national institutions, analyses of statistical data (Eurostat, Central Statistical Office, Cedefop), as well as case studies and examples of good practices in Poland and other European countries.

● Analysis summary

This document presents a comprehensive overview of the current situation, trends, and future directions in the field of energy-efficient and sustainable housing, analysed within the broader framework of the European Green Deal and the dual green and digital transitions shaping the construction sector. The study synthesises regulatory developments, market dynamics, technological innovations, and vocational education needs, linking national realities with European policy objectives.

At the policy level, the report highlights the alignment of Poland's strategic documents - such as Poland's Energy Policy to 2040 (PEP2040), the National Energy and Climate Plan (NECP) and the forthcoming National Building Renovation Plan (KPRB) - with EU frameworks like the Fit for 55 package, the Energy Performance of Buildings Directive (EPBD 2024/1275), and the Renovation Wave Initiative. Together, these instruments establish a roadmap toward a low carbon, circular, and climate resilient built environment. Poland's Clean Air Programme complements these policies by targeting thermal modernisation and heating-system replacement in single-family homes.

At the market level, the construction cycle shows both resilience and transformation. After a temporary slowdown in 2024, new permits and housing starts point to renewed activity driven by EU and national funding streams. Cost pressures and skill shortages remain constraints, yet digitalisation and green regulation continue to stimulate innovation. The sector is evolving toward data driven, performance based

construction, where digital workflows, life cycle carbon accounting, and energy efficient design are becoming standard requirements rather than optional features.

The green transition is reshaping technical requirements and workforce competences. The EPBD introduces zero-emission standards for new buildings, renovation passports, and mandatory disclosure of whole-life carbon (GWP). These regulatory shifts generate sustained demand for specialists in energy modelling, low carbon building services, quality assurance, and renewable integration. Simultaneously, circular economy practices such as selective demolition, material passports, and water reuse, are gradually entering mainstream practice, though adoption remains uneven.

The digital transition complements this shift. Poland has developed a robust digital ecosystem in construction, including *e-Budownictwo*, *SOPAB*, the *Electronic Construction Logbook (EDB)*, and the *Digital Building Book (c-KOB)*. These tools increase transparency, simplify permitting, and facilitate compliance with energy and carbon standards. The staged introduction of Building Information Modelling (BIM) into public procurement is accelerating the sector's move toward integrated, collaborative, and verifiable workflows.

Labour market analysis reveals structural shortages in traditional trades and emerging demand for hybrid profiles combining craftsmanship, environmental literacy, and digital proficiency. Occupations such as BIM Manager, LCA/GWP Specialist, Digital QA Coordinator, and Heat Pump Technician are rapidly gaining relevance. To address this, Poland's Sectoral Qualifications Framework and the emerging network of Centres of Vocational Excellence (BCU) play a crucial role in modernising curricula, fostering teacher-industry collaboration, and delivering modular training aligned with EU priorities.

From a crosscutting perspective, the report emphasises that energy efficiency, digitalisation, and circular economy are mutually reinforcing dimensions of a single transformation process. Digital tools enable performance monitoring and traceability; circularity complements energy goals by reducing embodied emissions and both transitions rely on a skilled workforce capable of managing complex, integrated systems.

In conclusion, the Polish construction sector is moving toward a more sustainable, digital, and innovation driven model. The success of this transition depends on coordinated policy implementation, targeted financing and a proactive approach to workforce development.

● Indicative outline

● Introduction

Purpose of the report: to present the state of knowledge and practices in the field of energy efficiency and sustainable housing construction, with particular emphasis on qualifications, innovation, and market trends.

Scope: analysis of the construction sector (housing – new buildings and renovations), policies, regulations, technologies, innovations, and links to vocational education.

Methodology:

- desk research (EU reports, Eurostat, Central Statistical Office, Cedefop, PARP, KOBiZE),
- analysis of market and technological trends,
- case studies (pilot projects, good practices from Poland and the EU),
- regional comparisons.
- **General Context: European Construction Sector & Energy Transition**
 - o Policy and Regulatory Landscape (e.g., EPBD, European Green Deal, Renovation Wave, EU Taxonomy relevant to construction)
 - o Overall Market Dynamics and Key Trends in Construction (e.g., investment, growth drivers, consumer demand for sustainable housing)
 - o Impact of Green and Digital Transitions on the Broader Construction Sector

The European context and energy transition:

European Green Deal – EU growth strategy launched in 2019. The initiatives are aimed at energy transition and achieving climate neutrality by 2050. The Green Deal emphasizes the importance of all sectors in sustainable transformation. In the fight against climate change, support is given to measures in areas such as energy, transport, industry, agriculture, sustainable financing, etc. Our future depends on the condition of our planet, and increasingly frequent and severe extreme weather events have tragic consequences for people and the economy.

“The European Green Deal aims to make the EU the world's first climate-neutral region by 2050, reduce pollution, and restore nature and ecosystems to a healthy balance.”

The key objectives are:

- Climate neutrality – reducing gas emissions (EU as the first climate-neutral region);
- Circular economy – an economic model in which products are reused, repaired, and recycled (conserving resources and reducing waste).
- Clean industry – cleaner, more sustainable, and energy efficient industry that is well-adapted to the European and global market.
- Healthier environment – nature restoration and pollution control to ensure a healthy environment for future generations.
- More sustainable agriculture – eco-friendly farming practices will help protect the environment and provide healthy affordable food.
- Climate justice and equality – a fair and inclusive transition that does not exclude and leaves no one behind and helps those most affected.⁶

EPBD Directive – The Energy Performance of Buildings Directive, which was recast in 2024, is a continuation of the regulations on the energy efficiency of buildings introduced since 2002 at both national and EU level.

“The aim of the regulations is to rationalize energy consumption in existing buildings and to construct new buildings that meet appropriate energy standards.”

⁶ Rada Europejska – Rada Unii Europejskiej, 2025, *Europejski Zielony Ład*, <<https://www.consilium.europa.eu/pl/policies/european-green-deal/>>

Requirements and effects:

- “Reducing energy consumption and its carriers, thereby improving energy security,
- reducing energy consumption costs in buildings,
- improving the standards of new and existing buildings,
- providing information to a wide range of stakeholders on the technical and energy status of buildings and the possibilities for improvement,
- contributing to the achievement of climate goals by reducing greenhouse gas emissions and other pollutants from buildings,
- focusing support tools on the most effective measures and the development of new and low-carbon solutions”.

Solutions resulting from the directive:

- minimum requirements for the energy performance of buildings – requirements are regularly modified and increased due to advances in construction, energy, and installation technology, growing user demands, and new policies. The requirements are tailored to optimize costs and stipulate that new public buildings must be carbon neutral by January 1, 2028, and other new buildings by January 1, 2030,
- improving the energy performance of buildings undergoing major renovation – renovation is the right time to improve the energy performance of a building. Various support systems are available, such as thermal modernization subsidies and programs such as Clean Air,
- national building renovation plan and progressive renovation trajectory for residential building stock (Polish KPRB document) – “The National Building Renovation Plan is an extension and replacement of the current long-term building renovation strategy. The document will define the concept of building renovation and the necessary measures to achieve high energy efficiency and low carbon emissions in buildings in Poland by 2050. The KPRB will be a strategic document containing the assumptions of a comprehensive policy integrating measures aimed at ensuring the renovation of the national stock of residential and non-residential buildings, both public and private, into highly energy-efficient, zero-emission, and decarbonized building stock by 2050. The document will also establish a progressive renovation trajectory for residential buildings and minimum energy performance standards for non-residential buildings”,
- new buildings with solar energy – EU countries are required to adapt their regulations to take into account the need to use solar energy; the requirements will come into force on December 31, 2026,
- renovation passport system – documents setting out action plans for the renovation of buildings, adapted as necessary to improve energy performance,
- requirements for technical building systems, infrastructure for sustainable mobility – requirements for technical building systems and infrastructure requirements for sustainable mobility will be updated to ensure consistency with the directive,
- financial incentives and market barriers – in order to ensure that financial support schemes for building renovation are effective, adequate, and targeted primarily at vulnerable households, people affected by energy poverty, and people living in social housing, rules based on the new directive should be introduced. The requirements include a ban on financial incentives for the

installation of individual fossil fuel-fired boilers from January 1, 2025. After this date, the purchase of such equipment may not be financially supported by the state,

- one-stop shops for energy performance of buildings – it will be important to establish a new technical assistance infrastructure, which, among other things, will provide comprehensive services to citizens in the context of improving the energy efficiency of buildings,
- energy performance certificates – “the current national regulations need to be amended to bring them into line with the new directive, taking into account the state of standardization and the conclusions drawn from the functioning of the regulations to date. A draft regulation on the methodology for determining the energy performance of a building or part of a building and energy performance certificates implementing this provision is currently being processed. The energy performance certificate system has been in force in Poland since 2009. The provisions of the directive indicate the obligation to unify and establish the determination of the energy performance of a building through energy performance classes”,
- technical system inspections – systems such as heating, ventilation, air conditioning, etc. should undergo inspections to check their efficiency. Laws related to inspections should be updated to take into account new provisions.⁷

Fit for 55 – The European Union's Fit for 55 package was announced in 2021 and contains a set of new climate regulations. The legislation was adopted to achieve a mandatory reduction of emissions in the EU by at least 55% by 2030. It will also help make the EU climate neutral by 2050. The document was developed by the Council working groups responsible for the given policy. Members discussed the matter in order to find a common position, so that an agreement could be prepared within the 27 countries. As part of the reform, the EU ETS (EU Emission Trading System) will be changed and made more ambitious. In addition a new separate emissions trading system was also created for buildings, road transport and fuels in additional sectors.

“The package has to:

- ensure that the transformation is socially just.
- maintain and increase the innovation and competitiveness of the EU industry, while guaranteeing equal opportunities for economic operators from third countries.
- strengthen the EU's position as a leader in the global fight against climate change”.⁸

For Poland, this means a significant acceleration of energy efficiency improvements, renewable energy integration, and low-carbon technologies in housing and transport. The inclusion of buildings and road transport in a new emissions trading system creates strong incentives for modernization, but also raises challenges. Higher renovation and energy costs could increase the risk of energy poverty, while carbon pricing on fuels may worsen social acceptance, particularly in a country with high car dependency and a still coal-intensive energy mix. At the same time, the package offers opportunities to modernise housing, stimulate green jobs, and improve long-term competitiveness of the Polish economy.

⁷ Ministerstwo Rozwoju i Technologii, *Dyrektywa w sprawie charakterystyki energetycznej budynków (EPBD)*, <https://www.gov.pl/web/rozwoj-technologie/dyrektywa-w-sprawie-charakterystyki-energetycznej-budynkow-epbd>, access 18.08.25

⁸ Rada Europejska – Rada Unii Europejskiej, 2025, „Gotowi na 55”, <https://www.consilium.europa.eu/pl/policies/fit-for-55/>

Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse – The regulation aims to improve water resource management in the European Union. The document highlights the importance of water reuse in the current situation.

“Water resources in the Union are under increasing pressure, leading to water scarcity and deterioration in water quality. The development of cities and agriculture has significantly contributed to the reduction of fresh water availability, particularly due to climate change, unpredictable weather phenomena, and droughts.

The Union's ability to respond to the growing pressure on water resources can be increased by promoting the reuse of treated wastewater, limiting the exploitation of single surface and groundwater bodies, limiting the effects of releasing treated wastewater into surface waters, and promoting water conservation through the multiple use of municipal wastewater, while ensuring a high level of environmental protection”.⁹

Policy and regulations in Poland:

Poland's energy policy until 2040 (PEP2040) – the policy outlines a vision for an energy transition strategy that aims for low- and zero-emissions and must ensure energy security. PEP2040 is one of nine Strategies for Responsible Development and was created for entrepreneurs, local governments, and citizens in mind. “PEP2040 involves strategic investment decisions aimed at leveraging the country's economic, raw material, technological, and human resources potential and creating, through the energy sector, leverage for economic development that promotes a just transition”.

According to plans, zero-emission sources are expected to account for more than half of installed capacity by 2040. The implementation and development of an offshore wind power system in Poland and the launch of a nuclear power plant will be key. These will be two new areas offering many opportunities – for development of national industry sector, human resource manager abilities, new workplaces, and generation of added value for domestic economy.¹⁰

National Energy and Climate Plan (NECP, pl. KPEiK) – The National Energy and Climate Plan is developed on the basis of Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action. EU Member States are obliged to update the NECP every 5 years and to prepare a new plan every 10 years.

The Energy Union, established in 2019, is based on:

- decarbonisation,
- energy efficiency,
- energy security,
- the internal EU energy market,
- research, innovation and competitiveness.

“The document integrates a very broad scope of issues – from the consumption of raw materials and energy and greenhouse gas emissions in individual sectors of the economy, to macroeconomic impacts. Energy forecasts are developed on the basis of methodologies and categories standardized at the

⁹ REGULATION (EU) 2020/741 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL from May 25, 2020 on minimum requirements for water reuse

¹⁰ Ministerstwo Klimatu i Środowiska, 2025, *Polityka energetyczna Polski do 2040r.*, <<https://www.gov.pl/web/klimat/polityka-energetyczna-polski>>

international level. Greenhouse gas emission projections are prepared in accordance with the IPCC classification”.

The documents of each EU Member State are published on the European Commission’s website.¹¹

Construction Law Act – the Act regulates activities related to the design, construction, maintenance, and demolition of buildings, and defines the principles of operation of public administration bodies in these areas.

The scope includes:

- the principles of shaping the state’s energy policy, the rules and conditions for the supply and use of fuels and energy, including heat, and the activities of energy enterprises, as well as the designation of authorities competent in matters of fuel and energy management,
- the conditions for carrying out and controlling activities involving the transmission of carbon dioxide for the purpose of underground carbon dioxide storage,
- the principles governing the functioning of the measurement system and the central energy market information system.

“The purpose of the Act is to create the conditions for the sustainable development of the country, to ensure energy security, the economical and rational use of fuels and energy, the development of competition, the prevention of negative effects of natural monopolies, the consideration of environmental protection requirements, the fulfillment of obligations arising from international agreements, and the balancing of the interests of energy enterprises and fuel and energy consumers”.¹²

Clean Air program – Clean Air is a comprehensive plan of actions aimed at improving energy efficiency and reducing emissions of dust and other pollutants into the atmosphere, as well as avoiding air pollution from new single-family homes. This is achieved through thermal modernization and the replacement of old household stoves and boilers. The program's beneficiaries are natural people who own single-family homes or a separate unit in a single-family building with a separate land registry book, as well as people who have permission to start building a single-family building. Individuals seeking funding can receive grants and/or loans. Under the program, it is possible to implement various types of investments:

- “Purchase and installation of new heat sources that meet the requirements of the Clean Air Program;
- insulation of building partitions.
- replacement of window and door frames.
- replacement of the central heating and hot water systems.
- installation of renewable energy sources (solar collectors and photovoltaic systems);
- installation of mechanical ventilation with heat recovery”.¹³

¹¹ Ministerstwo Klimatu i Środowiska, *Krajowy Plan w dziedzinie Energii i Klimatu*, <<https://www.gov.pl/web/klimat/krajowy-plan-na-rzecz-energii-i-klimatu>>, access 18.08.2025

¹² 2025, *Ustawa Prawo energetyczne*, Dz.U.2025.418 t.j.

¹³ Program Czyste Powietrze, <<https://www.czyste-powietrze.org/program/>> access 26.08.25

European Union	Poland
European Green Deal (2019) – EU growth strategy aiming for climate neutrality by 2050; covers all sectors (energy, transport, agriculture, industry, finance). Core pillars: climate neutrality, circular economy, clean industry, healthy environment, sustainable farming, and a just transition.	Energy Policy of Poland until 2040 (PEP2040) – national energy strategy ensuring security of supply, promoting renewable and zero-emission sources (offshore wind, nuclear). Targets >50% zero-emission installed capacity by 2040.
Fit for 55 package (2021) – EU climate legislation to cut emissions by at least 55% by 2030. Includes EU ETS reform and new emissions trading for buildings and road transport.	National Energy and Climate Plan (NECP/KPEiK) – updated every 5 years, covering decarbonisation, energy efficiency, security, internal market integration, and innovation.
Energy Performance of Buildings Directive (EPBD, recast 2024/1275) – stronger efficiency standards; zero-emission public buildings from 2028 and all new buildings from 2030; mandatory GWP disclosure; renovation passports; ban on subsidies for fossil-fuel boilers from 2025.	National Building Renovation Plan (KPRB) – sets long-term renovation trajectory for residential and non-residential buildings to 2050. Clean Air Programme – subsidies and loans for thermal retrofits and replacement of heating systems in single-family houses.
Regulation (EU) 2020/741 on minimum requirements for water reuse – promotes safe reuse of treated wastewater to reduce pressure on resources.	Construction Law & Energy Law Acts – regulate design, construction, maintenance, and demolition of buildings; energy enterprises; CO ₂ transport and storage; national energy market operation.
Circular economy policies – e.g. EU C&D Waste Management Protocol (2024 update) requiring selective demolition, material passports, and recycling quality assurance.	Poland's Circular Economy Country Profile (EEA, 2024) – national priorities: secondary raw material markets, eco-innovation in construction, stronger municipal–industry cooperation.
EU financial support tools – targeted incentives for vulnerable households and energy-poor groups, one-stop-shops for building renovation advice.	National financial schemes – e.g. Clean Air subsidies, tax reliefs, and regional renovation funds aligned with EU directives.

The comparison highlights that EU initiatives establish the overarching strategic and regulatory framework for the energy transition, setting binding targets for climate neutrality, building performance, circular economy practices, and water reuse. Poland, in turn, translates these obligations into national strategies, sectoral policies, and support programmes such as PEP2040, the National Energy and Climate Plan (NECP), the National Building Renovation Plan (KPRB), and the Clean Air Programme. While EU policies provide the direction and ambition, national measures focus on implementation, financing, and adapting to local conditions. This dual framework ensures alignment with EU climate goals, while also addressing Poland's specific challenges such as coal dependency, energy poverty, and the modernisation needs of its building stock.

Market dynamics and key trends

Poland's construction cycle has been characterised by mixed signals. After a soft 2024, early-2025 data pointed to weaker permitting—building permits in Q1 2025 were down by about 21% year-on-year—while new housing starts held broadly stable, indicating near-term softness but a pipeline that can support activity as financing conditions normalise.¹⁴ At the same time, cost pressures, though easing from their 2023 peak, continued to weigh on real activity through 2024, with sector output estimated to have contracted before a projected recovery in 2025–2028 on transport, residential and renewables investment.¹⁵

On the demand side, regulation remains the primary structural driver. The 2024 recast of the Energy Performance of Buildings Directive (EPBD 2024/1275) raises minimum performance requirements, phases in whole-life carbon (GWP) disclosure for new buildings (large new buildings first, then all new buildings) and requires national roadmaps towards future GWP limit values - measures that elevate the need for performance-assured renovation and carbon-aware design.¹⁶ Labour-market indicators show a sector that has cooled from the 2022 peak but still faces recruitment frictions: Poland's construction job-vacancy rate was roughly 1.8% in Q1 2025, and EU vacancy rates in industry/construction remain above pre-pandemic norms.

Concurrently, digitalisation is reshaping process efficiency and compliance. The progressive roll-out of electronic permitting/records and the staged adoption of BIM in public procurement (ISO 19650 principles) are moving digital workflows from optional to expected, tightening interfaces between design, site execution and handover, and reinforcing quality-assurance requirements across the project lifecycle.

Impact of Green and Digital Transitions on the Broader Construction Sector

The combined effect of the green and digital transitions is reshaping the entire construction ecosystem in Poland and across the European Union. On the environmental side, the recast Energy Performance of Buildings Directive (EPBD 2024/1275) and the *Fit for 55* package create binding obligations that accelerate deep renovation, mainstream low-carbon technologies, and require whole-life carbon assessment in both new and existing buildings. These measures not only elevate performance standards, but also expand the scope of compliance, pushing the sector toward energy-efficient, circular, and climate-neutral practices. For firms, this means that investments in skills, quality assurance, and sustainable supply chains are no longer optional but prerequisites for market competitiveness.

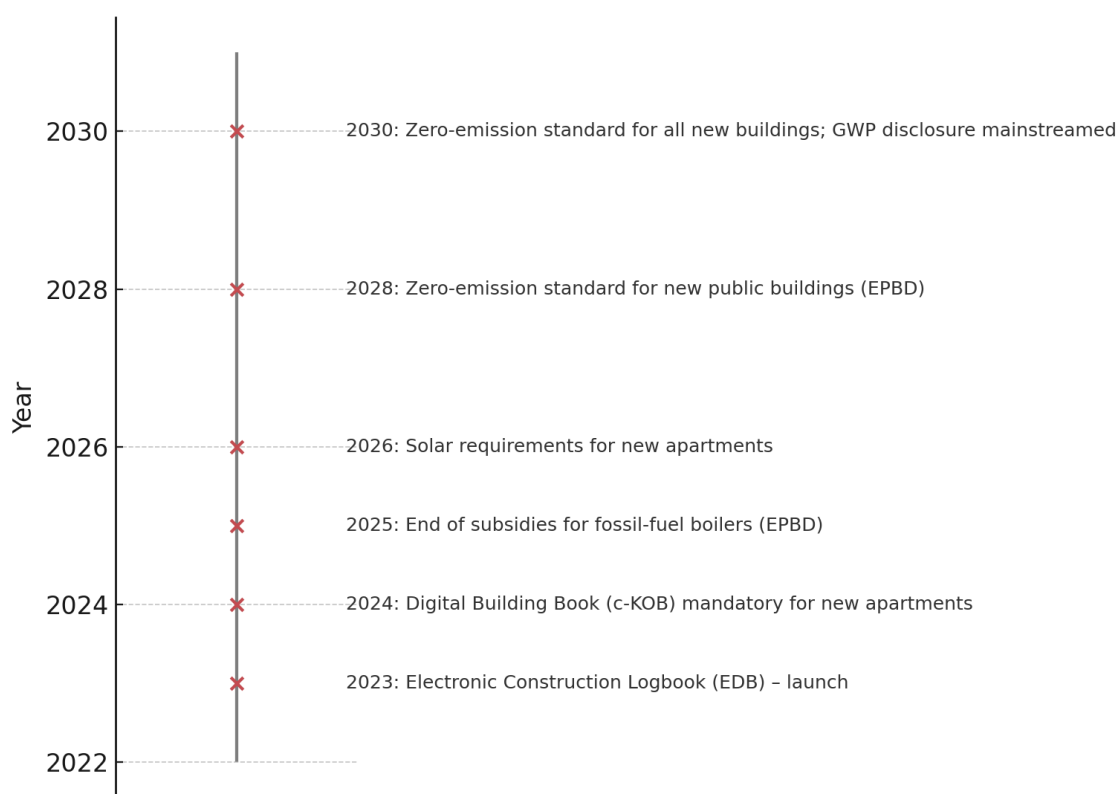
¹⁴ Kozierkiewicz P., 2025, *2025 Begins Cautiously: Fewer Building Permits, Stable Number of New Housing Projects* <
<https://polandinsight.com/2025-begins-cautiously-fewer-building-permits-stable-number-of-new-housing-projects-15843/>> access: 25.09.2025

¹⁵ 2025, *Poland Construction Market Size, Trends, and Forecasts by Sector - Commercial, Industrial, Infrastructure, Energy and Utilities, Institutional and Residential Market Analysis to 2029 (Q2 2025)*

¹⁶ 2025, *ANNEX to the COMMUNICATION TO THE COMMISSION Approval of the content of the draft Commission Notice providing guidance on new or substantially modified provisions of the recast Energy Performance of Buildings Directive (EU) 2024/1275*

Simultaneously, the digital transition is transforming how construction projects are planned, managed, and delivered. The roll-out of *e-Budownictwo*, the Electronic Construction Logbook (EDB), and the digital building book (*c-KOB*) embeds digital workflows in regulatory compliance, while the staged introduction of Building Information Modelling (BIM) into public procurement redefines collaboration across the value chain. Digital tools—ranging from 4D/5D BIM planning and scan-to-BIM technologies to field quality-assurance applications—are enhancing efficiency, transparency, and accountability. At the same time, they require the creation of new roles and hybrid competences that combine traditional craftsmanship with advanced data management.

For the broader construction sector, these dual transitions imply both opportunity and risk. Companies that adapt early by investing in workforce upskilling, digital infrastructure, and sustainable business models are likely to secure a competitive advantage, benefit from EU and national funding streams, and position themselves in emerging markets for green renovation and circular materials. Conversely, firms that lag in adaptation risk exclusion from public procurement, declining productivity, and heightened vulnerability to regulatory penalties. In aggregate, the sector is entering a phase where environmental compliance and digital proficiency are not peripheral, but central determinants of resilience, growth, and long-term profitability.



Currently needed qualifications and future jobs

Evidence from European and national sources converges on persistent shortages across core construction trades (e.g., bricklayers; concrete and reinforcement workers; roofers; carpenters; HVAC/RES installers), with Poland listed among Member States where “building and related trades workers (excluding

electricians)” remain in structural deficit and multiple regions signalling shortages for 2025.¹⁷ In parallel, EPBD implementation and growing client expectations are shifting competency profiles toward: (i) high-performance envelope execution (airtightness, thermal-bridge mitigation, moisture-safe insulation; QA protocols including blower-door testing and commissioning), (ii) low-carbon building services (heat pumps, balanced MVHR, low-temperature hydronics, PV integration and smart controls), and (iii) compliance-grade documentation and verification aligned with energy and carbon rules.

Digital skills are now foundational across roles. The most acute gaps include BIM modelling and coordination (clash detection), 4D/5D planning, scan-to-BIM and drone-based as-built capture, field QA apps, and clean e-submission workflows; these are critical to delivering both EPBD-compliant performance and auditable, efficient project management. Looking forward, the job mix will increasingly feature hybrid technical-digital profiles such as: BIM/VDC coordinator, site digital QA lead, energy modeller, LCA/GWP analyst, heat-pump and RES commissioning technician, and selective-demolition & materials-recovery supervisor (supporting circular-economy requirements and quality-assured secondary materials flows). Policy and market signals suggest sustained demand for these roles as permitting pipelines convert to starts, funding for energy transition accelerates, and carbon-reporting obligations become mainstream practice.¹⁸

- **Thematic Analysis of State-of-the-Art**

- **Digitalisation in Construction (Housing 4.0)**

- Key Digital Technologies (e.g., Building Information Modelling (BIM), Digital Twins, Artificial Intelligence (AI) for energy management, Internet of Things (IoT) in buildings)
- Adoption and Impact in Construction Processes and Building Operation
- Current qualifications and emerging job profiles
- Relevant market trends shaping the demand and supply

Digitalisation in the construction industry is one of the key directions for the transformation of the sector. Implementing digital solutions at every stage (from design to construction) can help:

- reducing costs,
- increasing energy and operational efficiency,
- improving the quality and safety of construction work,
- monitoring of emissions and the environmental footprint of buildings.

In Poland, the digitalisation of the sector is still at an early stage, but there is growing interest, especially in large infrastructure projects and renovations funded by EU funds.

BIM – BIM technology is widely known, also in Poland, but implemented mainly in large design companies and for public contracts. In residential construction, it is used less frequently, mainly in premium projects.

¹⁷ European Labour Authority, 2024, *Report on labour shortages and surpluses* <https://145725293.fs1.hubspotusercontent-eu1.net/hubfs/145725293/EURES_Report_on_labour_shortages_and_surpluses_2024.pdf> access:25.09.2025

¹⁸ Kozierkiewicz P., 2025, *2025 Begins Cautiously: Fewer Building Permits, Stable Number of New Housing Projects*

The main barriers to using BIM include the problem of interoperability between systems and linking their data, as well as the shortage of BIM specialists. It is worth noting that during 'learning' phase of this methodology, the time taken to complete project can be up to 50% more than with traditional design, which can demotivate some companies¹⁹. Since 2022, the Polish Ministry of Development and Technology has been working to promote the BIM methodology among participants in the investment and construction process and representatives of the construction industry. This is being enforced through projects to digitize construction processes, where BIM documents, standards and templates are being prepared and processes identified where BIM technology can be used. A BIM working group has been established to develop strategies for implementing BIM.²⁰

Digital Twins – Digital twin technology is still relatively new concept in the Polish construction sector. It is mainly applied in pilot projects in commercial and office buildings, where it is used to monitor energy consumption, optimize HVAC systems, and improve facility management. In residential construction, adoption remains limited and mostly associated with innovative or premium developments. The main barriers include high implementation costs, lack of interoperability between software platforms, and the shortage of qualified specialists who can manage and analyze real-time data. Despite these challenges, the potential of digital twins is significant: they enable predictive maintenance, improve energy efficiency, and provide accurate simulations of building performance throughout the life cycle. With the growing importance of ESG reporting and life cycle assessment (LCA) in line with EU regulations, digital twin solutions are expected to gradually expand in Poland, particularly in large-scale housing estates and public housing projects supported by EU funds. Researchers from the Institute of Geodesy and Geoinformatics at Wrocław University of Life Science are working on the project related to digital twin – "Utilisation of urban digital twins to co-create flexible positive energy systems for districts". "It aim is not only to develop the technology, but also to put it into practice using interactive tools and information sharing platforms (...) that will help prepare communities to the implementation of Positive Energy Districts (PEDs) and enable the to co-create PEDs in their neighbourhoods".²¹

IoT – IoT solutions are increasingly used in residential construction in Poland, although adoption is still limited compared to Western Europe. Smart meters, air quality sensors, lighting and heating control systems, and basic home automation devices are the most common applications. Their use is concentrated mainly in newly built housing estates in larger cities and in projects marketed as "smart homes." The main barriers to wider adoption are the high cost of advanced IoT systems, the lack of interoperability between devices from different manufacturers, and low awareness among small and medium-sized developers. Nevertheless, rising energy prices and growing consumer demand for energy-efficient and comfortable housing are expected to accelerate the implementation of IoT technologies in the residential sector. The Ministry of Digitalisation's 2019 document presents a forecast of digital transformation adaptation in Poland compared to Central and Eastern Europe, as shown in Figure 1.

¹⁹ Kosiedowski W., Wirkus M., 2021, *Bariery i ograniczenia wdrażania technologii BIM – wyniki badań pilotażowych*, Builder Science

²⁰ Szuszman E., 2022, *BIM w Polsce*, Ministerstwo Rozwoju i Technologii

²¹ Uniwersytet Przyrodniczy we Wrocławiu, 2024, *Cyfrowy bliźniak pomoże w transformacji energetycznej miast*,

<<https://upwr.edu.pl/aktualnosci/cyfrowy-blizniak-pomoze-w-transformacji-energetycznej-miast-4257.html>>

“In the coming years, the market for IoT technologies and solutions is expected to grow at a high rate (approx. 13% year on year). This means that the Polish economy has great chances of absorbing this technology – removing the pertinent obstacles may only increase this potential. Removing the existing barriers concerning regulatory issues and the development of new communication technologies (including 5G) will result in the dynamic development of IoT in Poland”.²²

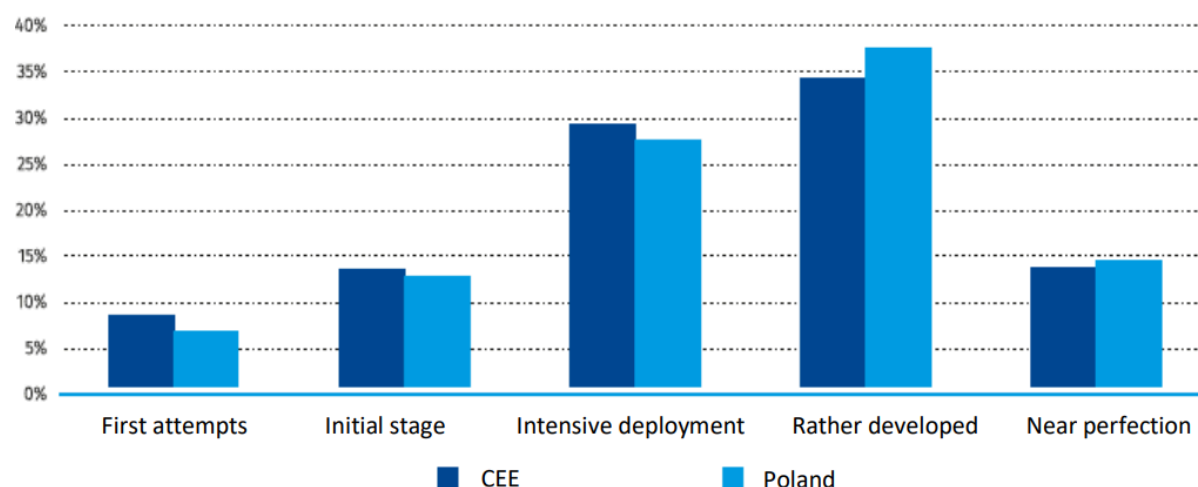


Figure 1. Declared level of adaptation of Digital Transformation solutions in Poland compared to Central and Eastern Europe²³

BMS – Building Management Systems are most common in the commercial and office building sector. In the residential, multi-family building sector, BMS solutions are only gradually entering the market. The main role is to integrate, automate and monitor technical systems (heating, air conditioning, ventilation, lightning, security systems or photovoltaic panels). There are many tools and technologies, they should be suited to the need and circumstances. For example in Warsaw in one of the residents’ associations (Wrzeciono 17) the SCADA system was implemented for monitoring, collecting and analyzing data. Such example was presented on the photo below (figure 2). Monitoring cameras were installed in order to observe the condition of the photovoltaics on the roof of the building. The association used management systems to plan and check the profitability and best location of the panels. For a year before installing PV they’ve monitored the roof to check how the shadows would act in the daily and yearly cycle. BMS systems can be helpful in many situations, even when the energy operator wants to force the purchase of unnecessary heat by increasing its temperature.

²² Maśniak L., Marcisz K and others, 2019, *IoT and the Polish Economy*, Report of the working group for the Internet of Things at the ministry of digital affairs

²³ IDC CEE Digital Transformation Survey, 2017; n=311



Figure 2. SCADA system monitoring photovoltaics on the roof

3D scanning, drones and robotics – 3D scanning, drones, and robotics represent another group of emerging technologies that are reshaping construction processes worldwide. 3D laser scanning allows for precise digital mapping of existing buildings and construction sites, improving the accuracy of renovation planning and progress monitoring. Drones equipped with cameras and sensors are increasingly used for surveying, safety inspections, and construction site supervision, enabling cost reductions and better control of project timelines. Robotics, meanwhile, holds promise for automating repetitive or dangerous tasks such as bricklaying, concrete printing, or prefabrication assembly.

In Poland, these technologies are being introduced gradually, with their use concentrated in larger companies and research projects. Drones are already being employed by developers for site inspections and by municipalities for urban planning and monitoring illegal construction. 3D scanning is mainly applied in renovation projects, particularly in heritage buildings, where precise digital documentation is required. Robotics remains at the pilot stage, with limited use in prefabrication plants and experimental applications in automated construction. Barriers to wider adoption include high equipment and training costs, legal issues related to drone operations, and the generally conservative nature of the construction sector. Nevertheless, as prefabrication and modular housing become more popular in Poland, and as EU funding supports digital and ecological transformation, the role of these technologies is expected to expand significantly.

AI & data analysis – Artificial intelligence (AI) and data analysis are becoming increasingly important tools in the global construction sector, offering opportunities to improve design processes, optimise energy use, and predict maintenance needs. These technologies support more efficient resource management by

using algorithms to simulate scenarios, analyse building performance data, and identify patterns that humans might overlook. Applications already include predictive modelling for energy consumption, optimisation of HVAC systems, risk assessment in construction project management, and automated quality control using image recognition.

In the Polish context, AI and advanced data analytics are still at an early stage of adoption. Their use is more common in pilot projects, often linked with research institutions or in collaboration with larger developers on commercial and public buildings. In residential construction, practical applications remain limited, mainly due to cost barriers, lack of structured data, and a shortage of specialists with combined knowledge of construction engineering and data science. However, the increasing requirements for ESG reporting and life cycle assessments (LCA) under EU regulations are expected to accelerate adoption. With growing pressure to monitor and reduce the carbon footprint of buildings, AI-driven solutions for data processing and reporting could soon become a standard, particularly in larger housing estates and public projects supported by EU funds.

Game “Estate with Climate” – “the game was created so that estate residents could take matters into their own hands and decide how to adapt their places of residence to climate change. The game was developed as part of the Co-Adapt Project – ‘Communities for Climate Change Action’, ‘Communities for Climate Change Adaptation Action’.”²⁴ It is a serious simulation game, which serves as an innovative tool to engage urban residents in designing and implementing climate adaptation measures for their housing estates. Players can select from 40 nature-based solutions, such as rain gardens, absorption basins, climbing plants, trees, and flower meadows, then simulate their effects using embedded algorithms: assessing reductions in air temperature, improved air quality, rainwater retention, contributions to biodiversity, and cost-effectiveness. The game functions with both board and electronic versions and is freely available online. Players enter their postal code, and the game renders their estate as a 3D model, allowing them to test and visualize the impact of adaptive interventions like planting trees, replacing paved surfaces with permeable materials, or installing rainwater storage systems. The advantage of such game is availability and ability to engage and involve people of all ages.

²⁴ Szkoła Główna Gospodarstwa Wiejskiego, *Osiedle z Klimatem*, <<https://osiedlezklimatem.sggw.edu.pl/?lang=en>>, access 21.08.2025

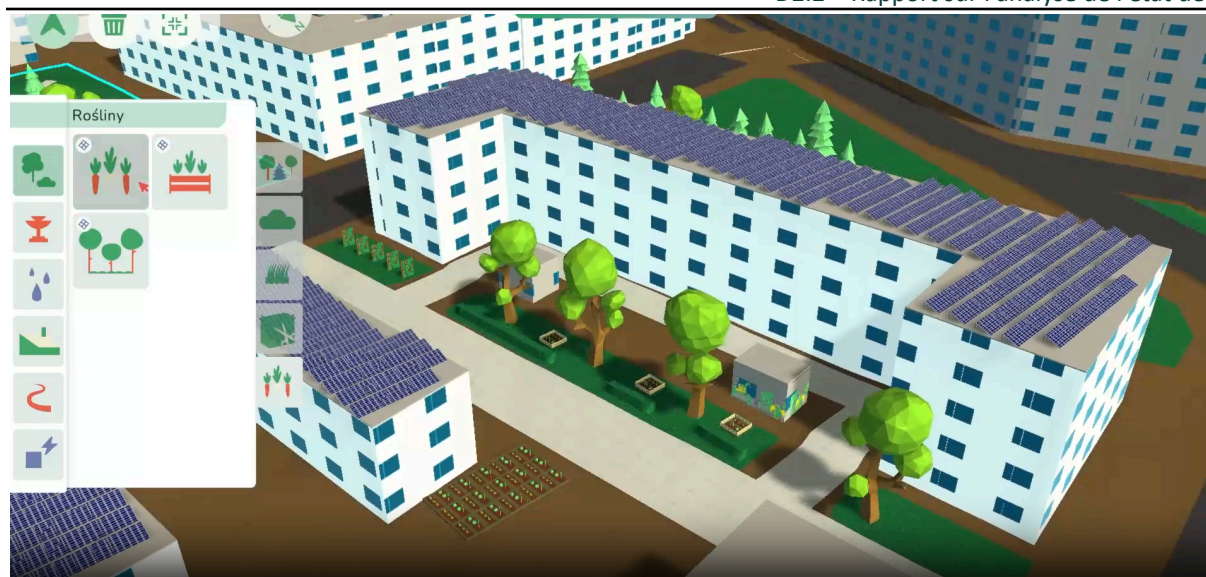


Figure 3. Game "Estate with Climate"

Digitalisation and the development of new technologies are becoming one of the key directions of transformation in the construction sector in Europe and in Poland. The adoption of innovative solutions such as BIM, digital twins, IoT, artificial intelligence and robotics affects not only the way projects are designed and implemented, but also energy efficiency, environmental sustainability, and the overall competitiveness of the sector. These trends are reshaping the labour market by requiring new skills, while at the same time creating opportunities to improve building quality, reduce operational costs, and meet the growing regulatory requirements of the European Union.

The digitalisation of construction is an important aspect that will pay off in the future and will be necessary, the implementation phase is crucial in this case, the learning process of the technology will be demanding and in the first months the working time will not necessarily be shorter than traditionally and the costs do not have to be lower. Stakeholders and beneficiaries should be supported in further joint development, especially in the most difficult stages.

Some of the advantages of implementation new technologies and methodologies are:

- Cost-effectiveness
- Quality assurance and on-time delivery
- Improving communication and collaboration
- Project optimization
- Sustainability and life-cycle analysis

The main challenges are, for example, financial, technological and legal barriers, cyber security aspects, contracting authority requirements and cultural barriers.

In today's fast-paced world, the job market and requirements will change. Some jobs may not exist in the near future, but new technologies and methodologies also create new jobs. Due to the technological development (as well as the green transition and changing EU policy) in the construction sector, there will be an increasing demand for specialists:

- BIM Coordinator / BIM Manager
- Digital Twin Engineer
- LCA/EPD Specialist

- Circular Economy Advisor
- Smart Building Systems Technician
- Renewable Energy Systems Designer/Installer
- Data Analyst

These emerging profiles illustrate how the construction sector is shifting towards a model that combines digital expertise with sustainable practices. They require not only technical skills in advanced software, data analysis, and renewable energy systems, but also interdisciplinary knowledge that connects engineering, environmental science, and project management. As the industry adapts to stricter EU regulations and investor expectations linked to ESG reporting, the demand for such specialists will continue to grow. This evolution highlights the importance of vocational education and training systems that can provide flexible pathways, including micro-credentials and lifelong learning opportunities, to equip the workforce with the necessary competences for the green and digital transition.

In Poland there is a tool called Sectoral Qualifications Framework (pl. Sektorowa Rama Kwalifikacji), it helps to systematize qualifications in various sectors and links them with Polish Qualifications Framework (PRK).

“It makes it easier to understand what skills and knowledge employees should have at different levels – from simple auxiliary tasks to advanced management of construction projects. (...) The main goal of the SRK update in Construction was to take into account the growing role of green and digital qualifications in construction. This is a response to the challenges of the European Green Deal, the National Recovery Plan, the Just Transition Fund, and the "Fit for 55" package. The construction industry has a huge impact on the environment, which is why it is necessary to prepare personnel to work in a more ecological, efficient, and responsible way. Green competences are cross-sectional and interdisciplinary in nature, encompassing technological aspects (e.g., renewable energy sources, circular economy), organizational aspects (e.g., sustainable project management), and social aspects (e.g., environmental education, social participation). Their effective implementation requires precise definition and assignment to specific sectors of the economy, which is made possible by sectoral qualifications frameworks.”²⁵

There are many factors that influence the market and shape its development. Legal regulations, technical development, consumers and changing demands – all this has a great effect on present and future situation in this sector.

Polish ways of digitalisation

In recent years Poland has significantly expanded its portfolio of digital tools and registries to increase transparency, streamline administrative procedures, and improve the quality and safety of the built environment. These instruments are aligned with the objectives of the national *Building Information Modelling (BIM) Roadmap* as well as with the broader digitalisation agenda promoted by the European Union.

- **e-Budownictwo** – the official government platform (operated by the General Office of Construction Supervision) that enables online submission of construction-related applications and

²⁵ Zintegrowany System Kwalifikacji, Zielone kompetencje w budownictwie – aktualizacja SRK w Budownictwie, <<https://kwalifikacje.edu.pl/zielone-kompetencje-w-budownictwie-aktualizacja-srk-w-budownictwie/>> access 22.08.2025

forms. It replaces traditional paper-based workflows and provides citizens, designers, and contractors with a single digital entry point.

- **SOPAB (System Obsługi Postępowań Administracyjnych w Budownictwie)** – the System for Handling Administrative Proceedings in Construction. It supports public authorities in managing building permits and related procedures electronically, ensuring consistency of decisions and reducing processing times.
- **Registers of Mandatory Inspections and Construction Disasters** – national registries that record compulsory building inspections and document serious construction incidents. They improve monitoring, transparency, and enforcement of safety regulations.
- **Central Register of Persons Holding Construction Licences** – introduced in 2023, this database contains official records of engineers and professionals authorised to perform independent technical functions in construction. It increases labour-market transparency and facilitates verification of qualifications.
- **Elektroniczny Dziennik Budowy (EDB, Electronic Construction Logbook)** – launched in 2023, this digital site diary replaces paper-based logs. It allows contractors, supervisors, and inspectors to record construction progress, decisions, and approvals in real time.
- **Cyfrowa Książka Obiektu Budowlanego (c-KOB, Digital Building Book)** – mandatory for new buildings since 2024, this digital record contains comprehensive documentation of a building's maintenance, upgrades, and inspections across its life cycle.

Together, these tools mark a decisive step toward a fully digital construction administration in Poland. They reduce paperwork and administrative burdens, ensure greater regulatory compliance, and provide reliable datasets for quality assurance and safety monitoring. In the longer term, they also prepare the sector for integration with BIM environments and for EU requirements on energy and carbon performance reporting.

Tool / Registry	Technology / Functionality	Implementation status in Poland	Potential for further development
e-Budownictwo (national e-construction portal)	Online platform for electronic submission of forms and applications; integrated with public registers.	Fully operational; widely used by citizens and firms for building permits and notifications.	Expansion of services (integration with BIM models and EU databases); user-friendly interface and mobile applications.
SOPAB (System for Handling Administrative Proceedings in Construction)	Case management system for public authorities; supports digital workflows in building permit procedures.	Deployed in public administration; gradually replacing paper-based workflows.	Potential to integrate with regional/local planning systems and EU-level permitting standards; AI-based document checking.
Registers of Mandatory Inspections & Construction Disasters	Centralised digital databases for recording compulsory building inspections and reporting serious incidents.	Functional; improving oversight and transparency.	Development of predictive analytics, linking with IoT sensors and risk-monitoring platforms

Central Register of Persons Holding Construction Licences	Online register of certified professionals; searchable by public and authorities.	Operational since 2023; improves verification of qualifications.	Could integrate with EU recognition of professional qualifications, digital ID cards for engineers
EDB (Electronic Construction Logbook)	Cloud-based platform for recording daily site activities, progress, and approvals.	Introduced in 2023; adoption increasing among contractors and supervisors.	Integration with BIM workflows, mobile QA apps, and automated reporting.
c-KOB (Digital Building Book)	Digital life-cycle record of building maintenance, inspections, and upgrades.	Mandatory for new buildings since 2024; early stage of use	Linking with LCA/GWP databases, smart-building sensors, and EU renovation passports.

Poland has already built a solid foundation of digital registries and administrative tools. The current challenge lies less in launching new systems than in ensuring interoperability, user uptake, and integration with BIM, smart-building technologies, and EU-wide platforms (e.g. for renovation passports, carbon reporting, or cross-border recognition of licences).

Market trends shaping demand

The Polish construction market is currently shaped by the combined effects of cyclical fluctuations and structural transformations linked to the green and digital transitions. Following a contraction in completions during 2024, forward-looking indicators such as building permits and housing starts point to a renewed pipeline of projects that will sustain activity in the coming years. This outlook is reinforced by the availability of EU recovery funding, national renovation programmes such as the *Clean Air Programme*, and investments in infrastructure. At the same time, cost pressures and financing constraints continue to weigh on short-term demand, particularly in the residential segment.

The green transition is emerging as a primary driver of demand. The recast *Energy Performance of Buildings Directive* (EPBD 2024/1275) introduces binding requirements for zero-emission new buildings, progressive renovation standards, and mandatory disclosure of whole-life carbon. For Poland, this creates a sustained need for deep energy renovations, low-carbon building services such as heat pumps, balanced ventilation systems and photovoltaic installations, as well as robust quality assurance practices including blower-door testing and commissioning. In combination with national strategies such as the *KPRB* and *PEP2040*, these regulatory requirements are expected to generate long-term growth in both the renovation and new construction markets.

In parallel, digitalisation is reshaping both administrative procedures and project delivery models. The introduction of platforms such as *e-Budownictwo*, *SOPAB*, the *Electronic Construction Logbook (EDB)*, and the *Digital Building Book (c-KOB)* has firmly embedded digital workflows into regulatory compliance. Moreover, the phased integration of Building Information Modelling (BIM) into public procurement is accelerating the adoption of integrated, data-driven project management practices. This transition creates rising demand for advanced roles such as BIM coordinators, digital QA specialists and data managers, but it also requires baseline digital literacy among site crews, office staff and supervisory personnel.

Labour market dynamics further amplify these pressures. Persistent shortages in core construction trades—such as bricklayers, reinforcement workers, roofers and HVAC/RES installers—coexist with growing demand for hybrid profiles that combine traditional craftsmanship with environmental and digital competences. Vacancy rates remain above pre-pandemic levels, underlining the structural imbalance between labour supply and the needs of a sector undergoing simultaneous decarbonisation and digital transformation.

Taken together, these trends point to both risks and opportunities. Firms that are able to invest in workforce upskilling, digital infrastructure and low-carbon solutions are likely to benefit from preferential access to public procurement, EU and national support mechanisms, and expanding demand for sustainable housing and infrastructure. In particular, enterprises specialising in deep renovation, renewable energy integration, BIM-enabled project delivery and circular-economy practices—such as selective demolition and the reuse of secondary materials—are well positioned to capture the benefits of the current transformation.

O Circular Economy & Sustainable Construction Materials

- Principles and Practices (e.g., reuse, recycling, waste management strategies)
- Sustainable Materials and their Application in Buildings
- Current qualifications and emerging job profiles
- Relevant market trends shaping the demand and supply

In Poland, the building sector is responsible for a large share of energy consumption and material use, while renovation and demolition activities generate a significant volume of construction waste. Sustainable materials, such as low-carbon concrete, cross-laminated timber (CLT), recycled aggregates, or bio-based insulation are increasingly recognised as viable alternatives to conventional, high-emission products. Their integration into housing projects not only reduces the environmental footprint but also creates demand for new competencies in design, installation, and material certification. The project also emphasises the adoption of design-for-disassembly approaches, material passports, and selective demolition practices, which make future reuse and recycling possible. These circular practices are still at an early stage in Poland, where the construction market remains cost-driven and fragmented, so there is a lot room for improvement.

Water recovery – Water efficiency is a critical aspect of circular housing. Greywater recycling systems, rainwater harvesting, water recovery from wastewater, and green infrastructure such as retention basins or green roofs help to reduce potable water use and mitigate climate risks like drought or urban flooding. In the Polish context, these solutions are still not widely applied in residential construction, but they offer high potential for sustainable housing estates. It can be assumed that the increase of public awareness and decrease of deepwater resources will contribute to greater interest in water recovery. Especially considering the fact that there is a visible increase in water and sewage fees in Polish cities.

Wastewater

“Due to the increase in water consumption in households and industry, the amount of wastewater is constantly growing. High costs of water transportation, as well as new environmental problems, such as

growing water shortages, make the topic of water recovery and reuse, as well as wastewater recycling, increasingly important”.²⁶

Warsaw Waterworks and the City Sewage Management Board (ZOM) have signed an agreement to ensure the use of water recovered from sewage. For this purpose, the potential and possibilities of using such water in urban space should be assessed. The recovered water will be assessed as part of the ReNutriWater project, which is funded by the EU's Interreg Baltic Sea Region program. Reclaimed water can be used for maintaining cleanliness in cities (cleaning streets and sidewalks), in urban agriculture (watering urban greenery), and in industry. As a result, the use of drinking water, i.e. treated water, for cleaning and economic purposes should be reduced, and the capital city of Poland will gain a modern and sustainable tool for maintaining cleanliness and the environment.²⁷

Greywater

Greywater, which includes relatively clean wastewater from sources such as showers, sinks, and washing machines, represents a significant opportunity within the framework of the circular economy. Its treatment and reuse can substantially reduce the demand for potable water in households, particularly for non-potable uses like toilet flushing, garden irrigation, or cleaning. In circular housing systems, greywater recycling not only conserves water but also reduces the volume of wastewater requiring treatment, lowering energy use and operational costs in centralized sewage systems.

In Poland, however, the implementation of greywater systems in residential buildings remains limited and there are few challenges to overcome. The primary barriers include lack of clear legal frameworks, low public awareness, and relatively low water prices, which reduce the economic incentive for investment in such technologies. Despite these challenges, pilot projects and increasing interest from municipalities and developers indicate a growing recognition of greywater's potential, especially in the context of rising water stress and the need for more sustainable urban infrastructure.

An example of such a water recovery solution is the Aqua Park in Międzyzdroje. Green Water Solutions, a company specializing in water recovery technologies (grey water recycling and rainwater recovery), helped launch the modern GreenLife installation at the facility. The system operates at a capacity of 11m³ per day and allows for the efficient recovery of grey water, mainly from showers, which after an advanced purification process is fed back into the system – it is used, among other things, to flush toilets in the facility.²⁸

Rainwater

Rainwater harvesting is one of the more widely recognized and accepted water-saving strategies within the circular economy framework, especially in residential and urban settings. It involves collecting, storing, and using rainwater. Typically from rooftops for non-potable purposes such as garden irrigation, toilet

²⁶ VEOLIA, *Ponowne wykorzystanie wody*,

<<https://www.veoliawatertechnologies.pl/oferta/zastosowania/odzysk>> access 26.08.2025

²⁷ Wodociągi Warszawskie, 2025, Wodociągi Warszawskie i Zarząd Oczyszczania Miasta zbadają możliwość efektywnego dla miasta wykorzystania wody odzyskanej ze ścieków,

<<https://www.mpwik.com.pl/view/wodociagi-warszawskie-i-zarzd-oczyszczania-miasta-zbadaj-mozliwosc-efektywnego-dla-miasta-wykorzystania-wody-odzyskanej-ze-sciekow&i=1315>>

²⁸ Green Water Solutions, Uruchomienie systemu odzysku wody szarej w Aqua Park Międzyzdroje,

<<https://www.greenwatersolutions.pl/aktualnosci/uruchomienie-systemu-odzysku-wody-szarej-w-aqua-park-miedzyzdroje/>> access 29.08.25

flushing, or cleaning surfaces. This not only reduces the demand for treated tap water but also helps manage stormwater runoff, mitigating the risk of urban flooding.

In Poland, rainwater harvesting is gaining traction, particularly in response to more frequent extreme weather events, including both droughts and intense rainfall. Local governments increasingly promote the installation of rainwater systems through subsidies and awareness campaigns. However, despite growing interest, the adoption rate in residential construction remains moderate. Barriers include limited integration into urban planning policies, lack of unified national regulations, and uneven financial support across regions. Still, compared to greywater systems, rainwater harvesting is more familiar to the public and often seen as a first step toward more comprehensive water reuse practices in Polish cities.

Rainwater has a high potential for use, also on a large scale. The Maerl hotel project in Kołobrzeg (scheduled to be completed by mid-2026) includes the installation of an advanced rainwater recovery system. Due to the size and modernity of the building, innovative solutions were chosen. The water recovery system is designed to efficiently collect rainwater from the entire roof surface of the facility, providing an ecological and economical source of technical water for purposes such as flushing toilets, watering plants, or washing external surfaces.²⁹

In the case of Poland, it is important to develop a plan that takes into account the profitability of the projects. Reclaimed water is often used for irrigation, and in Poland, the average demand for irrigation water is relatively low compared to the rest of Europe.

²⁹ Green Water Solutions, Zaawansowany projekt systemu odzysku wody deszczowej w hotelu Maerl w Kołobrzegu, <<https://www.greenwatersolutions.pl/aktualnosci/zaawansowany-projekt-systemu-odzysku-wody-deszczowej-w-hotelu-maerl-w-kolobrzegu/>> access 29.08.25

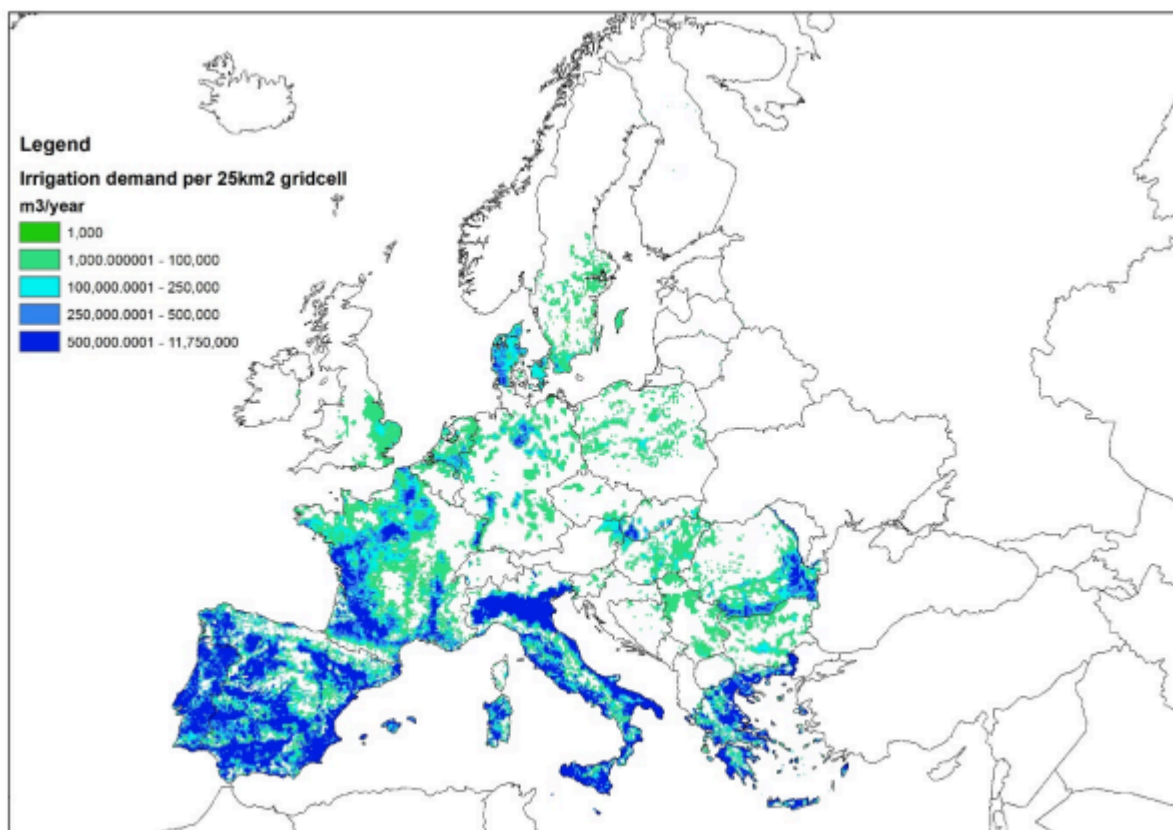


Figure 4. Average water demand for irrigation, calculated using EPIC³⁰

Given this, on June 22, 2023, the Minister of Infrastructure issued a decision to exclude the country's area from the application of Regulation (EU) 2020/741 of the European Parliament and of the Council of May 25, 2020, on minimum requirements for water reuse. According to the decision, the reuse of water for irrigation in agriculture will not be used in the areas of nine river basins in Poland. The reason was the criterion of profitability, taking into account all costs, both environmental and resource costs; it was shown that alternative solutions would be more optimal in this case.³¹

Water reuse solutions such as rainwater harvesting, greywater recycling, and wastewater recovery align strongly with the principles of the circular economy and offer tangible benefits for sustainable urban development. While their implementation in Poland remains limited, growing environmental pressures and rising water costs may drive wider adoption in the future. Strategic planning, supportive regulation, and increased public awareness will be key to unlocking their full potential.

Waste heat – In residential construction, waste heat recovery is an increasingly important circular solution. Technologies such as mechanical ventilation with heat recovery (MVHR), wastewater heat

³⁰ Pistocchi, A., Aloe, A., Dorati, C., Sanz, L. A., Bouraoui, F., Gawlik, B., Grizzetti, B., Pastori, M., Vigiak, O. (2017) *The potential of water reuse for agricultural irrigation in the EU: a hydro-economic analysis*, Publications Office of the European Union, Luxembourg, Join Research Centre, EUR 28980 EN <https://publications.jrc.ec.europa.eu/repository/handle/JRC109870>

³¹ Decision of the Minister of Infrastructure of June 22, 2023, on excluding the country from the application of Regulation (EU) 2020/741 of the European Parliament and of the Council of May 25, 2020, on minimum requirements for water reuse

exchangers, or district systems that reuse excess heat from industry can significantly reduce energy demand in buildings. Integrating waste heat recovery into housing projects aligns with the EU's decarbonization goals and supports both cost savings for residents and emission reductions. Currently, the heat emitted by devices often goes into the atmosphere, where it is wasted. There are many places where such waste heat would be useful and could be recovered to heat other infrastructure elements. Such heat can be reintroduced into the cycle, reducing the need for production and thus reducing costs. It can be recovered from many infrastructure elements, but data centers, which work continuously generating large amounts of heat, deserve special attention.

“The data processing center sector, which is in a phase of dynamic development, has significant potential for using waste heat for heating purposes. Heat generated in server rooms is characterized by year-round availability and stable power. Using heat pump technology, its temperature parameters enable efficient supply to district heating systems, which significantly supports the implementation of decarbonization goals in the national energy sector, as well as the diversification of available waste heat sources.

In Poland, there is significant potential for heat recovery from data centers, which can play a key role in the energy transformation process and in the new model of heat market operation.

The use of heat recovery systems in Data Centers is a justified action both from the perspective of improving the energy efficiency of these facilities and compliance with the priorities of national and European climate policy.

Key advantages of recovering waste heat from the data processing process:

- large amounts of waste heat per unit and concentration in major urban agglomerations,
- estimated total waste heat potential: 19,700 TJ (2030),
- temperature of the heat pump's lower source in the range of 20-50°C,
- stable source of waste heat with a predictable annual profile,
- availability of the existing data center power connection for powering heat pumps.

Key challenges:

- r. location of the data center relative to existing district heating networks (connection costs),
- s. the scope of responsibility of individual members of the process (data center operator,
- technological limitations of heat pumps in terms of the ability to produce water with temperatures equal to the water supply temperature of high-temperature systems (>120C) under the design conditions of the outdoor air temperature in winter,
- obligation to obtain a permit for thermal power > 5 MWt”.³²

Unlocking the full potential of waste heat recovery particularly from data centers will require closer cooperation between stakeholders, infrastructure planning, and targeted investment. As both energy prices and climate ambitions rise, this circular solution may become a key component of Poland's sustainable energy transition.

Technological disposal – Construction and demolition waste represents one of the largest waste streams in Poland. Selective demolition, material sorting, and technological disposal techniques such as advanced crushing, separation, or upcycling of aggregates enable materials to re-enter the construction cycle. These practices help reduce landfill volumes and resource extraction, and they create new business models in the field of construction waste management.

³² Polish Data Center Association, 2025, *Odzysk ciepła odpadowego z Centrów Przetwarzania Danych (CPD) wsparciem procesu dekarbonizacji polskich sieci ciepłowniczych*

Sustainable materials – Replacing conventional materials with low-emission and renewable alternatives is central to the transition. Examples include low-carbon concrete blends, cross-laminated timber (CLT), bio-based insulation (hemp, cellulose, wood fibre), and recycled steel or aluminium. Their use lowers embodied carbon and supports a market shift towards more climate-neutral construction. However, uptake in Poland is limited by higher costs, lack of awareness, and gaps in supply chains.

LCA/EPD – To evaluate sustainability, life cycle assessment is becoming a standard tool in EU housing policy. LCA allows stakeholders to measure not only operational energy use but also embodied emissions from materials, transport, and construction processes. Environmental Product Declarations (EPDs) provide transparent data on materials' performance, enabling architects, developers, and regulators to make evidence-based choices. Promoting these methodologies through projects like Excel4Housing ensures alignment with EU taxonomy and green financing requirements.

- **Cross-Cutting Analysis & Opportunities**

- Interlinkages and Synergies between the Thematic Areas
- Common Challenges and Barriers across Diverse European Regions (e.g., policy, financial, skills-related)
- Innovation Opportunities in VET for Sustainable Construction (identifying promising areas for intervention)

The three thematic areas analysed in this report—energy efficiency and climate-neutral housing, digitalisation of construction processes, and circular economy practices—are not isolated domains but interconnected dimensions of the same systemic transition. The recast Energy Performance of Buildings Directive (EPBD 2024/1275) demonstrates this interdependence clearly: it raises minimum energy performance standards, introduces renovation passports, requires whole-life carbon disclosure, and promotes material passports. As a result, green and digital transitions increasingly converge at the regulatory level, and their successful implementation demands the simultaneous development of competences across all three domains.

Digitalisation directly supports energy efficiency by enabling transparent monitoring, modelling, and verification of building performance through tools such as BIM, dynamic simulations, and electronic logbooks. Circular-economy principles are likewise inseparable from digital solutions, since selective demolition, reuse, and material quality assurance rely on traceability ensured by interoperable data systems. At the same time, energy efficiency and circularity complement one another: combining deep renovation with reuse of secondary resources reduces both energy demand and material waste, maximising climate benefits and lowering costs.

Despite these synergies, several persistent barriers remain across European regions. Regulatory fragmentation and uneven national implementation of EU directives create uncertainty for firms and training providers. Financial barriers, particularly the high upfront costs of deep renovation, selective demolition, and digital infrastructure, discourage investment—especially among SMEs with limited access to capital. Skills-related shortages represent perhaps the most structural obstacle: deficits in traditional

trades coexist with limited availability of advanced competences such as BIM coordination, LCA/GWP assessment, and digital quality assurance. Teacher capacity and training infrastructure remain insufficient to meet the pace of change.

These challenges also create opportunities for innovation in vocational education and training (VET). The emerging network of *Branżowe Centra Umiejętności* (Centres of Vocational Excellence) provides a platform for piloting integrated curricula that combine green and digital skills with transversal competences such as teamwork, health and safety, and ESG awareness. Practical laboratories and demonstration sites can be established to simulate real construction conditions, from airtightness testing to BIM clash detection and selective dismantling. Short, modular courses for adult learners can help to address immediate shortages while providing flexible pathways into new hybrid professions such as energy modeller, renewable energy commissioning technician, or circular-construction supervisor. Teacher secondments to industry and closer cooperation between training institutions, municipalities, and firms are essential to ensure that curricula remain aligned with technological developments and regulatory requirements. By pursuing these opportunities, Poland—and other EU Member States facing similar challenges—can reinforce resilience in the construction sector while accelerating progress toward EU climate and digitalisation goals.

- **Conclusions and Recommendations for WP4**

- Key Findings Summary (synthesis of the most important insights)
- Strategic Insights for Curriculum and Training Programme Design (direct recommendations for WP4)

The evidence collected across thematic areas demonstrates that the construction sector in Poland, as in the wider EU, is undergoing a dual transformation driven by green and digital imperatives. Regulatory frameworks such as the European Green Deal, the Fit for 55 package, and the recast EPBD set increasingly ambitious requirements for energy performance, carbon neutrality, and transparency across the building life cycle. Simultaneously, national reforms have introduced a comprehensive suite of digital tools, including e-Budownictwo, SOPAB, the Electronic Construction Logbook, and the Digital Building Book, embedding digital workflows into regulatory compliance. In parallel, labour-market shortages remain acute: deficits persist in traditional building trades while demand grows for hybrid roles that combine technical craftsmanship with digital and environmental competences. Circular-economy principles, embodied in the updated EU Construction and Demolition Waste Protocol and national profiles, are progressively entering mainstream practice, yet implementation is uneven and markets for secondary materials remain underdeveloped.

In light of these findings, the design of curricula and training programmes under WP4 should adopt an integrated and forward-looking perspective. Training content must combine green and digital competences rather than treating them as separate pathways. BIM-enabled design, energy modelling, and life-cycle assessment (LCA/GWP) should be embedded into core curricula alongside skills in airtightness, building services decarbonisation, and selective demolition. Practical learning environments must be established, including demonstration laboratories and pilot sites where learners can apply knowledge in conditions that mirror real construction challenges. Teacher training should include systematic

secondments to industry to ensure a continuous exchange of knowledge between practice and education. Adult learning programmes should be modular, allowing workers to reskill quickly in areas of high demand such as heat pump installation, drone-based as-built capture, and digital renovation passport management.

It is equally important that transversal competences—project management, teamwork, occupational health and safety, and ESG fundamentals—are integrated into all training pathways, as these are increasingly central to employer expectations and project delivery. The Centres of Vocational Excellence should be positioned as hubs for innovation, piloting new curricula, hosting digital and circular laboratories, and coordinating partnerships between schools, municipalities, and companies. Training standards developed under WP4 should also be aligned with EU-wide frameworks, enabling mobility of workers and mutual recognition of qualifications.

The future of the construction sector will belong to firms and workers capable of integrating technical, digital, and environmental skills. For WP4, this means creating a coherent and flexible training framework that addresses immediate labour-market shortages while preparing the workforce for a decarbonised, digitalised, and circular construction sector. In this way, the recommendations presented here will not only support the successful delivery of project objectives but also contribute to the long-term competitiveness and sustainability of the European construction industry.

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Annex 8: State-of-the-Art National Report - Portugal



REPORT ON THE STATE OF THE ART

Portugal

● Introduction

The state of the art in the construction sector in Portugal aims to provide a comprehensive analysis of sustainability and energy efficiency practices within the sector, focusing on the development of skills and the strengthening of the sector through training and qualification of the various actors involved.

This document, based on a review of relevant literature, analysis of case studies and best practices, review of methodologies, and consultations with stakeholders, aims to offer an overview of the sector, serving as a foundation for the development of new approaches, methodologies, tools, and resources aimed at the sustainable and innovative growth of this sector in the partner countries of the project.

– Indicative outline

▪ Introduction

The construction industry stands as a cornerstone of economic activity, generating around 18 million direct jobs and accounting for approximately 9% of the European Union's (EU) gross domestic product (GDP). Its value chain spans a diverse array of activities, including the extraction of raw materials, the manufacture and distribution of construction products, as well as the design, construction, management, and supervision of building works. It also extends to the maintenance, renovation, and demolition of structures, along with the recycling of construction and demolition waste (EC, 2016).

To achieve carbon neutrality by 2050, the EU has launched a “Renovation Wave” aimed at enhancing energy performance. This initiative targets the renovation of 35 million buildings by 2030, with an annual renovation rate of 3% (EC, 2020; Thung et al., 2023).

This task, grounded in bibliographic research and analysis and focused on the Portuguese context, aims to identify and characterize the state of the art of the national construction sector. It also seeks to contribute to a broader analysis within the framework of the EXEL4HOUSING 4.0 project, supporting the development of methodologies, resources, and tools designed to strengthen the capacities of the project's target groups.

▪ General Context: European Construction Sector & Energy Transition

- o Policy and Regulatory Landscape (e.g., EPBD, European Green Deal, Renovation Wave, EU Taxonomy relevant to construction)

When it comes to public policies related to the construction sector, Portugal is aligned with the European framework, and policies and regulations have been progressively adopted and promoted at the national level.

In this regard, the following can be highlighted:

National Energy and Climate Plan 2021–2030 (PNEC 2030). Adopted within the framework of the European Green Deal, the EU's Circular Economy Action Plan (CEAP), as well as the Portuguese CEAP 2030, outline specific actions to promote a circular economy across all industrial sectors, including

construction. In particular, under the Sustainable Products Policy, it promotes product design aimed at durability, reuse, and recyclability, as well as the EU Strategy for Sustainable and Smart Mobility, which supports the use of sustainable construction materials and the reduction of emissions from the construction sector.

The **European Green Deal**, which aims to make Europe the first climate-neutral continent by 2050, has significant implications for the construction industry. This includes a push for energy-efficient buildings, reducing the carbon footprint of the construction sector, and promoting circular economy models. It complements the EU's broader environmental agenda and fosters sustainable construction practices through policy incentives.

Strategy for the Sustainability of the Built Environment. The EU's CEAP states that the European Commission will launch a new Strategy for the Sustainability of the Built Environment to ensure coherence in key action areas such as climate, energy efficiency and resource efficiency, construction and demolition waste (CDW) management, accessibility, digitalization and skills. It will promote circularity principles throughout the building life cycle through measures such as:

- t. performance requirements for construction products in terms of sustainability under the revised Construction Products Regulation (Regulation (EU) 2024/3110);
- u. promoting measures to improve the durability and adaptability of built assets in line with circular economy principles for building design;
- v. creating digital building logbooks;
- w. applying the Level(s) Framework to integrate life-cycle assessment into public procurement and the EU sustainable finance framework;

exploring the feasibility of setting carbon-reduction targets and the potential for carbon storage, among other aspects.

The **Construction Products Regulation** ensures that construction products in the EU meet minimum sustainability and safety standards. It includes provisions for the environmental performance of construction products, aligned with circular economy objectives, promoting the use of recycled materials, reducing the carbon footprint, and facilitating product reuse.

The **Waste Framework Directive** (2008/98/EC) establishes a hierarchy of waste management practices (reduce, reuse, recycle). For the construction sector, this Directive sets the framework for CDW management, encouraging recycling and the reuse of construction materials. It also sets specific recycling targets for CDW, focusing on reducing the environmental impact of waste. Under the Waste Framework Directive, the EU has set ambitious targets for recycling and reducing landfill use.

The **Ecodesign for Sustainable Products Regulation** will allow the establishment of ecodesign and information requirements for almost all categories of physical goods placed on the EU market. The new Ecodesign Regulation builds on the current Ecodesign Directive, which currently only covers energy-related products. It aims to significantly improve circularity, energy performance, and other aspects of the environmental sustainability of products placed on the EU market.

The **Energy Performance of Buildings Directive** (EPBD) together with the **Energy Efficiency Directive** (EED) both aim to achieve a fully decarbonised building stock by 2050. In particular, the revised EPBD will drive the Renovation Wave by creating national building passport schemes to guide owners through renovation towards zero-emission buildings. The revised directive also introduces disclosure of whole-life-cycle emissions of buildings. A requirement to calculate the life-cycle global warming

potential of new buildings constitutes a first step towards greater consideration of whole-life performance of buildings and of a circular economy.

- o Overall Market Dynamics and Key Trends in Construction (e.g., investment, growth drivers, consumer demand for sustainable housing)

In Portugal, as in most European countries, several measures have been adopted to promote circular economy practices in the construction sector, such as agendas, plans, procurement strategies, among others, both at national and regional levels. These initiatives mainly focus on the following aspects:

- 11 **Product design:** encouraging the design of innovative and efficient buildings, infrastructures, and product systems that are adaptable, repairable, and made with efficient and sustainable materials;
- 12 **Building life cycle:** promoting the assessment of the environmental impact of buildings throughout their entire life cycle, from construction to demolition, fostering durability and the optimization of their use;
- 13 **Material passports:** developing and promoting the use of material passports, which track the materials and components used in buildings, facilitating their reuse or recycling at the end of a building's life.

Regarding the construction sector market, Portugal is currently experiencing a growth cycle driven by increased investment and the demand for more sustainable housing. This type of housing continues to face challenges in terms of costs and associated bureaucracy; however, a set of factors is shaping the future in this direction, among which the following can be highlighted:

- **Growing Investment:** Construction investment is expected to increase by around 4.9% in 2025 and 5.1% in 2026, according to recent forecasts by the Instituto Nacional de Estatística (INE, 2024) and sectoral studies from AECOPS.
- **High Demand vs. Limited Supply:** Demand for housing, particularly sustainable and affordable housing, significantly exceeds supply, driving prices up. According to the 2024 Housing Observatory, Portugal faces a deficit of over 100,000 affordable housing units, especially in metropolitan areas.
- **Rising Sustainable Housing:** Consumers are increasingly aware and place greater value on energy-efficient buildings, sustainable materials, and reduced environmental footprints. The PRR (Plano de Recuperação e Resiliência) allocated 2.7 billion euros to housing, with specific lines to support sustainable renovation and social housing.
- **Industrialization and Modular Construction:** There is a growing trend towards industrialized, prefabricated, and modular construction, with Portuguese companies such as Jular, Martifer, and Casais investing in production units to scale these technologies.
- **Incentives and Public Policies:** Various national and regional programmes (e.g., “Mais Habitação”, PRR, and IFRRU 2020) are supporting sustainable construction, reinforcing urban rehabilitation and the construction of affordable housing. Some municipalities have introduced property tax exemptions (IMI) for sustainable buildings certified under LEED, BREEAM, or LiderA.

- **Persistent Challenges:** High material and labour costs, a shortage of skilled professionals (especially in energy efficiency and digital construction), and bureaucratic delays continue to hinder the market's ability to meet demand.
- **Future Outlook:** Housing prices are expected to remain on an upward trajectory in the short term, while sustainable housing continues to consolidate its position. According to Confidencial Imobiliário (2025), more than 30% of new housing projects licensed in 2024 were already designed with sustainability and energy efficiency as key drivers.

o Impact of Green and Digital Transitions on the Broader Construction Sector

According to the 2024 Green Transition Index, Portugal has advanced in the green economy rankings, now holding 15th place among 29 European countries evaluated. This upward movement is largely driven by the country's growing commitment to sustainable technologies. Published in February 2025, the Index measures Europe's progress across seven key areas of ecological transition: Economy, Nature, Industry, Energy, Transport, Buildings, and Waste (Fritz, Willendorf, & Zangemeister, 2024).

One of the report's main highlights is Portugal's performance in the Buildings category, particularly in energy efficiency. This success stems from the widespread adoption of renewable energy for household heating, improvements in construction energy efficiency, and urban rehabilitation projects guided by sustainable principles. Together, these initiatives have led to significant reductions in energy consumption across both public and private buildings.

Regarding the digital transition, in the current context, characterized by the exponential digitalization of society and the economy, it is imperative for Portugal to transition to a more digital, and consequently more competitive and internationally stronger country. In this sense, the Action Plan for the Digital Transition was created, which assumes the role of the country's transformation engine, aiming to accelerate Portugal, leaving no one behind, and promote the country globally. To this end, the Action Plan for the Digital Transition has as its main focus areas the digital empowerment of people, the digital transformation of businesses, and the digitalization of the State (Governo de Portugal, 2020)..

The dual Green and Digital Transition is one of the main drivers of transformation for the Construction sector in Portugal, and, although traditionally less digitalized, the sector is being pushed to become more efficient, competitive, and sustainable.

The impacts of this dual transition manifest in Digital Transformation with an increase in efficiency and productivity, focused on modernizing processes and work tools, aiming to improve productivity and reduce errors and costs through the implementation of BIM (Building Information Modeling), which allows for the creation of interactive and collaborative 3D models, improving the planning, execution, and management of the building lifecycle.

Several pilot initiatives are already underway in Portugal. For example, Infraestruturas de Portugal adopted BIM Level 2 in projects like the Porto–Lisboa high-speed railway, and the Digital Twin pilot project in the Porto Metro expansion is testing real-time operational modeling.

In the private sector, companies like Grupo Casais and DST Group are adopting Digital Twins, IoT systems, and off-site construction tracking tools to improve productivity and sustainability performance.

Other technologies gaining ground include:

- **AI-driven tools** for energy performance simulations and predictive maintenance.
- **IoT-based systems** for smart energy metering in buildings.
- **Augmented Reality (AR)** for on-site worker training and design validation.
- **Drones** used in topography, façade inspection, and progress monitoring.

Despite these advances, a 2024 survey by the Ordem dos Engenheiros Técnicos (OET) noted that only 1 in 5 SMEs in the Portuguese construction sector has implemented digital tools beyond basic CAD, mostly due to lack of qualified personnel and investment capacity — reinforcing the urgent need for targeted training programs.

Several pilot projects and digital tools are already being implemented in Portugal. Infraestruturas de Portugal has adopted BIM Level 2 in several large-scale infrastructure projects, including high-speed rail lines and bridge rehabilitation. Additionally, platforms like eConstrução 2.0, developed under the Simplex urbanístico initiative, are simplifying digital licensing processes and promoting interoperability between public authorities.

In terms of workforce digital readiness, the study by OET revealed that only 22% of construction SMEs regularly use BIM, while 54% report a lack of trained staff in digital tools, revealing a significant training opportunity.

Regarding the Green Transition, focused on Sustainability and Decarbonization, new requirements are being imposed, aimed at reducing the carbon impact and the use of resources. In this sense, Decarbonization and Energy Efficiency with the construction of more energy-efficient buildings and infrastructure, with the goal of reducing emissions; the use of Sustainable Materials with the demand and use of materials of natural origin and with a low carbon footprint; the promotion of Environmental Product Declarations (EPDs); and Modular and Pre-fabricated Construction all have the potential to develop the sector."

- **Thematic Analysis of State-of-the-Art**
 - **Digitalisation in Construction (Housing 4.0)**
 - Key Digital Technologies (e.g., Building Information Modelling (BIM), Digital Twins, Artificial Intelligence (AI) for energy management, Internet of Things (IoT) in buildings)
 - Adoption and Impact in Construction Processes and Building Operation

- Current qualifications and emerging job profiles
- Relevant market trends shaping the demand and supply
- o **Circular Economy & Sustainable Construction Materials**
 - Principles and Practices (e.g., reuse, recycling, waste management strategies)

The construction sector—a major contributor to emissions and waste generation—holds immense potential to mitigate environmental impact while simultaneously fostering economic growth and social well-being (BUILD UP Team, 2024).

The shift to sustainability and circularity in this sector requires fundamentally rethinking the building process, from design to end-of-life considerations. By maximizing resource efficiency, promoting material reuse and recycling, adopting circular business models, and deploying innovative solutions, Europe can meet its climate targets and pave the way for a more sustainable future.

Circular Construction requires a comprehensive re-evaluation of building design practices. The central objective is to create, use, and repurpose assets, including buildings, infrastructure, and components in a way that minimizes natural resource depletion, environmental pollution, and negative impacts on ecosystems.

To support this, the European initiative Buildings As Material Banks (BAMB) introduced the concept of Material Passports, which is being explored in Portugal through pilot projects coordinated by LNEG and IST. These passports register detailed data about materials used in construction to enable future reuse, facilitating circular supply chains.

There is also growing interest in design for disassembly, with new guidelines being tested in Lisbon and Porto municipal tenders for public buildings. These include:

- Mandatory life-cycle analysis (LCA) pre-project.
- Integration of reused or recycled components (e.g., steel beams, window frames).
- Use of prefabricated components for easier dismantling.

The development of Circular Business Models in the construction sector is also accelerating, such as “product-as-a-service” models, where façade systems or HVAC equipment are leased and maintained by the supplier, increasing accountability for end-of-life recovery.

Aligned with the principles of the circular economy, which seeks to keep resources in use for as long as possible (Severin & Michalíková, 2024), new construction must prioritize efficiency and the right material selection by integrating the following core aspects:

- Design for Deconstruction: Ensuring easy and safe disassembly for future recovery.
- Material Reuse and Recycling: Prioritizing secondary materials and minimizing virgin resource intake.
- Resource Efficiency: Achieving efficiency through optimized design, prefabrication techniques, and lean construction practices.

- Circular Business Models: Developing new models that support extended product life and service provision over ownership.
- Digitalization and Data Management: Utilizing technology for better tracking, inventory (material passports), and informed decision-making regarding material flow.
- Sustainable Materials and their Application in Buildings

In Portugal, the construction sector was responsible for generating around 3.5 million tonnes of construction and demolition waste in 2022, with a considerable recovery of 3.1 million tonnes (through recycling, backfilling, and other recovery operations) (APA, 2024). However, since 2016, there has been continuous growth in the extraction of natural resources. In 2020, a total of approximately 60 million tonnes of minerals were extracted, of which 90% are minerals for construction (Fonseca et al., 2022).

The commitment to sustainability is essential, and the materials consumed in this sector play a crucial role. It is therefore important to use more sustainable materials, which are of natural and local origin, have a low embodied energy value, and are reusable and/or recyclable, as well as investing in innovation in sustainable construction materials. The trend in the sector points towards the introduction of innovative materials and technological solutions that transform design and development. Some examples in this regard are:

- **ICF Systems and EPS Blocks:** ICF (Insulated Concrete Forms) and EPS (Expanded Polystyrene) blocks are materials that offer superior thermal insulation, reducing heat loss and increasing energy efficiency. Made from recycled materials, such as plastic or polystyrene, they contribute to sustainability by retaining heat and decreasing dependence on heating systems.
- **The integration of Nanotechnology,** a revolutionary innovation that offers improvements in the strength and performance of materials, allowing for example, the development of self-cleaning surfaces and glass that blocks UV radiation, contributing to the durability and energy efficiency of buildings. Nanoparticles also increase crack resistance and reduce the need for maintenance, thus increasing durability.
- **Bioconstruction,** through the use of organic materials, where renewable and biodegradable materials such as bamboo, hemp, straw and others are used. These materials reduce the carbon footprint of constructions due to production and process with a reduced environmental impact.
- **The use of alternative substitution materials** such as industrial and urban waste, ashes, recycled plastics, recycled wood, recycled metals, etc."

Portuguese companies have been at the forefront of innovation in sustainable materials. For example:

- **Amorim Cork Composites** develops insulation products made from recycled cork, offering excellent thermal and acoustic performance.
- **Gypotec Ibérica** produces plasterboards incorporating post-consumer recycled content, reducing the environmental footprint of interior partitions.
- **CIMPOR** and **SECIL** have launched low-carbon cements, aligned with the EU taxonomy for sustainable activities, supporting CO₂ reductions in structural works.

In addition, there is a growing use of geopolymers, recycled aggregates from CDW, and bio-based materials such as mycelium-based composites for insulation and finishes — technologies currently under testing in research projects like ReBuild 2024 (LNEG).

- Current qualifications and emerging job profiles

According to the **IEFP (2024)**, the construction sector in Portugal faces an acute skills gap in several areas:

- BIM and digital coordination.
- Energy efficiency auditing.
- Site logistics for modular construction.
- Circular economy consultancy and material passport implementation.

New professional profiles are emerging, including “Construction Circularity Manager”, “BIM Integrator”, and “Sustainable Materials Specialist”. These roles require multidisciplinary skills, combining traditional construction knowledge with digital tools and sustainability practices.

- Relevant market trends shaping the demand and supply
- **Cross-Cutting Analysis & Opportunities**
 - o Interlinkages and Synergies between the Thematic Areas
 - o Common Challenges and Barriers across Diverse European Regions (e.g., policy, financial, skills-related)
 - o Innovation Opportunities in VET for Sustainable Construction (identifying promising areas for intervention)
- **Conclusions and Recommendations for WP4**
 - o Key Findings Summary (synthesis of the most important insights)
 - o Strategic Insights for Curriculum and Training Programme Design (direct recommendations for WP4)

The current trends in training and education for the construction sector are strongly linked to digitalization, sustainability, circularity, new construction methods and new materials, reflecting the sector's need to modernize and respond to environmental, cultural and productivity and efficiency challenges.

According the Direção-Geral do Ensino Superior (2024), there is a critical lack of formal training pathways in areas like modular construction assembly, advanced BIM coordination, and circular economy design. Therefore, the Exel4Housing 4.0 project should consider integrating the following targeted modules into training programs:

Digital Technologies and Automation

- **BIM for Site Managers:** Focused on coordination between field and office.
- **IoT and Data Management:** Smart building integration and monitoring.

- **AR/VR for Safety and Design Review:** Use of immersive tools for planning and worker training.

Sustainability and Circular Economy

- **Circular Construction and CDW Management:** Focus on reuse, sorting, and reporting obligations.
- **LCA and Carbon Accounting:** Training to calculate and report GWP (Global Warming Potential) for new buildings.
- **Sustainable Materials Lab:** Hands-on training in selecting and testing low-carbon and recycled materials.

Innovative Construction Methods

- **Modular Assembly and Logistics:** Skills for off-site assembly and on-site integration.
- **3D Printing Techniques:** Introduction to hardware and design tools for printed elements.
- **Material Passports and Digital Twins:** Use of digital tools for end-of-life planning and asset management.

In summary, there is a clear need to rethink VET pathways in construction, aligning curricula with the sector's evolving demands. This includes stronger partnerships between industry, vocational schools, and higher education institutions to co-develop programs that are flexible, modular, and tailored to real-world applications.

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Annex 9: State-of-the-Art National Report - Spain



REPORT ON THE STATE OF THE ART

SPAIN

● Introduction

The purpose of this task is to provide a state-of-the-art analysis of energy efficiency and sustainable housing practices, with a focus on how these are being integrated into training, qualifications, and innovation frameworks within Spain. Specifically, the report aims to:

- Identify current practices and innovations in sustainable housing, with emphasis on digitalisation (Housing 4.0) and circular economy approaches.
- Map how these innovations intersect with education and training, particularly within VET systems and lifelong learning.
- Highlight market and policy trends shaping the demand for new qualifications and skills.
- Provide insights into how ongoing publicly funded projects are fostering synergies between sustainability, digital transition, and workforce development.

The analysis has been conducted using a desk research methodology, combining the following approaches:

- Literature review: Examination of academic studies, policy documents, EU strategies, and Spanish national frameworks related to sustainable housing, energy efficiency, and training.
- Case study analysis: Identification of specific initiatives and projects (both national and EU-funded) that demonstrate innovative practices in circular construction, digitalisation in housing, and related training approaches.
- Comparative framework analysis: Review of methodologies and key performance indicators (KPIs) from projects, with attention to how these are applied in training and upskilling contexts.
- Stakeholder mapping: Identification of the main target groups (construction professionals, decision-makers, VET institutions, and end-users and their training and qualification needs in the context of the green and digital transitions.

● General Context: European Construction Sector & Energy Transition

This section describes the general context of the European Construction Sector & Energy Transition in Spain. It reviews (1) the policy and regulatory landscape, (2) the overall market dynamics and key trends in construction (e.g., investment, growth drivers, consumer demand for sustainable housing), and (3) impact of green and digital transitions on the broader construction sector.

2.1. Policy and Regulatory Landscape

In Spain, the EU directives (i.e., European Green Deal, the Energy Performance of Buildings Directive (EPBD), the Renovation Wave, the EU Taxonomy for Sustainable Activities, and the Circular Economy Action Plan) are transposed and complemented by the following national frameworks:

- National Energy and Climate Plan (PNIEC 2021–2030) [1]: Sets the target of reducing greenhouse gas emissions by 23% by 2030 (compared to 1990), increasing renewables to 42% of final energy use, and improving energy efficiency by 39.5%. Buildings are a priority sector, with emphasis on renovation and renewable integration.
- Spanish Long-Term Renovation Strategy (ERESEE 2020) [2]: Aligned with the Renovation Wave, this strategy seeks to modernise Spain's ageing building stock (around 80% of homes were built before 2000), prioritising energy retrofitting and tackling energy poverty.
- NextGenerationEU and Recovery, Transformation and Resilience Plan (PRTR) [3]: Spain has allocated significant funds (over €6.8 billion) to building renovation, energy efficiency, and sustainable urban development. This is a major driver of current renovation activity, particularly in residential and social housing.
- Spanish Circular Economy Strategy (España Circular 2030) [4]: Sets objectives to reduce material consumption by 30%, cut waste generation by 15%, and improve recycling and reuse in construction. The strategy positions construction as a key sector for implementing circular principles.

2.2. Overall Market Dynamics and Key Trends in Spain

The Spanish construction sector is a major contributor to the economy, representing around 5.5% of GDP and employing over 1.3 million workers. Its transformation is being shaped by EU policy drivers, financial incentives, and evolving consumer preferences:

- Renovation demand: According to Fundación Naturgy (2021) [5], Spain's current renovation rate is far below what's required by EU policy; there are around 9.4 million homes in urgent need of refurbishment, and to meet Green Deal targets, Spain would need to increase its building renovation effort by up to 25 times the current rate.
- Investment growth: The PRTR funds—with a budget of 3420 million euros and target approximately 410,000 housing renovation actions by mid-2026 to reduce non-renewable energy consumption in homes by at least 30% and lowering heating/cooling demand by at least 7%—have boosted investment in renovation and sustainable housing. Municipalities and regional governments are launching large-scale renovation programmes targeting both private and social housing [6].
- Market pull for sustainable housing: Buyers and tenants increasingly value low-energy, healthy, and smart homes. Certifications such as Passive House, BREEAM, and VERDE (Spain's national certification system) are expanding in the residential sector [7].
- Innovation ecosystem: Spanish firms are investing in prefabrication, digitalisation (BIM, digital twins), and low-carbon materials (recycled concrete, bio-based insulation). For instance,

RECONSTRUCT project [8]— developing low-carbon alternatives to Portland Cement; use of recycled and bio-based materials; applying both on-site and prefabricated components; digital tools for material lifecycle tracking. Also, 011h (Spanish proptech) [9]— a company using a digital platform with prefabricated elements, timber, carbon-neutral materials, etc., with aims to cut build time and emissions. Additionally, Industrialized Social Housing, Vivas Arquitectos & EXE Arquitectura — project in Barcelona using modular prefabricated systems; optimizing assembly, reducing carbon footprint, combining passive + active strategies [10].

- Labour and skills gap: Like the EU overall, Spain faces shortages in qualified professionals able to perform deep energy renovations, manage circular materials, and apply digital tools. The challenge is particularly acute in vocational training, where new qualifications and curricula are needed [11, 12, 13].

2.3. Impact of Green and Digital Transitions on the Spanish Construction Sector

Spain reflects the European trend of a twin green and digital transition, with local particularities:

- Green Transition:
 - Priority on large-scale energy retrofitting to reduce emissions and alleviate energy poverty [14,15].
 - Integration of solar photovoltaic systems in residential and public buildings, supported by subsidies [16, 17].
 - Adoption of circular construction practices through regional initiatives, e.g., Catalonia's promotion of recycled aggregates and Basque Country's Circular Housing pilots [18, 19].
- Digital Transition (Construction 4.0 / Housing 4.0):
 - Increasing use of BIM (mandated for public procurement in many cases since 2019), digital twins, and smart building management systems [20].
 - Growth of start-ups and SMEs offering digital monitoring solutions for energy efficiency and renovation tracking [21,22].
 - Pilot initiatives integrating material passports and traceability systems for construction waste and recycled materials [23].
- Convergence of Green & Digital:

- Application of BIM to design energy-efficient renovations and track lifecycle impacts [24, 25].
- Use of digital material passports to support circular practices [23].
- Training initiatives are beginning to integrate digital and green skills into construction curricula [26, 27, 28].

● Analysis summary

3.1 Digitalisation in Construction (Housing 4.0)

3.1.1. Key digital technologies:

The construction / housing value chain is integrating several digital technologies that together define “Housing 4.0”:

- Building Information Modelling (BIM) — used from design through construction to operation; increasingly required or incentivised in public procurement and used to coordinate multi-disciplinary teams, simulate performance, and embed product/material data. (Seen in BIM4Ren pilots and national BIM plans.)
- Digital Twins — real-time or near-real-time virtual replicas that combine BIM with IoT sensor feeds for operation, predictive maintenance and occupant comfort optimisation (demonstrated in Spanish pilots such as Tecnalía/WellBIM-style work and the digital twin demo references).
- IoT & smart building management systems (BMS) — sensors for energy, indoor air quality, occupancy and equipment status that feed dashboards and automated control systems. These are commonly paired with digital twins and BMS for operational optimisation.
- Digital Material Passports / Product Passports — structured digital records of material composition, provenance, recyclability and LCA data to support reuse, traceability and circular practices (seen in pilot initiatives and private solutions like CircularPass / materials-passport projects).
- Life-Cycle Assessment (LCA) / LCSA tools integrated with BIM — tools that calculate embodied carbon, embodied energy and other life-cycle impacts directly from modelled elements.

- Cloud platforms / dashboards / analytics & AI — for energy monitoring, renovation tracking, predictive maintenance, and decision support (used by start-ups and SMEs offering energy monitoring and renovation management).
- Prefabrication & digital fabrication interfaces — CAD/CAM links between BIM and off-site manufacturing, enabling modular/panelised housing and quality control of low-carbon prefabricated elements.

It is worth noting that these technologies are complementary: BIM provides the information backbone; digital twins + IoT operationalise the building; material passports + LCA enable circularity, and cloud/AI layers provide analytics and decision support.

3.1.2. Adoption and impact in construction processes and building operation

The following adoption trends have been observed:

- Design & procurement: BIM adoption has grown rapidly in public procurement and large private projects (multiple Spanish public tenders and national BIM plans). BIM is being used not only to produce 3D models but to coordinate disciplines, clash-detect, quantify materials and link to procurement and prefabrication workflows.
- Construction: Use of prefabricated elements and factory production is increasing where BIM links to off-site manufacturing; traceability and digital quality control reduce rework and waste. Pilot projects (prefab low-carbon façade panels in RECONSTRUCT) show how digital design + off-site assembly shorten timelines and reduce embodied carbon.
- Operation: Buildings instrumented with sensors and managed through BMS/digital twins show measurable improvements in energy performance, occupant comfort and maintenance costs (pilot evidence and case studies). Digital twins enable predictive maintenance and continuous commissioning, improving system uptime and enabling demand-side response.
- Circularity & materials: Digital product passports and traceability pilots are still at demonstration scale, but they are being trialled to capture material composition, facilitate deconstruction, and feed LCA metrics. Projects like VALREC and RECONSTRUCT show practical routes for CDW valorisation and tracked reuse.

Which have led to the following impacts:

- Quality & speed: BIM + prefabrication improve build quality and reduce construction time and errors.
- Energy & carbon: Integrating LCA into BIM and using digital twins for operation yields better whole-life carbon outcomes — both embodied (through material choices, prefab) and operational

(through BMS optimisation). Early demo targets (e.g., RECONSTRUCT) aim for significant reductions in embodied carbon (e.g., ~20% in specific demo strategies).

- Waste reduction / circular flows: Traceability and CDW valorisation pilots enable higher recycled content (recycled aggregates, reuse of components), but scaling depends on standards, supply chains and procurement.
- Economic & social: Digitalisation can reduce lifetime operating costs, but adoption requires upfront investment, new capabilities and supply-chain alignment. People-centric pilots emphasise occupant acceptance as critical—circular/low-carbon solutions must meet comfort and affordability objectives.

Also, the following barriers have been observed:

- SME capacity and skills — many small contractors lack staff trained in BIM, digital twins or material passport workflows.
- Data & interoperability — heterogeneous data standards, incomplete product data, and the need for open standards (buildingSMART / openBIM) still limit seamless integration.
- Regulation & procurement — public procurement increasingly uses BIM, but procurement models and building codes must further incentivise circular content and whole-life performance.
- Costs & supply — recycled/bio-based materials and novel prefabricated solutions can face cost & availability constraints until scale is reached.

▪ Current qualifications and emerging job profiles

In the one hand, INCUAL / CNCP defines national vocational qualifications used by FP (Formación Profesional) and Certificados de Profesionalidad. Several construction qualifications already include modules relevant to energy efficiency, rehabilitation, and building systems. Fundación Laboral and sectoral bodies provide short courses and in-company training. In the other hand, VET / FP cycles (Grado Medio / Grado Superior) cover construction trades, building services, and some energy/installation modules. Short, practical courses (e.g., Fundación Naturgy's 175–195-hour FP courses on rehabilitation) complement full cycles.

As far as emerging job profiles are concerned, the following ones have been identified:

- BIM Manager / BIM Coordinator (Construction): coordinates models, ensures data integrity, links BIM to off-site production and procurement. Requires BIM authoring skills, standards knowledge, and data exchange competency.

- Digital Twin / Building Lifecycle Engineer: integrates sensor data with models, manages digital twin platforms, performs performance analytics and predictive maintenance. Skills: IoT, data analytics, building services and systems knowledge.
- Low-Carbon Prefab Technician / Off-site Manufacturing Specialist: designs and assembles prefabricated low-carbon elements; requires knowledge of prefab production, logistics and quality control.
- Material Passport / Circularity Specialist: assesses material flows, produces/consumes product passport data, oversees deconstruction planning and CDW valorisation. Skills: material science basics, LCA, traceability systems.
- Energy Retrofit Technician / Heat-Pump Installer / Building Envelope Specialist: hands-on retrofit roles; skilled in insulation, airtightness, HVAC decarbonised systems and energy audits.
- Building Data Analyst / Energy Manager for Housing Portfolios: aggregates building-level data, identifies retrofit priorities, manages portfolio energy strategies.
- Sustainability / Circular Procurement Officer: public purchaser who specifies circularity KPIs and enforces material / LCA requirements in tenders.

In terms of qualification gaps, it has been seen that existing VET training courses often lack integrated modules combining BIM + LCA + circularity + hands-on prefab training. Trainer upskilling is a bottleneck — Fundación Naturgy's "train the trainer" courses and Construction Blueprint initiatives aim to address this. There is also a need for micro-credentials and modular short courses for in-service workers.

- Relevant market trends shaping the demand and supply

The following demand-side drivers have been identified:

- Policy & funding: PRTR/NextGeneration funds, PREE and other Spanish subsidy programmes drive immediate demand for renovation and green retrofits, creating a market pull for trained teams able to deliver energy-efficient renovations.
- Regulation & procurement: Mandatory or encouraged BIM in public procurement, energy performance standards (EPBD), and renovation incentives push demand toward digital workflows and whole-life assessments.
- Consumers / occupiers: Growing preference for energy-efficient, healthy homes increases demand for certified, smart, low-energy dwellings. Certifications (Passive House, BREEAM, VERDE) increase asset value.

- Corporate sustainability & social housing: Housing providers and local authorities are targets for large retrofit programmes, often requiring scalable prefabrication and digital management.

The following supply-side drivers have been identified:

- Innovation & scale-up of prefab / low-carbon materials: Demonstrator projects (RECONSTRUCT, VALREC) are building supply-side capacity for recycled aggregates, low-carbon panels and prefabrication methods. As these scale, costs will fall and adoption accelerate.
- Start-ups & SMEs: Growth of digital monitoring and SaaS platforms for building energy and renovation tracking; these create service models that integrate with traditional contractors.
- VET & training supply: Expansion of short targeted courses, public FP centre upgrades (e.g., renovated FP centres with PV & green roofs), and Blueprint/Green Growth projects that produce curricula and trainer materials are increasing supply of trained labour — but not yet at required scale.

This leads to the following market tensions/risks:

- Shortage of qualified workforce slows project delivery despite funding availability.
- Fragmented supply chains and regional differences in CDW processing capacity constrain standardisation of circular materials.
- Upfront financing / business models: While subsidies help, long-term business cases for low-carbon materials or prefabrication rely on scale and lower cost curves.

3.2 Circular Economy & Sustainable Construction Materials

3.2.1. Principles and Practices

- Design for disassembly and reuse: maximise the ability to take buildings or building elements apart so components can be reused with minimal loss of value. Demonstrator projects (RECONSTRUCT) explicitly promote deconstruction planning and prefabricated, demountable façade and panel systems to enable reuse.
- Material substitution and low-carbon choices: replace high-embodied-carbon materials (e.g., Portland cement) with low-carbon alternatives (industrial by-products, recycled aggregates, bio-based insulation). RECONSTRUCT demos target significant cement substitution and recycled content increases.

- Circular material loops (closing resource loops): treat construction & demolition waste (C\&DW) as feedstock (recycled aggregates, reprocessed concrete, reclaimed façade elements) rather than as disposal. VALREC-type initiatives and regional programs in Spain are piloting CDW processing to create usable, certified secondary materials.
- Digital enablement / traceability: use material/product passports and traceability systems to record composition, provenance and reuse history; these enable trust and enable circular procurement. Pilots (CircularPass / Digital Product Passport demos, Sacyr materials passport work) are testing models.
- Life-cycle thinking (LCA/LCCA): evaluate environmental impacts across stages (embodied + operational) to make decisions that minimise whole-life carbon, not just upfront cost. SIRCULAR integrates LCA/KPIs; projects link LCA tools with BIM for practical workflows.
- Selective demolition & deconstruction: replacing brute-force demolition with careful dismantling to recover high-value components (windows, frames, HVAC modules). Demonstrators embed deconstruction steps in project planning.
- On-site sorting & improved CDW logistics: segregated collection, on-site crushing, local recycled aggregate production facilities (VALREC models), to reduce transport carbon and improve material purity.
- Prefabrication & modular construction: off-site production reduces waste, increases precision, and facilitates future disassembly; RECONSTRUCT and other pilots combine prefab with recycled/bio-based materials.
- Quality assurance & standards for secondary materials: testing, certification, and procurement standards are crucial so recycled materials meet structural and durability requirements; projects and industry consortia are developing these frameworks.

3.2.2. Sustainable Materials and their Application in Buildings

- Recycled mineral aggregates & secondary concrete: used as coarse/fine aggregates in concrete mixes and prefabricated concrete panels; projects (VALREC, RECONSTRUCT) aim to scale up recycled content while ensuring performance.
- Low-carbon binders and cement substitutes: partial replacement of clinker with industrial by-products (fly ash, blast-furnace slag) or innovative binders to cut embodied CO₂. RECONSTRUCT demos are explicitly trialling such mixes.

- Bio-based materials: wood/timber systems, cross-laminated timber (CLT) for structural elements, and bio-insulation (hemp, wood-fibre, cork), used in prefab panels and interior finishes to reduce embodied carbon and enable circular end-of-life options.
- Reclaimed elements: doors, windows, metal fittings, sanitaryware reused in refurbishment projects (where selective deconstruction enables recovery).
- Innovative insulation & façade systems: prefabricated insulated panels combining recycled or bio-based core materials with durable outer skins; SIRCULAR prototypes focus on such façade elements to balance thermal performance and circularity.
- Materials with digital passports: products embedded with data (QR/blockchain) describing composition, maintenance history and reuse potential to ease future reuse and LCA calculation.

3.2.3. Current qualifications and emerging job profiles

- Deconstruction Specialist / Dismantling Supervisor: plans and oversees selective deconstruction operations, identifies reusable components, ensures safe dismantling and sorting for reuse. Skills: structural understanding, salvage techniques, safety, materials identification.
- Material Recovery & Reprocessing Technician: operates CDW processing equipment (crushing, sorting), performs quality control on recycled aggregates and secondary materials. Skills: plant operation, QA/QC testing, regulatory compliance.
- Circular Materials Designer / Specification Specialist: selects low-carbon, recyclable or reusable materials, prepares material passports and interfaces with procurement. Skills: materials knowledge, LCA basics, specification writing, familiarity with product passports.
- Material Passport/Data Manager: records, verifies and maintains digital product passport data; links passports to BIM models and procurement. Skills: data management, digital standards (DPP/DPD), interoperability knowledge.
- Recycled Materials Quality Assessor / Lab Technician: conducts testing and certification to validate structural/physical properties of recycled materials. Skills: lab testing, standards, sampling protocols.
- Circular Procurement Officer: designs tendering processes to prioritise circular KPIs (recycled content, deconstruction clauses), evaluates supplier claims. Skills: procurement law, KPI assessment, LCA interpretation.

3.4 Conclusions and Recommendations for WP4

- Modular micro-credentials: Create short, stackable modules combining BIM basics + LCA + material passport entry + retrofit practice (e.g., 120–200 hours) to quickly upskill installers and supervisors.
- Train-the-trainer nationwide programme: Scale initiatives like Fundación Naturgy's trainer courses to rapidly expand teacher competencies in digital/circular topics.
- Living-lab placements: Formalise placements at demo sites (SIRCULAR/RECONSTRUCT/VALREC demos) so trainees gain hands-on experience with prefab panels, recycled materials, and digital twins.
- Dual pathways & apprenticeships: Expand hire-and-train models (e.g., Bedmar y Garcéz project) where trainees are employed while obtaining certificated skills, with pathways to Certificados de Profesionalidad / FP grado.
- Interoperability & standards training: Ensure curricula cover open BIM standards (buildingSMART, IFC), digital passport standards, and basic data governance to reduce interoperability friction.
- Career maps & new profiles: Define clear qualification maps for emerging roles (BIM Manager, Digital Twin Engineer, Material Passport Specialist) and align them with INCUAL/CNCP units.
- Create competency maps linking CNCP/INCUAL units to emerging circular roles (e.g., Deconstruction Specialist, Material Passport Manager, Circular Procurement Officer) so Certificados de Profesionalidad and VET cycles can be updated.

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Annex 10: State-of-the-Art National Report - Sweden



REPORT ON THE STATE OF THE ART

SWEDEN

● Introduction

This report is mapping the European construction sector's policy drivers, market dynamics, and technological trends, and examines their implications for skills, jobs, and vocational training. The purpose is to understand how the green and digital transitions—driven by EU legislation such as the Energy Performance of Buildings Directive, the EU Taxonomy, the Net-Zero Industry Act, and the Renovation Wave—are reshaping business models, construction processes, and investment priorities. Using structured desk research, the analysis combined EU-level sources with a detailed case study of Sweden, highlighting its leadership in digitalisation and circular construction practices. The findings were then translated into concrete opportunities for VET, with a focus on curriculum design, micro-credentials, and living-lab approaches. In doing so, the analysis bridges European regulatory and market developments with national best practices and identifies how vocational education and training can equip the workforce with the competences needed to deliver on the climate and digital ambitions of the sector.

● Analysis summary

The analysis shows a clear arc from EU policy to practice to training. With the EPBD, the Taxonomy, ETS2/SCF and the NZIA, Europe is steering construction toward zero-emission, whole-life-carbon performance, electrified heating and verifiable, data-rich operations. Despite a short-term slump in housing starts and heat-pump sales, medium-term demand is pulled by renovation and rooftop PV. Digitalisation is now basic infrastructure: BIM, digital twins and IoT enable predictive O&M and industrialised, DFMA-style delivery. Sweden offers a mature blueprint—BIM is standard for major clients, city-to-building digital twins and smart-meter ubiquity support “Housing 4.0,” and circularity is accelerated by climate declarations, product databases and rapid advances in timber, low-carbon concrete and near fossil-free steel. Frictions persist—uneven transposition, split incentives, skills shortages and interoperability gaps—so VET must pivot to stackable, role-based micro-credentials that turn project data into audit-ready evidence: BIM-to-FM data continuity, LCA/EPD and climate declarations, energy analytics, off-site retrofit and reuse coordination, advanced HP/PV/storage operations, and green procurement/Taxonomy literacy. Embed living labs, a standard toolchain (IFC/i2, EPD software, BEAst/PEPPOL, twin platforms) and assessment built on finance-grade KPIs.

● Indicative outline

● Introduction

Purpose of the task and methodology used

- **Map the landscape:** Summarise the European construction sector's policy drivers
- **Assess impacts**
- **Deep-dive Sweden**

- **Translate to VET action: Structured desk research (EU, national):**
 - EU primary sources
 - Sector statistics and outlooks
 - Sweden sources for practice and standards

- **Analytical lenses:**
 - **Policy & regulation:** compliance and finance signals;
 - **Market & technology:** adoption, maturity, supply chains;
 - **Skills & jobs:** current qualifications and emerging roles;
 - **VET implications:** training needs, assessment artifacts, KPIs.

- **Triangulation & relevance filter:** Prioritised authoritative and most recent sources; cross-checked quantitative figures
- **Scope & timeframe:** EU-27 with a Sweden deep dive; evidence current to Oct 2025; focus on residential and public buildings (new build + renovation)

- **General Context: European Construction Sector & Energy Transition**

Policy and Regulatory Landscape (e.g., EPBD, European Green Deal, Renovation Wave, EU Taxonomy relevant to construction)

- **EPBD (recast, Directive (EU) 2024/1275).** New buildings: public from 2028 and all from 2030 must be zero-emission; disclosure of life-cycle GWP scales up from 2028/2030; countries must file National Building Renovation Plans to steer stock toward ZEB by 2050. Expect national roadmaps and targets (rather than strict EU-level MEPS for each building).
- **Renovation Wave (Green Deal flagship).** Goal to double renovation rates and renovate 35 million buildings by 2030, linking energy savings with local jobs.
- **EU ETS2 + Social Climate Fund.** A new carbon market for fuels in buildings & road transport becomes operational in 2027 (upstream at fuel suppliers), with the Social Climate Fund from 2026 cushioning vulnerable households and financing efficiency/renovation.
- **EU Taxonomy.** “Green finance rulebook” shaping capital flows: construction & real estate activities (new build, renovation, acquisition/ownership) have technical screening and DNSH criteria; alignment can materially affect financing costs and investor access.
- **Net-Zero Industry Act (NZIA).** In force June 2024; aims for ~40% EU manufacturing capacity of strategic net-zero tech by 2030 (heat pumps, PV, batteries, etc.), with faster permitting—relevant to supply chains and capex for building decarbonisation. (Directive, EU 2024, Regulation EU 2020)

Overall Market Dynamics and Key Trends in Construction (e.g., investment, growth drivers, consumer demand for sustainable housing)

- **Cyclical headwinds vs structural demand.** High rates and costs have hit residential starts (e.g., Sweden's house-building slump; Germany's permit gap amid housing need), yet underlying demand for affordable, efficient homes remains strong.
- **Electrification & rooftop solar**—strong but bumpy. EU added ~65 GW solar in 2024, with a slight slowdown expected in 2025 as some rooftop incentives fade, though cumulative capacity keeps climbing. Heat-pump sales fell ~22% in 2024 after two boom years, reflecting policy uncertainty and energy-price swings; long-term targets (e.g., 60 m units by 2030) still pull demand.
- **Investment outlook.** Despite the near-term dip, analysts project medium-term growth in European construction driven by renovation of ageing stock, urbanisation, and green-building practices—with product markets signaling opportunity in retrofit solutions.
- **Skills & capacity.** EU's Transition Pathway for Construction highlights labour/skills shortages, digital adoption gaps, and the need for industrialised renovation (prefab, BIM) to meet targets at scale. (FIEC 2025, SolarPower Europe 2024).

Impact of Green and Digital Transitions on the Broader Construction Sector

- **Business models shift to performance & whole-life carbon.** EPBD's life-cycle GWP disclosure and Taxonomy screens push developers toward low-carbon materials, circularity, and EPC-backed, taxonomy-aligned assets to unlock financing.
- **Electrify heat + integrate DERs.** Policy plus ETS2 pricing steers heat away from fossil fuels to heat pumps, solar PV, storage, and smart controls; grid-interactive buildings and prosumer models gain value.
- **Digitalisation** becomes mandatory plumbing. BIM/digital twins, IoT, and data analytics enable predictive maintenance, energy optimisation, and off-site industrialised renovation, changing contractor skill profiles and site logistics.
- **Social dimension & affordability.** The Social Climate Fund hard-wires equity into the transition (subsidies for renovation, clean heating, mobility), aiming to contain energy-poverty risks as carbon pricing expands. (European Commission 2023, Directive (EU) 2024)

Thematic Analysis of State-of-the-Art

Digitalisation in Construction (Housing 4.0) in Sweden

- Key Digital Technologies in use
- **BIM as “default” for major clients.** Public infrastructure clients (esp. Trafikverket) have driven BIM uptake and standardisation; BIM Alliance Sweden maintains sector guidelines and promotes uninterrupted information flows across planning–build–operate.

- **Digital twins from district to building scale.** Active research/demonstrators include KTH's Dig-IT Lab (building/microgrid twins) and Smart Built Environment projects (e.g., rainfall modelling), plus city-scale pilots such as Stockholm Royal Seaport's digital-twin approach (see best practice report).
- **AI for energy & operations.** Recent Swedish studies and pilots show AI-driven analytics improving building energy efficiency and operational decisions (fault detection, tariff-aware control, portfolio optimisation).
- **IoT & smart metering as infrastructure.** Sweden's early smart-meter rollout (and second-wave upgrades) enabled hourly metering and data access that underpin proptech/optimisation services in housing.
- **Industrialised/off-site digital fabrication.** Model-based design-to-factory with timber modules (e.g., Lindbäcks) illustrates digital production flows for multi-storey housing.
- **Digital supply-chain & e-business standards.** BEAst standards (ordering, logistics, invoicing) and PEPPOL adoption streamline data exchange across contractors and suppliers. (Smart Built Environment 2024, BIM Alliance 2024)
 - Adoption and Impact in Construction Processes and Building Operation
- **Design & construction.** BIM is widely specified in public works; the remaining friction is contractual (AB/ABT/ABK alignment) and information-requirements maturity rather than tooling. Impacts include fewer clashes, better quantities, and enabling industrialised methods.
- **Handover & operations.** Swedish research flags the gap between project BIM and facility management; initiatives (BIM Alliance guidelines/fi2 standards) aim to improve data continuity into the O&M phase.
- **Energy-smart housing in practice.** Flagship sites demonstrate integrated PV-storage-heat-pump systems with advanced controls (e.g., Brf Viva using second-life bus batteries; Akademiska Hus pilots), showing energy-cost and flexibility benefits when paired with data-driven operation.
- **City/system integration.** Digital-twin pilots link buildings to grids, water and mobility, supporting resilience and planning (e.g., Stockholm microgrid twin demonstrator). (BIM Alliance 2024, Trafikverket 2024)
 - Current qualifications and emerging job profiles
- **Baseline upskilling needs.** National skills analyses (MYH) and labour-market outlooks point to persistent shortages and a cross-cutting need for digital competence, BIM literacy, AI/data skills, sustainability & circularity, plus geospatial/GNSS skills.
- **BIM/VDC Coordinator–Manager** (model standards, CDE workflows, IDMs/BEAst alignment).
- **Digital Construction Engineer / Site Digitisation Lead** (laser scanning, 4D/5D, IoT on site).
- **Building Energy/Proptech Data Analyst** (BMS+IoT data, AI-assisted optimisation, demand response).
- **Digital Twin Engineer** (model federation, sensor integration, simulation).
- **Industrialised House-Building Production Engineer** (design-for-manufacture, timber modules/CLT).

YH and higher-ed programmes are already branding for “hållbart och digitalt byggande” and teaching BIM-centric workflows.

- Relevant market trends shaping the demand and supply
- **Strategic push via Smart Built Environment.** Sweden’s long-running national innovation programme coordinates R&D, open standards and pilots to keep the sector at the digital forefront.
- **Proptech & energy-flexibility momentum.** With smart meters ubiquitous, business models that monetise flexibility (tariffs, aggregator services) and optimise building portfolios are expanding—supported by research and high energy-price volatility experience.
- **Productivity drive through industrialisation.** Timber-based modular building and factory-driven processes are scaling, supported by BIM and digital QA—seen as key to addressing housing needs despite cyclical headwinds.
- **Data & digital-infrastructure considerations.** National attention to the energy footprint of data centres and digital systems underscores the need for efficient data pipelines and edge processing in AEC/proptech solutions.
- **Public-sector procurement & standardisation.** Continued emphasis on digital deliverables, open formats and e-procurement (BEAst/PEPPOL) is reinforcing adoption through the supply chain. (MYH 2024, Arbetsförmedlingen 2025).

What this means for Excel4Housing / VET design

- Bake BIM-to-FM data handover and CDE literacy into all curricula.
- **Add** AI/analytics for energy modules that use Swedish smart-meter/BMS datasets.
- Include industrialised timber workflows (DFMA, 4D/5D) and BEAst/PEPPOL basics.
- Target upskilling for BIM/DT managers, proptech analysts, and site digitisation leads—where demand is growing fastest.

Circular Economy & Sustainable Construction Materials

- Principles and Practices
- **Regulatory pull:** Since Jan 1, 2022, new buildings must file climate declarations (A1–A5) using Boverket’s Klimatdatabas; government has tasked Boverket to introduce carbon limit values (gränsvärden)—earliest start was proposed for 2025 with further steps by 2028/2030. This is pushing early-stage design choices and product selection toward lower-carbon options.
- **Reuse infrastructure:** CCBUILD (IVL) provides inventories, a marketplace for reclaimed products, and tools that integrate with project workflows—lowering barriers to reuse at scale.
- **Public procurement:** The Upphandlingsmyndigheten issues circular criteria and guidance (e.g., for demolition, mass handling, packaging) so contracting authorities can require reuse, recycled content, and documentation.

- **Waste & selectivity:** Sweden targets high recovery of construction & demolition waste; Naturvårdsverket data show the sector generates a large share of national waste, keeping circularity a policy priority.
- **Digital enablers for circularity:** R&D (e.g., Smart Built Environment – Fenix) uses BIM + AI to identify reusable components and support material decisions. (Boverket 2022, Naturvårdsverket 2024)
 - Sustainable Materials and their Application in Buildings
- **Mass timber (CLT/glulam):** Strong national capability and know-how (Svenskt Trä, Trästad Sweden) underpin widespread use in housing and public buildings.
- **Low-carbon concrete:** Industry guidance for klimatförbättrad betong (blended binders, optimization) is mainstreaming; roadmap targets neutral concrete by 2045 and product availability ~2030. Parallel plan: Cementa Slite CCS to capture ~1.8 MtCO₂/yr by 2030.
- **Fossil-free steel: SSAB** is scaling hydrogen-based steel with a new Luleå mini-mill (target **2028**)—relevant for structure and façade systems in low-carbon projects.
- **Material databases & certifications:** Byggvarubedomningen and SundaHus steer non-toxic, circular product choices; **SGBC NoIICO2** sets whole-life carbon targets and baselines, increasingly used alongside Boverket rules. (Trafikverket 2022)
 - Current qualifications and emerging job profiles
- **Skills baseline:** MYH's 2024 sector analysis flags needs in **circular construction, LCA/EPD, climate declarations, and digital competencies.**

Roles on the rise:

- **Återbrukssamordnare / Reuse coordinator** (pre-demolition audits, inventories, logistics, QA).
- **LCA/Climate-declaration specialist** (A1–A5 modeling, data governance via Klimatdatabas/EPDs)
- **Circular procurement specialist** (criteria setting, supplier due diligence).
- **Materials & product data manager** (BVB/SundaHus logbooks; compliance).
- **Design-for-disassembly engineer / Digital reuse analyst** (BIM-driven component tracking; AI tools like Fenix). (MYH 2024, Boverket 2022)
 - Relevant market trends shaping the demand and supply
- **Tightening carbon governance:** Climate declarations are in place; limit values and broader scope are being prepared—creating steady demand for low-carbon and reusable products.
- **Procurement as a lever:** Public clients increasingly specify reuse/recycled content and documentation, scaling market readiness and supplier capabilities.
- **Investment & finance signals:** EU Taxonomy criteria for construction/real estate are influencing developers and lenders—rewarding projects with lower embodied carbon and robust data.

- **Supply-side innovation:** Rapid advances in timber, low-carbon concrete, CCS cement, and (near) fossil-free steel expand the materials toolkit for circular/low-carbon projects.
- **Data & transparency:** Widespread use of EPDs, Boverket's Klimatdatabas, and building-level certifications (e.g., NollCO2) standardise reporting and benchmarking across projects (Boverket 2022, Upphandlingsmyndigheten 2022).
- **Cross-Cutting Analysis & Opportunities**

Interlinkages and Synergies between the Thematic Areas

- **Whole-life carbon as the common spine.** EPBD (ZEB trajectory + GWP disclosure) and the EU Taxonomy pull the market toward measurable carbon outcomes; this directly links to **digitalisation** (BIM/DT for data capture), materials choices (timber, low-carbon concrete, fossil-free steel), and procurement (proof via EPDs, product databases).
- **Electrification + flexibility = value stack.** ETS2 pricing + SCF support electrify heat (HPs), PV and storage. Digital twins/IoT turn buildings into grid-interactive assets (demand response), enhancing the business case for smart O&M and new performance-based contracts.
- **Industrialised renovation at scale.** Renovation Wave targets pair naturally with off-site / DFMA methods guided by BIM (Sweden's timber modular know-how), cutting time on site, waste, and cost variance—while easing skills bottlenecks through more factory-centred workflows.
- **Finance-readiness meets data-readiness.** Taxonomy alignment depends on reliable evidence (LCA/LCC, energy KPIs); common data environments (IFC/fi2) bridge design→build→operate so assets stay financeable across their lifecycle.
- **Social equity built-in.** The Social Climate Fund's focus on vulnerable households aligns with affordable, efficient housing solutions and community-level retrofits; digital tools enable targeting, verification, and impact tracking.

Common Challenges and Barriers across Diverse European Regions

- **Policy transposition & permitting lag.** Uneven, evolving national rules (EPBD transposition, carbon limits, grid interconnection) slow planning and add developer risk.
- **Financing frictions & split incentives.** Condominiums and rental markets struggle to capture paybacks; SME contractors face working-capital gaps for industrialised methods and digital tooling.
- **Skills and capacity constraints.** Shortages in BIM-FM data, LCA/EPD, heat-pump installation/commissioning, and controls & analytics; site crews need upskilling for prefab/DFMA and safe handling of new materials.
- **Data fragmentation & interoperability.** Gaps between project BIM and FM systems; inconsistent use of open standards (IFC, fi2), product data (EPDs), and e-procurement schemas (BEASt/PEPPOL).

- **Supply-chain volatility.** Price swings (energy, materials), limited availability of low-carbon cement binders, battery systems, or heat pumps in some regions; uneven access to reuse marketplaces.
- **Demand risk & consumer confidence.** Households weigh upfront costs and disruption; public clients vary in circular/low-carbon criteria maturity.

Innovation Opportunities in VET for Sustainable Construction

A. Data-to-decision skills (across the lifecycle)

- **BIM: FM Data Continuity Micro-credential.** Hands-on with CDEs, IFC/i2, asset tags, and O&M handover; deliver a digital logbook ready for Taxonomy/EPBD evidence.
- **LCA/EPD & Climate-Declaration Bootcamp.** Applied A1–A5 modelling using EPDs and national databases; assign a materials substitution case that hits a project-level GWP target.
- **Energy Analytics for Operators.** From BMS/IoT data to fault detection, tariff-aware control, and demand response; include a heat pump + PV + storage lab in a digital twin.

B. Industrialised renovation & circularity

- **DFMA / Off-site Retrofit Practitioner.** 4D/5D planning, laser scanning to prefab, on-site assembly sequencing, QA with digital checklists.
- **Reuse & Deconstruction Coordinator.** Pre-demolition audits, digital inventories (BIM-linked), **marketplace workflows**, documentation for procurement/compliance.
- **Low-carbon materials integrator.** Practical modules on timber detailing, klimatförbättrad betong specification, and (near) fossil-free steel use, with buildability and fire/acoustics basics.

C. Electrification & prosumer operations

- **Heat-Pump Installer–Commissioner (advanced).** Hydraulics, refrigerants, smart controls, commissioning templates; integrate flexibility services (aggregator basics).
- **On-site PV & Storage Technician.** Design, safety, interoperability, monitoring; KPI dashboards aligned to performance contracts.

D. Procurement, finance & compliance literacy

- **Green Public Procurement & Taxonomy for Practitioners.** Translating criteria into contracts; contractor documentation packs; audit-ready evidence.
- **Client-side Retrofit Coordinator (multi-owner contexts).** Decision support for HOAs/condominiums; phasing, cost-benefit under ETS2, and SCF/social tariffs.

E. Programme design features to ensure uptake

- **Stackable micro-credentials** (EQF-referenced, ESCO-mapped) that combine into **job-ready profiles** (e.g., BIM/DT Manager, Reuse Coordinator, Energy Data Analyst).
 - **Work-based learning with living labs** (municipal portfolios, campus buildings) where learners deliver **measurable** energy/carbon/reuse outcomes.
 - **Digital toolchains included:** IFC/fi2 workflows, EPD software, e-procurement (BEAst/PEPPOL), and twin platforms—so graduates can “plug into” real projects day one.
 - **Assessment by performance:** evidence packs (models, EPD calculations, commissioning reports) that mirror client deliverables.
- **Conclusions and Recommendations for WP4**

Key Findings Summary and strategic Insights for Curriculum and Training Programme Design (direct recommendations for WP4)

1 Policy is the prime mover

- The EPBD (2024) locks in a shift to zero-emission new buildings by 2030 and whole-life carbon (GWP) disclosure, pushing data-driven design and low-carbon materials.
- Renovation Wave, EU Taxonomy, ETS2 & Social Climate Fund, NZIA together steer capital, supply chains, and skills toward large-scale renovation, electrified heating, and verifiable sustainability performance.

2) Market dynamics: short-term dip, long-term pull

- Cyclical slump (rates/costs) contrasts with structural demand for affordable, efficient homes.
- Electrification & rooftop PV keep expanding, though with near-term volatility (e.g., heat pump sales dip in 2024); medium-term growth pivots to retrofit solutions.

3) Business models go “performance + data”

- Developers, owners, and lenders increasingly require taxonomy-aligned, evidence-rich assets (energy & carbon KPIs, EPD/LCA), enabling performance-based contracts and new service revenues (flexibility/demand response).

4) Digitalisation is now essential infrastructure

- BIM/DT/IoT/analytics underpin predictive maintenance, energy optimisation, and industrialised renovation (DFMA, 4D/5D).
- Persistent BIM: FM handover gaps make CDE literacy and open standards (IFC/fi2) critical.

5) Sweden's state of the art (Housing 4.0)

- BIM is de facto standard for major public clients (e.g., Trafikverket); BIM Alliance and Smart Built Environment drive national guidance.
- Active digital-twin pilots (building: district), smart-meter ubiquity, and timber-based industrialised housing show scalable pathways from design to factory to operation.
- Supply-chain standards (BEAst/PEPPOL) streamline e-procurement and data exchange.

6) Circularity & low-carbon materials accelerate

- x. Since 2022, climate declarations (A1–A5) and forthcoming carbon limit values are shifting early-stage design and product choices.
- y. Sweden's materials toolbox: mass timber (CLT/glulam), low-carbon concrete (on a CCS pathway), (near) fossil-free steel, plus product databases/certifications (BVB, SundaHus, NollCO2).
- z. Reuse infrastructure (CCBuild) lowers barriers to component recovery at scale.

7) Cross-cutting synergies (and frictions)

- Whole-life carbon links policy → finance → digital → materials; industrialised renovation addresses cost, quality, and skills bottlenecks.
- Key frictions: policy/permitting lag, financing split incentives, skills shortages (BIM-FM data, LCA/EPD, HP commissioning, controls), interoperability gaps, and supply-chain variability.

8) VET opportunities with the highest payoff

- Data-to-decision skills: BIM: FM data continuity; LCA/EPD & climate declarations; energy analytics (FDD, tariff-aware control, DR).
- Industrialised renovation & circularity: DFMA/off-site retrofit; reuse/deconstruction coordination; low-carbon materials integration.
- Electrification & prosumer ops: advanced heat-pump commissioning; PV+storage tech with KPI dashboards.
- Procurement & finance literacy: green public procurement, EU Taxonomy evidence packs, client-side retrofit coordination (e.g., HOAs).

9) What to prioritise next (Excel4Housing)

- 14 Build stackable micro-credentials mapped to roles (BIM/DT Manager, Reuse Coordinator, Energy Data Analyst).
- 15 Anchor training in living labs (municipal/campus buildings) with measurable outcomes: GWP reduction, kWh/m², peak-load shaving, reuse tonnage.
- 16 Standardise toolchains (IFC/i2, EPD software, BEAst/PEPPOL, twin platforms).

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Annex 11: State-of-the-Art National Report - Ukraine

REPORT ON THE STATE OF THE ART

UKRAINE

1. Introduction

This State-of-the-Art Report provides an evidence-based overview of the Ukrainian construction sector and its vocational education and training (VET) system—taking into account current market dynamics, reconstruction needs, green and digital transformation trends, and workforce requirements. It aims to offer a clear analytical foundation for the design of VET curricula and training programmes under WP4 of the Exel4Housing project.

Methodology: desk-review of recent statistical data (2024–2025), analysis of industry reports, public data from the national statistics agency (construction output, employment, material production), and review of national and international reconstruction and education policy documentation.

2. Analysis Summary

In 2024, the total volume of completed construction work in Ukraine reached **UAH 204.7 billion**, marking a **23.5% increase** compared to 2023. (Interfax-Ukraine, 2025, March 27)

By January–July 2025, construction output rose further by **16.1%** compared to the same period in 2024 — reaching **UAH 117.7 billion**. (Interfax-Ukraine, 2025, September 29).

There is a growing need for a workforce capable of energy-efficient renovation, sustainable construction, and modern building technologies, which calls for modernized VET provision.

3. Indicative Outline

- **General Context: European Construction Sector & Energy Transition**

Ukraine's reconstruction after large-scale war damages demands alignment with EU energy efficiency and climate standards. The scale of reconstruction, renovation, and new construction is immense, placing construction and building-sector VET at the core of recovery efforts.

- **Policy and Regulatory Landscape**

Ukraine is gradually aligning national legislation and recovery frameworks with European standards: energy-efficient building codes, sustainability norms, and reconstruction strategies. The reconstruction agenda envisions large-scale modernization of housing, infrastructure, and public buildings with improved energy performance, climate resilience, and sustainability.

- **Overall Market Dynamics and Key Trends in Construction**

2024 growth in construction activity: total output at UAH 204.7 bn (+23.5% vs 2023) (BZNS media, 2025,

March 31).

Breakdown (2024): residential construction — UAH 26.6 bn; non-residential — UAH 57.7 bn; engineering construction — UAH 120.4 bn. (Interfax-Ukraine, 2025, March 27)

In 7 months of 2025: overall output UAH 117.7 bn; building construction +27.7%; residential +12%; non-residential +36.4%. (Interfax-Ukraine, 2025, September 29)

These trends reflect intense reconstruction, renovation, and new investments — leading to increased demand for skilled labour, energy-efficient solutions, and modern construction practices.

Moreover, Ukraine's construction materials sector has significant potential: domestic production can cover up to 90% of reconstruction material needs — which could create up to ~180,000 jobs if fully mobilized. (Odessa Journal, 2024, August 12).

This indicates substantial opportunities for VET graduates across multiple trades: construction, energy-efficiency works, materials processing, and supply-chain roles.

○ **Impact of Green and Digital Transitions on the Broader Construction Sector**

The convergence of reconstruction demand, sustainability, European alignment pushes Ukraine's construction sector toward:

Energy-efficient practices: thermal insulation, modern windows/doors, efficient roofs, using of photovoltaic power systems, maintenance of internal engineering systems, installation of heating and renovation to “green building” standards.

Ukraine significantly intensified its integration into the European Green Deal during 2020–2025, establishing this framework as the foundation for the transition to a climate-neutral economy, improved energy efficiency, and the development of green infrastructure. As early as 2020, Ukraine and the EU agreed on joint energy and climate priorities within a strategic partnership, which included alignment with the principles of the European Green Deal (European Commission, 2020).

The first official Ukraine–EU meeting dedicated to the implementation of the Green Deal and Ukraine's green transition was held in 2021. This dialogue consolidated the policy framework for further decarbonization and sustainable recovery (European Commission, 2021). In 2023, a strategic partnership was signed to advance renewable gases—particularly hydrogen and biomethane—which are essential for green energy and energy-efficient construction (State Agency on Energy Efficiency, 2023).

The year 2025 marked the beginning of the official screening of Ukrainian legislation under the “Green Agenda and Sustainable Connectivity” cluster. This process signifies large-scale harmonization of national regulations with EU eco-requirements and standards, including those related to energy-efficient and sustainable buildings (Government Office for Coordination of European and Euro-Atlantic Integration, 2025). The “Green Transition Report for Ukraine,” published the same year, identified specific priority directions for green transformation, among them the modernization of the construction sector (Government Office, 2025).

Sustainable material supply: leveraging domestic materials, circular economy principles, waste recycling and reuse

Digitalization: increased use of digital design tools (BIM), digital planning and permitting, remote monitoring, smart building technologies — especially relevant given war risks and reconstruction scale.

Thus, the green and digital transitions significantly raise requirements to workforce skills and training quality, reinforcing the need for modernized VET.

- **Thematic Analysis of State-of-the-Art**

- **Digitalization in Construction (Housing 4.0)**

Digitalization is crucial for transparency, efficiency, and meeting high energy performance targets.

Key Digital Technologies in Demand: BIM, digital planning, building energy modelling, remote surveying (drones), IoT-based building monitoring, smart energy systems.

Current Adoption: Larger firms and reconstruction contractors increasingly adopt digital tools; public-procurement projects push for digital compliance; demand rising for digital-construction specialists.

Emerging and Required Professions: BIM Technician, Digital Construction Technician, Smart Building/Energy Systems Installer, Unmanned aircraft systems operators, Digital Quality Control Specialist.

Given reconstruction needs and EU-aligned standards, demand for these profiles is expected to grow rapidly.

- **Circular Economy & Sustainable Construction Materials**

Material Production Potential: Ukraine's industry can supply ~90% of reconstruction material needs, which could support ~180,000 jobs under full mobilization. (Odessa Journal, 2024, August 12).

Sustainability Focus: Emphasis on use of local materials, recycling rubble, promoting sustainable building materials, and reducing reliance on imports — critical during wartime and for cost-efficiency.

Required Skills & Professions: Eco-material Technicians, Waste-management specialists, Sustainable Construction Installers, Quality Control for recycled materials.

These trends highlight the growing relevance of circular economy skills for VET.

- **Modernization of VET in Construction (Ukraine)**

VET reform is a strategic priority to meet reconstruction and market needs. A flagship initiative is the **#100 Workshops Project**.

The “100 Workshops” Initiative

Government-led, under the Ministry of Education and Science of Ukraine 73 modernized/ new training workshops across the country, 5 workshops dedicated to construction trades Funded by the European Union under the **Ukraine Facility** Plan.

Establishment of the Training and Practical Centre “Energy-Efficient Construction”

At the **Sumy High Vocational School of Construction and Design** a new centre will be created as part of #100 Workshops. Its key roles:

Deliver short-term and modular training programmes for construction trades, focused on energy efficiency and modern building technologies.

Bridge labour market gaps by preparing specialists for reconstruction, renovation, insulation works, and sustainable building tasks.

Provide flexible learning formats (online, evening, daytime) to accommodate diverse groups — including retraining adults, veterans, displaced persons, or those seeking career change.

Promote inclusion by offering targeted support for persons with disabilities, veterans, and vulnerable groups.

Planned Training Programmes

1. Window and door systems installer
2. Thermal insulation installer
3. Flat roof installer
4. Advanced Building Thermomodernization Systems Technician
5. Decorative plastering and airless painting technician

These programmes correspond to high-demand trades in reconstruction, energy efficiency, and renovation — aligning with market trends and sustainability goals.

Thus, VET modernization via this initiative contributes directly to national reconstruction, energy-efficiency targets, and creation of a skilled workforce.

● Cross-Cutting Analysis & Opportunities

○ Interlinkages and Synergies

Green building ↔ sustainable materials ↔ domestic materials production ↔ job creation

Digitalization (BIM, smart building) ↔ efficiency, reconstruction speed, quality control

VET modernization (100 Workshops) ↔ labour market demand ↔ social inclusion ↔ reconstruction capacity

○ Common Challenges & Barriers

Shortage of qualified labour despite high demand

Lack of standardized national legislation / norms for sustainable materials, circularity, digital construction practices

Regional disparities in VET infrastructure and access

Urgent need to update curricula and provide flexible training formats

- **Innovation Opportunities in VET for Sustainable Construction**

Modular, stackable micro-credentials in energy efficiency, digital construction, sustainable materials

Dual education / apprenticeship models with reconstruction companies

Remote / blended learning for theory + hands-on labs

Inclusive training pathways for vulnerable / displaced / veteran populations

- **Conclusions and Recommendations for WP4**

- **Key Findings**

The Ukrainian construction sector is growing rapidly — **2024 saw +23.5% output growth**; further growth in 2025.

Reconstruction and renovation needs remain enormous, driving demand for energy-efficient, sustainable, and modern construction practices.

Domestic material production has significant potential (~90% of reconstruction needs), offering job creation and supply-chain stability.

Digitalization and circular economy trends create demand for new professional profiles and competencies.

The #100 Workshops initiative provides a critical framework to modernize VET, meet labour demand, and support reconstruction.

- **Recommendations for WP4 Curriculum & Training Design**

1. Develop modular VET programmes (micro-credentials) in: energy renovation, insulation, roofing, efficient window/door installation, decorative and finishing works.
2. Include digital construction skills: BIM, digital design, smart building technologies, material tracking.
3. Embed sustainable materials & circular economy principles in curricula (reuse, recycling, eco-materials).
4. Design inclusive training paths: part-time, evening, online, for veterans / displaced / adults changing career.

5. Establish partnerships with local industry and reconstruction companies to ensure demand-driven training and employment pathways.
6. Monitor labour market demand regularly and update curricula accordingly.

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List of Abbreviations and Acronyms

Abbreviation / Acronym	Full Term
AKMI	Partner Name - implied
ARCA	Architettura Comfort Ambiente (Italian wood certification)
BIM	Building Information Modelling
CAM	Criteri Ambientali Minimi (Italian minimum environmental criteria)
CE	Circular Economy
CEAP	Circular Economy Action Plan
CEEC	Partner Name - implied
CLT	Cross-Laminated Timber
COM	European Commission Communication
CSRD	Corporate Sustainability Reporting Directive

Abbreviation / Acronym	Full Term
CTE	Código Técnico de la Edificación (Spanish National Building Code)
DfD	Design for Disassembly
DNSH	Do No Significant Harm (Principle)
EACEA	European Education and Culture Executive Agency
EC	European Commission
EPC	Energy Performance Certificate
EPBD	Energy Performance of Buildings Directive
ERASMUS	EU Programme
ESRS	European Sustainability Reporting Standards
ESG	Environmental, Social, and Governance
ETS2	Emissions Trading System 2
EU	European Union
FCRBE	Facilitating the Circulation of Reclaimed Building Elements
GEG	Buildings Energy Act (Germany)
GHG	Greenhouse Gas
HE	Higher Education
HVAC	Heating, Ventilation, and Air Conditioning
JRC	Joint Research Centre (European Commission)
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LVL	Laminated Veneer Lumber
MEPS	Minimum Energy Performance Standards
NBRP	National Building Renovation Plan
NFRD	Non-Financial Reporting Directive
NWE	North-West Europe
NZEB	Nearly Zero-Energy Building
PEX-COVE	Partnerships for Excellence - Centres of Vocational Excellence

Abbreviation / Acronym	Full Term
PMP	Project Management and Data Control Plan
PNEC 2030	National Energy and Climate Plan 2021–2030 (Portugal)
PV	Photovoltaic
R&D	Research and Development
RRP	Recovery and Resilience Plan
SPU	Special Public Use (Dissemination Level)
TCFD	Task Force on Climate-related Financial Disclosures
TOTEM	Tool for Optimising the Total Environmental impact of Materials (Belgium)
VET	Vocational Education and Training
WBL	Work-Based Learning
WLC	Whole-Life Carbon
WP	Work Package
ZEB	Zero-Emission Building

Table 2. List of abbreviations and acronyms