FENESTRAE

Analysis of National Regulations and Technical Standards on Smart Building Envelope Solutions in IPA-ADRION Regions

2025

Report on the state of the art of national regulations

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Abbreviations

BACS	Building Automation and Control Systems
EE	Energy Efficiency
EMS	Energy Management Systems
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Contracting
EU	European Union
GA	Green Agenda
GHG	Green House Gases
NEEAP	National Energy Efficiency Action Plans
NCEP	National Energy and Climate Plan
NDCs	Nationally Determined Contributions
NZEB	Nearly Zero Energy Building
RES	Renewable Energy Sources
S3	Smart Specialization Strategy
SRA	Smart Readiness Assessment
WB6	Western Balkans

1. Executive Summary

This report consolidates the state of regulations, standards and market practice for smart building envelope solutions for advanced glazing, dynamic shading, façade-PV/BIPV, and building automation across six IPA-Adria countries (EU: Italy (Apulia & Molise Regions), Greece, Slovenia; and Western Balkans: Albania, North Macedonia, Bosnia & Herzegovina: Republic of Srpska). It combines desk research with partner inputs to map EU and national legislation (EPBD/EED/RED and transpositions), technical norms (e.g., UNI/EN, KENAK/TOTEE, PURES/TSG), finance/procurement levers (Eco Fund, CAM/GPP, Exoikonomo), and pilot evidence, then compares EU members and Western Balkans in a single analytical grid.

EU climate-energy law (Green Deal, Fit for 55, EPBD recast) was reviewed and each country's NECP/NDCs, building codes, product standards, and public-procurement rules; inventoried incentives and key finance lines; and captured demonstrative projects showing realized savings and technology readiness. The analysis is structured to highlight governance, building-code requirements (nZEB/ZEB), and market/smart-tech measures, with a side-by-side comparative table and short country digests. Key findings are summarized below.

EU trio (Italy, Greece, Slovenia). Frameworks are mature and enforceable (nZEB obligations, EPCs, RES integration; strong standardization and procurement). The bottleneck is **delivery at scale**—quality installation, dynamic simulation/BACS integration, contractor skills, and stable multi-year finance—especially for smart façades (electrochromic/triple glazing, automated external shading, façade-PV) and heritage-sensitive contexts.

Western Balkans (Albania, Bosnia & Herzegovina: Republic of Srpska, North Macedonia,). Foundations exist (EPBD-style laws, EPCs, RES policies), but **secondary legislation, enforcement, financing instruments and workforce capacity** are uneven. Municipal pilots (EMS/LED/GIS), BIM/IoT demos, and donor-backed credit lines show promise; the priority is turning pilots into standardized, fundable renovation packages embedded in NECPs and upcoming Building Renovation Plans.

Performance evidence: Pilots indicate **30–60% energy-need reductions** from envelope-led retrofits when high-performance glazing is paired with external shading, airtightness, and controls; Slovenia's best practices illustrate BIPV façades and smart windows meeting nZEB targets; Greece's public sector has adopted operational measures (indoor setpoints, mandatory shading, EMS); Italy's CAM/GPP and UNI standards translate policy into market specifications.

Cross-cutting insight. Smart envelopes are most effective when coupled with **digitalization (BACS/SRI), on-site RES and storage, and quality assurance** (airtightness/overheating checks). Public buildings, industrial/public roofs and carports, and mass housing offer the **fastest scale pathways**.

This evidence base will guide the next project steps to market assessment and investment models by pinpointing where standardized smart-envelope "kits," workforce training, and predictable finance can unlock rapid, replicable savings aligned with EPBD-driven renovation goals.

2. Introduction

This consolidated report has been developed within the framework of the project **FENESTRAE – Fostering Energy Efficiency by means of Smart Technologies to Retrofit Apertures and Building Envelope**, co-funded by the European Union under the IPA-ADRION Program. The document complements the national Analysis of the state of the art of regulations and technical standards in IPA-ADRION regions, as part of the project's initial work package *"Analysis of the state of the art of Smart windows in the regions involved."*

The purpose of this report is to consolidate information of the state of the art of national and regional regulations, technical standards, and European directives related to energy use in buildings, with a specific focus on smart building envelope solutions including advanced glazing, shading devices, and innovative technologies that can enhance energy savings and comfort conditions. The analysis covers both EU frameworks such as the European Green Deal and national regulatory frameworks in the IPA-ADRION region, with specific attention to Albania, Bosnia and Herzegovina (Republic of Srpska), Greece, Italy (Apulia & Molise), North Macedonia and Slovenia as illustrative cases.

Buildings across the region, as in the EU, represent a major opportunity for reducing energy consumption and greenhouse gas emissions. Building envelopes including walls, roofs, windows, and integrated smart technologies are central to this opportunity. The adoption of smart glazing, dynamic shading, and automated control systems can significantly improve energy performance while also enhancing indoor comfort.

The specific goals aim at:

- Summarizing existing frameworks at European, national, and regional levels that govern smart devices for building envelopes and their energy implications.
- Reducing discrepancies in knowledge among project partners on the regulatory and technical state of play in energy-efficient building envelopes.
- Identifying gaps, barriers, and opportunities for harmonization with EU policies, particularly in the context of the Nearly Zero Energy Building (NZEB) standard and updated EPBD requirements.
- Providing guidance for subsequent steps in the project, namely the market assessment of available smart technologies, evaluation of investment potential, and identification of business opportunities for local stakeholders.

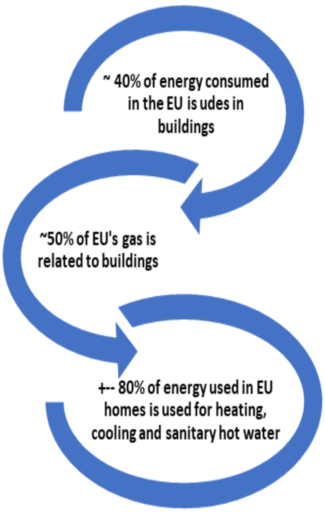
The information contained herein is derived from online meetings, bilateral discussions, and a regulatory review via desk research conducted by all project partners. It integrates national-level insights from all project countries into a comparative regional framework, ensuring a comprehensive understanding of both current progress and the road ahead.

Ultimately, this report is intended to serve the project partners and related stakeholders such as policymakers, academics, architects, engineers, and market actors as a practical reference for advancing the integration of smart building envelope solutions across the IPA-ADRION region, aligned with European climate and energy targets.

Consumption of energy in buildings

Buildings account for around **40% of the EU's total energy consumption** and **50% of its gas use**, with nearly **80% of household energy demand linked to heating, cooling, and hot water**.[1] This makes the building sector both a critical challenge and a prime opportunity for reducing emissions. Improving energy performance through the **Energy Performance of Buildings Directive (EPBD)**[2] is therefore essential to achieve a zero-emission building stock by 2050, as it directly addresses inefficiencies in existing structures, most of which were built before 2000 and perform poorly.

Consumption of energy in buildings in the EU



[1] Link to source

[2] Directive 2012/27/EU

The pathway to this transformation relies heavily on the **implementation of smart technologies**, such as intelligent building management systems, smart meters, and automated controls, which optimize energy use in real time. In parallel, advanced **smart glazing technologies**—including triple glazing and electrochromic windows with dynamic shading—significantly reduce thermal losses and cooling loads, enhancing envelope performance. Together, these measures reduce energy spending in buildings, improve comfort, and accelerate the EU's broader decarbonization and energy security goals.

Summary of the existing gaps for the EU BCT indicators based on the normalised values

	INDICATOR	ASSESSMENT	GAP
1	**CO_2 emissions emissions from energy use in buildings for households and services**	OFF TRACK	47.5%
	households	FAR OFF TRACK	57.2%
	service-sector	OFF TRACK	19.4%
2	**Final energy consumption in households and services**	FAR OFF TRACK	57.4%
	households	FAR OFF TRACK	82.9%
	service-sector	ON TRACK	-72.6%
3	**Renewable energy share**	FAR OFF TRACK	65.0%
	heating & cooling	FAR OFF TRACK	76.9%
	gross electricity consumption	ALMOST ON TRACK	9.7%
4	**Cumulative investment in renovation**	OFF TRACK	42.2%

In addition, the **EU Buildings Climate Tracker**[3] provides a comprehensive monitoring tool to assess whether the building sector is on track towards achieving climate neutrality by 2050. By combining multiple indicators—including energy use, emissions, and renovation progress—the Tracker highlights the persisting gaps between actual consumption trends and the required decarbonization pathway. Household energy consumption in both the EU and Central and Eastern Europe (CEE), makes this gap explicit. It shows that energy demand in households has remained above 2015 baseline levels throughout the period 2015–2021, with 2020 consumption exceeding target values by **7.6% in the EU** and **14.6% in the CEE region**. Instead of narrowing, the gap to the climate neutrality path is widening, with 2021 witnessing further increases due to colder winters and greater heating demand.

The table above provides a consolidated overview of the **main gaps across key indicators** used to assess the decarbonisation progress of the building sector. It highlights that, despite existing EU and national policies, there are persistent shortcomings in areas such as **renovation rates, energy demand reduction, emissions reductions, and financing mechanisms**. The table underscores that the pace of progress remains insufficient to align with the climate neutrality trajectory, especially when it comes to scaling up deep renovations, mobilising private finance, and ensuring equitable progress across Member States.

This evidence underscores the importance of the **Energy Performance of Buildings Directive** and complementary policies in accelerating renovation, scaling smart technologies, and improving building envelopes. Without significant progress in reducing household energy consumption, the EU's climate goals remain at risk, reinforcing the Tracker's role as a practical reference for policymakers and stakeholders to guide stronger action.

2.1. Definitions

Energy Efficiency (EE), as per the EU Energy Efficiency Directive[4], is defined as "the ratio of output of performance, service, goods, or energy to input of energy."

[3] BPIE (Buildings Performance Institute Europe) (2024). EU Building Climate Tracker, 3rd edition: Transforming buildings, empowering Europe: A pathway to prosperity, equity and resilience.

[4] Directive 2012/27/EU

Renewable Energy Sources (RES) are natural energy sources replenished at a higher rate than they are consumed. Examples include solar, wind, hydropower, and geothermal energy.[5] In this Report we mainly refer to solar energy.

Nearly zero-energy building (NZEB), as per Directive 2010/31,[6] is a building that has a very high energy performance, the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. The NZEB is anticipated to consume minimal energy for heating, cooling, ventilation, lighting, and hot water and the remaining energy needed must be extremely limited, as well as a "very significant extent" of the building's energy demand should be met from renewable sources, including solar (photovoltaics, solar thermal), biomass, geothermal and other RES from on-site or nearby production.

Smart building, as per recast EPBD 2018/844,[7] is building that is equipped with advanced automation and control systems, enabling it to adapt its operation to the needs of the occupants, optimize energy efficiency and overall performance, and interact with the energy grid.

The concept of smart buildings is further addressed via the **Smart Readiness Assessment** and Smart Readiness Indicator (SRI), that at the moment is an EU-wide scheme that assesses the readiness of buildings to operate smartly. The SRI complements the definition by quantifying how "smart" a building is, based on the deployment of digital and automation systems. SRI evaluates buildings in three main areas among which are Energy efficiency and operation; Responsiveness to occupant needs, and Flexibility to energy grids.

The EPBD and Smart Readiness Indicator contain the following essential elements:

- Smart buildings achieve energy efficiency optimization through system monitoring and control of heating and cooling and ventilation and lighting and other systems to minimize energy usage and emissions.
- The systems adjust their operations based on user activities and personal choices and actual occupancy numbers to enhance comfort and wellbeing.

[5] Available at link
[6] Directive 2010/31/EU
[7] Directive 2018/844

- Smart buildings allow demand response capabilities and facilitate the integration of renewable energy systems and energy storage and electric vehicle (EV) charging infrastructure.
- The systems use Building automation and control systems (BACS) and energy management systems (EMS) to perform real-time monitoring and adaptive performance.

Summary of observations and progress of the EU BCT composite index and single indicators[3]

Indicator	VALUES			DEVELOPMENTS		
	2015	2022 (achieved)	2022 (required)	2015-2022 (achieved)	2015-2022 (required)	How much of the required progress was achieved during 2015-2022?
1 CO_2 emissions emissions from energy use in buildings for households and services	447.2 $MtCO_2$	381.7 $MtCO_2$	322.3 $MtCO_2$	↓ 14.7%	↓ 27.9%	
households	316.9 $MtCO_2$	277.1 $MtCO_2$	223.9 $MtCO_2$	↓ 12.6%	↓ 29.3%	
service-sector	130.3 $MtCO_2$	104.5 $MtCO_2$	98.3 $MtCO_2$	↓ 19.8%	↓ 24.5%	
2 Final energy consumption in households and services	4,355.9 [TWh]	4,234.5 [TWh]	4,070.8 [TWh]	↓ 2.8%	↓ 6.5%	
households	2,860.4 [TWh]	2,819.5 [TWh]	2,621.9 [TWh]	↓ 1.4%	↓ 8.3%	
service-sector	1,495.5 [TWh]	1,415.0 [TWh]	1,448.9 [TWh]	↓ 5.4%	↓ 3.1%	
3 Renewable energy share	22.6%	28.9%	40.6%	↑ 6.3 percentage points (increased from 22.6% to 28.9%)	↑ 18.0 percentage points (should have increased from 22.6% to 40.6%)	
heating & cooling	20.3%	24.9%	40%	↑ 4.6 percentage points (increased from 20.3% to 24.9%)	↑ 19.7 percentage points (should have increased from 20.3% to 40%)	
gross electricity consumption	29.7%	41.2%	42.4%	↑ 11.5 percentage points (increased from 29.7% to 41.2%)	↑ 12.8 percentage points (should have increased from 29.7% to 42.4%)	
4 Cumulative investment in renovation	292.3 [billion EUR2015]	2,629 [billion EUR2015]	4,335 [billion EUR2015]	8 times the value in 2015	13.8 times the value in 2015	

According to the EU Building Climate Tracker, between 2015 and 2022, progress in reducing CO_2 emissions and final energy consumption in EU buildings has been positive but insufficient to stay on track with climate neutrality goals. CO_2 emissions decreased by around 15%, yet the required reduction was nearly 28%. Both households and the service sector fell short of the expected pace. Similarly, final energy consumption declined slightly (around 3%), while a 6.5% reduction was needed.

Renewable energy use in buildings grew, particularly in electricity consumption, but still lags in heating and cooling. The overall renewable share rose by 6.3 percentage points, less than half of the required increase. Investment in building renovation multiplied eightfold compared to 2015, but still achieved only about half of the necessary scale to meet targets.

Overall, while trends are moving in the right direction, the EU building sector remains off track, with significant gaps in emissions reduction, energy efficiency improvements, renewable energy deployment (especially in heating and cooling), and renovation investment.

Closing the investment gap in renovations will be critical to accelerate progress and align the sector with EU climate neutrality pathways.

3. Framework and Legislation Overview

3.1. Climate Frameworks and Key Directives

The Paris Agreement received ratification from EU countries such as Italy, Greece and Slovenia as well as from the Western Balkan countries including North Macedonia, Bosnia and Herzegovina and Albania. [8] The agreement creates a mandatory system to keep global warming below 2°C while targeting 1.5°C as the preferred temperature threshold compared to pre-industrial times. The effort receives backing from financial mechanisms (such as the Green Climate Fund), capacity-building initiatives (e.g., the SDGs knowledge platform), and technical assistance. The implemented measures work to decrease GHG emissions while strengthening climate change resistance through better adaptation and mitigation approaches. Moreover, the UNFCCC (2016) also recommends use of technologies to address climate change, including renewable energies such as solar power, in a form of any equipment, technique, practical knowledge, or skill needed to reduce greenhouse gas emissions or adapt to climate change. [9] Additionally, countries were required to regularly track progress and develop Nationally Determined Contributions (NDCs) and Biennial Update Reports.[10]

The European Union, closely following global developments and aiming to set an example, has reinforced the Paris Agreement objectives by introducing a wide range of climate and energy frameworks under the **European Green Deal**, supported by legally binding **European Climate Law** (Reg. 2021/1119), which anticipates climate-neutrality by 2050 and at least −55% GHG reduction by 2030.[11] Moreover, the Commission recommends a climate target of **−90% net GHG cut by 2040 and sets a** legislative proposal to be inserted into the Climate Law.[12] To operationalize these ambitions, the EU launched the **Fit for 55 package**, including reforms of the **EU Emission Trading System (ETS)**, a new **ETS2 for buildings and transport**, the **Carbon Border Adjustment Mechanism (CBAM)**, the **Social Climate Fund**, and binding national targets under the **Effort Sharing Regulation** and **Regulation on land use, land use change, and forestry**.[13]

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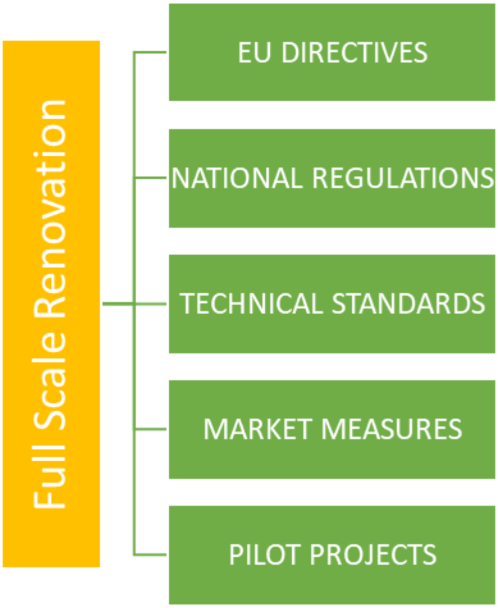
[8] Parties to the United Nations Framework Convention on Climate Change
[9] UNFCCC (2016) Technology and the UNFCCC Building the Foundation for Sustainable Development, available at link
[10] Available at link, Available at link
[11] European Green Deal, European Climate Law
[12] 2040 Climate Target
[13] Social Climate Fund Regulation, Report on the Effort Sharing Directive, LULUCF Regulation

From Regulation to Implementation



Complementary measures include the **Renewable Energy Directive (RED 2018/2001 as amended by 2023/2413)** raising the EU target to 42.5% renewables by 2030, the **Energy Efficiency Directive (EED 2023/1791, recast)** with stronger savings obligations, and the **Energy Performance of Buildings Directive (EPBD 2024/1275, recast)** steering the building stock towards zero-emission by 2050. Parallel frameworks such as the **Methane Regulation (Reg. 2024/1787)**, the **Ecodesign for Sustainable Products Regulation (ESPR 2024/1781)**, and the **Net-Zero Industry Act (NZIA 2024/1735)** strengthen industrial decarbonization, product sustainability, and clean-tech scaling, while the **Critical Raw Materials Act (CRMA2024/1252)** secures strategic inputs.

Energy Performance of Buildings Directive Implementation Timeline

31 December 2026	EU countries submit **final national building renovation plans**.
29 May 2026	**General transposition deadline** for the revised EPBD
31 December 2025	EU countries submit **draft national building renovation plans**
1 January 2025	Transposition deadline for **Article 17(15)** on phasing out financial incentives for fossil fuel boilers
28 May 2024	The **revised EPBD entered into force**
8 May 2024	The revised Directive was **published in the Official Journal of the EU**

December 2023	**Provisional agreement** between the co-legislators on the EPBD revision
March 2023	**European Parliament's position** adopted on the EPBD revision
October 2022	**Council General Approach** agreed on the EPBD revision
May 2022	**REPowerEU Plan**, including the EU "Save Energy" Communication
December 2021	**Commission proposal** for a revised directive
October 2020	**EU Renovation Wave Strategy** launched
May 2018	Adoption of **Amending Directive 2018/844**
May 2010	Adoption of **Energy Performance of Buildings Directive (2010/31/EU)**
December 2002	Original **Energy Performance of Buildings Directive (2002/91/EC)** adopted

The EU's climate ambition is also backed by **sustainable finance legislation**: the **EU Taxonomy for sustainable activities (Reg.2020/852)**, the **Sustainable Finance Disclosure Regulation (SFDR 2019/2088)**, the **Corporate Sustainability Reporting Directive (CSRD 2022/2464)**, and the **EU Green Bond Standard (Reg. 2023/2631),** all mobilizing capital toward low-carbon investments.

Ecosystem resilience is addressed through the **Nature Restoration Regulation (Reg. 2024/1991)**, the **EU Biodiversity Strategy for 2030**, and the **EU Adaptation Strategy**.

The **EU framework** is tightening requirements for building envelopes and smart technologies, combining **minimum performance standards, renovation targets, and financial incentives**. By **2025–2026**, Member States will submit **National Building Renovation Plans** under the recast EPBD, detailing pathways for modernizing building stock, training professionals, and financing upgrades.

While EU countries are legally bound to deliver these objectives, the **Western Balkan Six (WB6)** countries face additional and unique challenges. Severe air pollution, especially during winter heating months, derives from fossil fuel dependency, outdated and inefficient infrastructure, and high rates of energy poverty. The WB6 energy sector is undergoing two major transitions simultaneously: moving from state-controlled systems to liberalized markets and shifting from fossil fuel dependency toward decarbonization. However, progress remains slow, with renewable deployment limited mostly to hydropower and traditional biomass, and energy productivity lagging EU averages.

To bridge these gaps, the **Green Agenda for WB6**[14], closely linked to the **Economic and Investment Plan for the Western Balkans,** has been introduced to guide the region's

[14] Available at link, Available at link

transition.[15] The Green Agenda emphasizes sustainable economic development through decarbonization, clean energy adoption, pollution reduction, circular economy practices, biodiversity protection, and climate resilience. It aligns the WB6 countries with the broader EU frameworks, preparing them for eventual integration into the EU single market and energy union, while addressing socio-economic vulnerabilities in parallel with climate objectives.

3.2. National Frameworks

The construction industry accounts for around 50% of natural resource consumption and 25–40% of total energy use, sustainability in the building sector is both a strategic priority and an urgent necessity, requiring clear guidelines and regulatory frameworks. In this section, the key transposed regulations specific to each project country will be discussed.

3.2.1 Albania

Albania began EU accession negotiations in July 2022, with Cluster 4: Green Agenda & Sustainable Connectivity covering Chapter 15 (Energy) and Chapter 27 (Environment & Climate Change). The country has established a foundational policy framework aligned with EU directives through its Energy Community Treaty obligations, in particular:

- **Law 124/2015 on Energy Efficiency (amended 2020)** transposes the EU Energy Efficiency Directive; sets national savings targets, mandates audits for large consumers, and introduced three National Energy Efficiency Action Plans (latest 2019–2021). Draft NECP targets 15.5% primary energy savings by 2030 (vs. EU's 11.7% final energy reduction), emphasizes the **digitalization of energy and** is expected to encourage **smart building technologies** as part of demand-side management and grid integration efforts. This law encourages modern energy management practices. In implementation, it has enabled **Energy Performance Contracting (EPC)** schemes where energy service companies can retrofit buildings and recover costs from the energy savings
- **Law 116/2016 on Energy Performance in Buildings (EPB Law)** transposes EPBD 2010/31/EU; establishes Minimum Energy Performance Requirements

[15] Available at link, Available at link, Available at link, Available at link

(MEPRs), Energy Performance Certificates (EPCs), HVAC inspections, and the basis for Nearly Zero-Energy Buildings (NZEB). Enforcement and detailed NZEB definitions are still evolving. It also promotes the use of **smart meters and sensors** in monitoring building energy performance.
- **Law 7/2017 on Renewable Energy & National Energy Strategy (2018–2030)** **s**ets 42% RES share target by 2030, closely aligned with EU's 42.5%. GHG reduction target of –20.9% by 2030 remains below EU ambition.

Ministry of Infrastructure & Energy is the central focal point to these issues. The **Energy Efficiency Agency (2018)** implements programs and manages the **Energy Efficiency Fund**, while the **National Agency of Territory Planning** issues technical codes (KTP norms) with U-values for building envelopes (mandating double glazing/insulation but not yet NZEB-ready).

Albania's regulatory and market framework for smart building technologies is still at an early stage but shows gradual progress. **Urban planning law (2014)** gives municipalities authority to set local requirements, and some pilots (e.g., in Tirana) offer **fast-track permits or tax discounts** for green buildings, while minor retrofits often bypass full permits. **Technical norms (KTP)** define minimum U-values, effectively requiring double glazing, though standards remain below EU levels and lack provisions for shading or advanced glazing. **Financial incentives** are limited to donor programs (EU4Energy, EBRD GEFF loans) and planned initiatives like a **Green Innovation Fund**, with ESCO market potential still untapped. Overall, while no dedicated policy exists for smart envelopes, Albania is gradually integrating **digital and smart solutions** into laws and initiatives, with the next step being the creation of **formal incentives, guidelines, and professional training** to mainstream these technologies.

Implementation Challenges
- **Enforcement gaps:** EPC compliance inconsistent; many renovations bypass MEPR standards.
- **Capacity shortages:** Limited trained auditors, architects, engineers in advanced smart-envelope technologies (e.g., electrochromic glass, automated shading).
- **Low awareness/demand:** Investors and owners reluctant without incentives; demand for smart glazing/shading remains niche.
- **Financing constraints:** Domestic green loans/subsidies underdeveloped; heavy reliance on donor funding (EU, KfW, EBRD).

Strategic Outlook (2021–2030)

- Adoption of the first full **NECP (2025–2030 update)** to integrate efficiency, RES, and emission targets.
- Gradual strengthening of building codes towards NZEB standards.
- Improved inspections, compliance penalties, and broader use of EPCs.
- Development of **green financing tools** (via EU/IFIs) to scale up renovations.
- Promotion of smart technologies in buildings through guidelines, incentives, and training.

Key takeaways:

- EU directives transposed; enforcement still weak.
- 2030 targets: strong on energy/RES, weaker on GHG cuts.
- Institutions in place, but low capacity and financing gaps.
- Smart buildings & ESCO market still nascent.
- Outlook: NECP update, stronger codes, green finance, incentives needed.

3.2.2 Bosnia and Herzegovina: Republic of Srpska

Bosnia and Herzegovina was granted EU candidate status in December 2022, with reforms in governance, energy, and environment highlighted as priorities. In March 2024, the EU Council opened accession negotiations, placing energy efficiency under Cluster 4: Green Agenda and Sustainable Connectivity.

Bosnia and Herzegovina is a complex state composed of the Federation of Bosnia and Herzegovina, the Republic of Srpska, and the Brčko District, each with its own constitution under the national framework. While the country has committed to aligning with EU energy and climate directives through the Energy Community, progress is slowed by a **fragmented institutional structure**: the two entities have adopted separate energy efficiency laws (2013 and 2017), but a **unified state-level legal framework is still lacking**.

Energy Strategy to 2030 identifies the building sector consumes more that **50% of final energy consumption and therefore sets it as** major priority for decarbonization while promoting **low-energy buildings**, renovation of existing stock, and integration of **innovative/smart technologies** and advocates a **lifecycle approach** to building design and management.

Key Legislation

- **Law on Energy Efficiency (2013)**
    - Obligations for large energy consumers to prepare three-year energy efficiency plans.
    - Requires **energy audits, certifications, and energy labelling**.
    - Defines distributor obligations via promoting rational energy use and educating consumers.
- **Law on Spatial Planning & Construction (2013–2019 updates)**
    - Regulates planning, permits, legalization, and inspections.
    - Introduces **one-stop-shop & e-permits**, fees for legalizing buildings, exemptions for veterans' families.
- **Law on Renewable Energy Sources (2022)**
    - Promotes production/use of RES such as wind, solar, hydro, biomass, geothermal, biogas, landfill gas.
    - Define **support schemes** (investment aid, tax incentives, price support).
    - Recognizes **prosumers** and **joint prosumers**.
    - Aims to cut fossil use, foster innovation, jobs, and energy security.
- **Law on Construction Products (2011)**
    - Sets **quality, safety, and energy efficiency standards**.
    - Requires conformity labels ("C" national or "CE").
    - Ensures oversight via inspections and testing, fines for non-compliance.

In the Republic of Srpska, current regulations and strategies on energy efficiency focus on conventional buildings and do not address glazing technologies or transparency control systems in non-conventional structures such as greenhouses. This omission leaves a **policy gap**, as greenhouses are highly energy-intensive and dependent on precise thermal and light regulation are not covered by existing frameworks, despite the potential of smart glazing and adaptive envelopes to enhance energy performance, sustainable agriculture, and climate resilience.

Key Takeaways

- Relatively strong legal base exists, but implementation and enforcement remain uneven.
- Municipal projects show readiness for smart solutions and international cooperation.
- Integration of nZEB standards and advanced building technologies are still pending.

3.2.3 Greece

Up to 2010, Greece gradually developed its building energy framework starting with the **1979 Thermal Insulation Regulation (TIR)**, the **1998 KOXEE draft on rational energy use**, and culminating in **Law 3661/2008** adapting EPBD requirements, followed by the first **KENAK (2010)** and **laws on RES and energy inspectors**, which established minimum performance standards, EPCs, and renewable integration obligations. Since then, Greece has expanded its framework through updated KENAK regulations (2017), the **NECP (2019/2020)** with targets for renovations, nZEBs, digitalization, and financing mechanisms, and the **Long-Term Strategy to 2050**, aligning with EU Green Deal objectives for climate neutrality.

Key Legislation

- **2nd National Energy Efficiency Action Plan (2011)** evaluated progress toward national energy conservation targets and confirmed adequacy of measures set in the 1st NEEAP (2008).
- **Law 4122/2013** transposed the **EPBD 2010/31/EU**, introducing energy efficiency requirements for buildings; mandatory issuance of **Energy Performance Certificates (EPCs)** for new, sold, or rented buildings; and Systematic reporting of heating/cooling installations and a registry of energy inspectors.
- Revised **TOTEE Technical Guidelines (2014)** expanded with provisions on combined heat, power, and cooling systems, being mandatory since then.
- **Law 4342/2015** transposed the **Energy Efficiency Directive 2012/27/EU**; made EPCs mandatory for sales, rentals, or leases, and reinforced auditing/inspection requirements.

- **KENAK 2017 (FEK B' 2367/2017) u**pdated **Regulation on Energy Performance in Buildings**, refining minimum energy performance requirements, U-values, and calculation methodologies.
- Technical Chamber of Greece issued **TOTEE 2017 Technical Guidelines series** (thermal insulation, HVAC, audits, climate data, etc.).
- **National Plan for Increasing nZEBs (2018)** aligned with EPBD 2010/31 and 2018/844 amendments and further defined **nZEB** as buildings with high energy performance and >60% RES contribution to hot water needs and allowed increased building factor (+10%) for nZEBs to incentivize uptake.
- Greece's **National Energy and Climate Plan** set binding 2030 targets encouraged deep building renovations, especially in residential and commercial sectors, stricter building codes to ensure nZEBs as the norm, expansion of financing schemes (e.g., "Exoikonomo" program) and ESCO markets as well as deployment of **smart grids, meters, and digital management systems**.
- **Updates to EPC framework (2018):** EPCs became fully digital, incorporating harmonized classes.
- **Spatial planning and building codes:** Reinforced to support nZEB construction and RES integration in urban development.

Greece has reinforced energy efficiency and conservation measures in response to the energy crisis, with the public sector leading by example. New rules set indoor temperature limits (27 °C in summer, 19 °C in winter), mandate shading installations that preserve natural light, and require the deployment of energy management systems in public buildings. At the same time, households and SMEs benefit from the ongoing "Exoikonomo" subsidy program, which supports insulation upgrades, window replacements, and heat pump installations, helping to reduce energy consumption and promote renewable-based heating and cooling.

Over the following decades, national laws and EU directives shaped a modern system, culminating in the adoption of the **Regulation on Energy Performance in Buildings (KENAK, 2010 and 2017)**. KENAK introduced **minimum energy performance requirements**, **mandatory energy audits**, and efficiency measures for both new and renovated buildings, aligning Greece with European standards. Key legislation reinforced this trajectory by mandating ambitious **energy conservation goals** and **renewable energy integration**, including provisions for solar thermal use in buildings. The introduction of **EPCs** and successive **NEEAPs** further institutionalized monitoring and improvement of energy use across the sector. Looking ahead, sustaining this momentum through stricter implementation, wider uptake of nZEBs, and deeper integration of smart and renewable technologies will be essential for achieving Greece's **long-term climate neutrality and sustainability goals**.

2050 Strategy and Long-Term Vision

- **Long-Term Renovation Strategy (to 2050):** Provides a roadmap for climate neutrality, anchored in the NECP, with milestones for 2030, 2040, and 2050.
- **Targeted outcomes**
  - Progressive decarbonization of building stock.
  - Widespread deployment of RES-based heating/cooling.
  - Mainstreaming of **digital monitoring systems**, smart envelopes, and building automation.

Key Takeaways

- **KENAK 2017** marked a major leap, supported by mandatory technical guidelines (TOTEE).
- **NECP (2019/20)** and **nZEB Plan (2018)** provided the strategic direction, while **public sector measures (2022–24)** showed leadership in implementation.
- Financing and incentive programs like **Exoikonomo** remain critical for mobilizing households and SMEs.
- The country is on track to deliver **nZEB/zero-emission buildings**, though challenges remain in scaling renovations and ensuring affordability.

3.2.4 Italy: Apulia & Molise Regions

Italy's national framework for energy efficient buildings began with laws which introduced thermal insulation standards, system efficiency requirements, renewable energy promotion, and climate zone classifications that still underpin current regulation. Below is the key legislation related to nZEB:

- **Legislative Decree 192/2005** transposed **EPBD 2002/91/EC**; established methods for calculating building performance, minimum requirements, energy certification, inspections, and professional qualifications.
- **Legislative Decree 311/2006** tightened performance limits; introduced Energy Performance Index (EPi) by climate zone.

- **Presidential Decree 59/2009 & Ministerial Decree 06/2009** unified application across Italy; methodologies based on UNI/TS 11300; guidelines for EPCs.
- **Legislative Decree 28/2011 (Renewables Decree)** implemented **RED 2009/28/EC**; mandated RES integration in new/renovated buildings and disclosure of EPCs in sales/rentals.
- **Decree 63/2013 (Law 90/2013)** transposed **EPBD recast 2010/31/EU**; replaced ACE with **APE** (Energy Performance Certificate), made it mandatory for rentals, introduced penalties.
- **Three Decrees (2015)** defined **minimum requirements**, new EPC guidelines, and reference building methodology; introduced **nZEB obligations** (public: from 2019; all buildings: from 2021).

Technical Standards & Certification

- Energy performance classified via **EPgl.,nren** (non-renewable primary energy).
- **Reference building method** ensures compliance checks for new and major renovations (thermal transmittance, solar gain, HVAC efficiencies, etc.).
- **Minimum Environmental Criteria (CAM)** that is mandatory in public procurement; requires recycled content in insulating materials and minimum thermal/acoustic performance for frames; increasingly influencing private sector.
- **UNI Standards** adoptions that define performance and installation criteria for windows, doors, façades, and shading (e.g., UNI EN 14351-1, UNI 10818, UNI 11296, UNI EN 13115, UNI EN 12978**,** UNI 11673 series, UNI EN ISO 10077-1).

Key Innovations

- Progressive tightening of **U-values** for walls, roofs, floors, and transparent components across climate zones.
- Introduction of **nZEB** concept with RES integration requirements.
- Expansion of EPC scope with penalties for non-compliance.
- Mandatory **public procurement standards (CAM)** drive sustainable building components.
- Full technical framework supported by UNI standards ensures **safety, energy efficiency, durability, and sustainability** of building components.

At the regional level, Apulia has reinforced this trajectory by adopting Regional Law No. 13 of 10/06/2008 (Norme per l'abitare sostenibile) and the ITACA Protocol (2017), which provide a structured framework for assessing and promoting sustainability in buildings. These measures are ambitious, setting requirements for designing buildings and infrastructure with minimal environmental impacts. However, their effective implementation depends not only on regulation but also on cultural innovation and the development of new skills among professionals engaged in the construction process.

Molise

Molise regulates building energy performance primarily through a trio of regional laws (2009, 2015, 2015) that stimulate renovation, promote renewable integration (PV/solar thermal/biomass/heat pumps), and incentivize upgrades via fee reductions tied to energy class improvements. Complementary national and regional environment/landscape rules shape permitting and EIAs, including for greenhouse structures.

Regional Legislation

- **Regional Law 30/2009**
  - Extraordinary measures to revitalize construction, improve housing quality, and boost architectural/energy/safety features.
  - Requires **≥60% of domestic hot water (DHW) from RES** for specified interventions.
  - **Facilitates PV/solar integration**: technical volumes for PV/biomass plants don't count toward building volume; canopies/shelters for PV are permitted (incl. agricultural areas) with simplified notification.
- **Regional Law 7/2015 (amending L.R. 30/2009)**
  - Aligns aims explicitly with **EPBD 2010/31/EU** and **EED 2012/27/EU**.
  - Allows **extensions of existing/under-construction buildings** (baseline 20% of volume/covered area), and u**p to 30%** when energy class improves (to **Class C or higher**).
  - **Historic centers**: up to **10% extension** for livability/energy-efficiency/barrier removal.

Incentives

- **Cost reductions** on construction and urbanization fees scale with **achieved energy class** (B → A → A+).
- **Volume/extension bonuses** tied to attaining **Class A**.
- **Administrative facilitation** for PV/biomass technical volumes and PV canopies/shelters lowers non-energy barriers to envelope-PV hybrids.
- **Market/Smart Technology**: Clear push for **on-site RES** with simplified permitting elements; however, **explicit "smart envelope" provisions (e.g.,**

automated shading, electrochromic, SRI) are not yet singled out—an opportunity for future updates and procurement criteria.

Key Takeaways

- Enforceable standards with tightened U-values, mandatory EPCs, and the reference building method ensure compliance.
- nZEB & RES integration is required.
- Procurement driver via CAM criteria in public projects promote sustainable materials and influence the private sector.
- Regional leadership with the Apulia's Law 13/2008 and ITACA Protocol push sustainability beyond minimums but need cultural and skills support.

Italy has established one of the most **comprehensive energy efficiency frameworks in Europe**, evolving from early insulation rules in the 1970s to full **EPBD/RED compliance**, with binding **nZEB obligations**, strict **EPC requirements**, and mandatory **RES integration** in new and renovated buildings. National measures such as the **CAM (Minimum Environmental Criteria)** and the extensive **UNI standards** provide a robust technical and regulatory backbone, while public procurement serves as a key driver of sustainable construction.

At the regional level, **Apulia** and **Molise** demonstrate how EU and national goals are translated into practice:

- **Apulia** pioneered the **ITACA Protocol (2017)** alongside **Regional Law 13/2008**, introducing a multi-criteria framework that assesses environmental sustainability across site quality, resource use, environmental load, indoor comfort, and service quality. These tools push buildings beyond minimum compliance and foster adoption of sustainable materials and construction practices.
- **Molise**, through **Regional Laws 30/2009, 7/2015, and 13/2015**, links **fee reductions and building extension allowances** directly to higher energy classes (up to A+), mandates **RES contributions (≥60% DHW)**, and facilitates **PV/biomass integration** with streamlined permitting. These measures create strong market incentives for both deep renovations and renewable deployment.

Together, the Italian national framework and regional initiatives create a **multi-level system** that combines **ambitious national legislation** with **region-specific instruments** to accelerate sustainability. The key challenge ahead lies not in regulation design, but in

effective enforcement, cultural change, and skill development within the construction sector to ensure consistent implementation across regions.

Key Takeaways

- **Comprehensive framework**: Italy has a mature EPBD/RED-compliant system with nZEB, EPCs, RES integration, CAM, and UNI standards.
- **Enforceable standards**: Tightened U-values, mandatory EPCs, and the reference building method ensure compliance.
- **nZEB & RES**: RES integration is required; nZEB applies since 2019 (public) and 2021 (all).
- **Procurement driver: CAM criteria** in public projects promote sustainable materials and influence the private sector.
- **Regional leadership**: Apulia's Law 13/2008 and ITACA Protocol push sustainability beyond minimums but need cultural and skills support.
- **Future needs**: Stronger **enforcement, cultural innovation, and workforce training** are essential to fully realize the ambitious goals and ensure consistent application across regions.

3.2.5 North Macedonia

North Macedonia has committed to phasing out coal by 2030 and achieving ambitious climate targets of 51% GHG emissions vs 1990, moving toward an 82% net reduction by 2030. These goals are set out in the country's Nationally Determined Contributions (NDCs), which are anchored in the National Energy and Climate Plan (2022) and the National Energy Development Strategy to 2040, aligned with the EU Green Deal and the 2050 climate neutrality objective, and reinforced by international agreements such as the Energy Charter Treaty, the UNFCCC, and the Paris Agreement. The European Parliament Enlargement Report (2024) confirmed progress in EU alignment[16], though full compliance with the Fit for 55 package remains pending and new NDCs have to align with the recent updates.

Key legislation related to nZEB includes the following:

[16] Available at link

- **Energy Efficiency Law (**2020; 2021, 2023, 2024**)** sets **minimum standards** for buildings and mandatory **energy certification**; requires **energy management systems** in public/commercial buildings and mandates **regular HVAC inspections** and supports **financial incentives** for efficiency upgrades.
- **Energy Law** supports **RES uptake**, with provisions for subsidies and active consumers.

The related bylaws enhance the legislative framework and provide further guidance for smart buildings:

- **Energy Performance of Buildings** sets the EPC methodology, HVAC control, design standards.
- **Energy Audit of Buildings** provisions energy characteristics, minimum requirements, and mandatory solar collectors for sanitary hot water, in particular:
  - Methodology for determining energy characteristics – criteria for assessing the energy efficiency of buildings.
  - Minimum energy efficiency requirements – conditions that new and renovated buildings must meet.
  - Control of heating and air conditioning systems – methods for verifying the efficiency of heating and cooling systems in buildings.
  - Obligation to use renewable energy sources – mandatory installation of solar collectors for hot water in certain types of buildings.
  - Certification of energy characteristics – methods for labelling and certifying buildings based on their energy efficiency.

In addition, the related legislation supports the nZEB, such as the Renewable energy (generation and storage – batteries), Energy efficiency standards, Law on construction, and waste management regulations (how will be the glazing disposed, if anticipated, as it is considered as dangerous material; batteries disposal rules).
North Macedonia's **Smart Specialization Strategy** supports smart buildings by aligning with EPBD requirements, prioritizing sustainable materials and energy efficiency in public and residential stock, while progress is still pending on rulebooks and a long-term renovation strategy, with practical pilots using **BIM and IoT systems** already underway.[17]
The interest in using glass on large façades is growing, but applications remain limited to small, panelized elements, with most know-how borrowed from abroad. Research and doctoral work have begun to address glass façades in terms of **sustainability, energy efficiency, and sound insulation**, but local expertise is still scarce. The COST Action

[17] Link to S3

TU0905 Structural Glass prepared relevant recommendations and a manual for the application of glass in high-rise buildings. For this reason, this Action is of particular importance for the wider application of structural glass, as well as for further research in this area[18]. Hence, few authors analyze glass as a building material for facades. Miloševska-Janakieska[19] (2019) in her doctoral dissertation provides an overview of existing glass facades in the country and their impact on certain sustainability parameters in buildings, Nikolovski[20] (2011) addresses glass and glass facades from the perspective of energy efficiency, while Taskova (2022) reports on the sound insulation of glass facades.

Modern glazing now offers multiple functions—solar control, shading, noise protection—yet balancing **energy efficiency, daylight use, and acoustic performance** requires careful design. A **multidisciplinary approach** is recommended, integrating façade design with energy strategy, structural systems, and socio-economic factors, while ensuring stability and comfort. Compliance relies on EU-aligned standards (MKS EN 1215526, 13830,[21] 12153,[22] 12155, 12179,[23] 14501), covering **curtain walling - air permeability, watertightness, wind resistance, blinds and shutters – thermal and visual comfort, and visual comfort**. Shading systems are critical for user comfort but often compromise aesthetics, highlighting the need for better solutions that combine **thermal efficiency, daylight control, and architectural quality**.

Key Takeaways

North Macedonia has set ambitious **climate and energy goals** but lags in full **EU acquis transposition** (EPBD, EED, RED). Laws exist for energy efficiency and RES promotion, with partial alignment on smart building provisions. Pilot projects with BIM, IoT, and energy management systems show readiness, but scaling requires:

- Finalizing renovation strategy,
- Operationalizing the EE Fund,
- Strengthening rulebooks on audits & EPCs,
- Expanding incentives for smart glazing, facades, and shading, and,
- Mobilizing international finance to cover investment gaps.

[18] https://www.cost.eu/actions/TU0905/
[19] https://plus.cobiss.net/cobiss/si/sl/bib/3171721
[20] https://emiter.com.mk/napis/10558
[21] https://isrsm.gov.mk/mk/project/show/isrsm:proj:45482
[22] https://isrsm.gov.mk/en/project/show/isrsm:proj:77395
[23] https://isrsm.gov.mk/sq/project/show/isrsm:proj:31851

The framework is in place, ambition is high, but **implementation and financing** are the decisive factors for achieving 2030 targets and EU integration.

3.2.6 Slovenia

Slovenia's updated NECP[24] tightens climate ambition and couples it with strong buildings policy (PURES + TSG technical rules), fast-tracking RES deployment, energy efficiency, and affordability. The approach blends EU-acquis alignment (EPBD/EED/RED) with practical delivery tools: Eco Fund finance, green public procurement, self-supply/energy communities, and clear construction/waste rules. Slovenia's 2024 NECP sets ambitious goals: a 55% GHG reduction by 2033 (with coal phase-out), 33% RES by 2030, and final energy capped at ≤50.2 TWh, while targeting 70% fewer building emissions through deep renovations and 30% RES use in industry via waste heat and clean technologies.

The **nZEB/Zero-emission trajectory** aligned with **EPBD** (nZEB for new builds since 2021; moving toward zero-emission stock), in addition **PURES regulations (2010/2017/2022)** set minimum performance and methods (incl. dynamic modelling in 2022 update). [25]

- **TSG-1-004:2022 — Energy efficiency in buildings (key nZEB minimal)[26]:**
  - Space-heating need **QH ≤ 25 kWh/m²·a** (climate/design adjusted).
  - Primary energy **QP ≤ 75 kWh/m²·a**.
  - **RES share ≥ 50%** of total energy input.
  - **Ventilation with heat recovery** (or equivalent) + summer **overheating prevention** and thermal comfort.
  - Low-impact materials and robust envelope insulation.

Smart envelope solutions—such as **switchable glazing, ventilated/green façades, and PV-integrated shading**—are promoted to enhance insulation, optimize daylight and solar gains, reduce cooling demand, and generate on-site energy, particular enablers are:

- **ZUNPEOVE (2023)** identifies priority areas (large rooftops, closed landfills, energy corridors), streamlines grid connections & storage.[27]

[24] NECP Slovenia
[25] Rules on the Efficient Use of Energy in Buildings
[26] TGS -1-004:2022
[27] **ZUNPEOVE**

- **ZSROVE (2021) + ZSROVE-B (2024) that** transposes **RED III** elements, simplifies admin for RES & storage; extends deadlines for **net-metering** uptake.[28]

Other relevant regulations are the Decree on Self-Supply enables individual/collective self-consumption and renewable energy communities[29], Electricity Supply Act **(ZOEE, 2021)[30]** that defines active customers and citizen energy communities; covers generation, TSO/DSO, storage, and supply.

Slovenia supports energy efficiency through the **ZURE Act** (2020),[31] the Eco Fund providing grants and loans for renovations and RES, and mandatory Green Public Procurement (GPP) [32] that drives demand for high-performance, sustainable building solutions.

Slovenia's construction framework combines the **Construction Act (GZ-1)**,[33] **Spatial Planning Act (ZUreP-3)**,[34] and **ZAID**[35] for professional licensing, with EU-aligned **product conformity (CPR/CE marking)** [36] and a **Decree on Construction Sites**[37] ensuring safety and compliance.

Related to the environmental and circularity framework, the **Environmental Protection Act (ZVO-2)** [38] sets the path to climate neutrality and biodiversity protection, while new rules on **batteries and storage (EU 2023/1542)** and **waste/C&D management** ensure proper recycling, hazardous waste handling, and compliance with EU standards. [39,40]

Slovenia's plan is coherent and delivery-oriented: firm NECP targets, mature building codes, and strong market enablers (Eco Fund,[41] GPP, self-supply). Scaling smart-

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28 [ZSROVE]
29 [Decree on Self-Supply]
30 https://pisrs.si/pregledPredpisa?id=ZAKO8141
31 https://pisrs.si/pregledPredpisa?id=ZAKO8136
32 https://www.gov.si/teme/zeleno-javno-narocanje/
33 https://pisrs.si/pregledPredpisa?id=ZAKO8244
34 https://pisrs.si/pregledPredpisa?id=ZAKO8249
35 https://pisrs.si/pregledPredpisa?id=ZAKO7342
36 https://pisrs.si/pregledPredpisaEU?celex=32011R0305
37 https://pisrs.si/pregledPredpisa?id=URED8499
38 https://pisrs.si/pregledPredpisa?id=ZAKO8286
39 https://pisrs.si/pregledPredpisa?id=URED5201
40 https://pisrs.si/pregledPredpisaEU?celex=32006L0066
41 https://www.ekosklad.si/

envelope retrofits and workforce capacity is the lever to lock in 2030 goals and the coal phase-out trajectory.

Slovenia has proactively aligned its building regulations with EU directives through **PURES 2022**, enforcing stricter nZEB standards and renewable integration. Pilot projects demonstrate that **smart building envelope technologies**—from glazing to BIPV and green façades—are key to achieving energy savings and zero-emission goals.

Key Takeaways

- **Update regulations** regularly to reflect new technologies and EU requirements.
- **Invest in training** to build workforce expertise in smart building solutions.
- **Introduce financial incentives** (grants, tax breaks, loans) to drive renovations.
- **Raise public awareness** of long-term benefits of smart, energy-efficient buildings.
- **Foster collaboration** among government, private sector, and research bodies to scale innovation.

3.3. Comparative Legislation & Market Grid

The comparative table highlights clear differences between **EU member states (Italy, Greece, Slovenia)** and the **Western Balkans (Albania, Bosnia and Herzegovina: Republic of Srpska and Republic of North Macedonia,)** in advancing smart building envelope frameworks. It provides a structured overview of how each group approaches governance, EPBD/nZEB implementation, and market measures, making it easier to see where progress is converging and where further alignment with EU standards is still required.

Country	NECP / Governance	Buildings (EPBD / nZEB rules)	Market & Smart-Tech Measures
Albania	EU accession track; draft NECP (2025–2030 update) to integrate efficiency, RES, and emissions targets; obligations under the Energy Community.	Law 116/2016 (EPB Law) sets MEPRs and EPCs; NZEB concept introduced but definitions/enforcement evolving; KTP norms set minimum U-values (double glazing required, triple not yet).	No broad subsidies; financing reliance on donors/IFIs (EBRD GEFF, EU4Energy, IPA funds); municipalities piloting fast-track permits/tax reductions for green buildings; Green Innovation Fund in preparation.

Country	NECP / Governance	Buildings (EPBD / nZEB rules)	Market & Smart-Tech Measures
B&H, Republic of Srpska	EU candidate (2022), accession negotiations (2024); governance fragmented across entities, slowing harmonization.	Law on Energy Efficiency (2013) requires audits/certification; Law on Spatial Planning & Construction regulates permits/legalization; NZEB standards not yet integrated.	RES Law (2022) supports prosumers/joint prosumers; Construction Products Law enforces CE/"C" conformity; municipalities piloting smart city tools (GIS, LED, EMS).
Greece	NECP (2019/20) and Long-Term Strategy to 2050; EU Green Deal alignment; public sector leads with 2022–24 rules on temperatures, shading, EMS.	KENAK (2010, 2017) + TOTEE guidelines set U-values, EPCs, audits, and RES integration; national nZEB plan (2018) mandates >60% RES for hot water in new buildings.	Strong subsidies via "Exoikonomo" program; EPCs fully digital with smart-readiness indicators; public sector upgrades with shading/EMS; growing ESCO and smart-metering deployment.
Italy – Apulia	Regional implementation of national EU-aligned framework; Regional Law 13/2008 and ITACA Protocol (2017) push sustainability.	ITACA provides multi-criteria sustainability assessment; UNI/EN standards for glazing/shading; Law promotes sustainable components in public/private works.	CAM (mandatory GPP) drives market demand for sustainable materials/components; ITACA certification leverages beyond-minimum performance.
Italy – Molise	Regional framework via Laws 30/2009, 7/2015, 13/2015; consistent with EU acquis; focus on RES integration and energy-class performance.	Obligations link building extensions and benefits to energy-class improvements (up to A+); ≥60% DHW from RES; PV/biomass integration facilitated by simplified permits.	Fee reductions (−40% to −80%) and planning facilitation incentivize deep retrofits; explicit smart-glazing/shading rules not yet included—future opportunity.
North Macedonia	NECP 2022 anchors NDCs (−51% GHG vs 1990, coal exit by 2030); alignment with EU acquis underway, Fit-for-55 not yet fully integrated.	Energy Efficiency Law (2020–24) and bylaws mandate EPCs, HVAC inspections, and solar collectors for DHW; NZEB/nZEB definitions in place but long-term renovation strategy incomplete.	Smart Specialization Strategy promotes smart materials, BIM, IoT pilots; incentives and EE Fund under development; guidance foresees smart glazing/shading criteria in procurement.
Slovenia	NECP 2024 targets: −55% GHG by 2033, 33% RES by 2030, ≤50.2 TWh final energy; aligned with EU Fit-for-55; strong governance.	PURES 2022 + TSG-1-004:2022: QH ≤ 25 kWh/m²·a, QP ≤ 75 kWh/m²·a, ≥50% RES input; ventilation with heat recovery, overheating prevention, low-impact materials.	Robust support via Eco Fund grants/loans; mandatory GPP stimulates smart materials/efficient systems; self-supply and energy communities enable DER-ready smart envelopes; pilots integrate BIPV, triple glazing, and automated shading.

4. Best Practices and Pilot Projects

In this section the focus is on pilot projects or best practices involving nZEB and smart facades. These practices across the IPA-Adria region show that **nZEB retrofits and smart glazing technologies can deliver significant energy savings, improve comfort, and preserve cultural value**, while also building local capacity and awareness. Albania's university and housing retrofits demonstrate **30–60% savings** and scalable models for historic and mass housing; North Macedonia's smart city and habitat projects integrate **BIM, sensors, and renewable systems**; Bosnia and Herzegovina's municipalities are advancing **smart energy management through digital tools**; and Slovenia showcases leading examples like the **Eco Silver House, INFINITE retrofits, and BIPV-integrated facades** that meet EU nZEB criteria. Together, these pilots highlight the feasibility of advanced building technologies in the region and underline the need to **scale them into national renovation programs, supported by funding, skills development, and cross-border knowledge sharing**.

4.2.1 Albania

Albania's pilot projects show that **energy savings of 30–60%** in building needs are achievable through envelope interventions. However, **context matters**: solutions must be tailored to specific building types, such as discreet shading for heritage structures, affordable local materials for public facilities, and scalable retrofit packages for mass housing.

These pilots also play an important role in **capacity building**, raising awareness among architects, engineers, and students and generating momentum for wider adoption. The **next step** is to transition from isolated pilots to comprehensive **national renovation programs**, supported by adequate funding mechanisms and standardized designs to ensure large-scale impact. Below are selected projects.

nZEB Retrofit – Polis University (Tirana): Demonstrated that deep retrofits with local materials, high-performance glazing, and integrated shading can achieve **near-NZEB standards**, proving feasibility in Albania's context and highlighting the role of universities in innovation.

Historic Building Retrofit – Polytechnic University of Tirana: Showed how **smart glazing and automated interior shading** can deliver **20–30% energy savings** while preserving cultural heritage, offering a scalable model for Albania's many historic buildings.

Mass-Housing Retrofits – Tirana & Shkodra: Upgrading glazing, insulation, and shading in communist-era apartment blocks reduced heating/cooling energy use by **~56%**, demonstrating cost-effective retrofit packages for widespread housing stock.

4.2.2 Bosnia and Herzegovina: Republic of Srpska

In terms of practical application, two local strategies provide concrete examples of smart energy management.

The Municipality of Kozarska Dubica has invested in modern LED lighting for public spaces (cca. €1.3 mil.), and allocates funds for the maintenance and energy costs of this infrastructure. The municipality is also exploring the introduction of local district heating systems and the use of **low-carbon energy sour**ces, combined with **digital tools for operational efficiency**.

The City of Prijedor, through its SECAP and cooperation with international partners (e.g., GIZ and UNDP), implemented GIS-based energy management systems and launched projects such as Urban LED 2019. Its participation in the Smart City initiative demonstrates a clear commitment to the adoption of intelligent infrastructure and digital technologies to optimize energy usage in public buildings and urban systems.

4.2.3 North Macedonia

North Macedonia's **Smart Specialization Strategy (S3-MK)** promotes smart buildings through sustainable materials, energy-efficient infrastructure, and digital tools like **BIM**. Some good examples are the following:

Skopje 2020 Smart Strategy Program, initiative aiming to enhance urban sustainability through smart solutions, including energy-efficient buildings, monitoring sensors, and infrastructure digitalization. The projects under this strategy focus on reducing urban emissions by 40% by 2030, incorporating solar power plants, biogas installations, and smart urban interventions.

LIFE23-CET-OSS HABITAT Project, that develops integrated energy efficiency services for buildings, with pilot dwellings in three cities.

4.2.4 Slovenia

Slovenia has implemented a selection of best practices, in particular:

Eco Silver House, Ljubljana[42]: The Eco Silver House is a multi-residential high-rise building that exemplifies nZEB principles. Key features include:

- **Thermal Envelope**: High insulation standards with U-values of 0.17 W/(m²·K) for walls and 0.14 W/(m²·K) for the roof.
- **Windows**: Triple-glazed windows with U-values of 0.83 W/(m²·K).
- **Airtightness**: Measured at n_{50} = 0.45 h^{-1} to 0.59 h^{-1}, surpassing the design target of 0.6 h^{-1}.
- **Energy Performance**: Achieved a primary energy use of 79 kWh/m²/year, meeting Passive House design criteria.

[42] https://www.ekosrebrnahisa.si/

INFINITE Building Renovation Project[43]: The project focuses on retrofitting existing buildings to nZEB standards and aims to achieve a primary energy use of 58.5 kWh/m²/year, demonstrating the feasibility of deep energy retrofits in Slovenia. Innovative solutions include:

- **Prefabricated Wooden Facades**: Incorporating smart glazing, photovoltaic panels, and green facades.
- **Smart Windows**: Utilizing triple-glazed windows with external venetian blinds regulated by smart sensors.
- **Building-Integrated Photovoltaics (BIPV)**: Integrated into the facades and roof to meet energy needs.

Velenje Public Building Renovation[44]: In Velenje, the renovation of a public building under the eCentral Project showcases:

- **Energy Reduction**: Targeting a 65% reduction in energy consumption.
- **Renewable Energy Integration**: Utilizing district heating and solar power.
- **Innovative Financing**: Combining crowdfunding with traditional funding methods.

[43] https://iri.uni-lj.si/project/infinite/

[44] https://www.velenje.si/projects/ecentral/

Lumar Zero Emission Living®[45] demonstrate homes designed to meet nearly zero energy standards, with heat demand under 25 kWh/m²·a and utilization of solar panels and energy storage systems to achieve energy self-sufficiency.

TIGR4smart[46] is the best practice that focuses on development of **wood-based building systems, with i**ntegrated **intelligent control components** for smart building management, **innovative façade systems (including electrochromic window). The construction** of a **demonstration modular residential unit** showcasing all developed solutions.

[45] https://www.lumar.si/trajnost
[46] https://www.fgg.uni-lj.si/projekt-tigr4smart/

5. Gaps, Barriers, and Opportunities

5.1. EU Countries (Greece, Italy, Slovenia)

Gaps

- **Enforcement + skills, not laws.** Legal/technical frameworks are already mature (nZEB/EPC/RES integration, CAM/UNI in Italy; KENAK/TOTEE + nZEB plan in Greece; PURES+TSG in Slovenia), but delivery is uneven without stronger market surveillance and a bigger trained workforce for smart-envelope design, dynamic simulation, commissioning and O&M.
- **Financing friction for deep retrofits.** Public procurement (e.g., CAM in Italy) and national funds help, yet scaling deep, smart-envelope retrofits still hinder stable multi-year incentives and streamlined approvals, especially where RES and façade-PV intersect with planning rules.
- **Specification-to-construction gap.** Reference-building methods and U-value tightening are clear on paper (e.g., Greece's KENAK), but translating to high-quality installation (airtightness, junctions, smart controls integration) remains a common weak point.

Barriers

- Fragmented local permitting for façade PV/solar and shading retrofits; heritage constraints can slow envelope upgrades (Greece/Italy).
- Capacity shortages in dynamic modeling/BACS, and limited contractor familiarity with electrochromic glazing, façade-PV, and automated shading.

Opportunities

- **Scale-up levers exist now:** Italy's CAM to steer product choices; Greece's "Exoikonomo" and public-sector rules; Slovenia's Eco Fund + energy communities + updated PURES/TSG to mainstream smart envelopes.
- **Quick wins:** façade-PV on public/industrial roofs, external automated shading to tackle cooling peaks, and standardized smart-window packages aligned with nZEB/zero-emission trajectories.

5.2. Western Balkans (Albania, Bosnia & Herzegovina: Republic of Srpska, North Macedonia)

Gaps

- **Partial transposition & missing secondary rules.** North Macedonia still finalizing rulebooks, audits/EPC details and long-term renovation plans; alignment with Fit-for-55 remains pending.
- **Fragmented governance.** Bosnia & Herzegovina's entity-level split hinders a unified state framework; Republic of Srpska has EE/RES laws, but consistent state-level coordination is lacking.
- **Early-stage market for smart envelopes.** Albania's codes set baseline U-values, but shading/advanced glazing aren't yet mainstream; incentives rely heavily on donor programs.

Barriers

- **Compliance and capacity.** Shortages of auditors/designers skilled in smart façades; EPC enforcement uneven; limited local know-how on structural/smart glass.
- **Financing gaps.** Sparse domestic subsidy lines and ESCO uptake; municipalities depend on projects/IFIs (all countries).

Opportunities

- **Fast followers to EU recast EPBD.** Upcoming National Renovation Plans can be the vehicle to codify NZEB/zero-emission envelopes, training, and digitalization.
- **Pilot-to-program scaling.** BIM/IoT pilots (e.g., North Macedonia) and municipal energy-management projects (e.g., Republic of Srpska) can seed standardized smart-envelope packages for schools, hospitals, and mass housing.

Across the EU trio (Greece, Italy, Slovenia) and the Western Balkans (Albania, Bosnia & Herzegovina: Republic of Srpska and North Macedonia,), the core gap is no longer the existence of rules but consistent delivery: enforcement, skilled workforce, and finance to execute deep, smart-envelope renovations at scale. EU members have mature frameworks (nZEB/EPC/RES, product and procurement standards) but face bottlenecks in high-quality installation, dynamic simulation, BACS integration, and heritage-sensitive permitting.

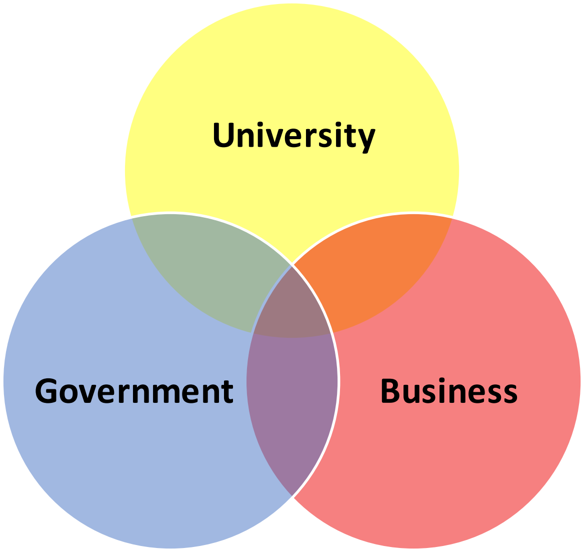
The Western Balkans are catching up on secondary legislation, audits/EPC rulebooks, and long-term renovation plans, with limited incentives and uneven capacity.

Common barriers include fragmented local permitting, scarce contractor familiarity with electrochromic glazing/façade-PV/automated shading, and financing friction for whole-building retrofits. The shared opportunity is to convert successful pilots and public-sector exemplars into standardized, fundable packages for façade-PV on large roofs/carports, automated external shading to cut cooling peaks, and smart-window bundles backed by multi-year finance, streamlined approvals, and targeted training that rapidly expands local supply chains.

6. Conclusions and Recommendations

Addressing these gaps and barriers requires a structured change management approach, and the Triple Helix model offers a useful framework to illustrate how effective collaboration between government and regulators, industry and market actors, and research and academia can drive the transformation of the building sector. The model implies the development of a trilateral network of organizational links, where universities and research institutions act as the main source of knowledge generation and dissemination. To commercialize research outcomes, link them with industrial processes, and foster new ventures, universities need to adopt an entrepreneurial role. Government, in turn, should provide strategic guidelines, implement direct and indirect measures, and ensure financing sources for R&D activities, particularly for projects of national importance that require significant investment. Industry's role is to concentrate resources on the commercial application of R&D, accelerating the market uptake of innovative solutions.

Triple Helix Diagram



By aligning these three spheres, the Triple Helix framework supports the implementation of the EPBD and promotes the adoption of smart glazing, digital controls, and other innovative building envelope solutions, ultimately advancing the transition towards zero-emission buildings. This approach is directly reflected in the **FENESTRAE project**, whose consortium is composed predominantly of universities and research institutions working alongside public authorities and market actors. The project aims to bridge regulatory requirements, technical innovation, and market implementation, making universities the central hub of knowledge and innovation, while enabling governments to provide strategic direction and firms to commercialize results for wide-scale impact across the IPA-ADRION region.

6.1. EU Countries (Greece, Italy, Slovenia)

Conclusions

These countries already operate within robust, enforceable frameworks: Italy couples EPBD/RED compliance with CAM/UNI standards and nZEB obligations; Greece has matured KENAK/TOTEE and moved to digital EPCs with public-sector leadership; Slovenia aligns NECP, PURES-2022 and TSG to drive nZEB/zero-emission envelopes. The bottleneck is:

- Execution at scale for high-quality installation,
- Skilled labor, and
- Stable finance rather than missing laws.

Priority Recommendations

Make delivery measurable. Tie permits and procurement bonuses to airtightness tests, SRI/BACS levels, and verified overheating control; expand market surveillance for EPC/APE quality.
Skill up the chain. Fund regional training/credentialing in dynamic simulation, façade integration (EC glazing, external shading, BIPV), and commissioning—using Italy's CAM and Slovenia's Eco Fund calls as demand signals.
De-risk deep retrofits. Lock multi-annual grants/soft loans; fast-track façade-PV/shading permits (heritage-sensitive templates) to compress timelines.
Standardize public stock. Issue reference smart-envelope "kits" for schools/offices (triple/EC glazing + automated external blinds + BACS) aligned to nZEB/zero-emission targets.

6.2. Western Balkans (Albania, Bosnia & Herzegovina: Republic of Srpska, North Macedonia)

Conclusions
Ambition is high, and the legal base exists in all three WB countries, but secondary regulations, enforcement, and finance remain the main hindrance. Municipal pilots show isolated initiatives for smart solutions; now the task is to codify, fund, and replicate across building typologies.

Priority Recommendations

Complete the rulebook stack. Finalize EPC/audit methods, long-term renovation strategies, and NZEB/zero-emission definitions; publish façade/shading/EC-glass guidelines compatible with EPBD cost-optimality.
Create predictable finance. Stand up/expand EE Funds and ESCO models; blend EU/IFI lines (GEFF, IPA) with municipal programs to co-finance standardized envelope packages for housing/public buildings.
National pilots → programs. Convert BIM/IoT and municipal EMS pilots into countrywide schemes with pre-approved technical solutions (glazing classes, automated shading, ventilated/green façades, façade-PV) and design catalogues.

Target skills + supply chains. Launch short courses with universities and chambers on smart envelopes; support local assembly/installation capacity for glazing, shading, and BACS to reduce costs and delays.
One-stop governance. In Republic of Srpska, strengthen state-level coordination and data to harmonize planning, monitoring and product conformity (CE/EN) across entities.

As a bloc, these six countries have the policy scaffolding to decarbonize building envelopes; the EU members must focus on execution quality and speed, while the Western Balkans must finalize alignment (EPBD/EED/RED), strengthen enforcement, and stand-up predictable funding. Priority moves that work across the region are: make delivery measurable (airtightness/overheating/SRI checks tied to permits and procurement), skill up the market (short courses and credentials in dynamic modelling, smart glazing, shading, BIPV and commissioning), de-risk deep renovations with stable grants/soft loans and heritage-ready templates, and scale public-stock "reference kits" (triple/EC glazing + automated external blinds + BACS) that can be replicated in schools, hospitals, and housing. Converting pilots into national/regional programs, blending EU/IFI lines with local funds, and coordinating governance (especially in B&H) will unlock faster uptake of smart, energy-efficient envelopes and keep all six countries on track for 2030 targets and a zero-emission building trajectory.

7. References

A.G. Gaglia, E.N. Dialynas, A.A. Argiriou, E. Kostopoulou, D. Tsiamitros, D. Stimoniaris, & K.M. Laskos. (2019). *Energy performance of European residential buildings: Energy use, technical and environmental characteristics of the Greek residential sector – Energy conservation and CO_2 reduction. Energy and Buildings, 183,* 86–104. https://doi.org/10.1016/j.enbuild.2018.10.042

A.G. Gaglia, A.G. Tsikaloudaki, C.M. Laskos, E.N. Dialynas, & A.A. Argiriou. (2017). *The impact of the energy performance regulations' updates on the construction technology, economics and energy aspects of new residential buildings: The case of Greece. Energy and Buildings, 155,* 225–237. https://doi.org/10.1016/j.enbuild.2017.09.008

Carvalho, C., Cleto, J., Monteiro, C., Fernandes, J., & Fragoso, R. (n.d.). *EPBD.wise: Energy Performance Certificates policy needs and best practices.*

Dascalaki, E.G., Balaras, C.A., Gaglia, A.G., Droutsa, K.G., & Kontoyiannidis, S. (2012). *Energy performance of buildings—EPBD in Greece. Energy Policy, 45,* 469–477. https://doi.org/10.1016/j.enpol.2012.02.058

Centre for Renewable Energy Sources and Saving (CRES). (n.d.). *EnergyHUB for All.* http://www.cres.gr/energyhubforall/index.html

Ministry of Environment and Energy, Hellenic Republic. (2024). *National Energy and Climate Plan (NECP).*

Ministry of Environment and Energy, Hellenic Republic. (2020). *Long-Term Strategy for 2050.*

Miloshevska Janakieska, M. (2019). *Glass facades' influence on certain parameters of sustainability of buildings.* https://plus.cobiss.net/cobiss/adz/sl/bib/3171721?ds=true

Official Journal of the Hellenic Republic. (2017). *Approvement of the Regulations on Energy Performance in the Building Sector (FEK B' 2367/2017).*

Official Journal of the Hellenic Republic. (2010). *Approvement of the Regulations on Energy Performance in the Building Sector (FEK B 407/2010).*

Official Journal of the Hellenic Republic, TOTEE-2, "Thermophysical properties of building materials and the adequacy control of thermal insulation of buildings"

Official Journal of the Hellenic Republic, TOTEE-3, “Hellenic climate data”

Official Journal of the Hellenic Republic, TOTEE-4, “Guidelines and forms for the energy audits of buildings, heating systems and air-conditioning systems”

Official Journal of the Hellenic Republic, Corrected TOTEE, “Error Corrections”

Official Journal of the Hellenic Republic, TOTEE-1, “Analytical national specifications of the parameters for calculating the energy performance of buildings and issuing an energy performance certificate”

Official Journal of the Hellenic Republic, FEK 4003/B/17.11.2017, “Approvement and implementation of the Technical Instructions TEE for the Energy Performance of Buildings”

Official Journal of the Hellenic Republic, FEK 5447/B/2018, “Approvement of the national plan to increase the number of buildings with Nearly Zero Energy Conservation”

Official Journal of the Hellenic Republic, FEK 2692/B/2024, “Measures for the energy efficiency’s enhancing and the energy conservation for buildings which belong or used from the public sector”

Official Journal of the Hellenic Republic, FEK 5432/B/2020,"Definition of the types and technical specifications for the construction of greenhouses and mushroom cultivation chambers, as well as greenhouses and greenhouse-type chambers for medicinal cannabis, and the procedure for their approval and inspection"

Government of the Republic of Slovenia. (2024). *Updated Comprehensive National Energy and Climate Plan (NECP 2024)*. Retrieved October 17, 2025, from https://www.gov.si/zbirke/projekti-in-programi/nacionalni-energetski-in-podnebni-nacrt/ Portal GOV.SI

Energy Portal Slovenia. (n.d.). *Comprehensive National Energy and Climate Plan 2024* [in Slovenian]. Retrieved October 17, 2025, from https://www.energetika-portal.si/dokumenti/strateski-razvojni-dokumenti/nacionalni-energetski-in-podnebni-nacrt-2024/ Energetika Portal

Government of the Republic of Slovenia. (2020). *Comprehensive National Energy and Climate Plan (NECP 2020)*. Retrieved October 17, 2025, from https://www.gov.si/novice/2020-02-27-vlada-je-sprejela-celoviti-nacionalni-energetski-in-podnebni-nacrt-republike-slovenije/ Portal GOV.SI

European Commission. (n.d.). *Reform of the Promotion of Renewable Energy Sources in Slovenia*. Retrieved October 17, 2025, from https://commission.europa.eu/projects/reform-promotion-renewable-energy-sources-slovenia_en European Commission

European Commission, Directorate-General for Environment. (2022, September 9). *EU Ecolabel – Slovenia User Manual* (Publication). Retrieved October 17, 2025, from https://environment.ec.europa.eu/publications/eu-ecolabel-slovenia-user-manual_en environment.ec.europa.eu

Republic of Slovenia. (n.d.). *Regulation on the management of waste generated during construction works* (Uredba o ravnanju z odpadki, ki nastajajo pri gradbenih delih). Retrieved October 17, 2025, from http://www.pisrs.si/Pis.web/pregledPredpisa?id=URED4788 Cinderela cinderOSS+1

Republic of Slovenia. (n.d.). *Regulation on the management of waste containing asbestos* (Uredba o ravnanju z odpadki, ki vsebujejo azbest). Retrieved October 17, 2025, from http://www.pisrs.si/Pis.web/pregledPredpisa?id=URED4787 Cinderela cinderOSS

Republic of Slovenia. (n.d.). *Regulation on the treatment of waste in mobile devices* (Uredba o obravnavi odpadkov v mobilnih napravah). Retrieved October 17, 2025, from http://www.pisrs.si/Pis.web/pregledPredpisa?id=URED4790 Cinderela cinderOSS

Republic of Slovenia. (n.d.). *Batteries Regulation (EU) Implementation* (Uredba o izvajanju Uredbe (EU) o baterijah in odpadnih baterijah). Retrieved October 17, 2025, from PISRS (Slovenian legislative portal) envenance-global.com

Jovović, I., Hrovatin, N., & Zorić, J. (2025). *The role of energy performance certificates and energy-related financial literacy in choosing an energy-efficient home: Evidence from Slovenian homeowners*. *Energy Efficiency, 18*, 30. https://doi.org/10.1007/s12053-025-10320-6 SpringerLink

Interreg IPA CBC , AWESOME: Agricultural WastE as Sustainable 0 km building MatErial https://awes0me.italy-albania-montenegro.eu/

Interreg IPA South Adriatic, AWESOME PLUS SA-0100231 : Agricultural WastE as Sustainable 0 km building MatErial PLUS

8. Appendices

Albania: Summary European Framework and National Framework

Aspect	European Union (EU)	Albania (Candidate Country)
Public Sector Lead	3% annual renovation of public buildings (floor area)	3% annual renovation goal for central government buildings (policy goal, not strictly enforced)
Energy Performance Certificates	Mandatory for buildings at sale/rent; common EU EPC format by 2025	Mandatory for new and public buildings; expanding to others gradually (compliance limited)
Nearly Zero-Energy Buildings	All new buildings NZEB/ZEB by 2030; public buildings by 2028	NZEB defined on paper (Law 116/2016) with some pilots, but not yet widely enforced
Energy Audits & Services	Large companies must do audits; ESCO markets promoted (per EED)	Audits required for big energy users; ESCO legal basis exists but market nascent
Lead Institutions	European Commission (DG ENER, DG CLIMA); national ministries in each Member State	Ministry of Infrastructure and Energy; National Energy Efficiency Agency
Implementation Plans	National Energy & Climate Plans (NECPs) by each Member State, updated every 10 years	NECP draft prepared (first version 2021); final update expected by 2024
Funding Mechanisms	Substantial EU funds: Recovery Fund, Cohesion Funds, Horizon Europe, LIFE, etc.	Heavily dependent on international donors: EU IPA, EBRD, KfW, World Bank
Policy Maturity	High – decades of evolving directives, standards, and market experience	Evolving – solid laws in place, but experience and enforcement still developing
Public Awareness	Moderate to high – EU-wide campaigns and incentive programs have raised awareness	Low – limited outreach; efficiency not yet a public priority, though growing interest

Greece: Summary European Framework and National Framework

European framework	National framework
	1979: Regulation of Building's Thermal Insulation (TIR). *1998*: Regulation on rational use and energy conservation in buildings (KOXEE).
European Directive 2002/91	*2008*: Law 3661/2008 *2010*: FEK 407/B/2010, Regulation on Energy Performance in the Building Sector (KENAK 2010). *2010*: Presidential Decree (PD) on energy inspectors.
European Directive 2006/32	*2008*: Minister Decision (MD) for the public buildings. *2008*: 1st NEEAP *2010*: Law 3855/2010 *2011*: Minister Decision (MD) for the ESCOs.

	2011: 2nd NEEAP.
European Directive 2009/28	*2010*: Law 3851/2010
European Directive 2010/31	*2013*: Law 4122/2013 *2017*: FEK B 2367/2017, Approvement of the regulations on Energy Performance in the Building Sector. *2017*: FEK B 4003/2017, The mandatory application of the regulations on Energy Performance in the Building Sector (KENAK 2017). *2024*: FEK B 2692/2024, Measures for the energy efficiency's enhancing and the energy conservation for buildings which belong or used from the public sector.
European Directive 2012/27	*2015*: Law 4342/2015 *2024*: FEK B 2692/2024, Measures for the energy efficiency's enhancing and the energy conservation for buildings which belong or used from the public sector.
European Directive 2013/30	*2016*: Law 4409/2016
European Directive 2018/844	*2018*: FEK B 5447/2018, Approvement of the national plan to increase the number of buildings with nearly zero Energy Conservation.

Republic of North Macedonia: Summary European Framework and National Framework

Policy/Plan/Study	**Implementation Status**	**Recommendations**
National Energy and Climate Plan (NECP)	71%	Adopted in May 2022, being updated to ensure full compliance with provisions of Governance Regulation. • Policy Measure PM_D23 Photovoltaic power plants on the roof • Policy Measure PM_D24 Solar thermal collector systems
Greenhouse Gas 2030 Target	80%	The 2030 climate target is not defined in national legislation but is included in NECP.
National Systems for Climate Reporting	40%	A national system for Policies and Measures (PaMs) and projections still needs to be established. North Macedonia has initiated reporting on national systems for policies & measures and projections but has yet to submit a report. Updated report is under development.
Long-Term Strategy and Climate Neutrality	44%	The legal basis for a long-term strategy has not been adopted. Nonetheless, North Macedonia has submitted the long-term strategy to the UNFCCC Secretariat in 2021. However, it does not contain the 2050 climate neutrality objective.
Energy Efficiency – Overall Implementation 66%		
2030 Energy Efficiency Targets and Policy Measures	69%	The 2030 energy efficiency targets in the adopted NECP are aligned with the 2030 targets set by the Energy Community. The 2020 Law on Energy Efficiency transposed the 2012 Energy Efficiency Directive and set the specific targets required under Articles 5 and 7. However, the proposed amendments to the Law, intended to align it with the Clean Energy Package requirements and the 2018 Energy Efficiency Directive, are still awaiting approval.
Directive on Energy	51%	The Law on Energy Efficiency transposed the 2010 Energy Performance of Buildings Directive, but it is not fully aligned with the 2018 amendments, i.e. Directive (EU) 2018/844. The adoption of drafted rulebooks on energy audits

Efficiency[47] and Directive on Energy Performance of Buildings (2023/1791); (2024/1275)[48]		of buildings and the energy performance of buildings is still pending. The long-term building renovation strategy has still not been finalized. • Energy audits and energy management systems • This is a potential, according to Art. 15 (2024/1275), assessment of the Smart readiness of buildings.
Energy Efficiency Scheme and Financing	61%	North Macedonia should adopt the amendments of the Law on Energy Efficiency and update the specific targets required in Article 35, introduced previously in 2020. It is in the process of setting up a National Energy Efficiency Fund, and the related law is in the parliament procedure. In October 2023 the amendments of the Law on the Development Bank of RS Macedonia were adopted establishing the legal framework for the Fund to be established in the Development Bank. The legal and regulatory framework for its operationalization remains to be adopted.
Energy Efficient Products – Labelling	76%	Rulebooks implementing Directive 2010/30/EU were adopted. Rulebooks implementing the Framework Labelling Regulation (EU) 2017/1369 and implementing acts on labelling are under preparation
Efficiency In Heating and Cooling	74%	In December 2022, North Macedonia added provisions for inspecting heating and air conditioning systems in the Law on Energy Efficiency. While the Transposition of District Heat Metering and Billing Provisions is in place, full implementation of consumption-based billing in Skopje's district heating system is lacking. Studies showed that consumption-based billing is not cost-efficient under current conditions but could be effective in new buildings. In 2023, the government introduced subsidies to improve energy efficiency, promote renewable energy, and transition to natural gas, benefiting around 2,500 households.
Directive 2004/107/EC	85%	Transposed with accompanying rulebooks
National Emission Reduction Plan[49]	100%	Adopted in 2017, has been implemented since January 2018, yet the goals set have to be further tackled
National Emission reduction Commitments Directive[50]		Adoption planned for 2019, of which some obligations were implemented, and some are still to be addressed
4th National Energy Efficiency Action Plan[51]		• Promoting the use of RES in a way that ensures sustainable development. • Stimulating RES for electricity generation • Electrification of the heating and cooling sector by using more efficient heat pumps
Renewable Energy Implementation – Overall 48%		

[47] Available at link
[48] Available at link
[49] Available at link
[50] Available at link
[51] Available at link

2030 Renewable Energy Targets	85%	North Macedonia aims to achieve a 38% share of renewable energy in its total energy consumption by 2030, in line with the Energy Community's target.
Renewable Energy In Heating And Cooling	33%	Subsidy programs for households to replace inefficient fossil fuel and biomass appliances with efficient heat pumps are in place, supporting the NECP's goal of 24% heat demand from heat pumps by 2030. Adopting a renewable energy law is crucial to promote renewable energy and waste heat in district heating, with further measures outlined in the NECP update to integrate these into Skopje's district heating system.
Directive 2018/844/EU: Smart technologies		Introduction of smart budlings and promoting introduction of smart technologies in buildings

Slovenia: Summary European Framework and National Framework

European framework	National framework
European Directive 2002/91	2008: Regulation on Efficient Use of Energy in Buildings (PURES 2008) 2010: Energy Act EZ-1
European Directive 2006/32	2014: Second Energy Efficiency Action Plan (AN URE 2020) 2015: Decree on Efficient Energy Use in the Public Sector
European Directive 2009/28	2020: National Energy and Climate Plan (NECP)
European Directive 2010/31	2017: PURES 2017
European Directive 2012/27	2023: Energy Efficiency Act (ZURE)
European Directive 2018/844	2024: Decree on Improving Energy Efficiency in Public Buildings

Italy: Summary of European framework and national framework

European Framework	National framework
• Directive 93/76/EEC (SAVE) •	• Legislative Decree 192/2005 transposed EPBD 2002/91/EC;
• Directive 2002/91/EC on the Energy Performance of Buildings first EPBD,	• Legislative Decree 311/2006
• Directive 2010/31/EU (Recast EPBD) replaced 2002/91/EC.	• Presidential Decree 59/2009 & Ministerial Decree 06/2009

• Directive (EU) 2018/844 amending EPBD 2010/31/EU	• Legislative Decree 28/2011 (Renewables
• Delegated Regulation (EU) 2020/2155 supplementing Directive 2010/31/EU	• Decree) implemented RED 2009/28/EC;
• Implementing Regulation (EU) 2020/2156	• Decree 63/2013 (Law 90/2013) transposed EPBD recast 2010/31/EU; replaced ACE with APE
• Directive (EU) 2024/1275 (new EPBD)	• Three Decrees (2015)
Molise regional framework: • Regional Laws 30/2009, • Regional Laws7/2015, and 13/2015	

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The preparation of the analyses, coordination of inputs, and final compilation were jointly implemented by the project partners (PP) of FENESTRAE, with a strong commitment to ensuring quality, accuracy, and policy relevance.

The team from **PP7 – Centre for Research and Analysis NOVUS** led the coordination, preparation, and consolidation of the document under the supervision of:

- **Gjorgi Milushev**, President of Centre for research and analysis NOVUS
- **Marija Taseva**, Programme Manager of Centre for research and analysis NOVUS

Significant analytical and expert contributions were provided by **MACEF – Macedonian Center for Energy Efficiency**, represented by:

- **Makedonka Dimitrova**, Adjunct Lecturer, School of Business Economics & Management, University American College Skopje; Co-founder/Senior Researcher in Sustainable Growth, Macedonian Centre for Energy Efficiency

- **Prof. Dr. Todorka Samardžioska**, Faculty of Civil Engineering - Skopje, Ss. Cyril and Methodius University

- **Prof. Dr. Konstantin Dimitrov**, Faculty of Mechanical Engineering - Skopje, Ss. Cyril and Methodius University; Co-founder/Senior Researcher, Macedonian Centre for Energy Efficiency

The team from **LP1 – Politecnico di Bari** completed the data preparation on the legislation in Italy.

The work was carried out by:

- **Prof. Ubaldo Ayr**, Researcher in Building Physics

- **Dr. Alessandro Cannavale**, Senior Research Fellow

- **Dr. Stefania Liuzzi**, Assistant Professor in Building Engineering
- **Dr. Chiara Rubino**, Research Associate

under the supervision of:

- **Prof. Francesco Martellotta**, Project Manager and Full Professor of Environmental Technical Physics

The team from **PP2 – GAL Molise** coordinated and prepared the completion of the document.

Contributions were provided by:

- **Mr. Adolfo Colagiovanni**, President of GAL Molise
- **Mr. Roberto D'Amico**, Project Manager
- **Mr. Alessandro Di Lallo**, Research and Development Expert
- **Mrs. Cinzia De Letis**, Communication and Dissemination Specialist

The team from **PP3 – University of Ljubljana, Faculty of Electrical Engineering** led the coordination, preparation, and consolidation of the document.

Significant analytical and expert contributions were provided by:

- **Marija Drev**, Researcher, Faculty of Electrical Engineering, University of Ljubljana
- **Mateja Hočevar**, Researcher, Faculty of Electrical Engineering, University of Ljubljana
- **Urša Opara Krašovec**, Researcher, Faculty of Electrical Engineering, University of Ljubljana

The **PP4 partner – Department of Physics, University of Patras** was responsible for delivering the available legislation in the Greek region.

Document preparation and editing were conducted by:

- **Asst. Prof. Dr. Georgios Syrrokostas**, Department of Physics, University of Patras
- **PhD(c) Ms. Eleftheria Merkoulidi**, Department of Physics, University of Patras
- **PhD(c) Mr. Georgios Rellias**, Department of Physics, University of Patras

The team from **PP5 – BIZNES ALBANIA** completed the data preparation on the legislation in Albania.

The work was carried out by:

- **Ergys Gezka,** Project Coordinator
- **Ida Borrelli**, Project Assistant

The team from **PP6 – Agricultural Cooperative Smart Village Knežica** completed the data preparation on the legislation in Bosnia and Herzegovina (Republic of Srpska).

The work was carried out by:

- **Đorđe Grujčić**, Project Manager
- **Jelena Matijaš**, Project Assistant

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