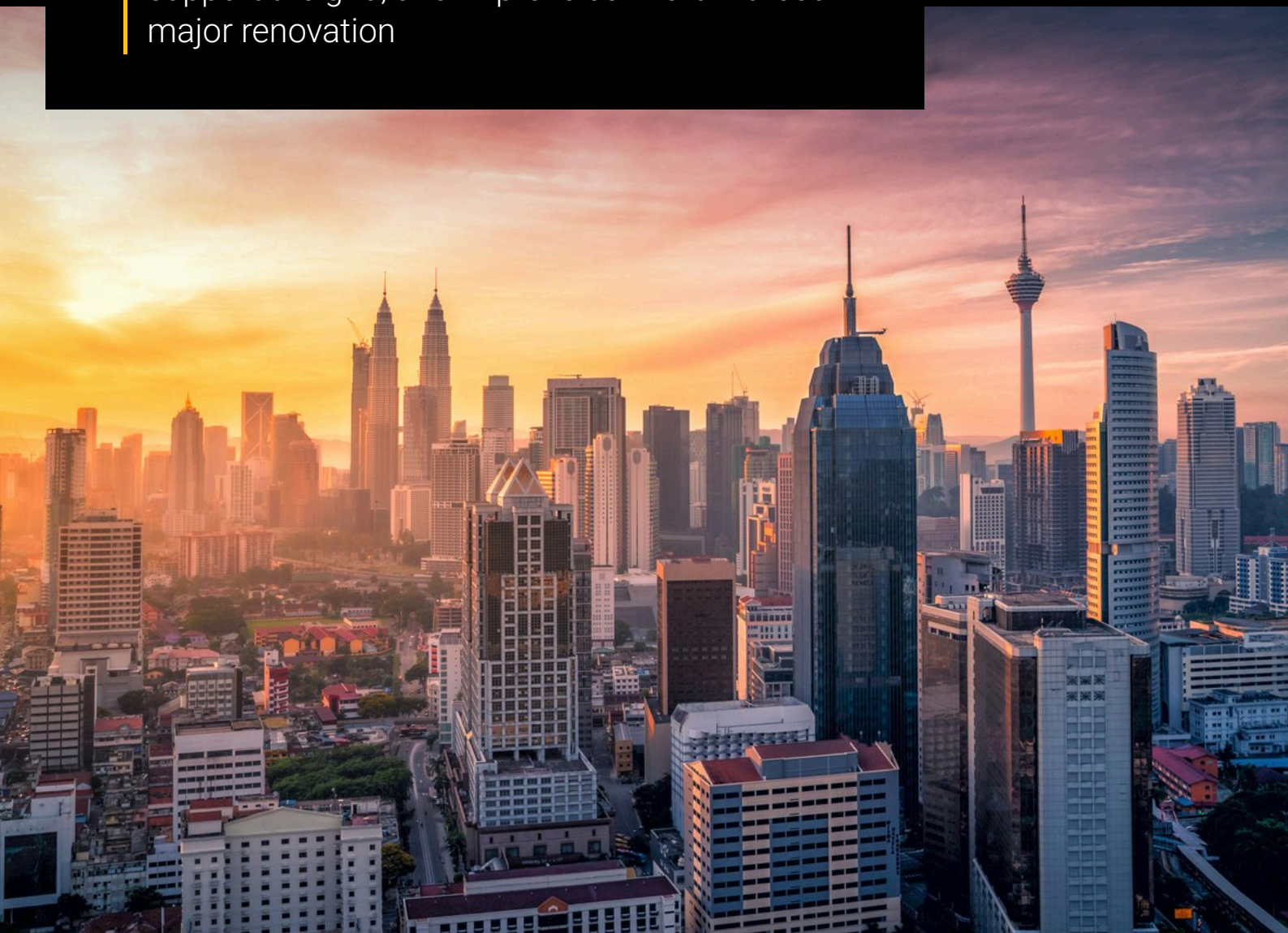
COLLECTiEF

Smart buildings for a flexible and resilient energy system

COLLECTiEF helps buildings reduce energy use, support the grid, and improve comfort without major renovation



Key messages for decision-makers

- Intelligent control can reduce building energy use by **18–35%** and peak demand by up to **50%**
- Existing buildings can become **active energy system participants**, without costly infrastructure upgrades
- The solution has been **demonstrated in real buildings across Europe**
- A **market-ready system and business approach** enables large-scale deployment
- Capacity building and stakeholder engagement are essential to unlock uptake

The challenge: buildings in a changing energy system

Europe's energy system is transitioning towards decarbonisation, driven by increased use of renewable energy sources such as solar and wind. While essential, these sources introduce variability in energy supply and require more flexible demand.

At the same time:

- demand peaks stress energy infrastructure
- extreme weather increases heating and cooling needs
- existing buildings remain largely passive



Buildings represent both a challenge and an opportunity.

Today, they:

- consume a large share of energy
- operate with limited responsiveness

But with the right solutions, they can:

- adjust consumption dynamically
- support renewable integration
- reduce pressure on energy networks



> **COLLECTiEF demonstrates how this transformation can be achieved.**

The COLLECTiEF solution

COLLECTiEF is an interoperable and scalable energy management system designed to transform buildings into active and intelligent energy assets.

It combines:

- adaptive control algorithms
- a digital system connecting building components
- user interfaces enabling interaction and control

The system continuously adapts building operation based on:

- indoor conditions
- weather
- energy prices
- user preferences

How it works

At the core of COLLECTiEF is a decentralised control approach, where individual zones or devices act as intelligent agents, making decisions locally while contributing to system-level objectives such as energy efficiency, flexibility, and comfort.

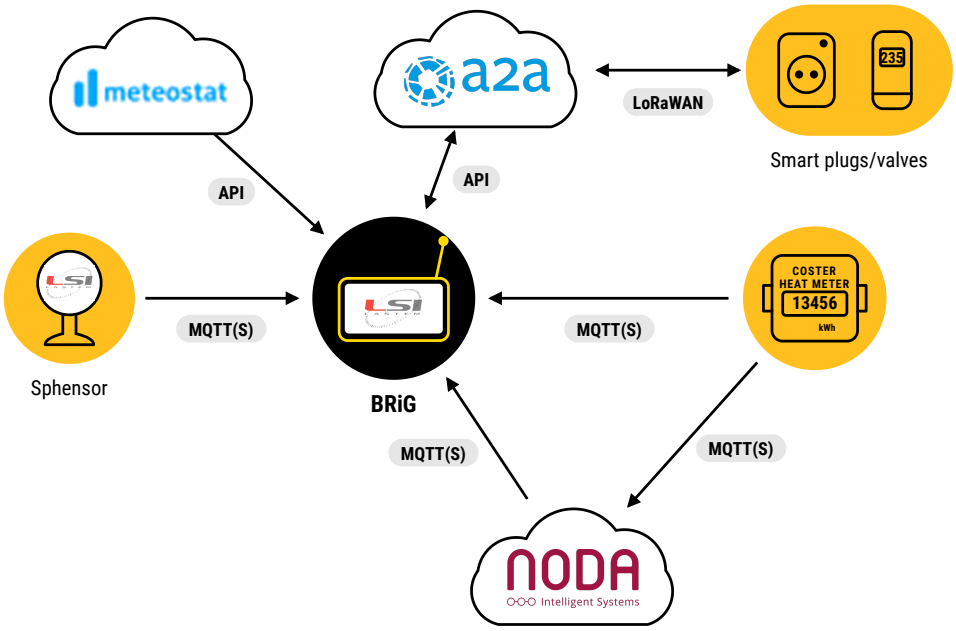


Figure 1 Example of the COLLECTiEF infrastructure in the Italian pilot buildings

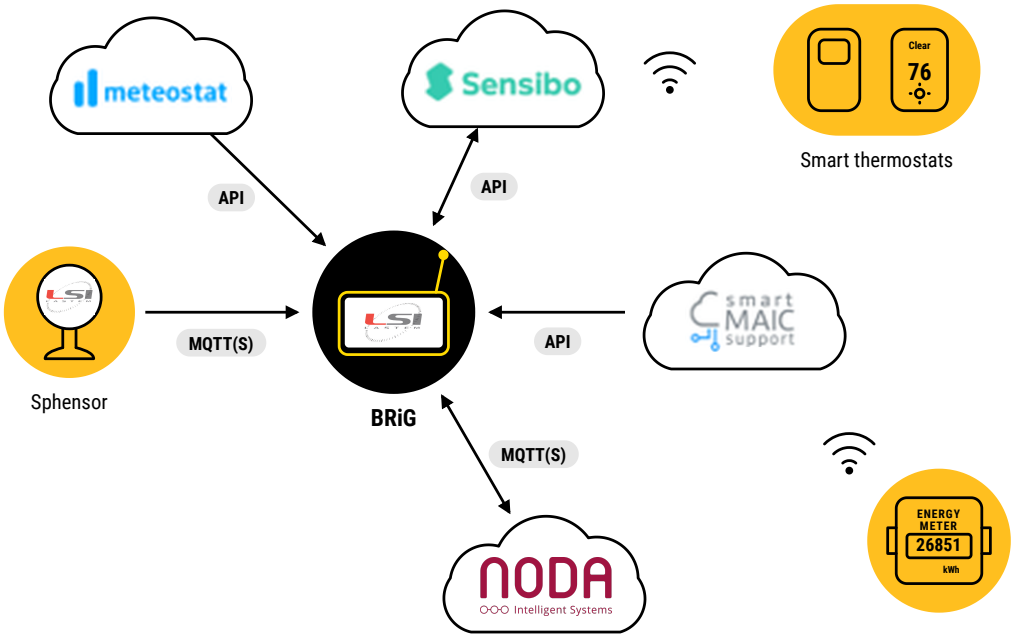


Figure 2 Example of the COLLECTiEF infrastructure in the Cypriot pilot building

Collective Intelligence

Most smart building systems optimise the operation of a single building using centrally managed data and control. COLLECTiEF takes a different approach.

Inspired by the collective behaviour observed in nature, where groups of individuals work together to achieve better outcomes than any single individual could achieve alone, COLLECTiEF applies the concept of collective intelligence to energy management. Instead of relying on a central controller, different building zones, devices, and systems act as intelligent agents that make local decisions while cooperating towards shared objectives.

This approach enables buildings to:

- respond more effectively to changing conditions;
- reduce the amount of data that needs to be exchanged;
- protect user privacy by keeping sensitive information local;
- improve energy flexibility while maintaining occupant comfort.

By allowing many individual building components to work together as a coordinated network, COLLECTiEF creates a smarter, more resilient, and more scalable approach to building energy management that can be deployed across large numbers of existing buildings.

System architecture

Buildings are equipped with sensors and connected through a digital platform that:

- collects data (temperature, humidity, energy use)
- processes information
- sends control signals to building systems



User interfaces allow:

- occupants to adjust preferences
- facility managers to monitor performance
- operators to manage clusters of buildings

Proven impact

COLLECTiEF demonstrates that significant improvements in building performance can be achieved **through smarter control of existing systems.**

Energy and cost savings

Across simulations and experimental validation:

- **18–35% reduction in total energy demand**
- **5–25% reduction in heating demand**
- **15–32% reduction in cooling demand**

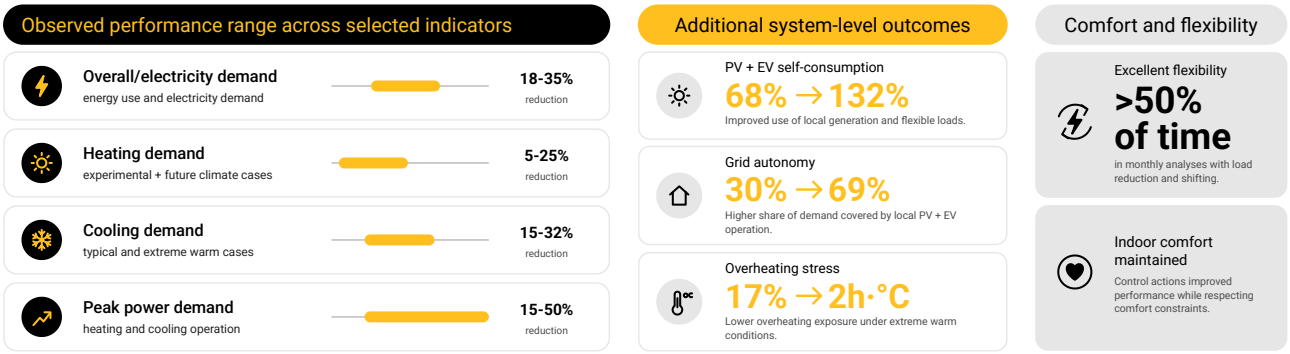


Figure 3 Overall performance range observed across selected indicators. Depending on the case, COLLECTiEF control reduced overall electricity or energy demand by 18-35%, heating demand by 5-25%, cooling demand by 15-32%, and peak power demand by 15-50%.

These results highlight that **substantial energy savings can be achieved without major renovation**, providing a cost-effective pathway to improving building performance.

Grid support and flexibility

COLLECTiEF enables buildings to actively support the energy system:

- **Up to 50% reduction in peak electricity demand**
- improved alignment with renewable energy production
- increased participation in demand-side flexibility



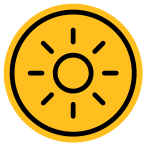
This reduces:

- stress on energy infrastructure
- the need for costly grid expansions

Better use of renewable energy

The system improves local energy optimisation by:

- increasing self-consumption of renewable energy
- improving coordination between demand and generation



Results include:

- increased self-consumption indicators
- increased grid autonomy (from **30% to 69%)**

Comfort and indoor environmental quality

COLLECTiEF ensures that energy improvements do not compromise user wellbeing.

The system continuously monitors:

- thermal comfort
- indoor air quality
- environmental conditions



User feedback is integrated through surveys, ensuring that optimisation aligns with occupant needs.

Climate resilience

COLLECTiEF has been evaluated under future climate scenarios, including extreme conditions.

Results show:

- reduced overheating risk
- maintained performance during extreme weather
- improved adaptability to climate stress



Proven in real-life conditions

COLLECTiEF has been tested in real buildings across Europe. These pilot sites represent a wide range of climates, building uses, and technical configurations:

- **Norway**: schools, healthcare centres, public buildings
- **Italy**: residential buildings
- **Cyprus**: offices, classrooms, laboratories
- **France**: testing and validation environments



Figure 4 Location of the COLLECTiEF pilot sites

Implementation in practice

Buildings were equipped with measurement and control technologies, including:

- Sensors for indoor conditions (temperature, humidity, CO_2)
- Systems for monitoring energy consumption
- Devices enabling control of heating and cooling

The solution was integrated with existing systems and infrastructure, allowing it to operate in real conditions without requiring major renovations or upgrades.



Figure 5 COLLECTiEF equipment being installed and in operation in the pilot buildings

Key takeaways

All pilot buildings improved their Smart Readiness, showing they are better equipped to interact with the energy system. This ensures that results are reliable, comparable, and relevant for policy decisions

The pilots demonstrate that COLLECTiEF:

- Works across different climates and building types
- Can integrate with diverse technologies and systems
- Delivers measurable results in real-life operation

This confirms the feasibility of applying the solution at larger scale.

Scalability & replication

To ensure the reliability of the results, COLLECTiEF applied a structured and comprehensive evaluation framework.

The system was assessed across multiple dimensions:



Figure 6 COLLECTiEF system assessment domains

The evaluation combined: measured data from pilot sites and simulation-based analysis.

Smart readiness evaluation

The project also assessed the **Smart Readiness Indicator (SRI)** of the pilot buildings, both before and after implementation.

Results show that all pilot buildings achieved at least a **one-class improvement in smart readiness**

This indicates an increased ability of buildings to:

- Adapt to user needs
- Optimise energy use
- Interact with the energy system



Integrated assessment framework

The use of a structured and transparent evaluation framework ensures that COLLECTiEF results are:

- Reliable and evidence-based
- Comparable across different building types and locations
- Relevant for policy and decision-making

From project to market

COLLECTiEF has been developed with a clear focus on scalability and real-world deployment.

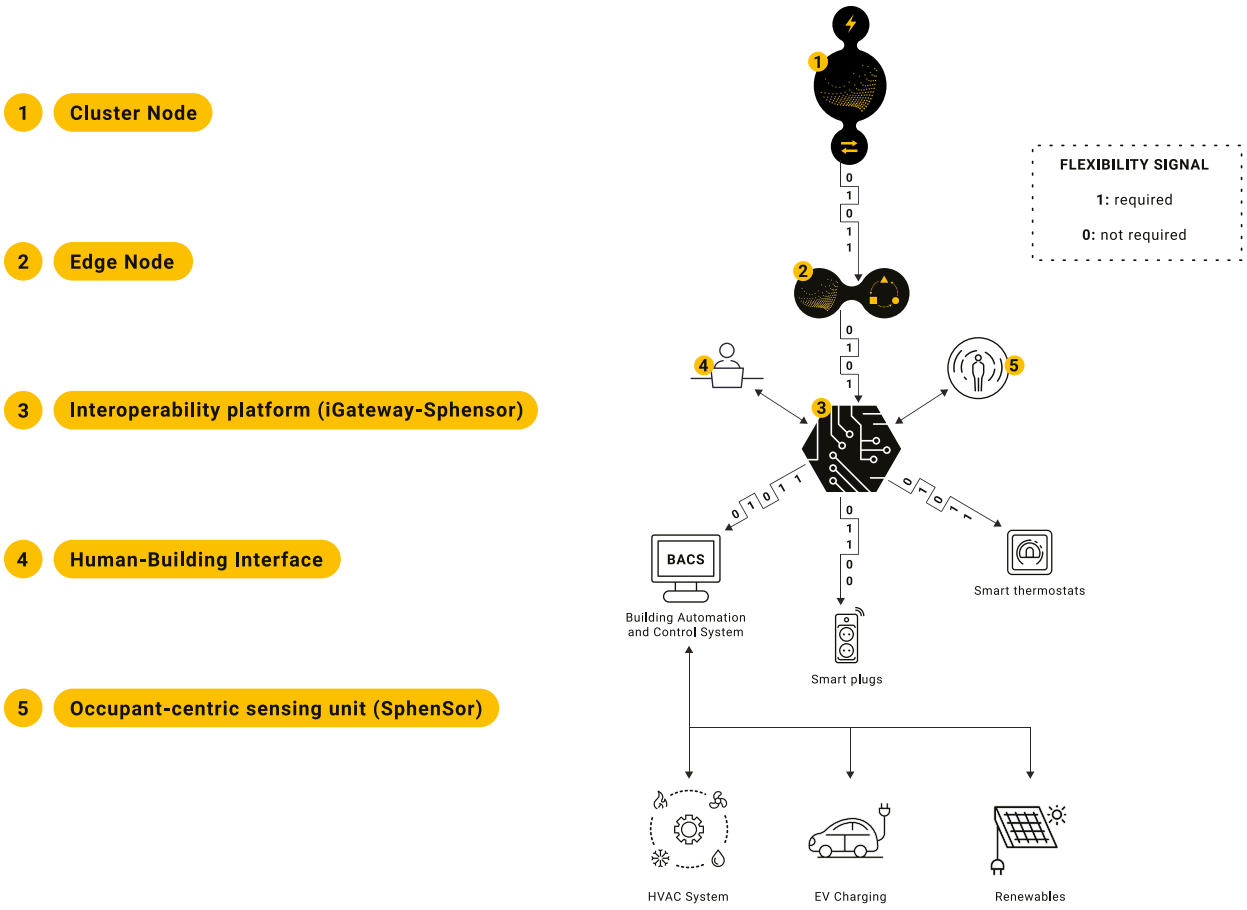


Figure 7 Main project results and MVP

A market-ready solution

A minimum viable product has been defined, consisting of:

- a control device integrating the system intelligence
- a user interface for monitoring and interaction
- integration services for existing building systems
- optional sensing components where needed

The system can be applied:

- at the level of a single building
- across multiple buildings, enabling coordinated control at cluster level

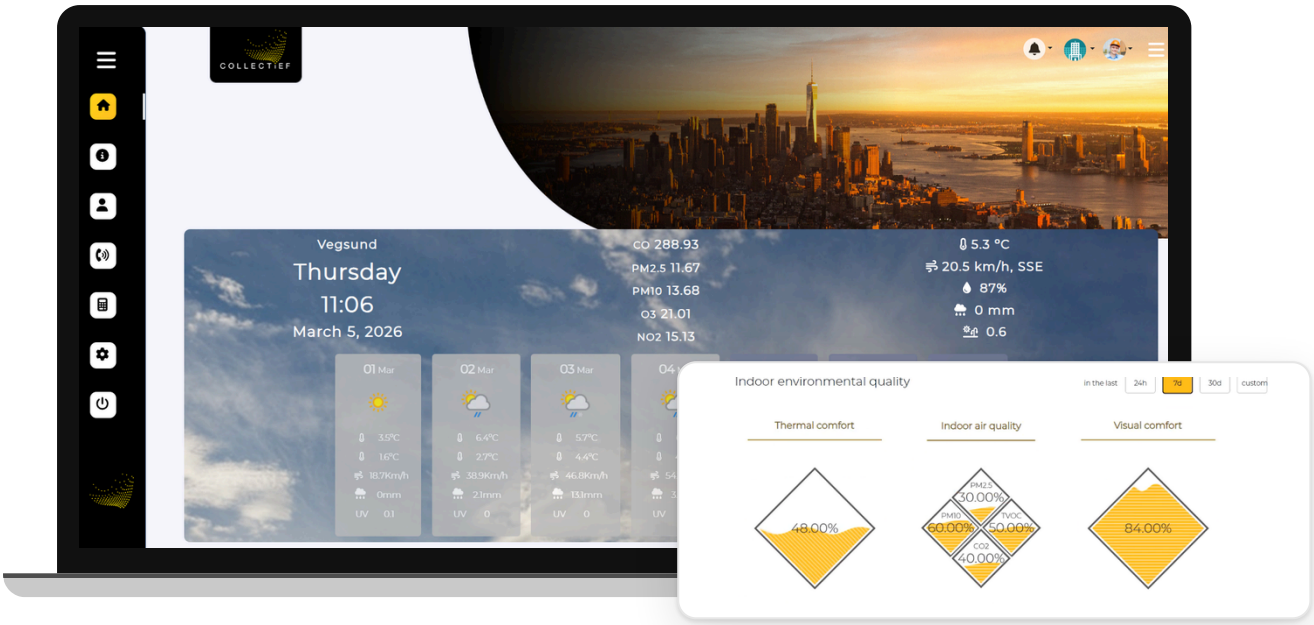


Figure 8 The COLLECTiEF dashboard: weather and air quality overview (left) and indoor environmental quality indicators (right)

Deployment advantages

Key features supporting adoption include:

- non-invasive installation, suitable for existing buildings
- minimal need for additional hardware
- compatibility with existing systems
- measurable and verifiable performance improvements

This is particularly relevant for Europe's existing building stock, where deep renovation is often complex and costly.

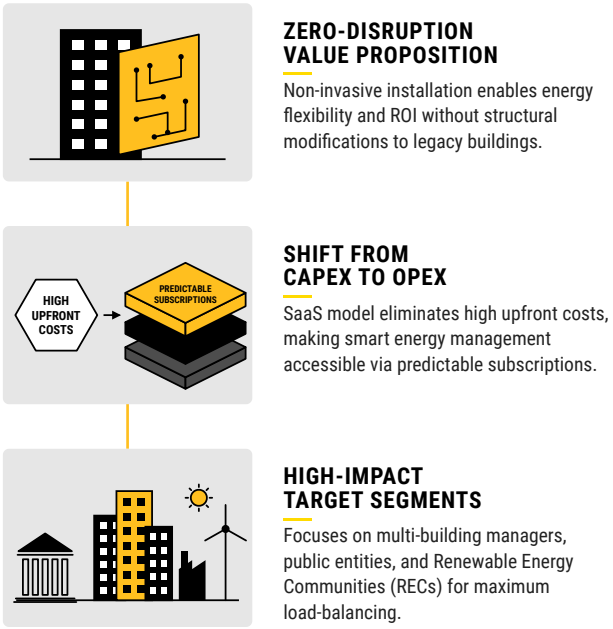


Figure 9 The COLLECTiEF value proposition

Business model

The project identifies a **Software-as-a-Service (SaaS)** approach as a key deployment model:

- reduces upfront investment
- shifts costs from capital expenditure to operational expenditure
- aligns with public procurement models and facilitates adoption by public and private actors

The solution is particularly relevant for:

- public building owners
- multi-building managers
- energy communities
- energy service companies



Key advantages for adoption

The COLLECTiEF system offers several advantages that support its scalability:

- integration with existing buildings without major disruption
- reduced need for additional hardware
- clear and measurable performance improvements
- potential participation in demand response and energy markets

The system also supports compliance with European policy frameworks, including building performance requirements and sustainability criteria.

Enabling large-scale adoption

Technology alone is not sufficient to drive uptake. Engaging building users directly, gathering their feedback and building trust and awareness is essential for the successful deployment of the system.

Capacity building

An open-access e-learning programme was developed to support adoption.

It:

- provides practical knowledge on system use and installation
- is tailored to different stakeholders
- enables continuous learning and reuse



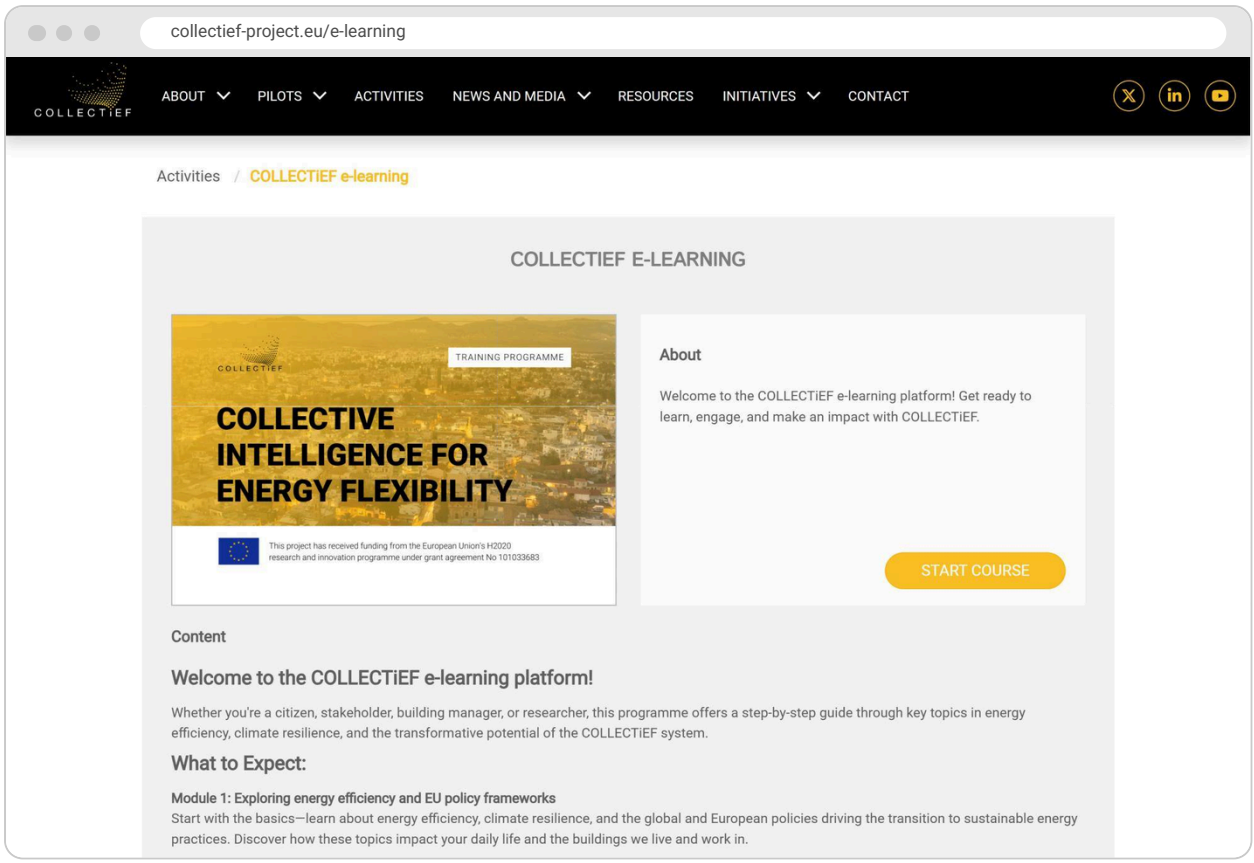


Figure 10 The COLLECTiEF open-access e-learning platform

It targets:

- citizens and building users
- facility managers
- installers
- researchers

These activities:

- reduce barriers to adoption
- align solutions with real user needs
- support long-term sustainability

They also informed business models and deployment strategies within the project.

Knowledge legacy

The project has also generated a range of scientific outputs and datasets to support further research and innovation.

These include:

- datasets related to building performance, energy flexibility, and indoor environmental quality
- scientific publications describing methodologies, algorithms, and results
- public deliverables and technical documentation



These resources ensure that the knowledge generated by COLLECTiEF can be reused and further developed by policymakers, researchers and market actors.

All public materials are available via the project website and open-access repositories.

Policy relevance and next steps

COLLECTiEF contributes directly to major European policy objectives, including:

- Energy efficiency
- Renewable energy integration
- Demand-side flexibility
- Climate adaptation and resilience



By enabling buildings to actively participate in the energy system, the solution reduces pressure on infrastructure and supports the transition towards a more sustainable and resilient energy system.

Implications for policymakers

The results show that:

- Significant energy savings can be achieved through smarter control of existing systems
- Buildings can provide flexibility without compromising comfort
- Digital solutions can accelerate the transition without requiring large-scale renovation

Next steps

To unlock this potential at scale, further action is needed:

- Support for the deployment of smart energy management solutions
- Integration of flexibility into building and energy regulations
- Continued investment in digitalisation and data-driven approaches

Conclusion

COLLECTiEF shows that smart control solutions can unlock the full potential of buildings as active participants in the energy system.

By combining technological innovation, real-world validation, and pathways to market, the project provides a concrete and scalable approach to achieving Europe's energy and climate objectives.

About COLLECTiEF

COLLECTiEF (Collective Intelligence for Energy Flexibility) was a Horizon 2020 project that developed and demonstrated innovative solutions to make existing buildings smarter, more flexible, and better connected to the energy system. Through real-life pilots across Europe, the project showed how intelligent control can reduce energy consumption, improve comfort, support renewable energy integration, and increase climate resilience, without major building renovation. The project also delivered business models, training resources, and open-access knowledge to support large-scale deployment of smart building solutions.

Consortium partners

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COLLECTiEF project

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