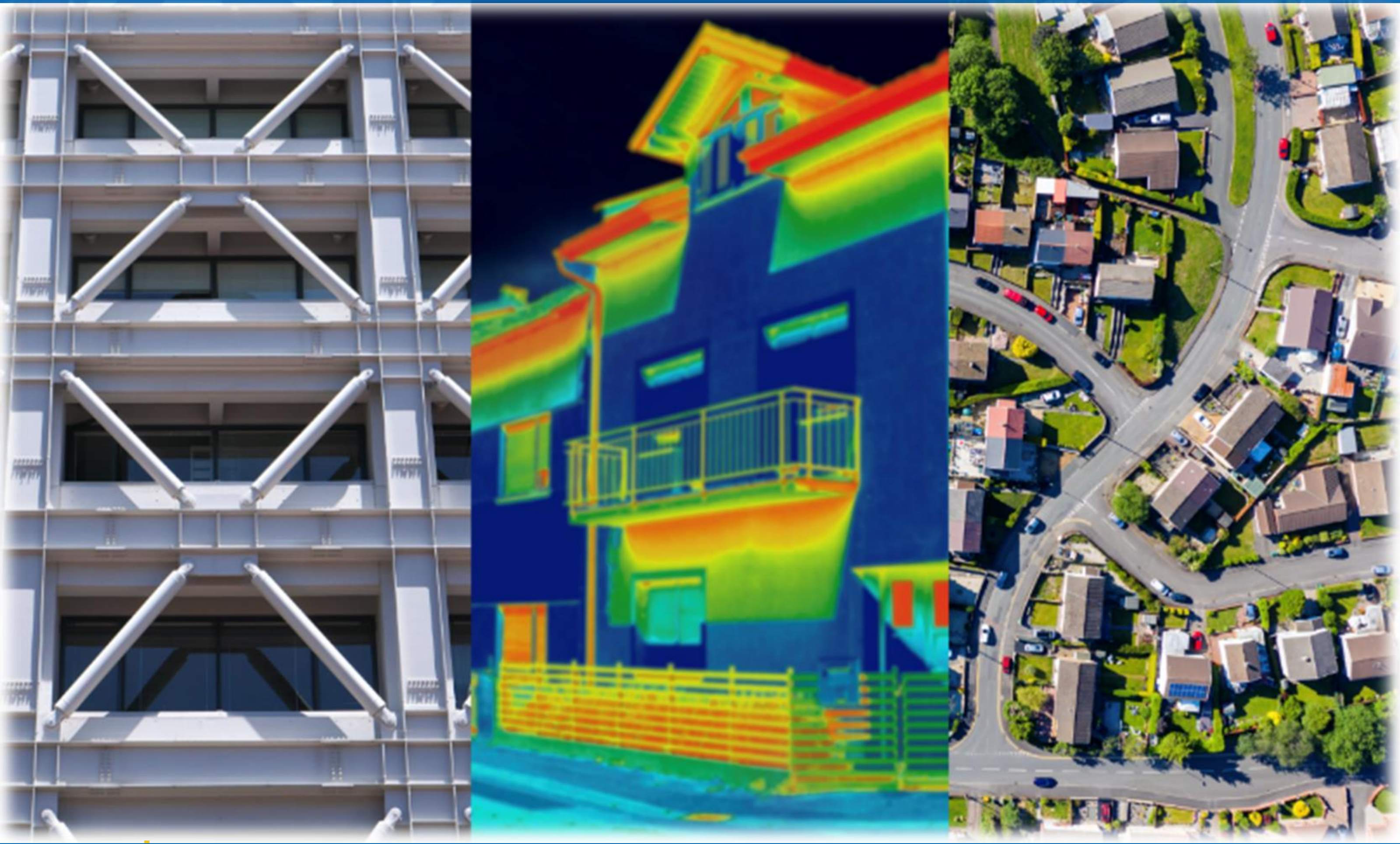
# MIDTERM WORKSHOP

*16 - 19 November 2020*

## Pilot Project

## Integrated Techniques for the Seismic Strengthening & Energy Efficiency of Existing Buildings



## ACTION 1

*17 November 2020*

## Overview and Classification of Technologies for Seismic Strengthening and Energy Upgrading of Existing Buildings

# Pilot Project: Integrated Techniques for the Seismic Strengthening & Energy Efficiency of Existing Buildings

## Work Progress in Action 1

*Elvira Romano, Paolo Negro*

*17 November 2020*

# Contents

# Introduction

# Action 1: Sub-actions

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Identify representative classes of buildings regarding both seismic & energy performance

**SUB-ACTION 1.2 - Technology options for seismic upgrading**

Classify technologies in terms of expected seismic safety improvement, cost and disruption of service, use of raw materials, Life Cycle Analysis effects, and compatibility with energy upgrading technologies

**SUB-ACTION 1.3 - Technology options for energy upgrading**

Classify technologies in terms of expected energy efficiency improvement, cost and disruption of service, use of raw materials, Life Cycle Analysis effects, and compatibility with seismic strengthening technologies



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# Action 1: Tasks

## 1 - TECHNOLOGIES FOR SEISMIC STRENGTHENING AND ENERGY UPGRADING

**SUB-ACTION 1.1**

- **Task 1.1.1**
  - Age distribution
  - Structural typologies
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  - Seismic exposure

EU

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Focus: **ITALY**

- **Task 1.1.4** – Masonry buildings
- **Task 1.1.5** – RC buildings

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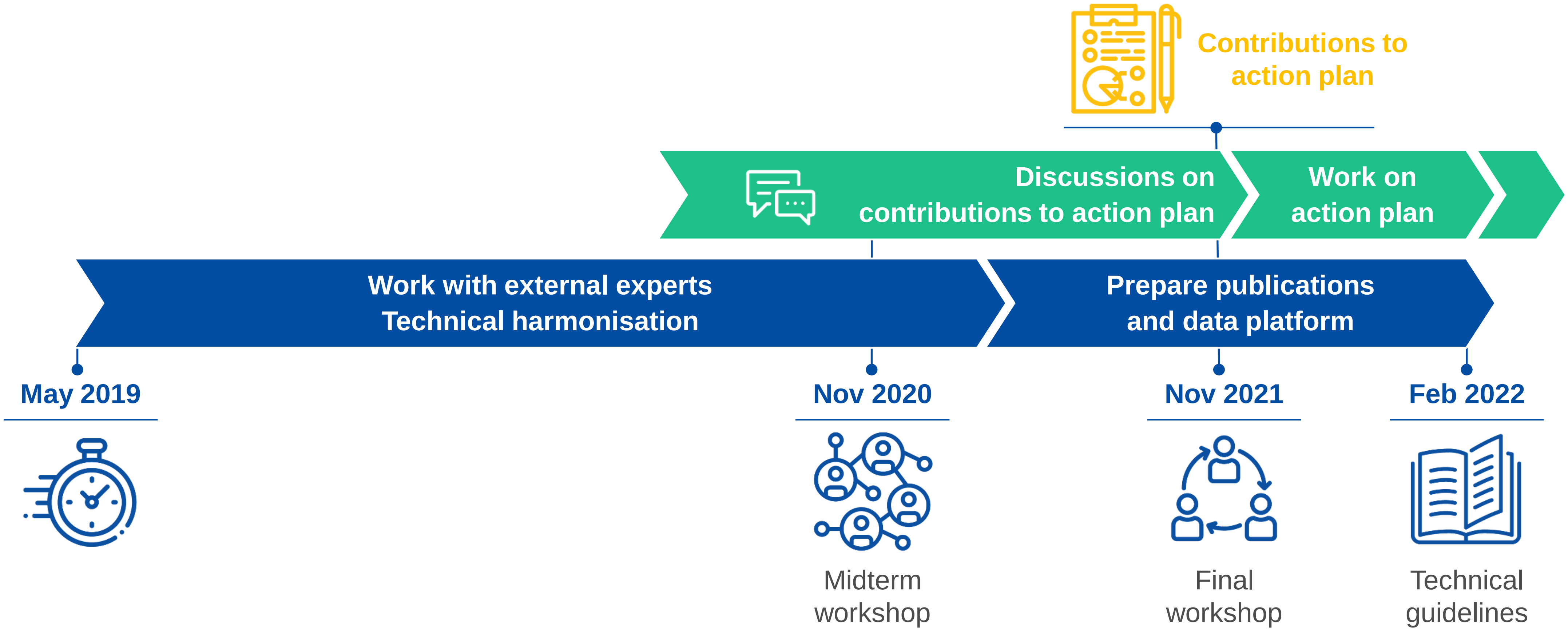
- **Task 1.2.1** – Technology options for seismic upgrading
- **Task 1.2.2** – Classification of seismic upgrading technologies by cost, disruption, compatibility with energy measures

**SUB-ACTION 1.3**

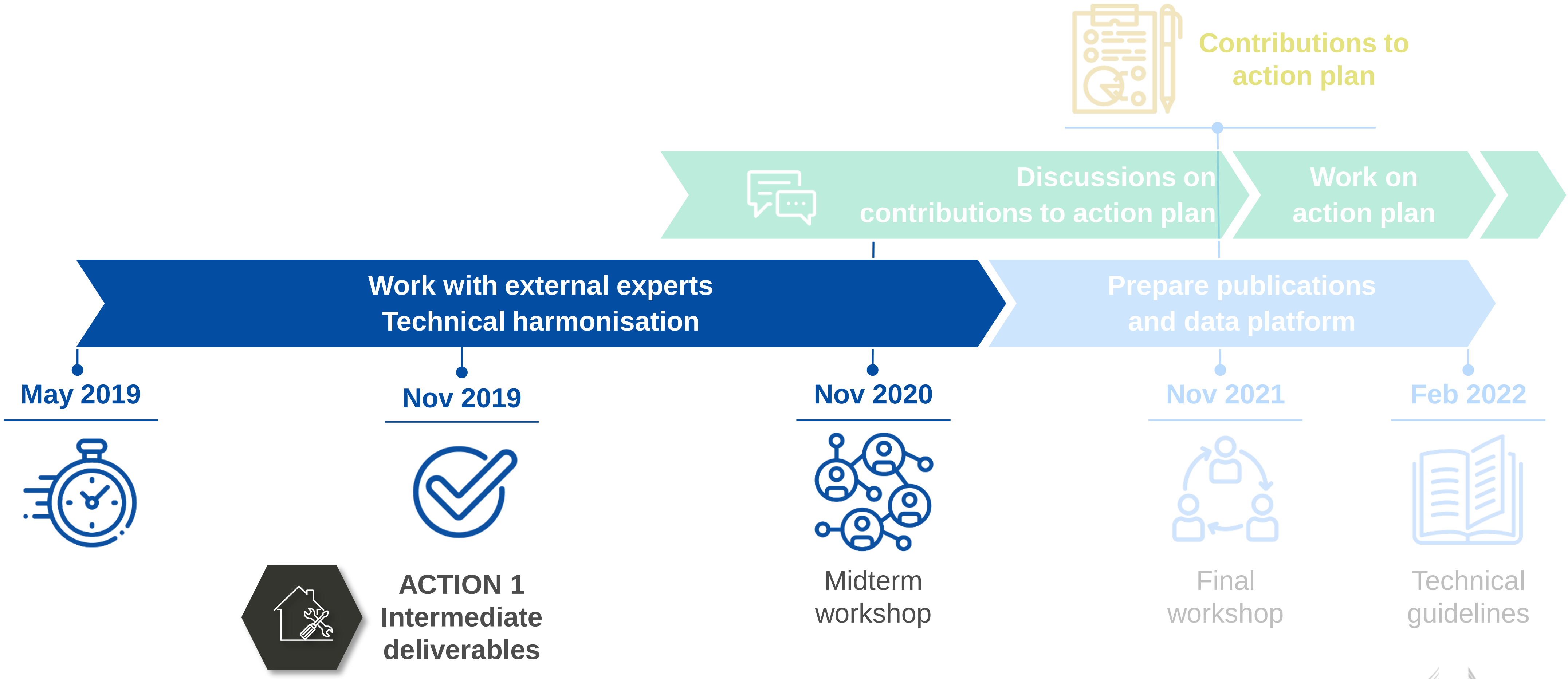
- **Task 1.3.1** – Technology options for energy upgrading
- **Task 1.3.2** – Classification of energy upgrading technologies by cost, disruption, compatibility with seismic measures

# Timeline



Contributions to action plan
Discussions on contributions to action plan
Work on action plan
Work with external experts
Technical harmonisation
Prepare publications and data platform
May 2019
Nov 2020
Nov 2021
Feb 2022
Midterm workshop
Final workshop
Technical guidelines

# Timeline



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# Sub-action 1.1

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# Building typologies needing upgrading

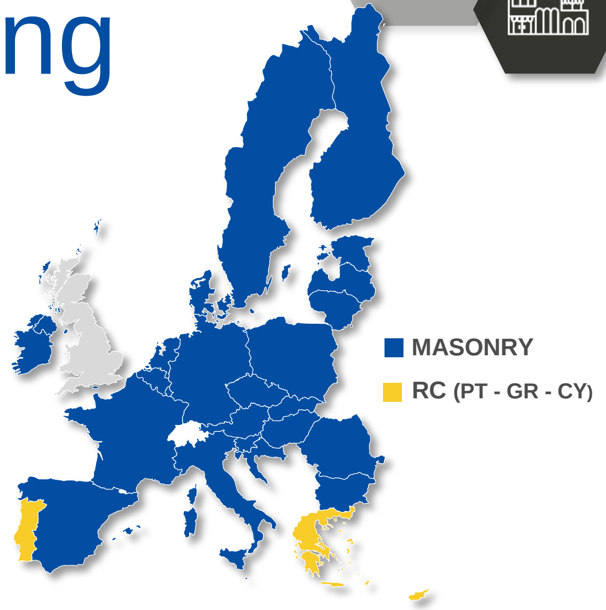
## Distribution of building typologies by year of construction

- Analysis of EU dwellings distribution by ***year of construction***, ***building typologies*** (based on number of dwellings), ***surface area***
- Classification of EU buildings by **construction technology** (EU projects: TABULA/EPISCOPE; NERA)
- Analysis of buildings share by year of construction at regional/province level per each EU country

**22%** Buildings before 1945

**79%** Buildings before 1991

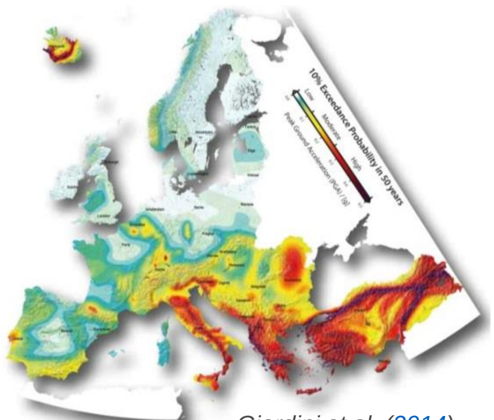
Data source:
European Statistical System (EES), *2011 Population and Housing Census* data - EUROSTAT, Census Hub




## European climatic zones & seismicity

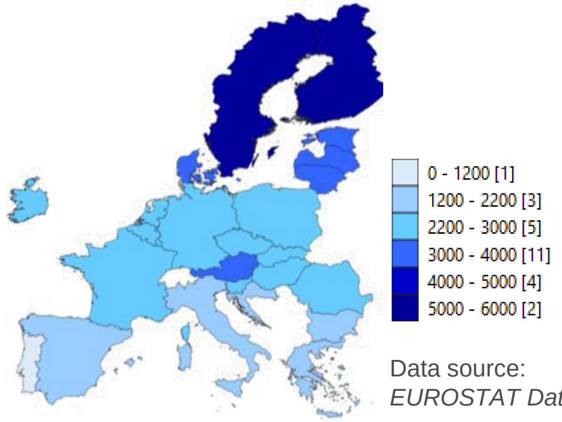
- Maps of Europe in terms of **seismic hazard** (ESHM13) and **climatic zones** (in terms of HDD)
- Specific analysis of seismic hazard and climatic zones per EU Member State
- Identification of EU regions with high seismic and climatic exposure: (1) **Bulgaria**, (2) **Croatia**, (3) **Greece**, (4) **Italy**, and (5) **Romania**

European Seismic Hazard Map



*Giardini et al. (2014)*

2019 Average HDD values per EU Member State




Data source:
*EUROSTAT Database*

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# Building typologies needing upgrading

## Prioritization of building typologies needing upgrading

- EU regions with moderate to high seismic exposure and high HDD climatic exposure (e.g. from Zone 3 to Zone 5)
- Correlation of seismic hazard-climatic zones with building distribution in terms of age of construction and construction technologies

Correlation matrix for the five selected EU Member States

| HDD | SEISMIC HAZARD LEVEL | | | EU Country |
|---|---|---|---|---|
| | Low | Moderate | High | |
| Zone 1 | | X (Andros) | X (Athens) | GR |
| Zone 1 | X (Sassari) | X (Salerno) | X (Naples) | IT |
| Zone 2 | | X (Pleven) | X (Plovdiv) | BG |
| Zone 2 | X (Zadar) | X (Split) | X (Dubrovnik) | HR |
| Zone 2 | | X (Kozani) | X (Thessaloniki) | GR |
| Zone 2 | X (Bari) | X (Pisa) | X (Perugia) | IT |
| Zone 2 | | X (Bucharest) | | RO |
| Zone 3 | | X (Sofia) | X (Blagovgrad) | BG |
| Zone 3 | X (Osijek) | X (Primorje-Gorski kotar) | X (Zagreb) | HR |
| Zone 3 | | X (Dykiti Makedonia) | | GR |
| Zone 3 | X (Como) | X (Vicenza) | X (Bergamo) | IT |
| Zone 3 | X (Cluj) | X (Satu Mare) | X (Vrancea) | RO |
| Zone 4 | X (Verbano-Cusio-Ossola) | | | IT |
| Zone 4 | X (Bistrita) | X (Hargita) | X (Covasna) | RO |
| Zone 5 | X (Aosta) | X (Bolzano) | X (Trento) | IT |

- **Masonry** constructions for the majority of buildings in **Bulgaria**, **Croatia**, **Italy**, and **Romania**
- Same fractions of **masonry** and **RC** constructions in **Greece**

## Focus on building typologies needing upgrading within the Italian context

| Seismic zone | Climatic zone | Combined demand | Number of masonry buildings | % of masonry buildings | Number of RC buildings | % of RC buildings |
|---|---|---|---|---|---|---|
| 1-2 | D-E-F | Very High | **2,413,644** | **33.4** | **1.169.256** | **31,07** |
| 1-2 | A-B-C | High | 813,921 | 11.3 | 550.449 | 14,63 |
| 3-4 | D-E-F | Medium | 2,962,771 | 41.1 | 1.321.892 | 35,13 |
| 3-4 | A-B-C | Low | 1,022,432 | 14.2 | 721.242 | 19,17 |
| Total | | | 7,212,768 | 100.0 | 3.762.839 | 100.0 |

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# Sub-action 1.2

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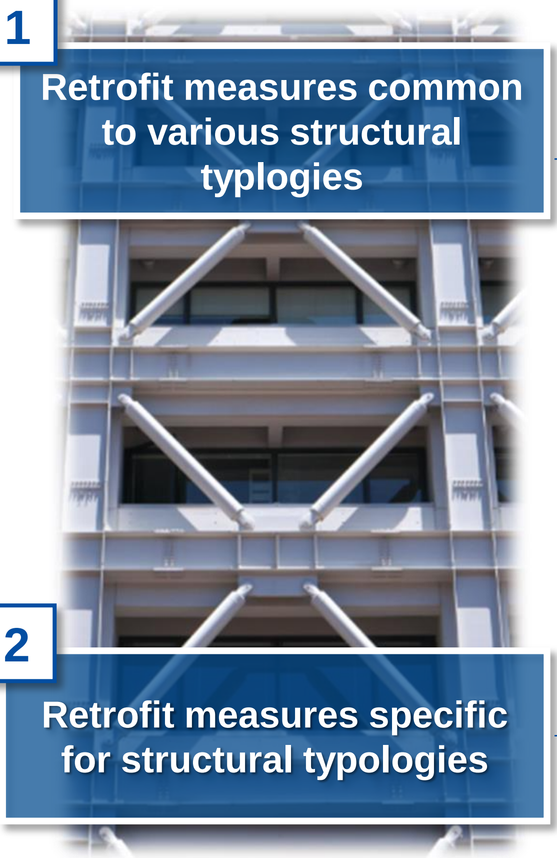
# Technology options for seismic upgrading

Overview of seismic strengthening technologies for existing buildings



- **1 Retrofit measures common to various structural typlogies**
  - **Reduction of seismic demand**
    - Additional damping
    - Seismic isolation
  - Provision of an effective **diaphragm floor**
    - **Intrados** solutions
    - **Overlay for RC - brick and block systems**
    - **Technology** for **wood floors**
    - **Technology** for **precast floors**
    - **Roof-box structure**
  - **Global retrofit measures**
    - **New bracing system**
      - Rocking walls e PreWEC system
      - Hinged walls
      - RC infills
      - Steel bracing (CBF - EBF - BRB)
      - RC walls
    - **External exoskeleton**
      - Diagrid systems
      - Cross laminated timber panels
      - Proprietary systems
- **2 Retrofit measures specific for structural typologies**
  - **Reinforced concrete structures**
  - **Masonry structures**
  - **Steel structures**
  - **Precast structures**
  - → **Local retrofit measures**

# Classification of technologies for seismic upgrading

## Classification by Life Cycle Thinking (LCT) criteria: 17 criteria and definition of grade (1–5)

| | LIFE CYCLE THINKING (LCT) CRITERIA | SCORE 1–5 | | | |
|---|---|---|---|---|---|
| A | **Holistic - integrated compatible** | 1 | No compatible with holistic | 5 | Fully compatible |
| B | **Incremental Rehabilitation** | 1 | No compatible with Incr. Rehab | 5 | Fully compatible |
| C | **Disruption of the occupants / relocation** | 1 | Relocation of occupants | 5 | Minimum disruption/short-no downtime |
| D | **Disruption to the building, such as to the electrical/plumbing distribution systems** | 1 | No disruption to electrical/plumbing systems | 5 | No disruption to electrical/plumbing systems |

## Classification by cost of intervention, disruption time, compatibility with energy upgrading

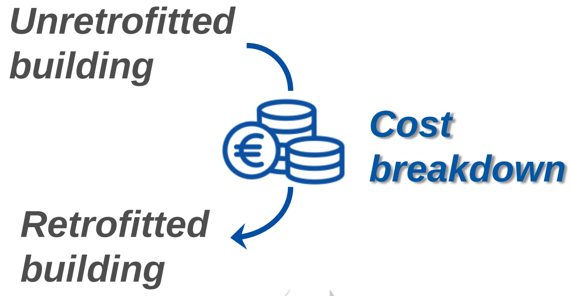
- Construction cost breakdowns of masonry and RC retrofitted buildings for a total of **25 case studies**
- Average **range of construction costs**
- Cost-effectiveness analysis exploring 3 iso-performance retrofit solutions on a selected RC building

**Masonry buildings: 4 case studies**

| Case study | Improvement in the quality of the masonry | Perimeter ties | Roof/floor diaphragm | Improving in-plane res. of the walls | Retrofit of foundation system | Retrofit for static actions |
|---|---|---|---|---|---|---|
| Historic palace - Mantova province, Italy (Table2) | ✓ (Local retrofit of masonry walls) | ✓ | ✓ | | | ✓ |
| Historical Palace, Garda lake, Italy (Table 3) | ✓ (Local retrofit of masonry walls) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Historical Church, Mantova province, Italy (Table 4) | ✓ (Local retrofit of masonry walls) | ✓ | ✓ | ✓ (diaphragm arches) | | ✓ |
| Residential Building, Bergamo province, Italy (Table 5) | | ✓ | ✓ | ✓ | ✓ | |

**RC buildings: 4 case studies**

| Case study | Strength. of frame joints | Exoskel. with shear walls | Shell exoskel. | Floor/roof diaphragm | Seismic base isolation | Retrofit for static loads | Energy efficiency retrofit |
|---|---|---|---|---|---|---|---|
| Gym Hall, Brescia, IT (Table7) | | | ✓ | ✓ | | | ✓ |
| School, Varese, IT (Table 8) | | ✓ | | | | | |
| School, Lecco, IT (Table 9) | | ✓ | | | | | |
| Residential Building, Garda lake, IT (Table 10) | | ✓ | | ✓ | | | ✓ |



# Sub-action 1.3

Work Progress

# Technologies options for energy upgrading

## Overview of energy upgrading technologies for existing buildings

**27 Passive Energy Efficiency Technologies (EETs)**

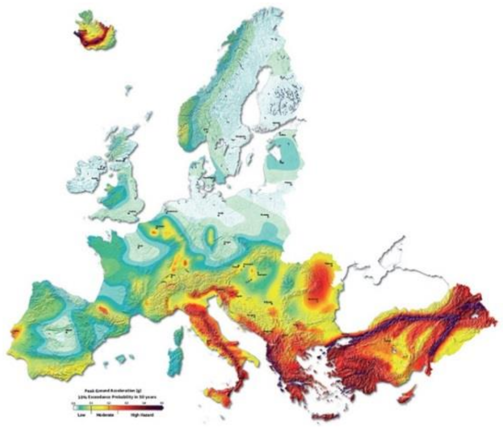
**Category**
- ENVELOPE

**Sub-categories**
- WALL
- FLOOR
- ROOF
- WINDOW
- DOOR

# Classification of technologies for energy upgrading

## Classification by building typologies

- Building typologies in **11 target countries**
  - *Single family house, Multi family house, Apartment Block, and non-residential buildings*
- Correlation of EETs with building typologies
- Impact of EETs on targeted building stock



Giardini et al. (2014)

| HIGH | MODERATE |
|---|---|
| **1. Bulgaria** | **1. Austria** |
| **2. Croatia** | **2. France** |
| **3. Cyprus** | **3. Portugal** |
| **4. Greece** | **4. Spain** |
| **5. Italy** | |
| **6. Romania** | |
| **7. Slovenia** | |

## Classification by cost of intervention, disruption time, compatibility with seismic upgrading

| | CRITERIA AND INDICATORS | MEASURE UNIT |
|---|---|---|
| 1 | **Unitary cost of implementation** | €/$m^2$ or €/unit |
| 2 | **Unitary energy saved** | kWh/$m^2$ or kWh/unit |
| 3 | **Unitary cost-effectivity** | kWh saved/€ invested |
| 4 | **(Unitary) Disruption time** | hours/$m^2$ or hours/unit |
| 5 | **Unitary environmental impact** | $KgCO_2/m^2$ or $KgCO_2$/unit |
| 6 | **Users' comfort achieved** | PPD/$m^2$ or PPD/unit |
| 7 | **Life span** | Years |
| 8 | **Recycling possibility** | Totally/Partial/Not applicable |
| 9 | **Potential health risks in case of fire** | High/Moderate/Low |
| 10 | **Degree of compatibility with seismic retrofit measures** | Totally/Restricted/Non compatible |
| 11 | **Degree of relevance** | Points |

- ***Indicator 10*** – 20 Seismic Retrofit Technologies (SRT) (global and local)
- **Classification** by selected indicators
- Ranking of EETs through **multi-criteria decision making** analysis

# Classification of technologies for energy upgrading

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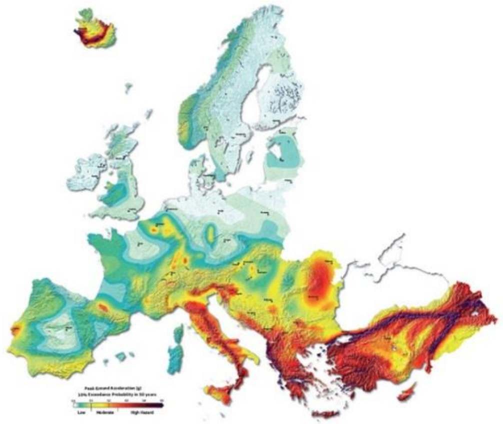

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## Classification by cost of intervention, disruption time, compatibility with seismic upgrading

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| 11 | **Degree of relevance** | Points |

→

**Example: ENV-WA-01**
**External Thermal Insulation Composite system (ETICS)**

| | Description | Value |
|---|---|---|
| 1 | Preparation of the supporting wall<br>Application of ETICS (Lower bound)<br>Application of ETICS (Higher bound) | 30 €/m$^2$<br>65 €/m$^2$<br>110 €/m$^2$ |
| 4 | Preparation of the supporting wall<br>Application of ETICS (Lower bound)<br>Application of ETICS (Higher bound) | 1 h/m$^2$<br>0.75 h/m$^2$<br>1.5 h/m$^2$ |
| 7 | Lower bound<br>Higher bound<br>Average | 16 years<br>35 years<br>30 years |
| 10 | EET – SRTs compatibility | 77.5 points |

# Action 1: Next steps

## 1 - TECHNOLOGIES FOR SEISMIC STRENGTHENING AND ENERGY UPGRADING

**SUB-ACTION 1.1**

- **Task 1.1.1**
  - Age distribution
  - Structural typologies
- **Task 1.1.2**
  - Climatic zones
  - Seismic exposure

EU

- **Task 1.1.3** – Building typologies most needing upgrading

Focus: **ITALY**

- **Task 1.1.4** – Masonry buildings
- **Task 1.1.5** – RC buildings

**SUB-ACTION 1.2**

- **Task 1.2.1** – Technology options for seismic upgrading
- **Task 1.2.2** – Classification of seismic upgrading technologies by cost, disruption, compatibility with energy measures

**SUB-ACTION 1.3**

- **Task 1.3.1** – Technology options for energy upgrading
- **Task 1.3.2** – Classification of energy upgrading technologies by cost, disruption, compatibility with seismic measures

**Completed** **In progress**

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# References


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Giardini, D., Wössner, J. & Danciu, L. (2014) ‘Mapping Europe’s seismic hazard’, *Eos Trans. AGU*, 95(29): 261–262, doi: 10.1002/2014EO290001

# Thank you

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