Achieving greater residential energy savings through optimised subsidy allocation

Danai Sofia Exintaveloni, Eirini Vasilakou, Dimitra Tzani, Alexandros Flamos

Technoeconomics of Energy Systems Laboratory (TEESlab)
Dept. of Industrial Management & Technology, University of Piraeus (UNIPI)

University of Piraeus Research Center (UPRC)

Session 01 – Buildings I

Energy Evaluation Europe Conference 2025

25-26 September 2025

With the contribution of the Green Fund.

Co-funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

CONTENTS

TEESlab
Technoeconomics of Energy Systems

ENERGY EVALUATION EUROPE CONFERENCE 2025
25 SEP - 26 SEP 2025
BERLIN

Introduction - Scope of ENSMOV Plus

Project name: Evaluation, QuaNtification and Strengthening of the IMplementation of the POlicies and EM&V under Article 7 (now 8) of the EED

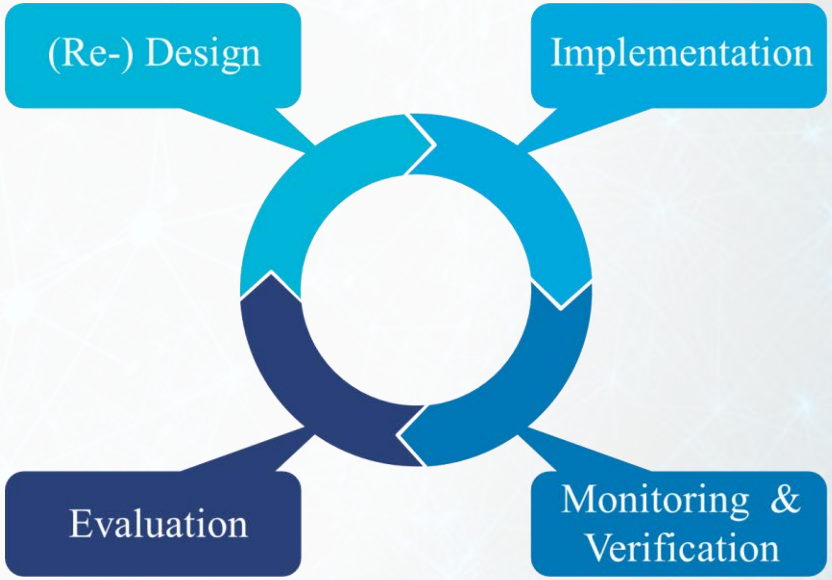
Article 8 (formerly Article 7) requires all MS to deliver **progressively increasing** annual savings:

- ✓ **1.3%** in 2024–2025
- ✓ **1.5%** in 2026–2027
- ✓ **1.9%** from 2028 onward

Facilitates knowledge exchange between peers

Strengthens M&V systems and evaluations

Provides tools, resources, and real-world policy support



Introduction – Buildings

Buildings account for the substantial share of 43% of the total final energy consumption in the EU.

Residential buildings in particular are responsible for 25% of the total energy consumption and 20% of greenhouse gas emissions.

Approximately 75% of European buildings are energy inefficient and 85-95% of them are expected to still be standing in 2050.

Retrofitting actions have been recognised as a key strategy for reducing energy use and achieving the national and international energy efficiency targets.

Introduction – Policy

- Public policy interventions are crucial in the renovation effort.
- EU Member States implement a wide range of policy instruments ranging from regulatory and behavioural measures to tax exemptions and financial incentives like grants and subsidies.
- Many programmes are designed without fully assessing the effectiveness of eligible interventions.
- Strategic allocation of funds is essential to maximise energy and achieve a higher overall impact.
- Studies have highlighted the need to consider cost-effectiveness and maximisation of energy savings in design and implementation.

Objective & Methods

The objective of this study is to present a multi-step approach for assessing the energy savings that can be delivered through a subsidy scheme for energy efficiency renovations.

Define the baseline building typologies to be used in the study

↓

Simulate the energy performance of the baseline buildings using the DREEM model

Weather data

Occupancy profiles

↓

Define the single energy efficiency measures and renovation packages under investigation

Subsidy scheme technical requirements

↓

Simulate the energy savings that can be delivered in each building typology from the various single measures or renovation packages

↓

Define an optimisation model to maximize the energy savings that can be delivered through a subsidy scheme subject to the budgetary constraint

Costs of each renovation measure

↓

Energy savings that can be achieved with the subsidy scheme

TEESlab Technoeconomics of Energy Systems

ENERGY EVALUATION EUROPE CONFERENCE 2025

Application

- Croatian subsidy scheme for **single family houses**
- **Overall available budget:** 120,000,000.00 euros

Activities covered:

- ❖ Complete energy renovation including improvement of the **thermal insulation** of the **building envelope** and **installation of energy systems** using **RES technology.**
- ❖ Improvement of **thermal insulation** of the building envelope.
- ❖ Installation of technical heating/cooling systems using **renewable energy sources.**
- ❖ Installation of technical systems for electricity production for own consumption using **renewable energy sources.**

Modeling energy performance - The DREEM model (1/2)

DREEM
Dynamic High-Resolution Demand-Side Management Model

Building sector

Energy demand *simulation model*

Energy Policy
Volume 161, February 2022, 112759

ELSEVIER

Monetising behavioural change as a policy measure to support energy management in the residential sector: A case study in Greece

Konstantinos Koasidis, Vangelis Ma
Doukas

Energy Conversion and Management
Volume 205, 1 February 2020, 112339

ELSEVIER

A modular high-resolution demand-side management model to quantify benefits of demand-flexibility in the residential sector

Vassilis Stavrakas, Alexandros Flamos

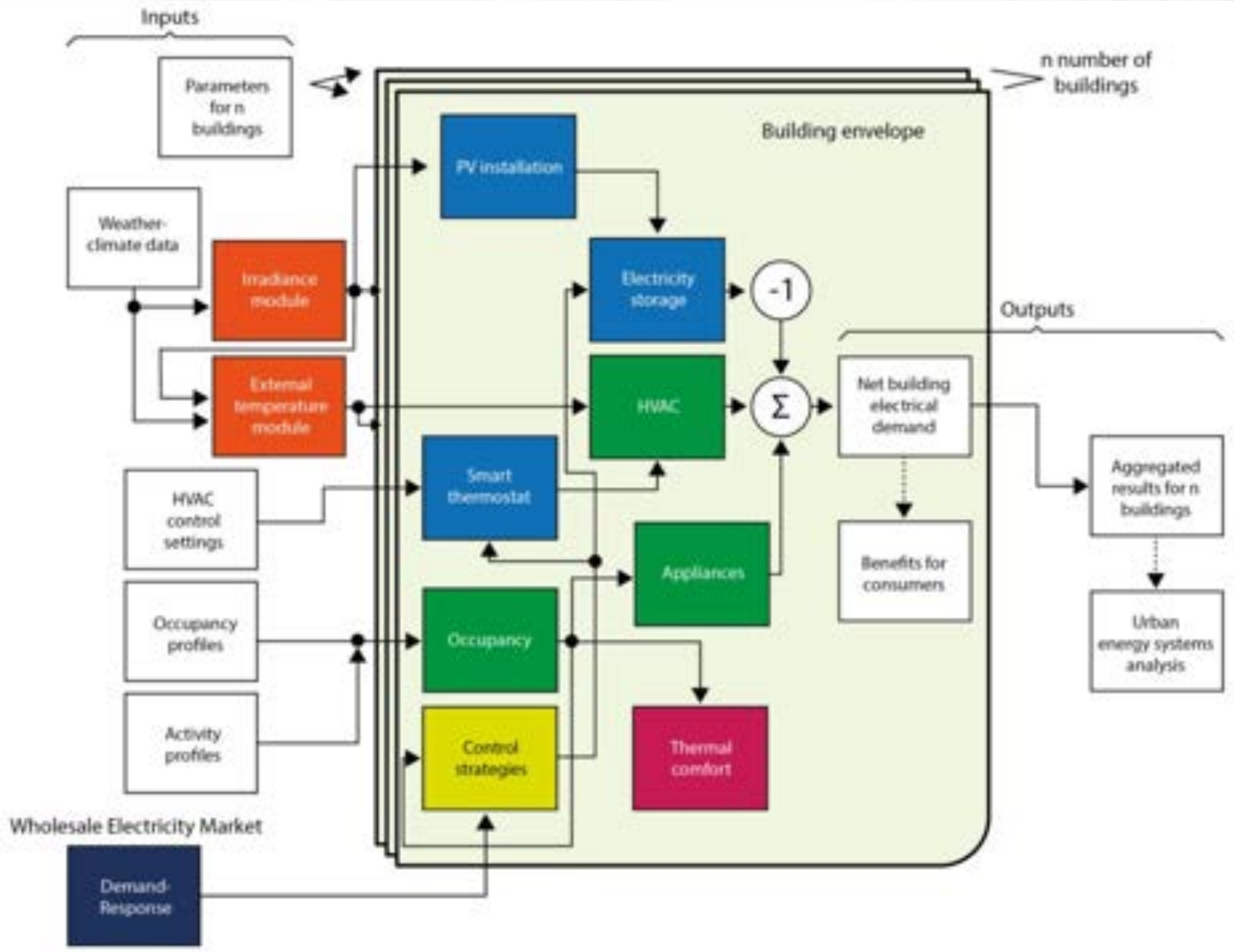
Modeling energy performance - The DREEM model (2/2)

Model characteristics

Main **principles** of **component- & modular-**based system modeling approach

- **interdependence** of decisions **within** modules
- **independence** of decisions **between** modules
- **hierarchical dependence** of modules on components embodying standards & design rules

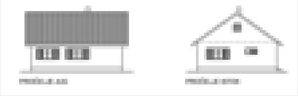
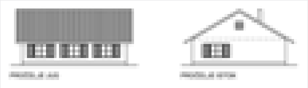
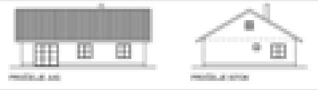
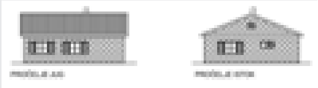
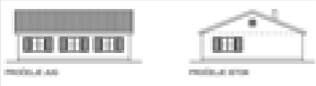
Modular *structure*



Building Typologies

6 Typologies are used according to the construction period and climate zone.

Coastal Climate Zone: Split
Continental Climate Zone: Zagreb

Parameter	Continental Croatia			Coastal Croatia		
	Typology 1	Typology 3	Typology 5	Typology 2	Typology 4	Typology 6
Year of construction	<1969 	1970-1989 	>1989 	<1969 	1970-1989 	>1989 
Type of building	Residential, detached	Residential, detached	Residential, detached	Residential, detached	Residential, detached	Residential, detached
Total floor area	69.8 m2	96.32 m2	104.03 m2	72.19 m2	95.39 m2	95.39 m2
Height	2.80 m	2.80 m	2.80 m	2.80 m	2.80 m	2.80 m
Total roof area	69.8 m2	96.32 m2	104.03 m2	72.19 m2	95.39 m2	95.39 m2
Total walls area	94.6 m2	104.03 m2	105.4 m2	97.38 m2	103.47 m2	103.47 m2
Total windows area	7.92 m2	12.48 m2	16.72 m2	7.91 m2	12.48 m2	12.48 m2

TEESlab Technoeconomics of Energy Systems

ENERGY EVALUATION EUROPE CONFERENCE 2025
25 SEP - 26 SEP 2025
BERLIN

Energy Efficiency Measures

Single Measures

- #1 Exterior Walls Insulation
- #2 Roof Insulation
- #3 Windows replacement
- #4 Biomass boiler installation
- #5 Heat pump installation
- #6 Solar thermal system
- #7 Photovoltaics (PV)

Packages of Measures

- #8 Walls & Roof Insulation
- #9 Walls, roof Windows
- #10 #12 #15 Walls, roof, windows & heating system
- #11 #13 #16 Windows & heating system
- #14 PV& EV charging station
- #17 Walls, roof, windows & PV

Optimisation

Aim: Optimise the allocation of the given budget while maximising energy savings from building renovations, taking into account pathways of constraints.

Simplified objective function

$$\text{Max} \sum_{i=1}^{n} \sum_{j=1}^{m} S_{i,j} * x_{i,j}$$

Where:
- $S_{i,j}$ = Energy savings of j renovation in typology i
- $X_{i,j}$ = number of j renovations in typology i

Main parameters used:

- **Costs** of renovation measures
- **Energy savings** achieved by each scenario, based on simulations with the DREEM model.

Major constraints

- **Available budget**: 120,000,000 euros
- **Max grant per application**: 62,120 euros
- **Max grant contribution per measure**
- **Building stock constraints**

Results - Annual Energy Savings (1/4)

Typology 1 (Continental before 1969)

Energy Efficiency measure	Annual energy savings (kWh/year)	Energy Efficiency measure	Annual energy savings (kWh/year)
#1	2900.648	#11	8619.238
#2	5670.07	#12	9167.788
#3	1646.518	#13	4362.113
#7	4270.44	#14	139.63
#8	8179.517	#15	9032.953
#9	8935.541	#16	2784.783
#10	**9868.461**	#17	**11375.17**

Typology 2 (Coastal before 1969)

Energy Efficiency measure	Annual energy savings (kWh/year)	Energy Efficiency measure	Annual energy savings (kWh/year)
#1	2660.29	#9	5904.843
#2	2934.534	**#10**	**6961.19**
#3	827.47	#11	5534.782
#7	5105.36	#14	139.63
#8	5392.902	**#17**	**8822.28**

Results - Annual Energy Savings (2/4)

Typology 3 (Continental 1970-1989)

Energy Efficiency measure	Annual energy savings (kWh/year)	Energy Efficiency measure	Annual energy savings (kWh/year)
#1	2772.238	**#10**	**12578.65**
#2	6996.004	#11	10897.87
#3	1018.064	#12	11402.33
#4	10726.11	#13	4941.428
#5	4279.079	#14	139.63
#6	1795.888	#15	11055.3
#7	4270.44	#16	2662.908
#8	9902.628	**#17**	**13243.67**
#9	10804.04		

Typology 4 (Coastal 1970-1989)

Energy Efficiency measure	Annual energy savings (kWh/year)	Energy Efficiency measure	Annual energy savings (kWh/year)
#1	3038.68	#9	7237.81
#2	3942.48	**#10**	**8704.408**
#3	619.87	#11	6832.11
#4	6659.515	#14	139.63
#7	5105.36	**#17**	**10155.25**
#8	6871.45		

Results - Annual Energy Savings (3/4)

Typology 5 (Continental after 1989)

Energy Efficiency measure	Annual energy savings (kWh/year)	Energy Efficiency measure	Annual energy savings (kWh/year)
#1	2787.87	**#10**	**13766.26**
#2	7498.01	#11	11997.03
#3	1509.34	#12	12466.3
#4	11742.99	#13	5664.85
#5	4673.68	#14	139.63
#6	1963.95	#15	12088.32
#7	4270.44	#16	3252.01
#8	10429.78	**#17**	**14255.97**
#9	11816.34		

Typology 6 (Coastal after 1989)

Energy Efficiency measure	Annual energy savings (kWh/year)	Energy Efficiency measure	Annual energy savings (kWh/year)
#1	1609.43	#9	4771.87
#2	2728.18	**#10**	**6263.7**
#3	700.69	#11	5119.74
#4	4923.25	#14	139.63
#7	5105.36	**#17**	**7689.31**
#8	4221.403		

Results - Preliminary on optimization (4/4)

Three scenarios:

Scenario 1: Baseline –envelop focused

Scenario 2: Emphasizing integrated renovations and electrification through heat pumps

Scenario 3: Emphasizing holistic transformation with additional focus on comprehensive and multi-measure retrofits

	Energy savings (kWh/year)		
Measures	**Scenario 1**	**Scenario 2**	**Scenario 3**
Integrated renovations (Envelop + Technical system)	12,860,558	35,230,124	48,953,713
Envelop renovations	119,802,304	158,110,482	154,359,596
Technical system replacement	2,089,759	46,014,946	46,063,596
PV & EV charging	8,861,105	29,052,308	29,052,308
	143,613,728	**268,407,860**	**278,429,213**

Increasing emphasis on electrification and holistic renovations (envelop + technical system) can significantly increase the savings delivered reducing also the cost per kWh saved for the programme by 33%.

Further Research & Next Steps

… What is next?

1. Explore different optimisation pathways and assess their impact on the results.

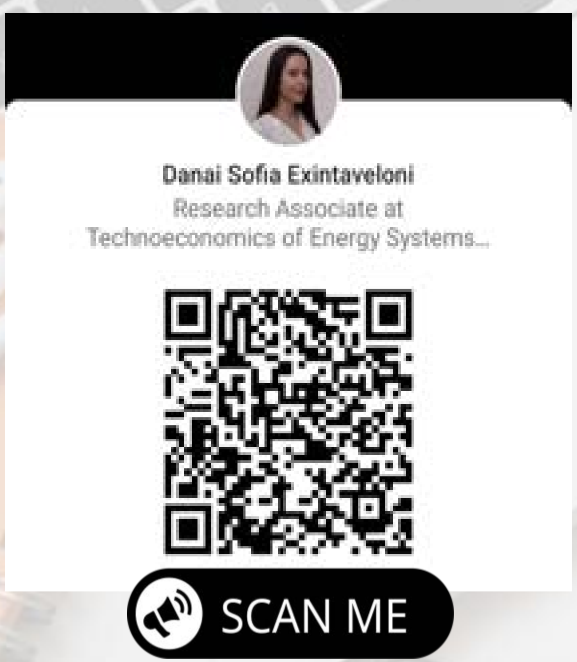
2. Conduct consultations with the Croatian authority to discuss the outcomes, benchmark them against available assessments, and integrate additional elements into the study.

3. Synthesize the final outcomes into targeted policy recommendations to support decision-making.

4. Investigate additional implications (e.g., in terms of cost-effectiveness)

TEESlab
Technoeconomics of Energy Systems

Thank you!



dexint@unipi.gr

Danai Sofia Exintaveloni

@TEES_Lab

https://teeslab.unipi.gr/

TEESlab – Technoeconomics of Energy Systems laboratory