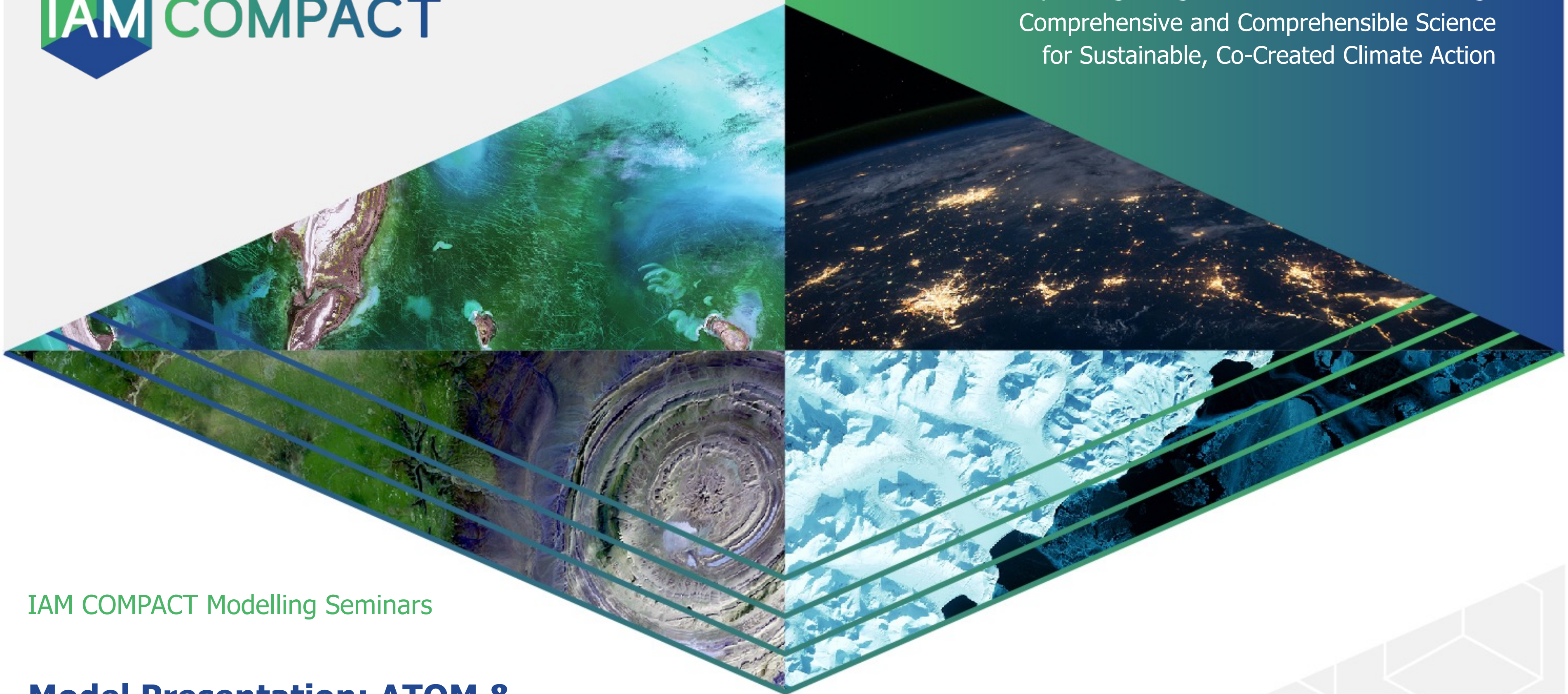
IAM COMPACT

Expanding Integrated Assessment Modelling:
Comprehensive and Comprehensible Science
for Sustainable, Co-Created Climate Action



IAM COMPACT Modelling Seminars

Model Presentation: ATOM & DREEM (TEEM suite)

Technoeconomics of Energy Systems Laboratory (TEESlab)

University of Piraeus Research Centre (UPRC)

The IAM COMPACT project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement No 101056306.

www.iam-compact.eu

Allow users to perform **participatory simulations** aiming to provide answers to many **"what if"** scenarios.

Models that can be coupled (i.e., **soft-** and/ or **hard-**linked) to provide answers to **complex** scientific/research questions.

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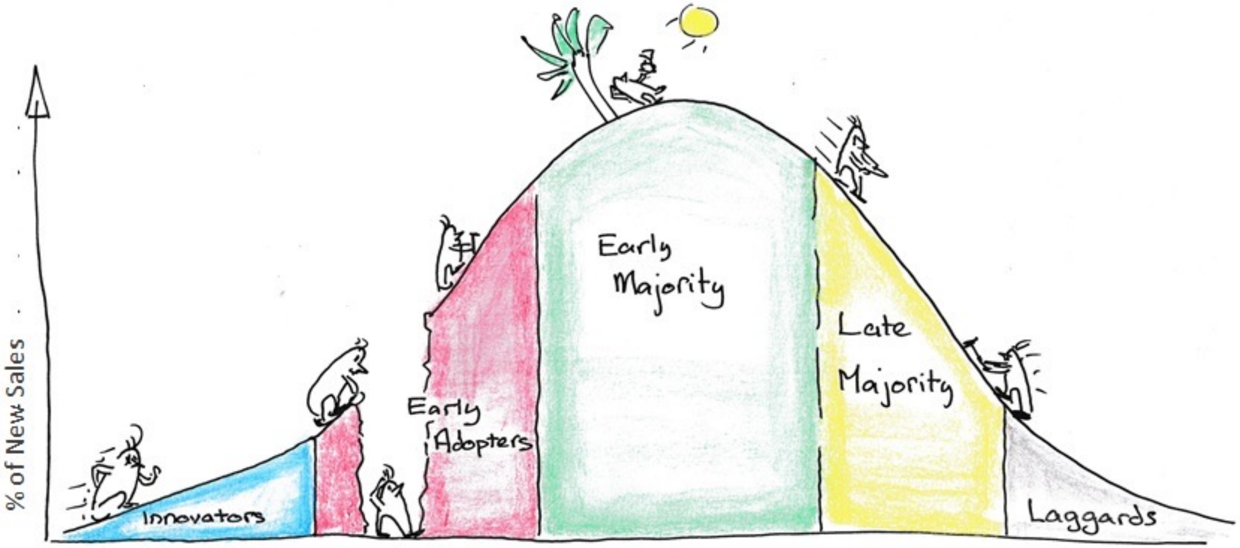
Agent-based Technology adOption Model (ATOM)

Electricity & Building sectors



Correlating *technology adoption with its* ***value*** *to consumers*

Expected effectiveness *of technology adoption under* ***policy schemes*** *of interest*

Quantifying uncertainties *related to* ***consumers'*** *decision-making process (i.e.,* ***behavioral*** *uncertainty)*

ATOM
Agent-based Technology Adoption Model

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ATOM
Agent-based Technology Adoption Model

3 modules

- Calibration
- Sensitivity analysis
- Scenario analysis

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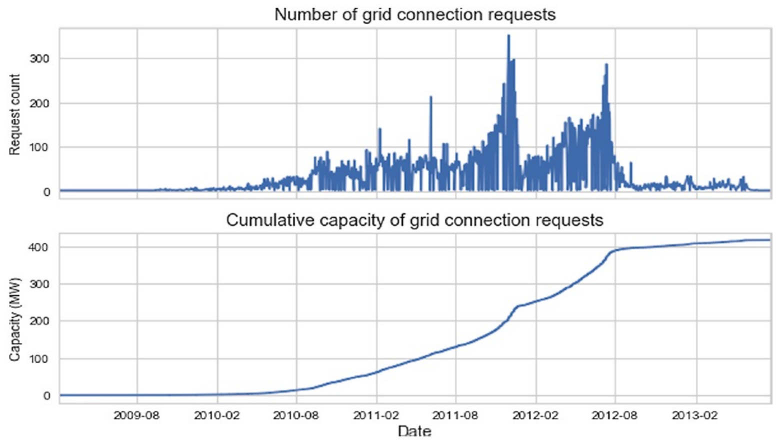
Historical data on PV capacity addition



Feed-in-Tariffs scheme in Greece
(2009-2013)

Gaussian Process emulation

Initial value ranges

Set of agent-related parameters*

*Inclusion of different **socioeconomic** & **demographic profiles** (e.g., income, education level, consumption profiles, etc.)

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Set of agent-related parameters

Initial value ranges

- 1-step **Global Sensitivity Analysis** (**Sobol** method)
- **Monte-Carlo** simulations
- **Historical matching** method

Final value ranges

Hybrid variance-based sensitivity analysis

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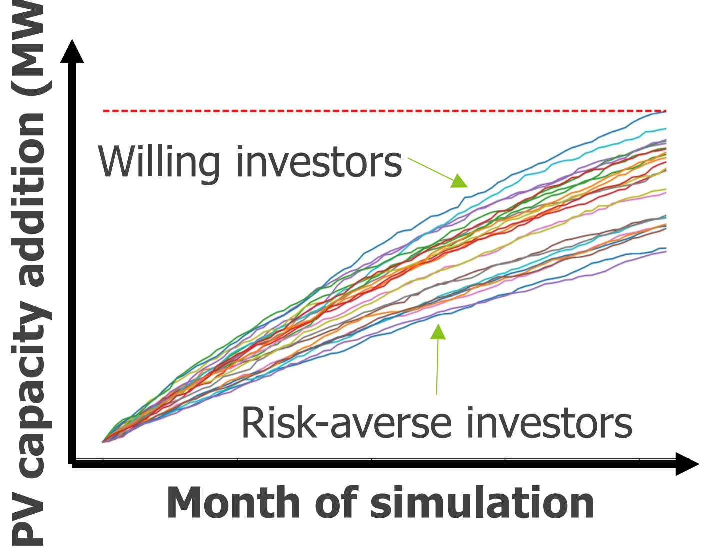
Set of agent-related parameters

Final value ranges

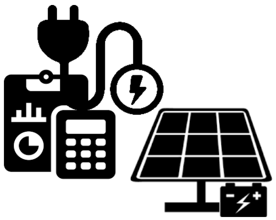
New small-scale PV capacity addition

different **realistic behavioral profiles** of agents (consumers)

adoption scenarios



Market Parameters



Poli(e.g., Net-Metering, Self-Consumption, etc.) **cy schemes**

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Diffusion scenarios of **energy communities** (e.g., 2020-2030)

The three main ways that grassroots innovations, as ecovillages, tend to influence larger society are through (1) **replication**, (2) **growth in scale**, and (3) **translation**.

- **Replication** as the **growth of the number** of energy communities
- **Growth in scale** as either the **growth of specific energy communities (case studies)** or the **growth of** their **influence** through partnerships & programs
- **Translation** as the **adoption of energy community policies & practices** by mainstream society and institutions

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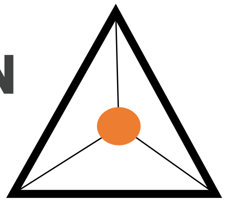
Adoption of small-scale PV by citizens towards 2030 in Greece based on 3 storylines of potential socio-political developments

QTDIAN

Government-directed storyline



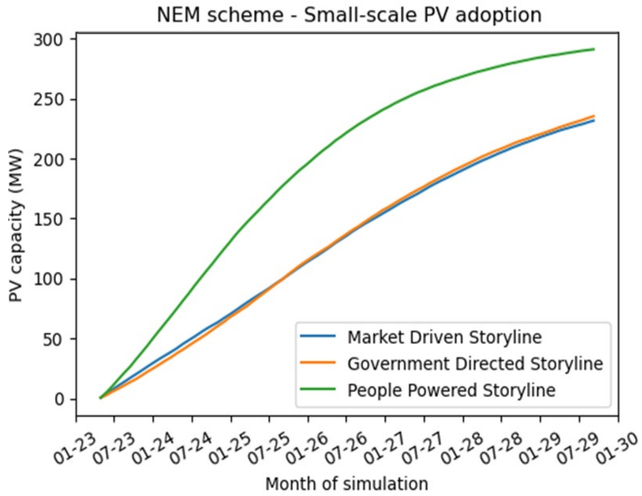
People-powered storyline

Market-driven storyline

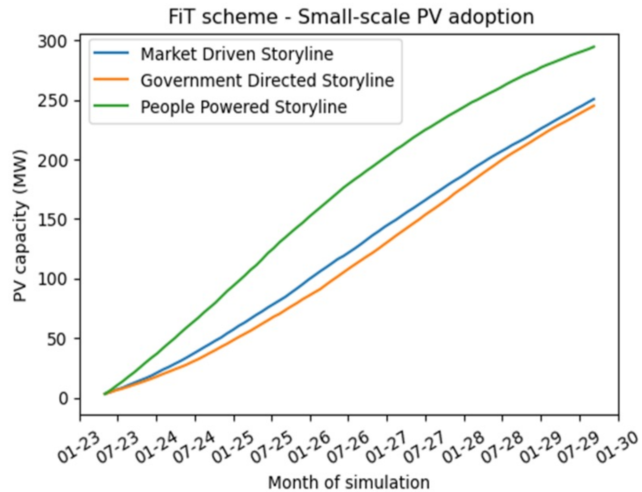
ATOM

Agent-based Technology Adoption Model

Net-metering



Feed-in-tariff



- **Market-driven storyline**
- **Government-directed storyline**
- **People-powered storyline**

- **Agent related** parameters
- **Market related** parameters
- **Policy schemes**

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SENTINEL

SUSTAINABLE ENERGY TRANSITIONS

Find more info

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Applied Energy
Volume 255, 1 December 2019, 113795

An agent-based model to simulate technology adoption quantifying behavioural uncertainty of consumers

Vassilis Stavrakas, Sotiris Papadelis, Alexandros Flamos

Energy Research & Social Science
Volume 92, October 2022, 102775

Original research article

Why energy models should integrate social and environmental factors: Assessing user needs, omission impacts, and real-word accuracy in the European Union

Diana Süsser, Nick Martin, Vassilis Stavrakas, Hannes Gaschnig, Laura Talens-Peiró, Alexandros Flamos, Cristina Madrid-López, Johan Lilliestam

Energy Policy
Volume 139, April 2020, 111350

A transdisciplinary modeling framework for the participatory design of dynamic adaptive policy pathways

Serafeim Michas, Vassilis Stavrakas, Sotiris Papadelis, Alexandros Flamos

zenodo

Report on model application in the case studies: challenges and lessons learnt: Deliverable 7.2. Sustainable Energy Transitions Laboratory (SENTINEL) project

SpringerLink

An Application of Calibration and Uncertainty Quantification Techniques for Agent-Based Models

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Dynamic high-Resolution dEmand-sidE Management (DREEM) model

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DREEM
Dynamic High-Resolution Demand-Side Management Model

Building sector

***Energy demand** simulation model*

DigiBUILD

SOCIALWATT

SENTINEL
SUSTAINABLE ENERGY TRANSITIONS

TIPPING+

ENPOR

FORTESIE

ENCLUDE
Energy Citizens for Inclusive Decarbonization

ENSMOV

*Assess **benefits** & **limitations** of demand-flexibility primarily for **consumers** and other **power actors** involved*

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*Outputs at a high resolution (**1 minute**)*

*Occupant **behavior** & determination of **end-use qualities***

*Linking to **other** models & **easily** re-used*

DREEM

Dynamic High-Resolution Demand-Side Management Model

***Modular** structure*

***Bottom-up** structure*

*Linking to **economic** development & **technological** breakthrough*

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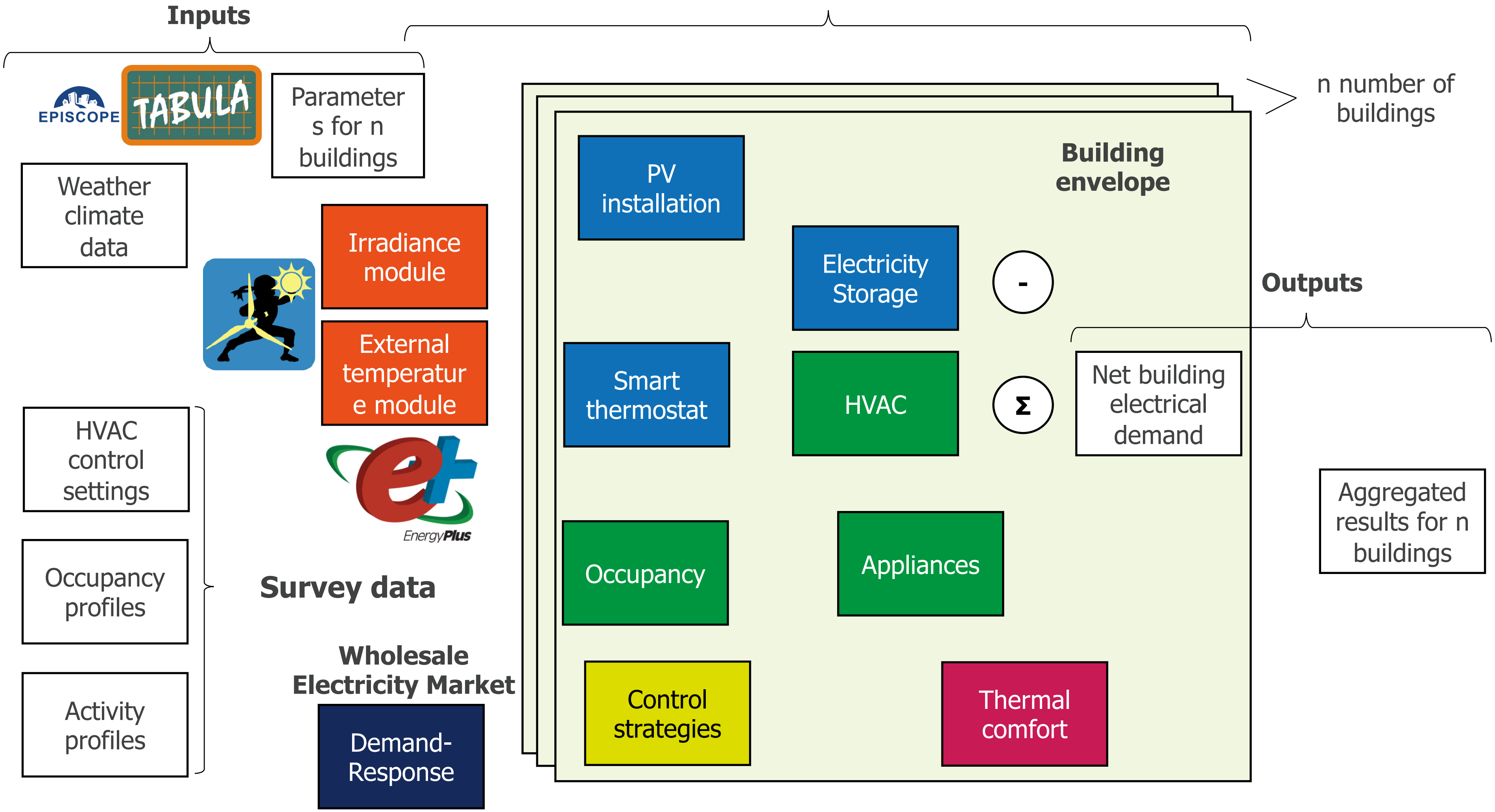
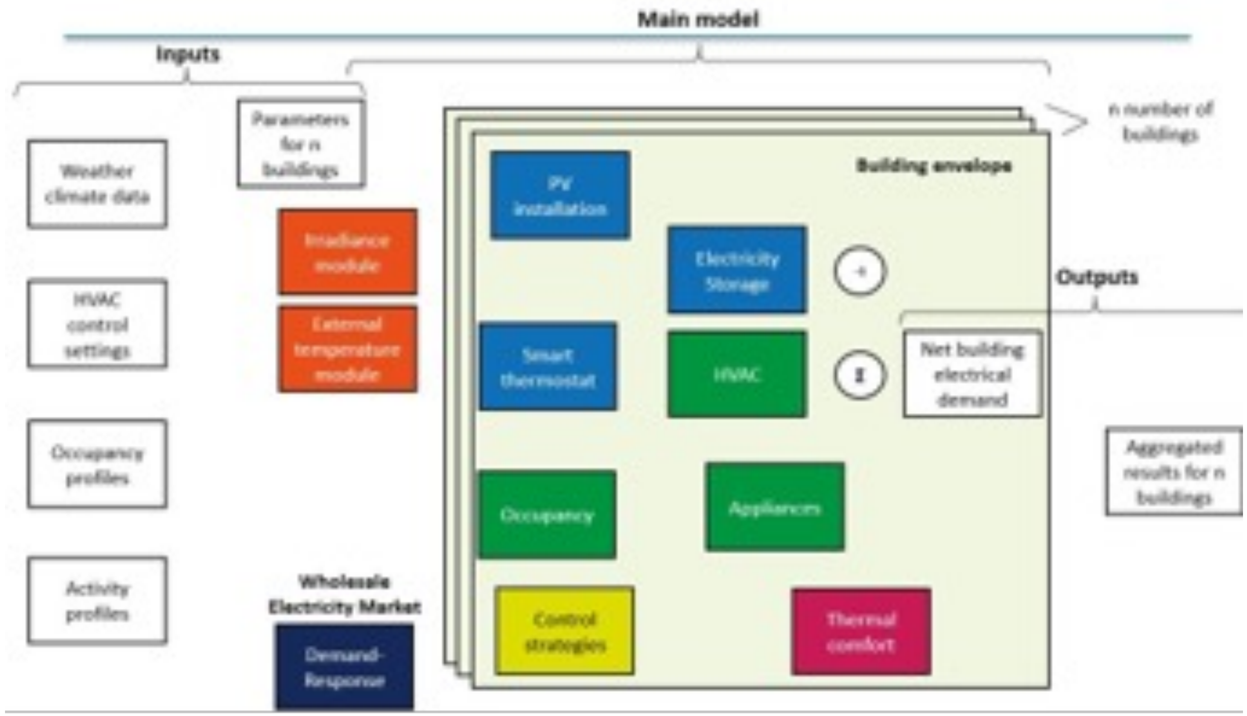


The IAM COMPACT project has received funding from the European Union’s Horizon Europe Research and Innovation Programme under grant agreement No 101056306.

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 <u>standards</u> & <u>design rules</u>

Modular *structure*



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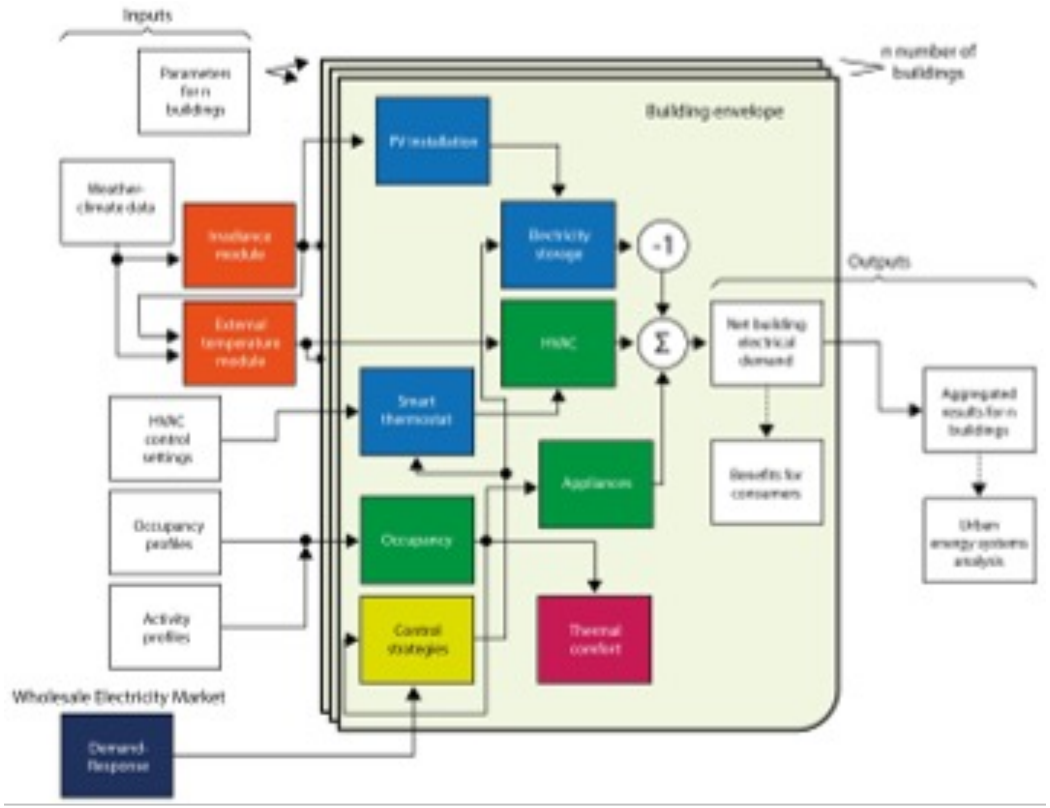
- **Incremental** modeling: **sub-models** in multiple levels
- **Control** capabilities: **managing** the **complexity** of large systems
- **Realistic representations** of dynamic systems
- Fast development & simulations: **computational efficiency**



Wide range of **applications** on Europe's energy transition towards **2050**

The IAM COMPACT project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement No 101056306.

Weather-Climate data

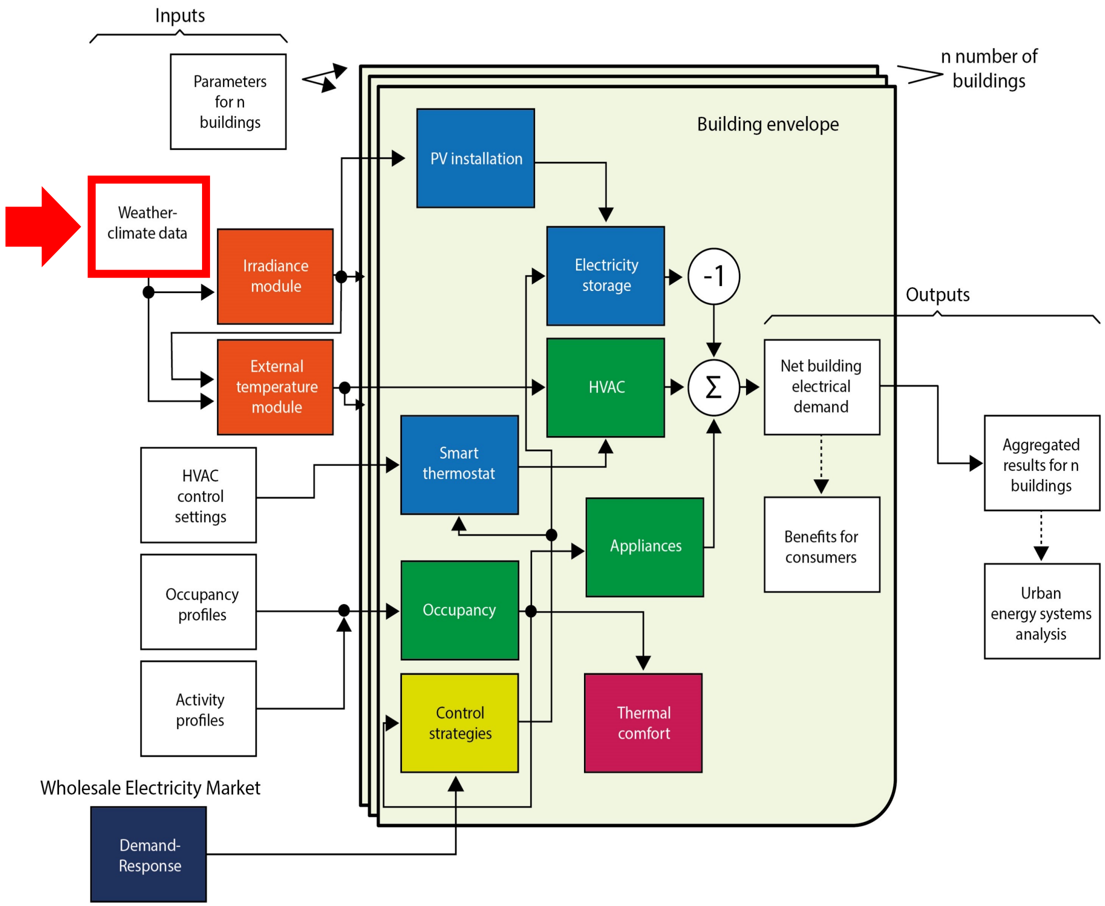
Climate.OneBuilding.Org

WMO

Renewables.ninja

Typical Meteorological Years (TMY) for **several regions** in the demo countries.

Q_1: Specify regions to use more accurate weather data



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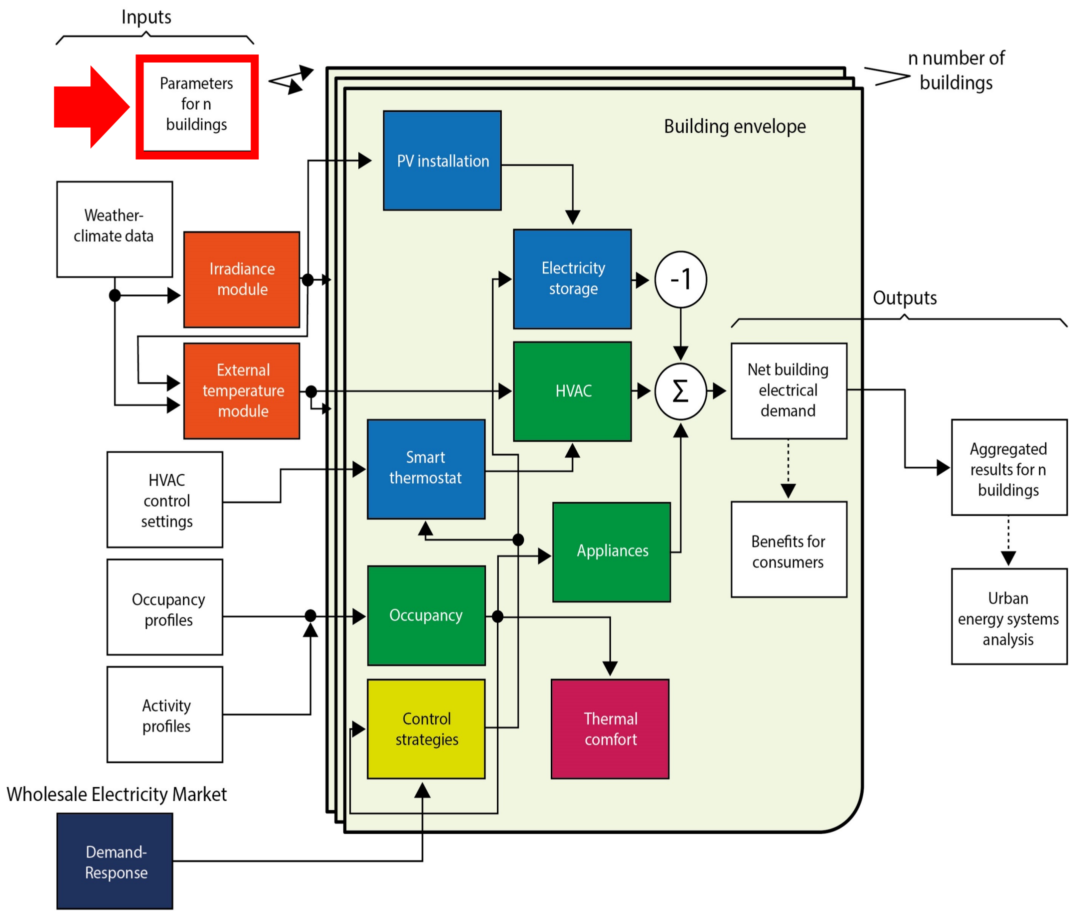
Building parameters

Construction year
Type of building
No. of floors
Total floor area, Height
Total roof area
Total walls area
Total windows area
U-values

Q_2: Custom building characteristics & Existing typologies



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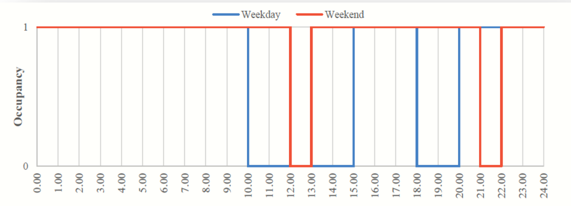
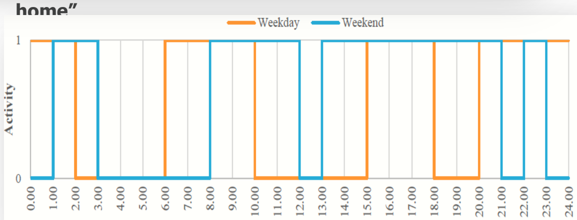
Occupancy & activity profiles

Building composition, occupancy & activity patterns



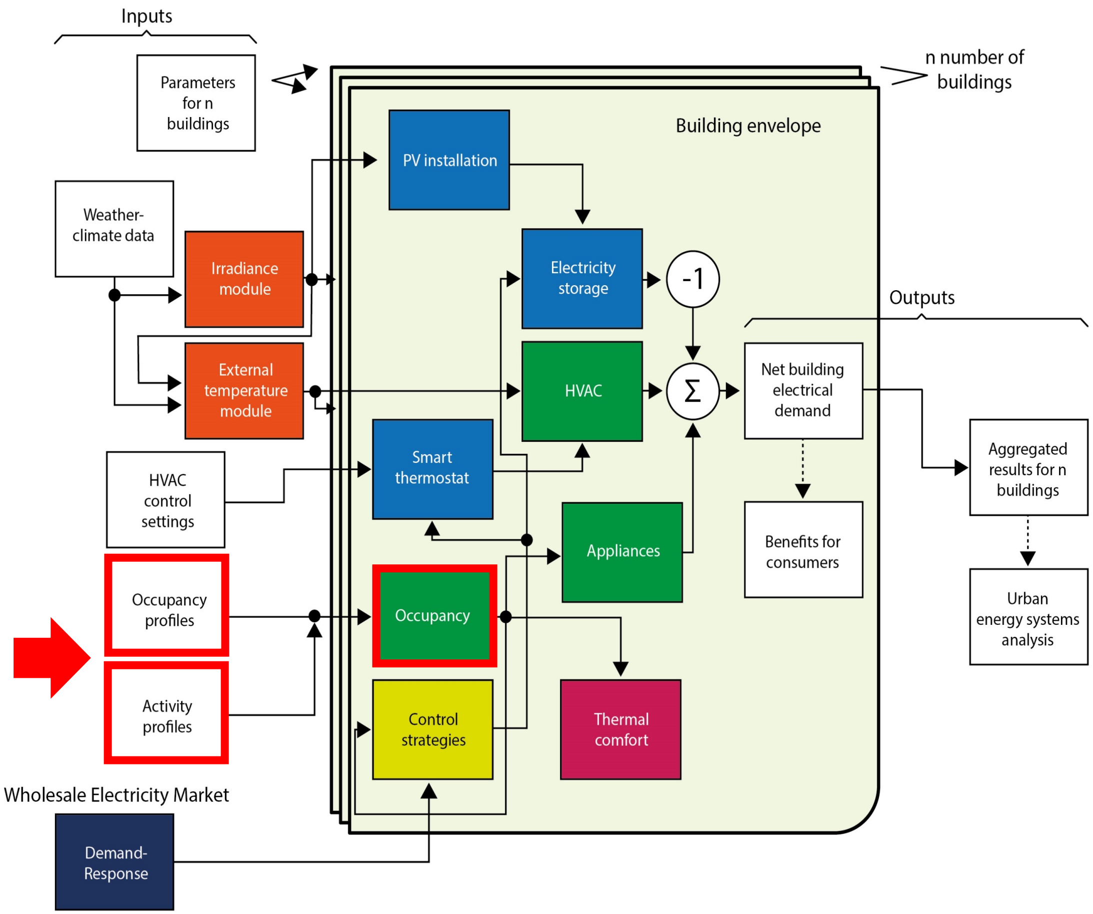
1= "at home", 0= "not at home"



1= "active", 0= "not active"

Q_3: Occupancy/Activity data

National Household Budget Surveys (HBS)



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Model parameterisation (4/4)

Occupancy & Activity profiles

HVAC & Appliance ownership/use

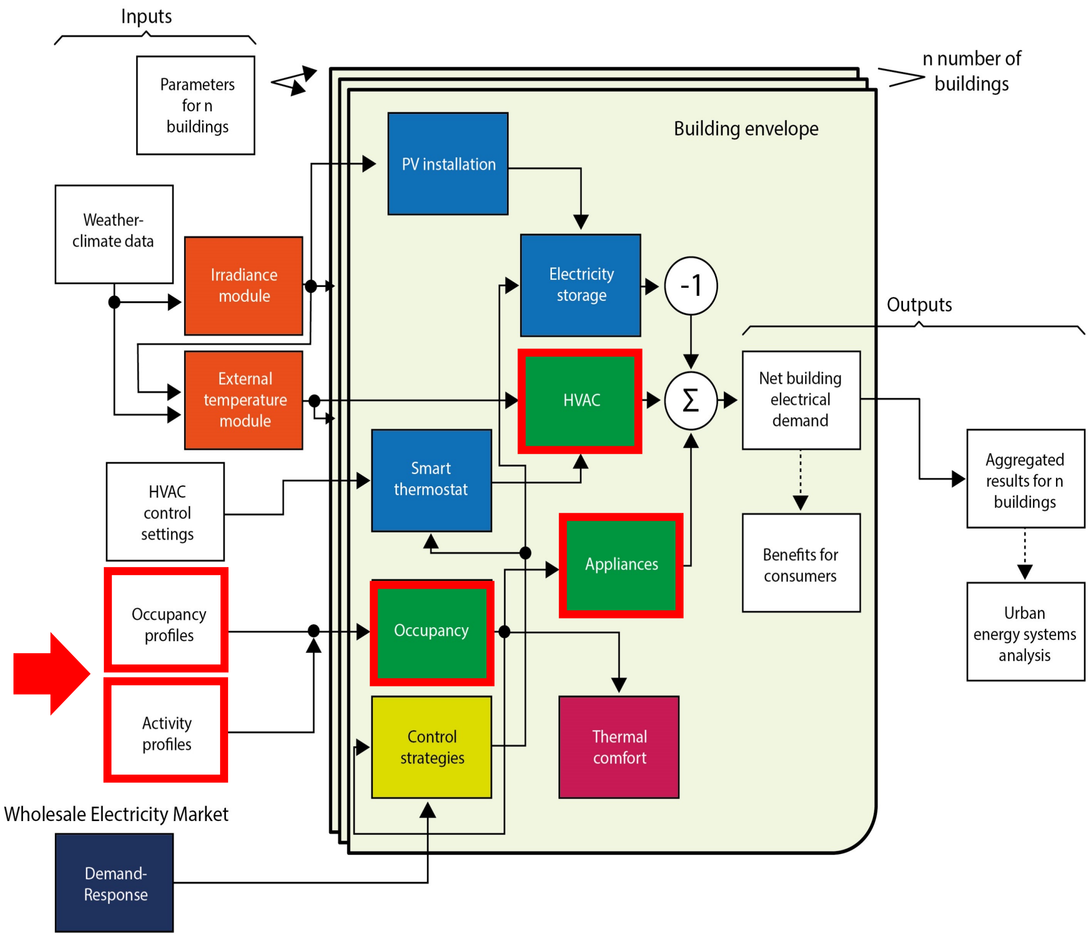
National Household Budget Surveys (HBS)

Survey on energy consumption in households (SECH) data

Weekly energy consumption from appliances based on the SECH 2012–2013 survey data in Greece.

Appliances	Ownership rate (%)	Nominal power (W)	Time Of Use (TOU) (days/week)	Time Of Use (TOU) (hours/day)	Weekly consumption (kWh/week)
Cooking					
Hobs	91.82	1600	1.56	1.92	4.77
Electric cooker with oven	86.89	2150	2.86	3.21	19.75
Microwave oven	33.33	1150	2.13	1.03	2.51
Toaster	61.80	1300	2.52	0.20	0.66
Coffee maker	36.91	1100	2.32	1.00	2.55
Water boiler	31.41	1250	1.79	1.00	2.23
Cooker hoods	89.64	108	1.56	1.89	0.32
Lighting					
Incandescent lamp (x6)	80.54	80	7.00*	3	1.68
LED lamp (x2)	4.75	10	7.00*	2	0.14
Night light (x1)	95.01	1	7.00*	8	0.06
Other appliances					
Fridge-freezer	80.57	150	7.00	24.00	25.20
Dishwasher	29.02	1350	3.09	0.52	4.95
Washer (without tumble dryer)	94.30	500	2.46	0.50	1.76
Iron	94.98	1000	1.82	0.31	2.15
Vacuum cleaner	78.06	450	2.19	0.21	0.67
Color-television set	99.03	100	7.00	5.19	3.63
DVD or VCR	37.05	40	2.51	0.39	0.11
Stereo	30.59	24	4.21	1.00	0.17
Computer (desktop, laptop, tablet, etc.)	41.84	300	3.06	0.53	1.10
Peripheral devices (printer, scanner, etc.)	13.91	50	0.56	0.13	0.05
Internet devices (printer, scanner, etc.)	38.21	10	7.00	24.00	1.68
Video Game Consoles	6,36	160	3.73	0.77	0.86
Charger: mobile phone charger	99.36	1	6.58	1.27	0.08

Indicative appliance data for the case of Greece



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Energy transition in the European residential sector (1/3)

Performing modelling analysis to assess the **energy saving potential** & **cost-effectiveness** of **nine (9)** different Energy Efficiency Measures (**EEMs**),

in the context of **eight (8) European countries**.

EEM #1

Exterior Wall Insulation of the building envelope

EEM #2

Roof Insulation to reduce the heat load of the buildings under study

EEM #3

Thermal upgrade through **Double-glazed Windows**

EEM #4

Smart Thermostat: Setback states without compromising thermal comfort of the occupants

EEM #5

Replacement of an **oil-fired** boiler with a **modern oil condensing** boiler

EEM #6

Replacement of an **oil-fired** boiler with a **natural gas condensing** boiler

EEM #7

Replacement of an **oil-fired** boiler with a with a **biomass** boiler

EEM #8

Replacement of an **oil-fired** boiler with a high temperature **heat pump**

EEM #9

Replacement **of traditional incandescent** light bulbs with **LED** ones

Tzani et al. (under preparation). SENTINEL working paper. Available online here.

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Energy transition in the European residential sector (2/3)

Climate & Weather data

Copernicus Europe's eyes on Earth

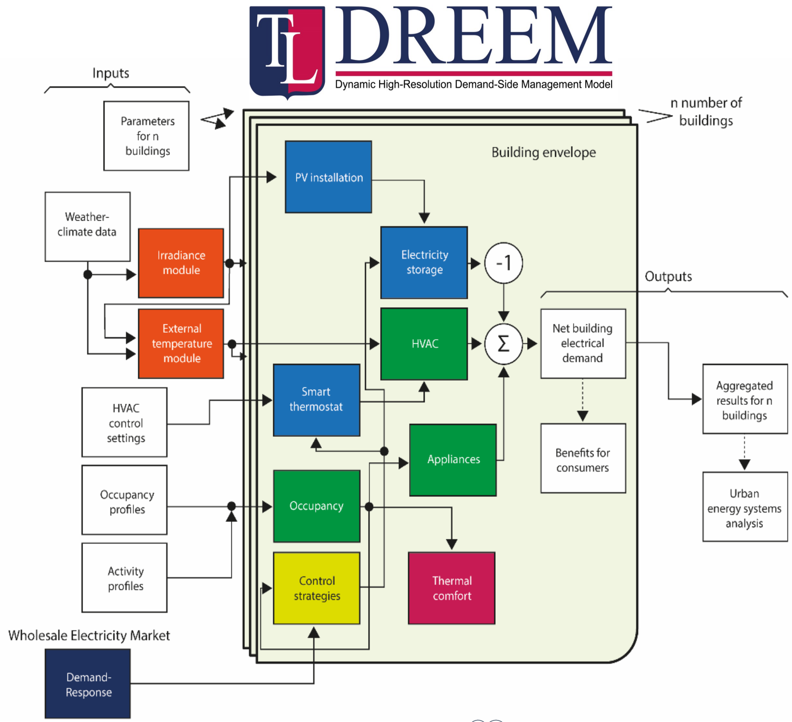
EnergyPlus

Renewables.ninja

Different building typologies & construction periods

TABULA

ENTRANZE



Energy demand simulation model

Building sector

$$Levelized\ Cost\ of\ Saved\ Energy = \frac{(CRF * Cost_{investment}) + Cost_{O\&M}}{Energy\ Svings\ (kWh)}$$

$$Capital\ Recovery\ Factor\ (CRF) = \frac{r * (1+r)^N}{(1+r)^N - 1}$$

Tzani et al. (under preparation). SENTINEL working paper. Available online here.

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How the **different construction periods** (**building characteristics**) **& geographical contexts** can **affect** the **energy-saving potential** & **cost-effectiveness** of different **EEMs?**

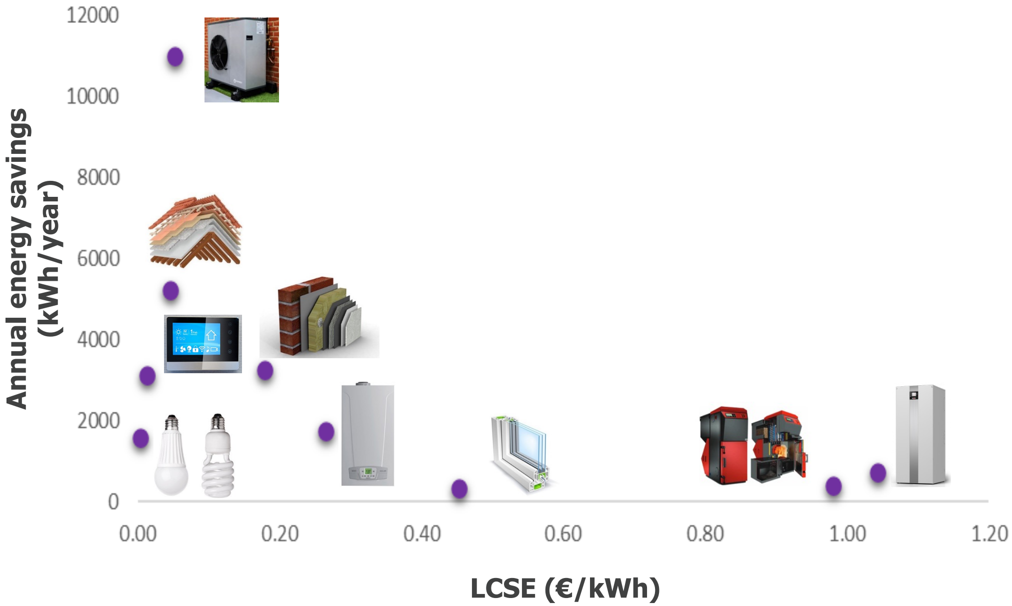
2 categories of buildings based on their construction period

Category I: buildings that have been built **before 1981** (the requirements for thermal insulation of buildings was set after 1981).

Category II: Building that have been built in the period **1981-2006**.

- Energy-saving potential of the EEMs is commonly **higher** for buildings in **Category I**.
- The replacement of an old heating system with a **heat pump** is among the **most cost-effective measures** for all countries, while also illustrates **high energy-saving potential**.
- Investing in **more energy-efficient diesel boilers** is shown to be the **least cost-effective measure** in most cases.
- **Double-glazed windows rank low** in terms of cost-effectiveness in many cases.

Indicative results for a single-family building in Spain (city of Madrid) constructed during the period 1960-1979



Tzani et al. (under preparation). SENTINEL working paper. Available online here.

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Energy Transition in the Greek Residential Sector

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DREEM
Dynamic Demand-Response Simulation Model

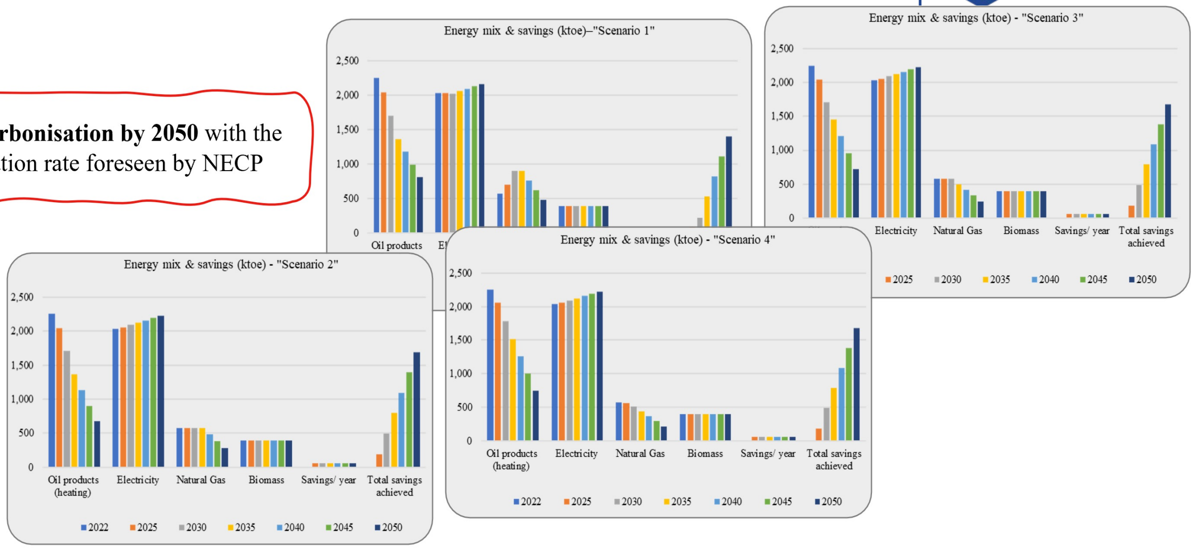
1 **Scenario 1:**
"Baseline - Natural gas as a transition fuel"

2 **Scenario 2:**
"Investing in heat pumps & phasing out of natural gas #1"

3 **Scenario 3:**
"Investing in heat pumps & phasing out of natural gas #2"

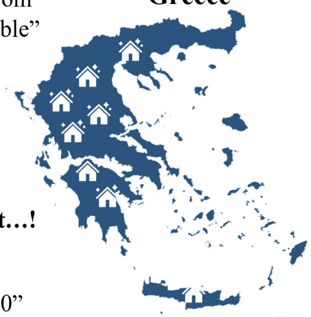
4 **Scenario 4:**
"Complete independence from natural gas as soon as possible"

No decarbonisation by 2050 with the renovation rate foreseen by NECP



National scale

Greece

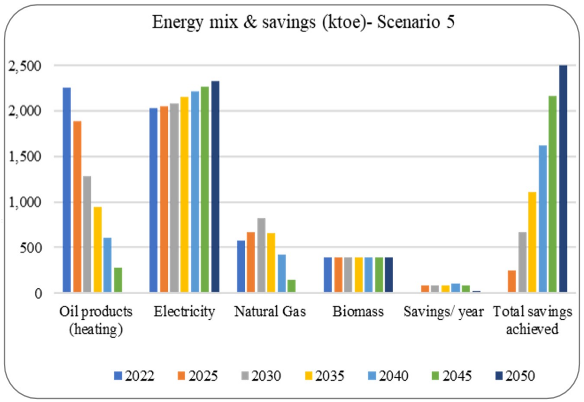


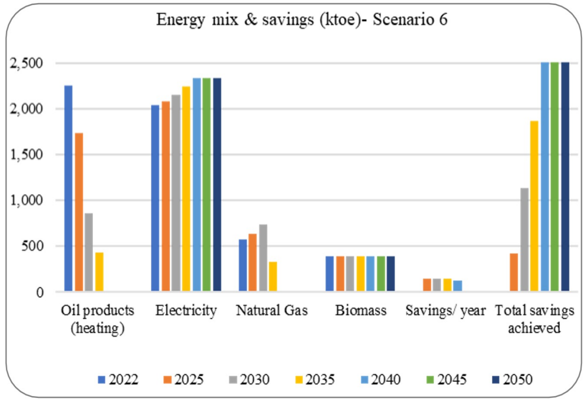
If decarbonisation is the target…!

5 **Scenario 5:**
"Decarbonisation by 2050"

6 **Scenario 6:**
"Decarbonisation by 2040"

2.5% annual renovation rate to achieve **decarbonisation** by 2050

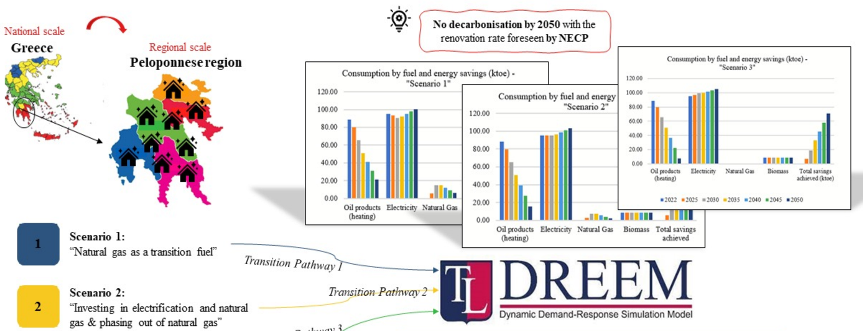




3.5% annual renovation rate to achieve **decarbonisation** by 2040

The IAM COMPACT project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement No 101056306.

Stavrakas et al. (under preparation). SENTINEL working paper. Presented @ECEMP_2022; recordings available here. Presentation available online here.

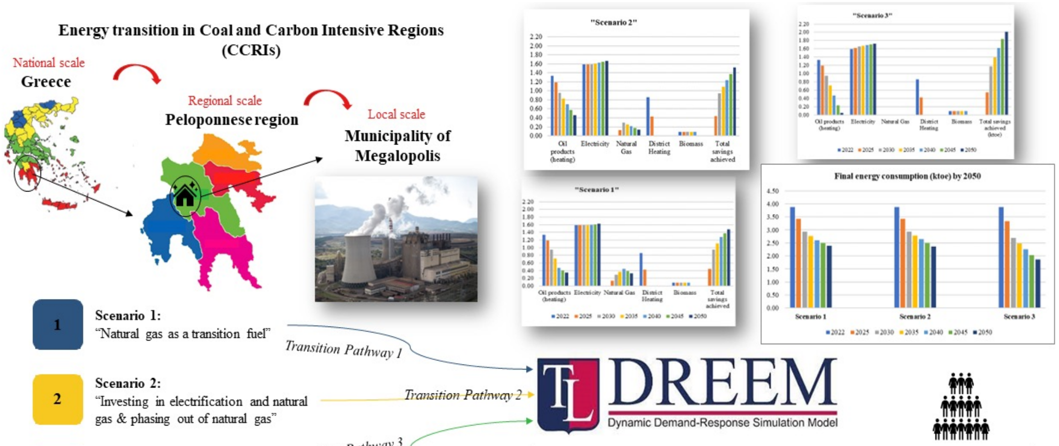


Total costs towards 2050 (ETS, fuel & renovation)	Household level (ETS=30-100€/tnCO$_2$)	Regional level (ETS=30-100€/tnCO$_2$)
No renovations	68,290€	12,878.1M
"Scenario 1"	60,308€	11,372.8M
"Scenario 2"	58,767€	11,082.3M
"Scenario 3"	57,768€	10,893.8M

	Annual number of renovations required to achieve decarbonisation	Annual renovation rate required to achieve decarbonisation
"Scenario 1"	4,115	~2.2%
"Scenario 2"	3,700	~2.0%
"Scenario 3"	3,285	~1.8%

New natural gas infrastructures at the region of Peloponnese.

Just Transition pathways in Coal and Carbon Intensive Regions (CCIRs)



Total costs towards 2050 (€) (ETS, fuel & renovation)	Household level (ETS=30-100€/tnCO$_2$)	Local level (ETS=30-100€/tnCO$_2$)
No renovations	57,337€	203.3M
"Scenario 1"	53,194€	188.6M
"Scenario 2"	54,398€	192.8M
"Scenario 3"	50,256€	178.1M

Increased financial benefits at both household & local level

Natural Gas

OR

Electrification?

Decarbonisation pathways in the residential sector in Greece at **regional**, and **local** scales considering **national targets** & planning regarding **new natural gas** infrastructure/**phase-out** of lignite.

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For more info

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ELSEVIER

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

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

Vassilis Stavrakas, Alexandros Flamos

ELSEVIER

Energy Research & Social Science
Volume 90, August 2022, 102662

Existing tools, user needs and required model adjustments for energy demand modelling of a carbon-neutral Europe

Souran Chatterjee [a], Vassilis Stavrakas [b], Gabriel Oreggioni [c], Diana Süsser [d], Iain Staffell [c], Johan Lilliestam [d, e], Gergely Molnar [a, f], Alexandros Flamos [b], Diana Ürge-Vorsatz [a]

ELSEVIER

Energy Policy
Volume 161, February 2022, 112759

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

Konstantinos Koasidis [a], Vangelis Marinakis [a], Alexandros Nikas [a], Katerina Chira [a], Alexandros Flamos [b], Haris Doukas [a]

zenodo

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September 15, 2022

Project deliverable Open Access

Report on model application in the case studies: challenges and lessons learnt: Deliverable 7.2. Sustainable Energy Transitions Laboratory (SENTINEL) project

Serafeim Michas; Nikos Kleanthis; Vassilis Stavrakas; Amanda Schibline; Andrzej Ceglarz; Alexandros Flamos; Dimitra Tzani; Dimitris Papantonis; Leonidas Kliafas; Diana Süsser; Johan Lilliestam; Miguel Chang; Jakob Zinck Thellufsen; Henrik Lund; Souran Chatterjee; Gergely Molnar; Diána Ürge-Vorsatz; Bryn Pickering; Raffaele Sgarlato; Nieves Casas Ferrús; Cornelis Savelsberg; Cristina Madrid López; Nick Martin; Laura Talens Peiró; Gabriel Oreggioni; Iain Staffell; Alexandra Psyrri; Stefan Pfenninger; Jakob Mayer; Gabriel Bachner; Karl Steininger; Stratos Mikropoulos; Hsing-Hsuan Chen; Mark Roelfsema

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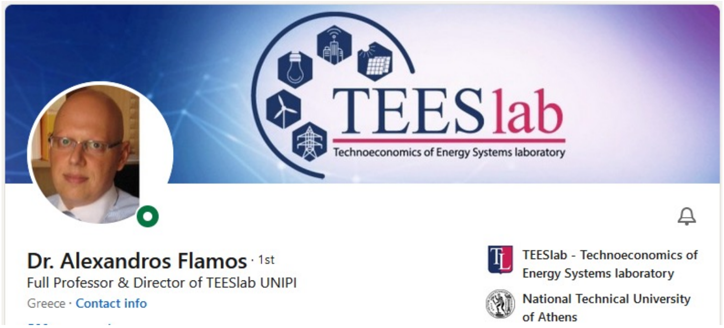
SCAN ME



Email us:

aflamos@unipi.gr
vasta@unipi.gr

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Thank you!

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