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Energy Policy Design in the Eastern Mediterranean Basin: A Roadmap to Energy Efficiency

Dr. Bertug Ozarisoy

PhD, MA, MSc, BSc (Hons)

[a] Lecturer in Architecture: Technology in the School of the Built Environment and Architecture at the London South Bank University, London, United Kingdom

Correspondence e-mail: bertug.ozarisoy@lsbu.ac.uk

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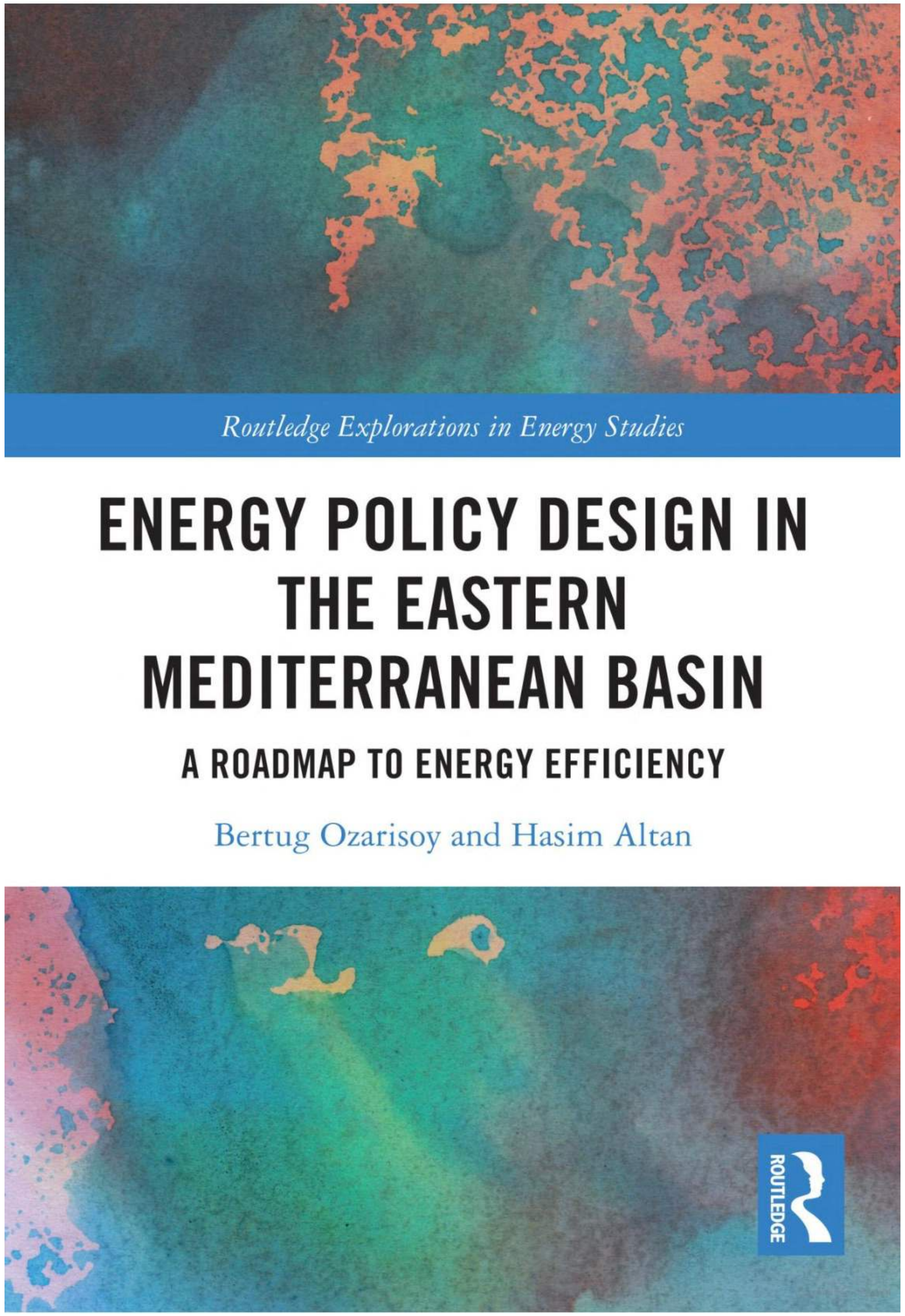
Reference Book



Source: **Ozarisoy, B.** and Altan, H. (2023). Energy Policy Design in the Eastern Mediterranean Basin: A Roadmap to Energy Efficiency, Taylor & Francis Group, Routledge Explorations in Energy Studies, ISBN 9781032493046, https://www.routledge.com/Energy-Policy-Design-in-the-South-Eastern-Mediterranean-Basin-A-Roadmap/Ozarisoy-Altan/p/book/9781032493046

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4. Results and Discussions (Contribution 1): Feed-forward household interviews
5. Results and Discussions (Contribution 2): Occupancy patterns and Habitual adaptive behaviour on home-energy performance
6. Results and Discussions (Contribution 3): Regression forecasting of neutral adaptive thermal comfort
7. Results and Discussions (Contribution 4): Building-performance evaluation and Energy-model calibration
8. Results and Discussions (Contribution 5): Building energy simulation and Retrofitting strategies
9. Conclusions: Roadmap to EU Energy-policy framework
Outputs: Publications and Contribution to global research databases (Repositories)

Overview: South-eastern Mediterranean island of Cyprus

Research context: Case study location and Archetype housing stock

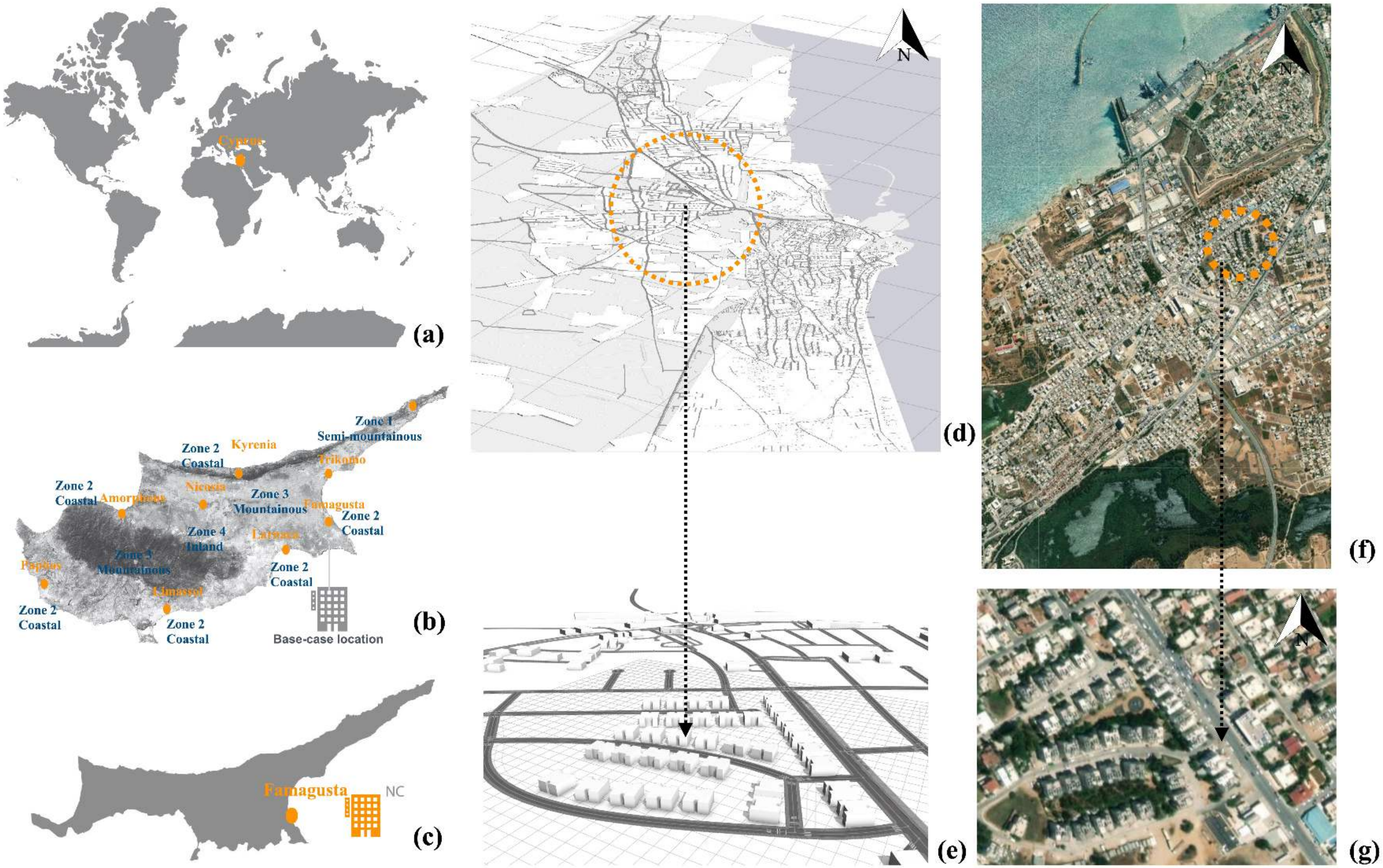


Figure 1: (a) Cyprus geographic position and **(b)** geological characteristics; **(c)** Northern Cyprus; **(d)** Famagusta vulnerable neighbourhood, **(e)** 3D model of medium-rise RTBs and **(f)** residential area urban tissue; **(g)** base-case morphology characteristics.

Climate: South-eastern Mediterranean basin

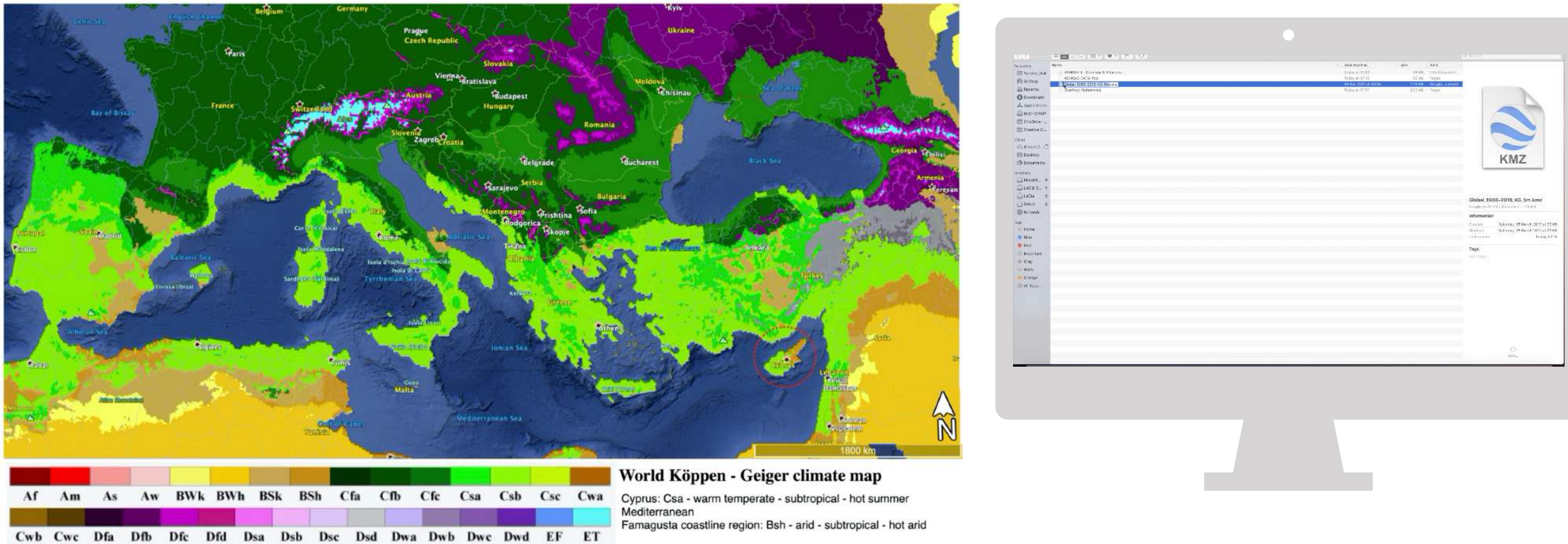


Figure 2: (a) The map of Köppen-Geiger climate classification in the Mediterranean region; **(b)** Integration of raw dataset files into Google Earth Pro software suite to demonstrate the World climate classification.

Source: Rubel et al., (2017) - Interactive mapping of world-climate data accessed at http://koeppen-geiger.vu-wien.ac.at (April 14, 2021)

Overview: Climate characteristics of Cyprus

Local climate parameters: Temperature, Relative Humidity Index, Solar radiation and Solar irradiance

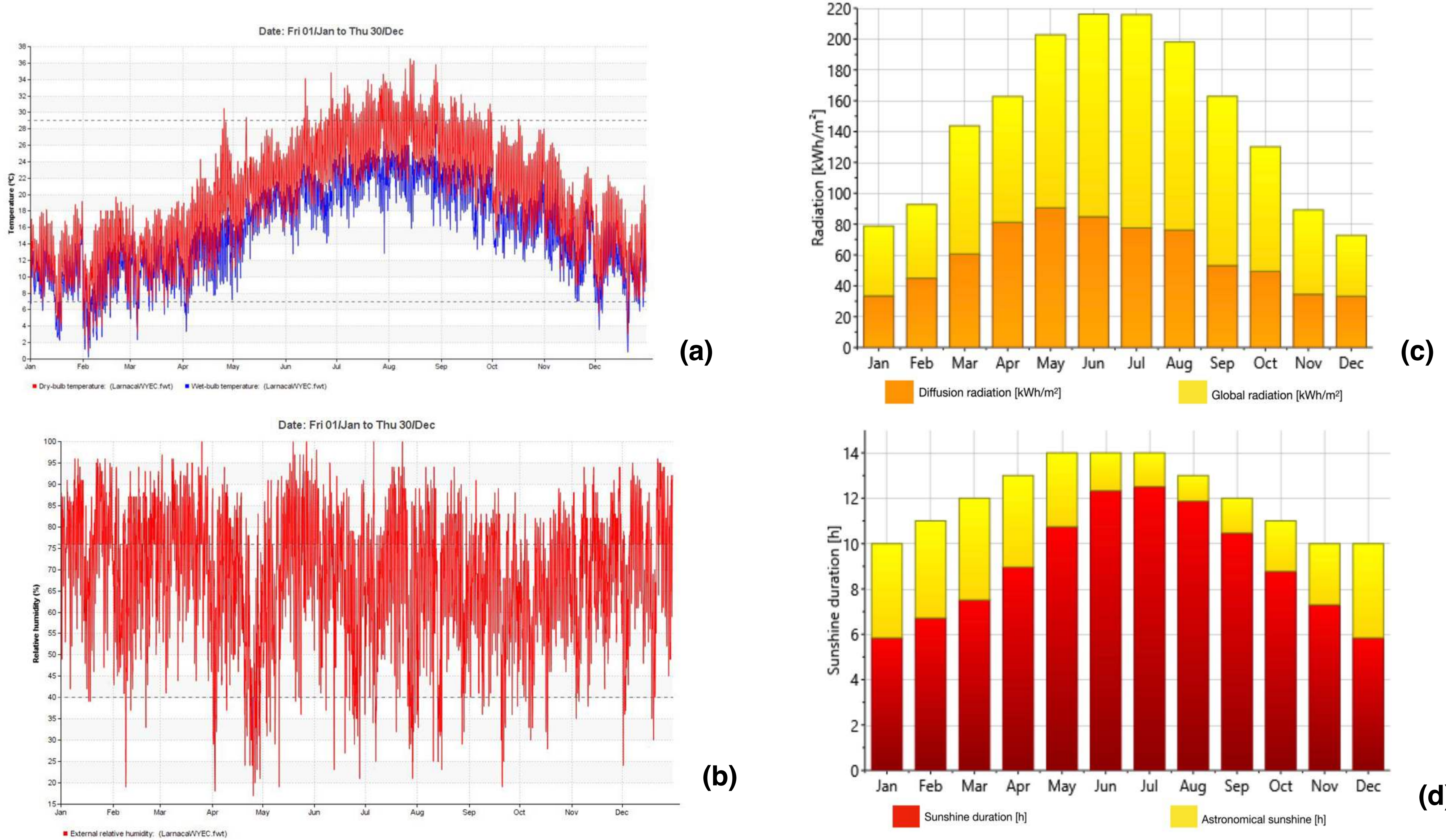


Figure 3: Environmental conditions of case study location: **(a)** Average hourly air temperature fluctuations **(b)** relative humidity fluctuations; **(c)** solar irradiance; **(d)** sunshine hours. ***Sources: (a)-(b)*** Integrated Environmental Solutions (IES) software suite version 2021.1.0. ***(c)-(d)*** Meteonorm version 8; software suite developed by Meteotest AG in 2020 (Germany).

European housing stock data by population and Population of Northern Cyprus

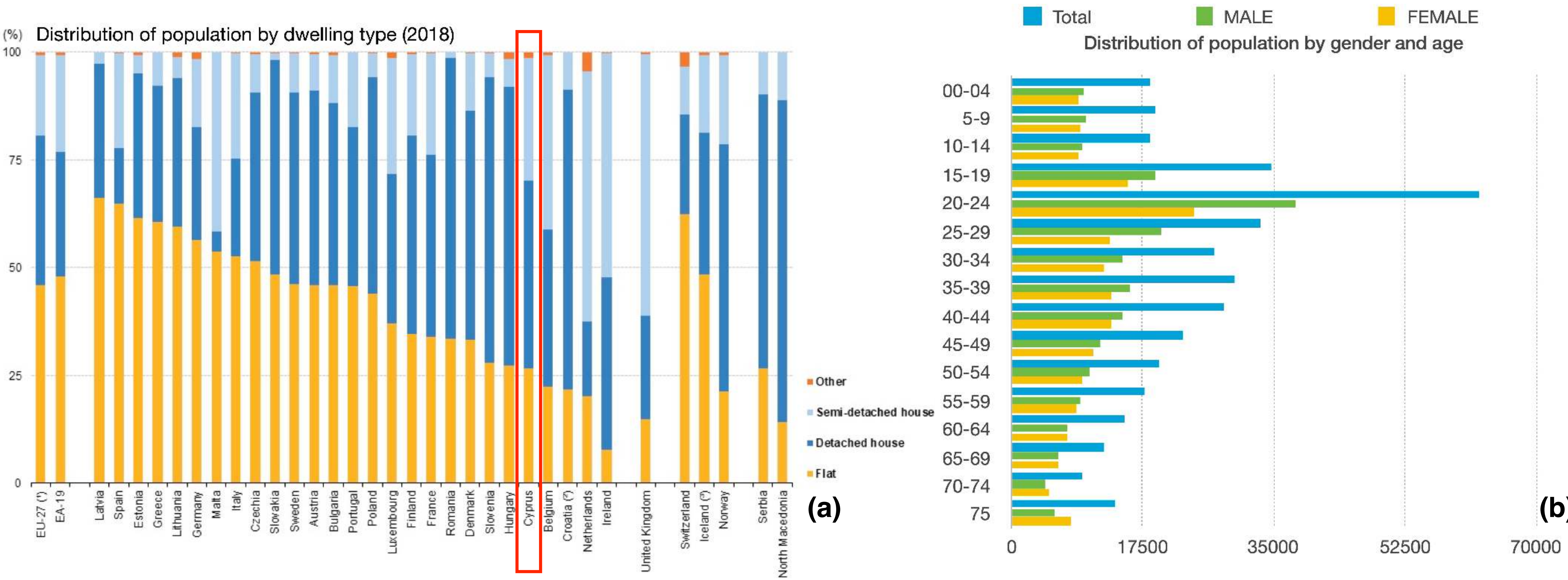


Figure 4: (a) Distribution of population by dwelling type in EU member states in 2018 **(b)** Distribution of Northern Cyprus's population by gender and age. ***Sources: (a)*** Data on the distribution of population by degree of urbanisation, dwelling type and income group extracted from 2018 EU SILC survey in Eurostat database. Data only represents population and housing stock in the southern territory of the RoC; NC housing stock is not included due to being an isolated *de facto* state. ***(b)*** Annual Statistical Report for 2019, published by the Northern Cyprus Statistical Office.

Housing typology classification: Evolution of social housing estates in Cyprus

	Arch. 1	Arch. 2	Arch. 3	Arch. 4	Arch. 5
A - Construction period	before 1919	1919-1945	1946-1970	1985-1991	1990-1997
B - Urban context	Cul-de-sac	Detached	Semi-detached	Detached	Free standing
C - Roof potential	Sloped roof	Sloped roof	Sloped / Flat roof	Sloped roof	Flat roof
D - Façade potential	Single storey	Two storeys	Two storeys	Two storeys	4 or 5 floors
E - Architectural quality Level of protection	Refurbished	Dilapidated	Good in condition	Poor in quality	Poor in quality
Categories of residential buildings					
Urban tissue	Heritage site	Industrial site	City centre	Natural lake district	Commercial district
Typology	Social housing Low-income Courtyard	Railway workers' house Row houses	Social housing Middle-income Row houses	Social housing Middle-income Row houses	Social housing Middle-income Apartments

Figure 5: Taxonomy of existing Cypriot housing stock to identify archetypes.
Source: Data obtained from the Ministry of Housing, Dept. Of Rural Affairs and Development, Cyprus

Classification of high-density social housing estates in Cyprus: Demand on high-, medium- and low- rise residential tower blocks

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
A - Construction period	1950-1974	1980-1997	1997-2002	2002-2004	2005 - Today
B - Urban context	Free standing	Free standing	Free standing	Detached	Free standing
C - Roof potential	Flat roof	Flat roof	Flat roof	Sloped / Flat roof	Flat roof
D - Façade potential	High-rise	4 or 5 floors	4 or 5 floors	1 or 5 floors	High-rise
E - Architectural quality Level of protection	Dilapidated	Poor in quality	Poor in quality	Vacant	Poor in quality
Categories of residential buildings					
Urban tissue	Shoreline	Urban/Suburban	Urban agglomeration	Suburban	Urban (city centres)
Typology	High-rise Residential Tower Block	Social housing Middle-income Apartments	Medium-rise Middle-income Apartments	Mass scale Housing estates	High-rise Residential Tower Block
Urban block configuration					

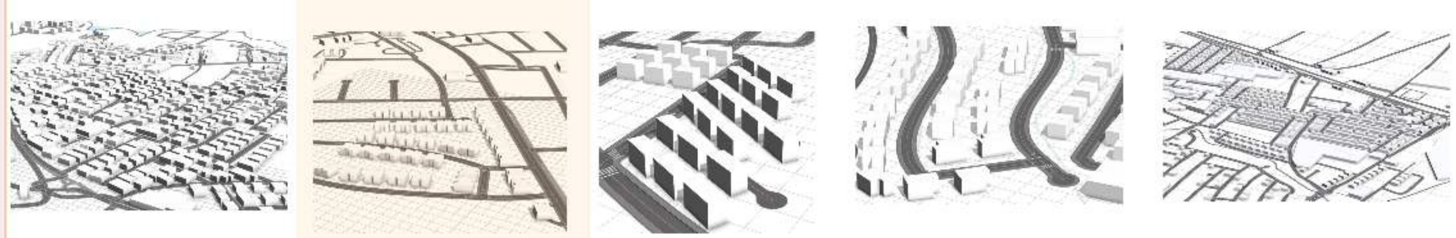
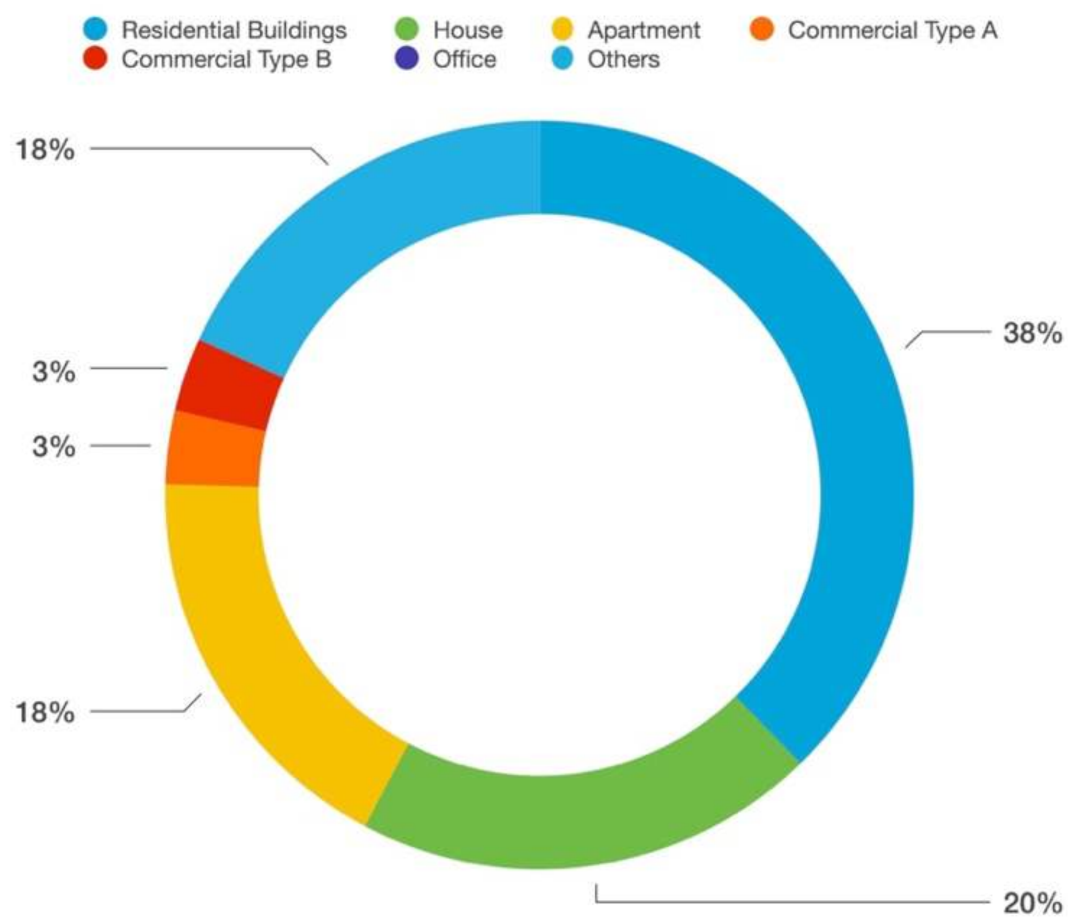


Figure 6: National representativeness of high-, medium- and low- rise residential tower blocks (RTBs) in Cyprus.
Source: Data extracted from the State Planning Organisation: https://www.devplan.org/index_en.html (Accessed on 21/01/2021)

National representativeness of housing stock



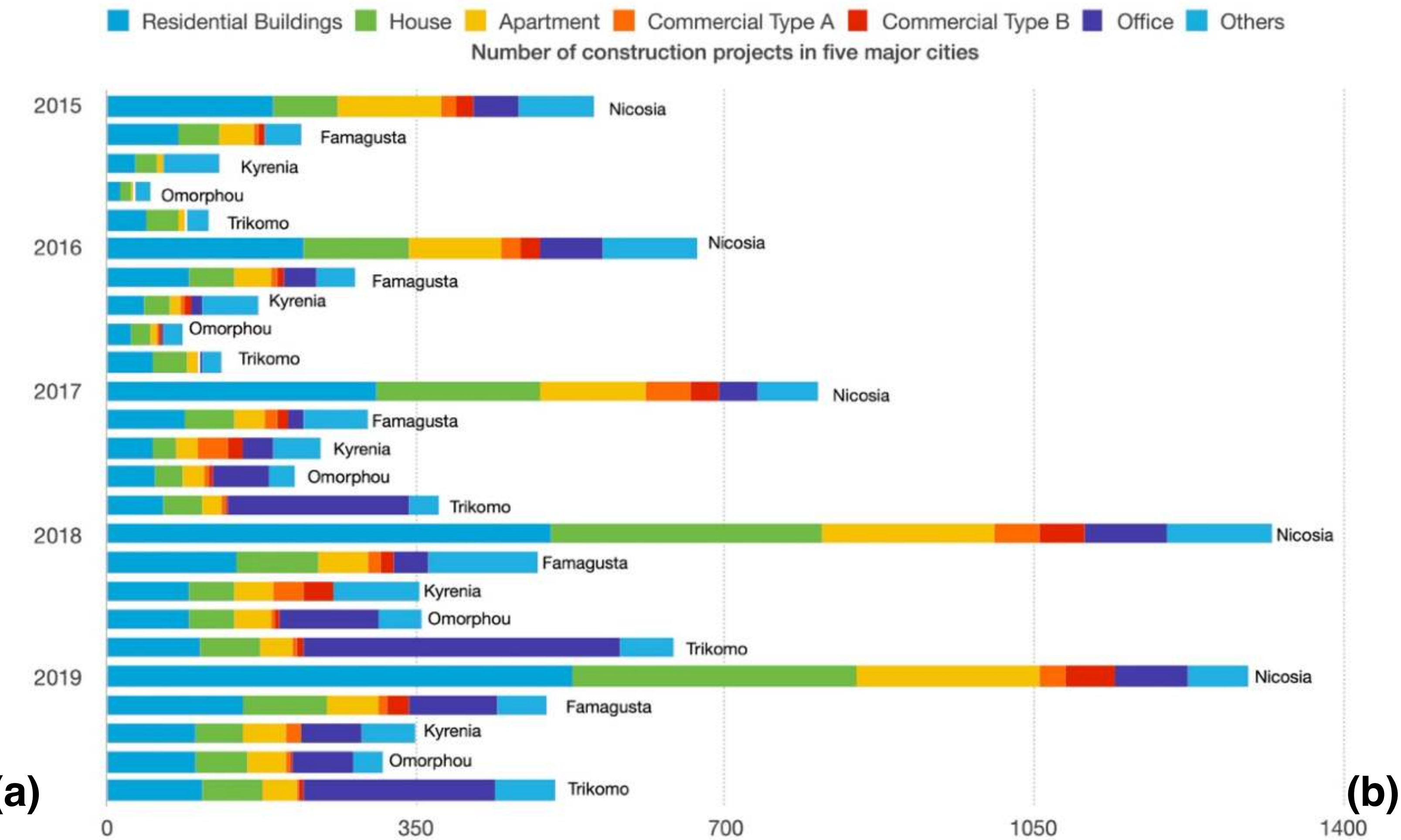


Figure 7: (a) Proportional percentages of building types constructed in Famagusta between 2015-2019; **(b)** Number of buildings constructed between 2015-2019 in five major cities: Nicosia, Famagusta, Kyrenia, Omorphou and Trikomo.
Source: Data extracted from the State Planning Organisation: https://www.devplan.org/index_en.html (Accessed on 21/01/2021)

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Overview: Energy consumption

Energy use of buildings by sectors and Energy use data

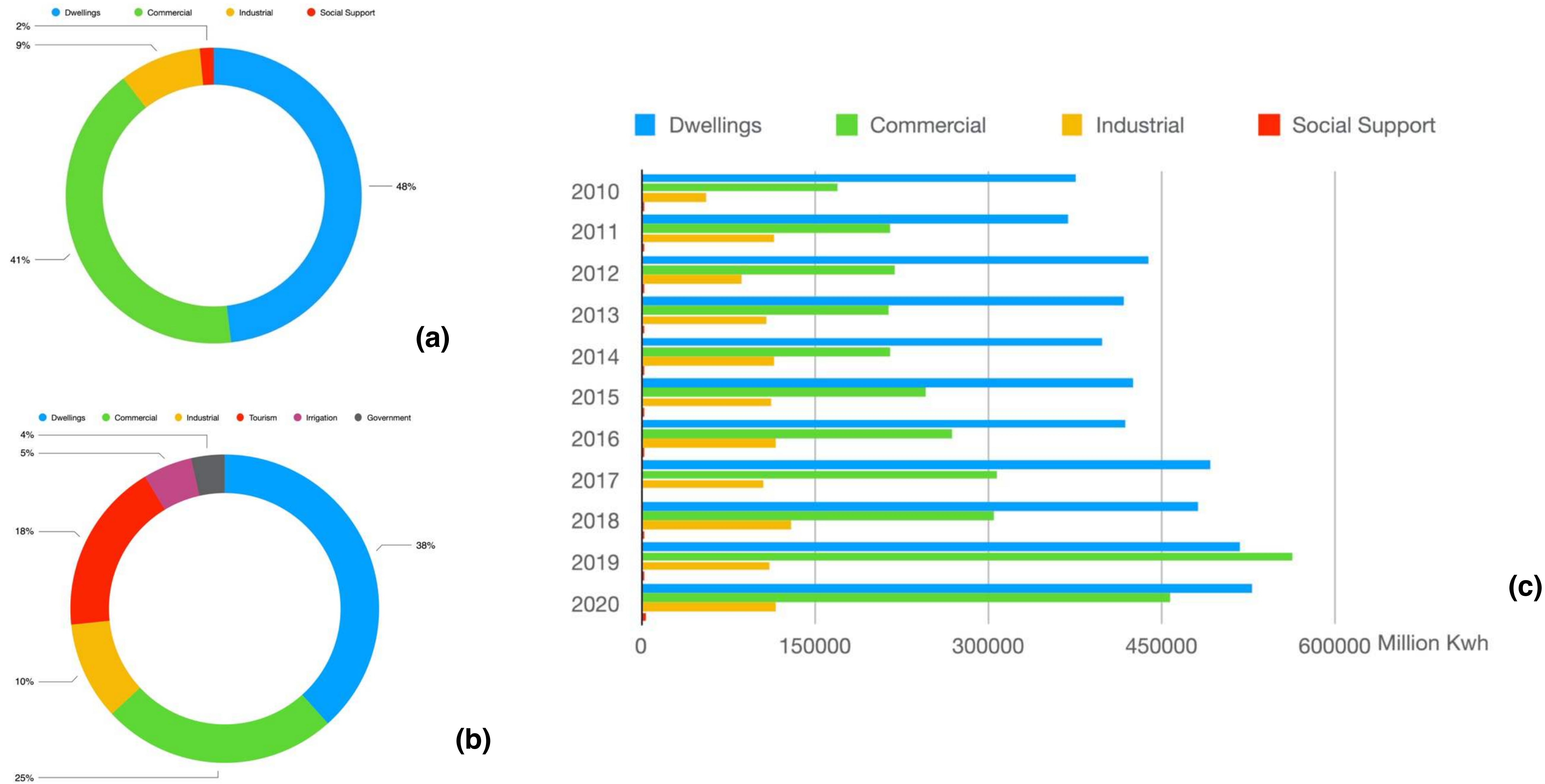

Figure 8: (a) Proportional percentages of total energy consumption of buildings in Northern Cyprus; **(b)** Proportional percentages of different energy consumers in Famagusta from 2017-2019; (c) Total energy consumption of buildings in Famagusta from 2010-2020.
Source: Data extracted from Cyprus Electricity Authority in 2020 (Accessed on 07/02/2021).

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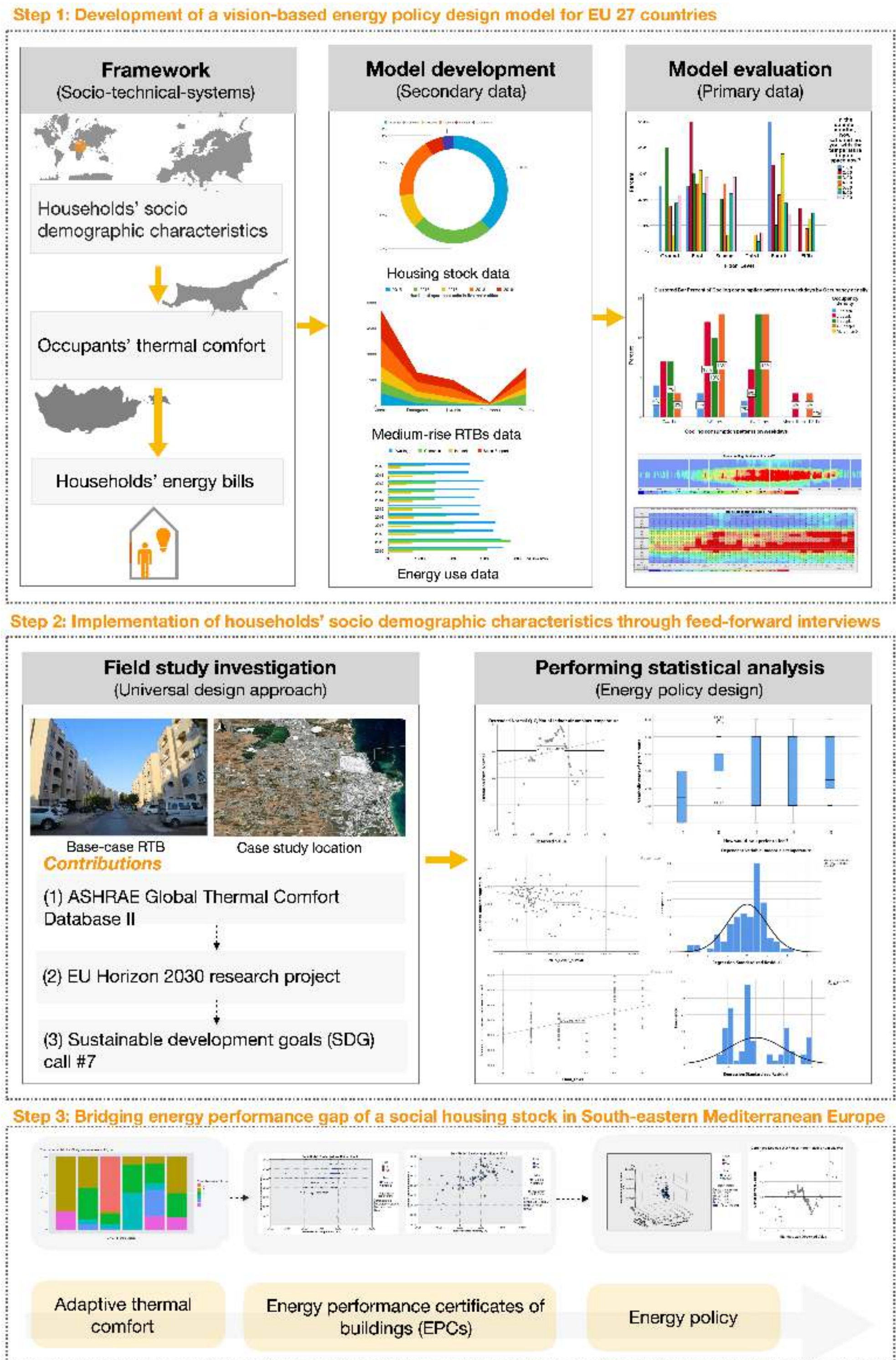
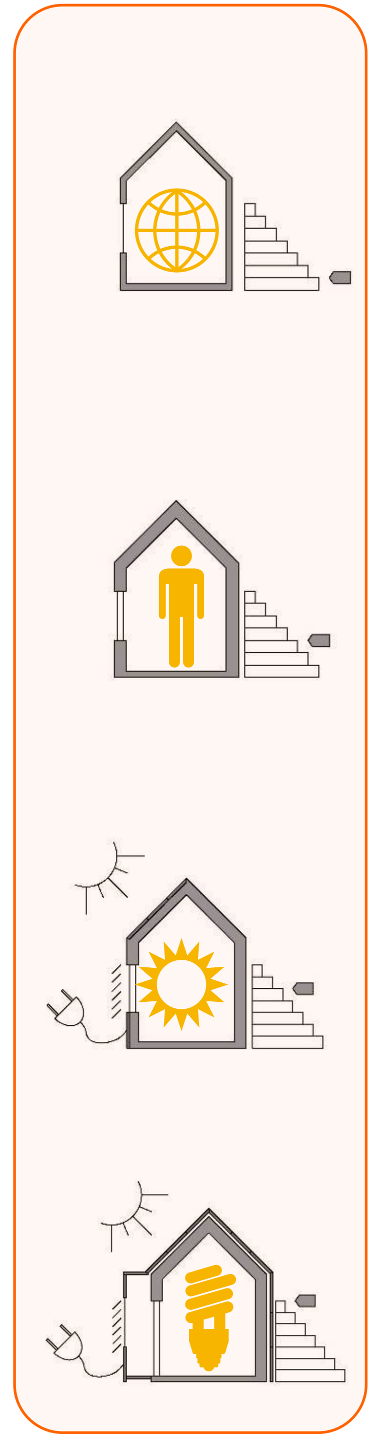
1. Introduction: Knowledge gap in energy-policy framework and Retrofitting existing housing stock

Setting the context: Energy governance in the South-eastern Mediterranean basin



Aim and Objectives



The main aim of this research is to fill the knowledge gap in the area of an evidence-based framework for energy-policy decision-making mechanisms related to the integration and implementation of the EPBD regulations at the conceptual and national levels.

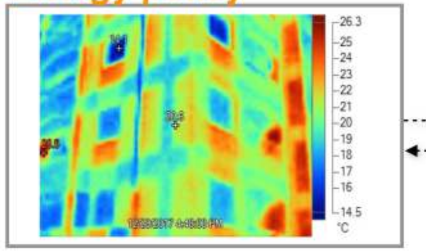
The objectives are three fold:

- To examine the significance of occupancy patterns and habitual adaptive household behaviour on home-energy performance by conducting feed-forward interviews with social-housing occupants;
- To investigate overheating risks and occupant thermal comfort within representative RTBs and subsequently provide primary data sources to build future performance evaluation studies; and
- To develop and test the applicability of a BES on base-case RTB prototypes to demonstrate a design method based on comprehensive accounting of energy governance in the EU.

Figure 9: Step-by-step research impact factor and its contributions to knowledge in developing evidence-based energy policy framework, considering households' adaptive thermal comfort.

Key research subjects and Contribution to knowledge

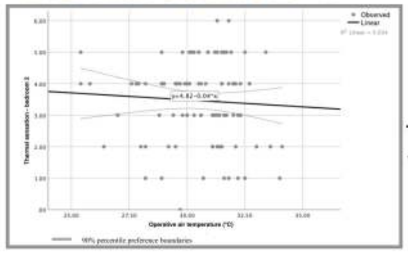
Energy policy



(Contribution 1)

- EU energy governance by integrating EPCs into building-energy-performance development of social-housing stock.

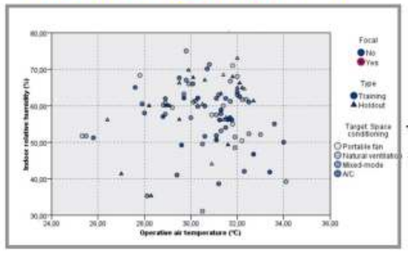
Thermal comfort - I



(Contribution 2)

- Donation of the neutral adaptive thermal comfort identified by a thermal-comfort survey of the Cypriot context to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Global Thermal Comfort Database II
- Donation of the neutral adaptive thermal comfort identified for the Cyprus climate to the EU Smart Controls and Thermal Comfort (SCAT) online database

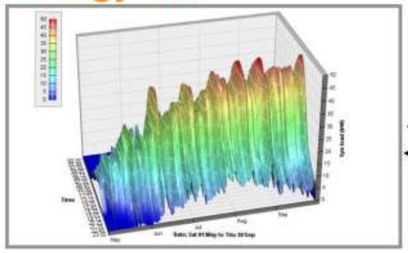
Thermal comfort - II



(Contribution 3)

- Dissemination of the optimum thermal-comfort level thresholds that were developed as a result of a field investigation in the south-eastern Mediterranean climate and can be applied to the European Norm EN 15251 standards - which are related to indoor environmental parameters

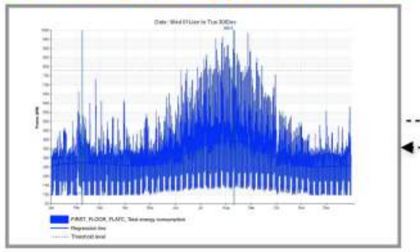
Energy use



(Contribution 4)

- Integration of the archetype housing stock into the EU's Horizon 2030 TABULA/EPISCOPE national database

Building energy simulation



(Contribution 5)

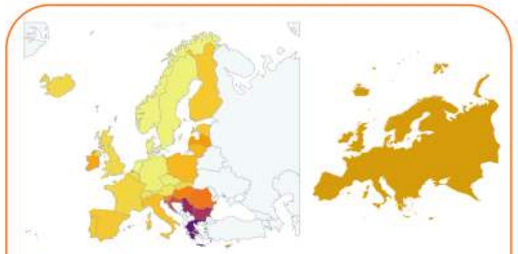
- Development of energy-calibration methods for archetype housing stock and analytical BEM with integrated human-based data from the questionnaire survey to demonstrate a policy design tool to the applied sciences field in energy use

Figure 10: The impact of key research areas to the contribution to knowledge.

1. Introduction: Novelty of study and implications for energy policy design

Impact to EU-27 energy policy framework: Developing an evidence-based retrofitting strategies to assess robust energy-performance evaluation and certification schemes in the South-eastern Mediterranean countries

Energy governance in Europe and Policy design



EU and Southeastern Mediterranean basin

Archetype selection criteria

- South-eastern Mediterranean climate of Cyprus where the weather is subtropical (*Csa*) and partly semi-arid (*Bsh*)
- Post-war social housing stock was selected as archetype buildings in four different climatic zones.
- Four climatic zones:

Zone 1 - semi-mountainous
Zone 2 - coastal
Zone 3 - mountainous
Zone 4 - inland

>

Households' socio-demographic characteristics

Social housing estates

Residential tower blocks (RTBs)

- To improve the current methods of design by including human behaviour
- To understand the occupants' real life experiences with energy use
- To investigate the significant impact of the buildings' thermal properties on occupants' thermal comfort
- To develop appropriately tailored approaches for energy policy design

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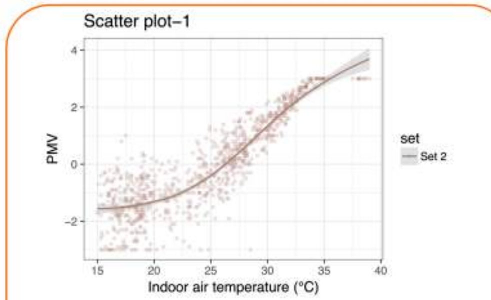
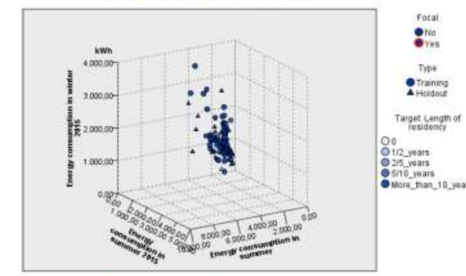
Energy performance and Occupants' thermal comfort



Thermal comfort



Energy forecasting

- Highlighting the importance of indoor air temperature and identification of thermal comfort levels.
- A base case model developed to inform policy making decisions in energy use.
- In-vivo data collected to improve occupants' health and well-being.
- Energy forecasting plans could be methodologically planned and put into action.

Figure 11: Road map to EU energy policy framework by making a contribution to knowledge.

- Integration and development of an effective methodological research approach to create a roadmap of future household energy-consumption profiles that will optimise occupant thermal comfort by providing policy for government initiatives.

Systematic review of bridging energy performance gap of a social housing and developing 'netural' adaptive thermal comfort of multi-family residential buildings: Theories, methodologies and cases in the South-eastern Mediterranean climate

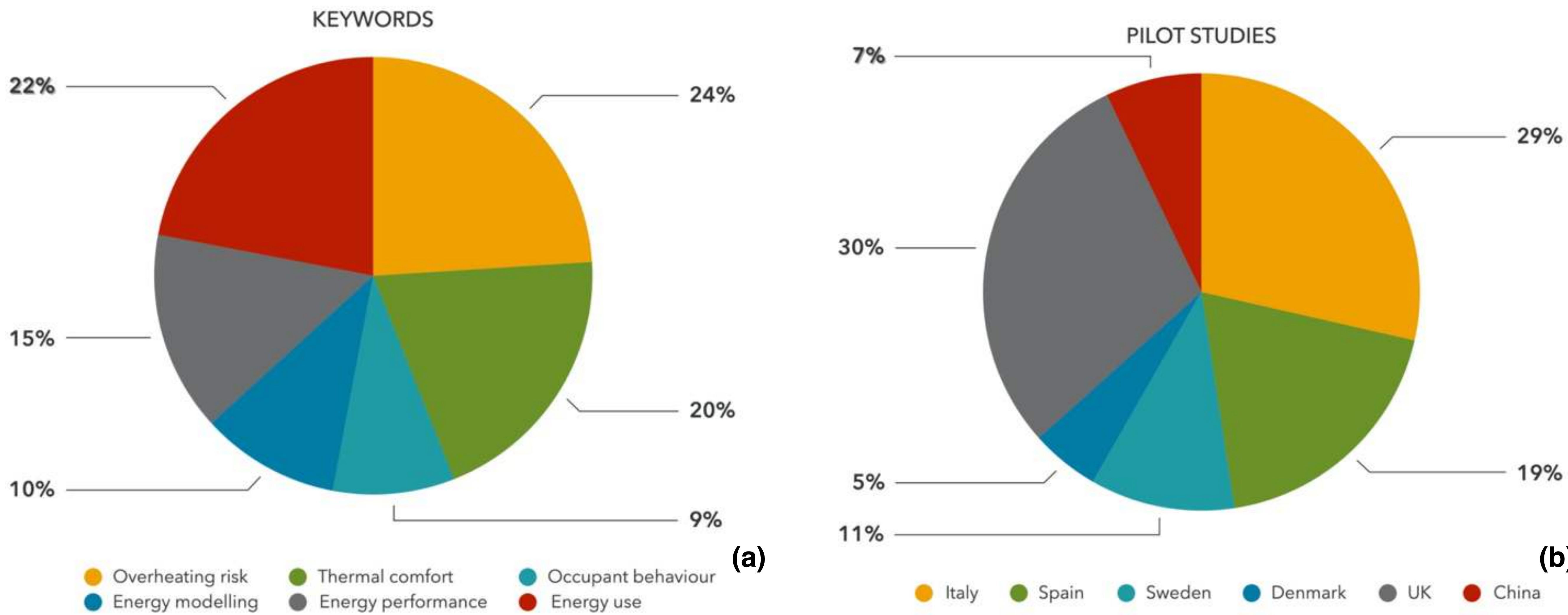


Figure 12: (a) Keywords and percentage distribution related to appearance; **(b)** countries of pilot studies according to keyword selection criteria.

Development of the ASHRAE Global Thermal Comfort Database II: Visualisation and Query builder

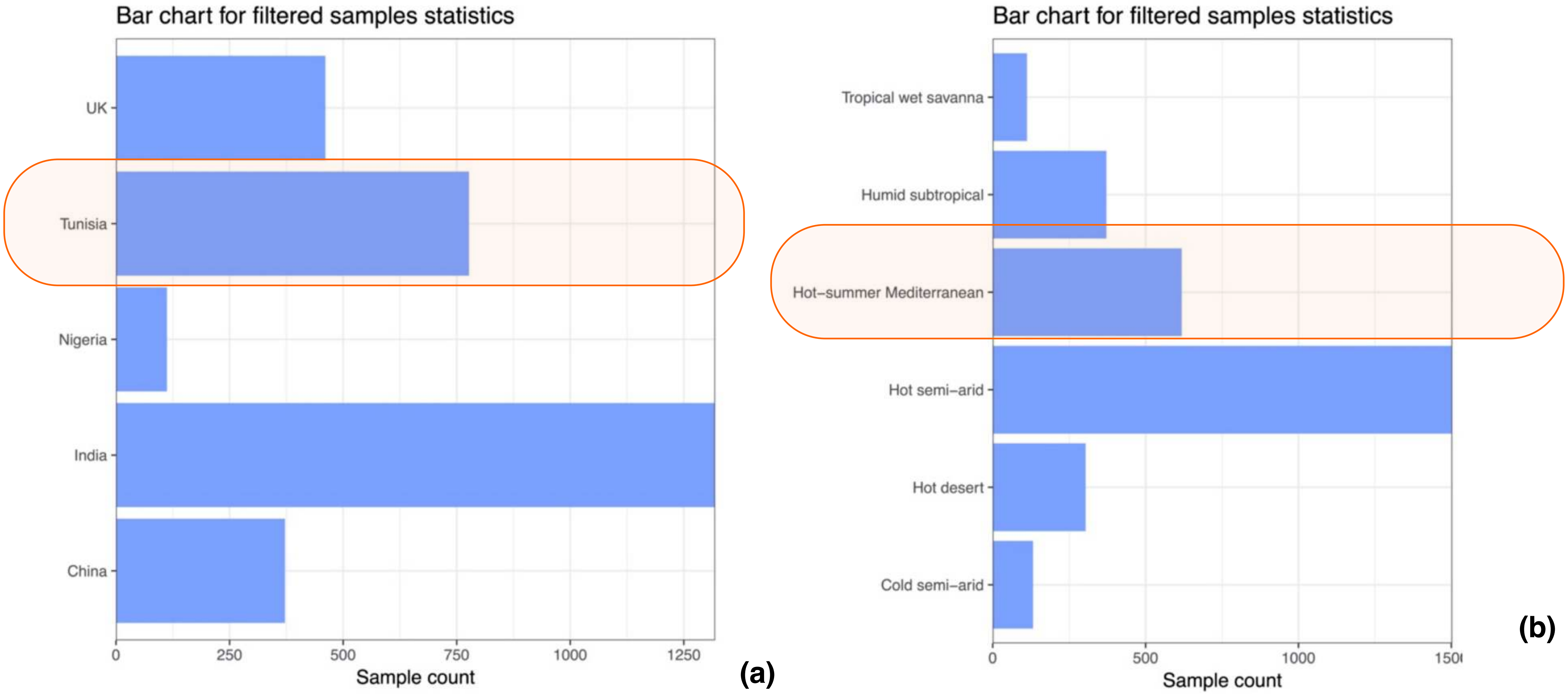
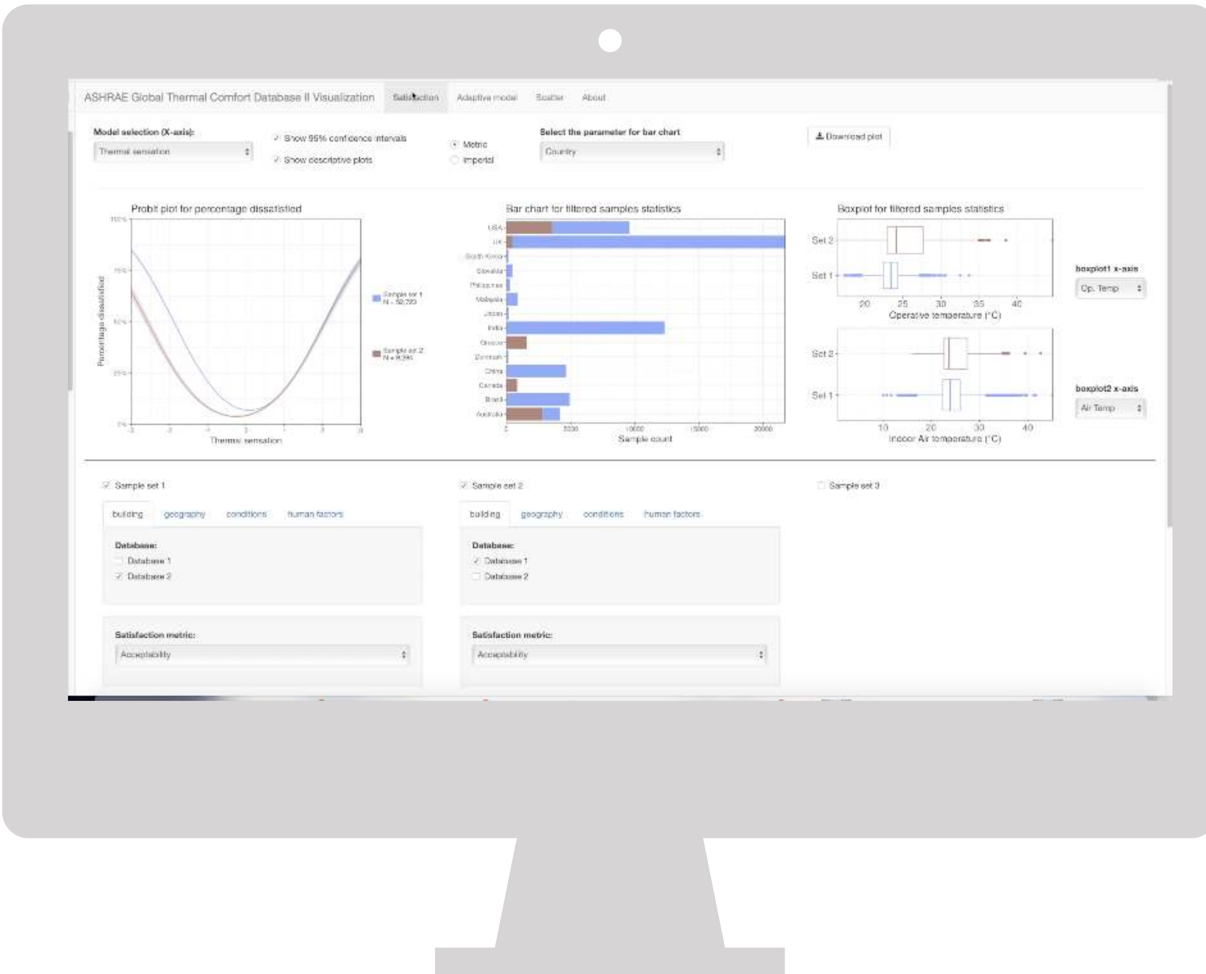


Figure 13: (a) Sample adaptive thermal comfort studies by country; **(b)** TSV configuration of field studies by climate type. ***Source:*** Data extracted from thermal comfort visualisation tool; available at https://cbe-berkeley.shinyapps.io/comfortdatabase (Földváry *et al.*, 2018).

Previously available pilot studies:

- Földváry, V., Bekö, G., Langer, S., Arrhenius, K., & Petráš, D. (2017). Effect of energy renovation on indoor air quality in multifamily residential buildings in Slovakia. Building and Environment, 122, 363–372. https://doi.org/10.1016/j.buildenv.2017.06.009
- Bouden, C., & Ghrab, N. (2005). An adaptive thermal comfort model for the Tunisian context: A field study results. Energy and Buildings, 37(9), 952–963. https://doi.org/10.1016/j.enbuild.2004.12.003

Development of the ASHRAE Global Thermal Comfort Database II: Visualisation and Query builder



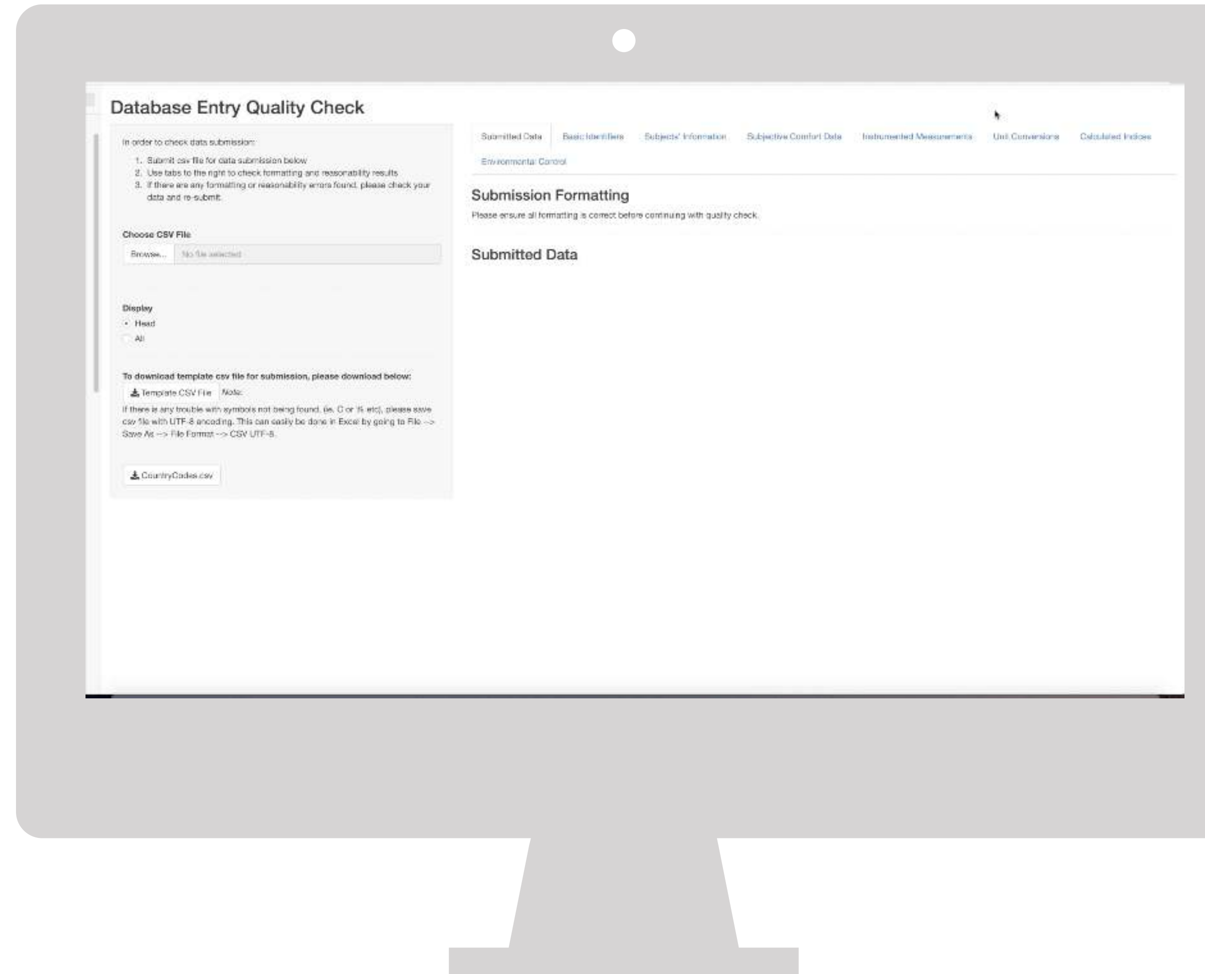


Figure 14: (a) Query builder which was developed to demonstrate global research data for the identification of 'neutral' adaptive thermal comfort; **(b)** Donation of field study investigation data conducted by the researcher to the ASHRAE Global Thermal Comfort Database II. ***Source:*** **(a)** Data extracted from thermal comfort visualisation tool; available at https://cbe-berkeley.shinyapps.io/comfortdatabase (Földváry *et al.*, 2018); (b) Data processed in Query builder dashboard; available at https://databaseqc.shinyapps.io/submission/

Socio-Technical-Systems conceptual framework and Energy-use integrity

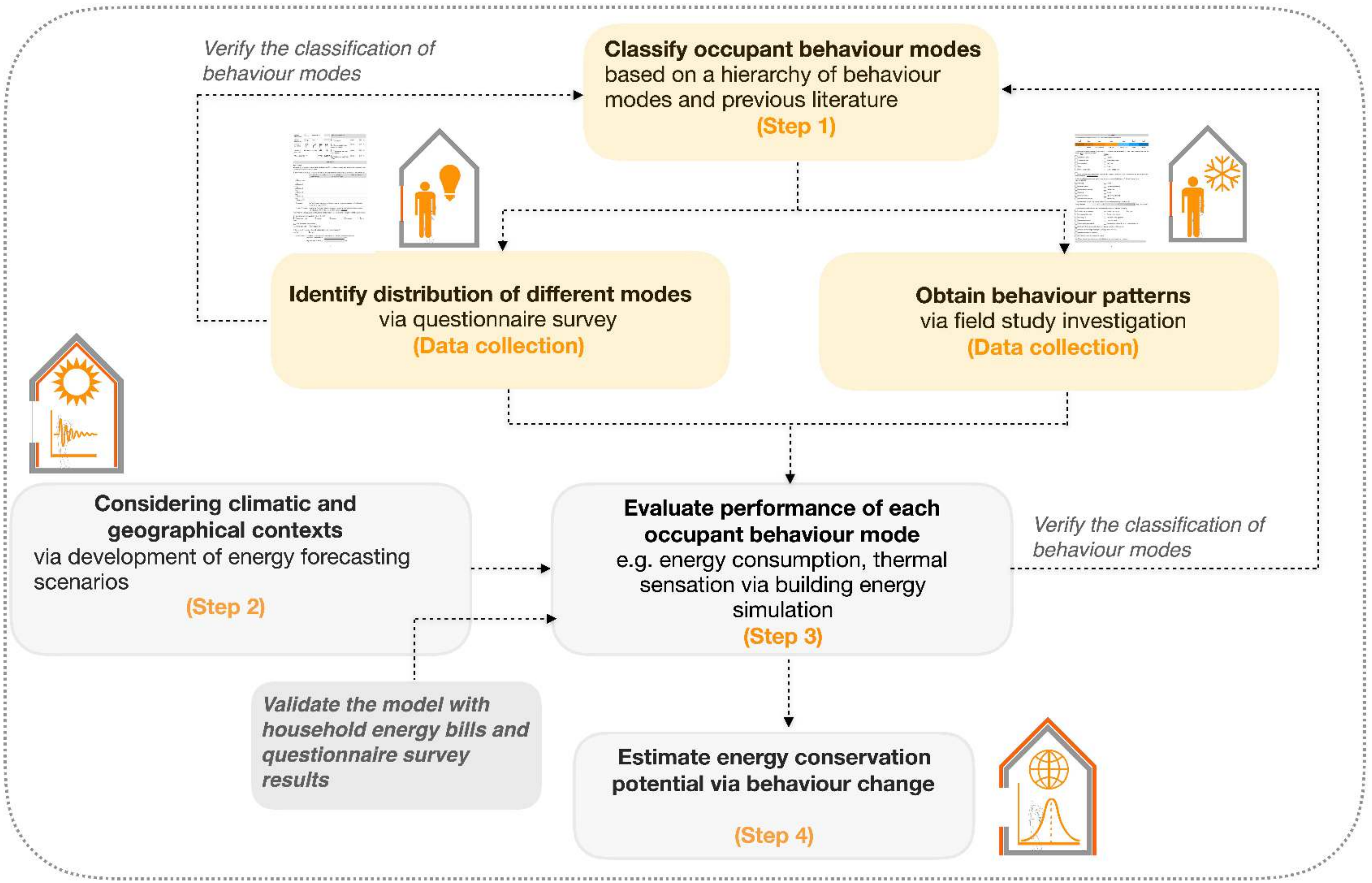


Figure 15: Research design and model showing interconnections between four key research areas of this study.

3. Methodology: A novel methodological framework for improving thermal performance of post-war social housing stock

Research Design: Contribution to EU energy governance and Implications for domestic energy use

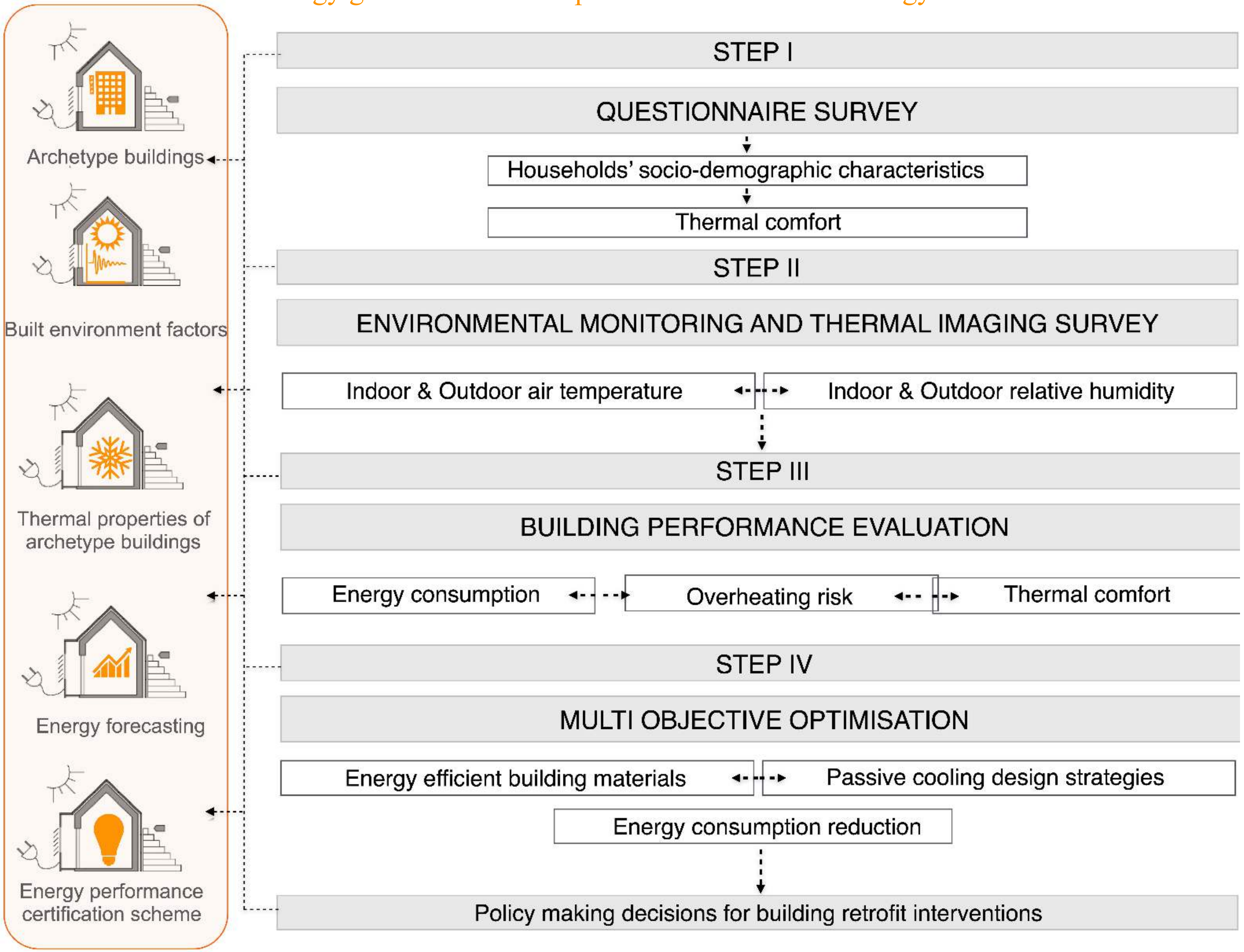


Figure 16: The conceptual framework of the study.

Research Design: Contribution to STS conceptual framework development

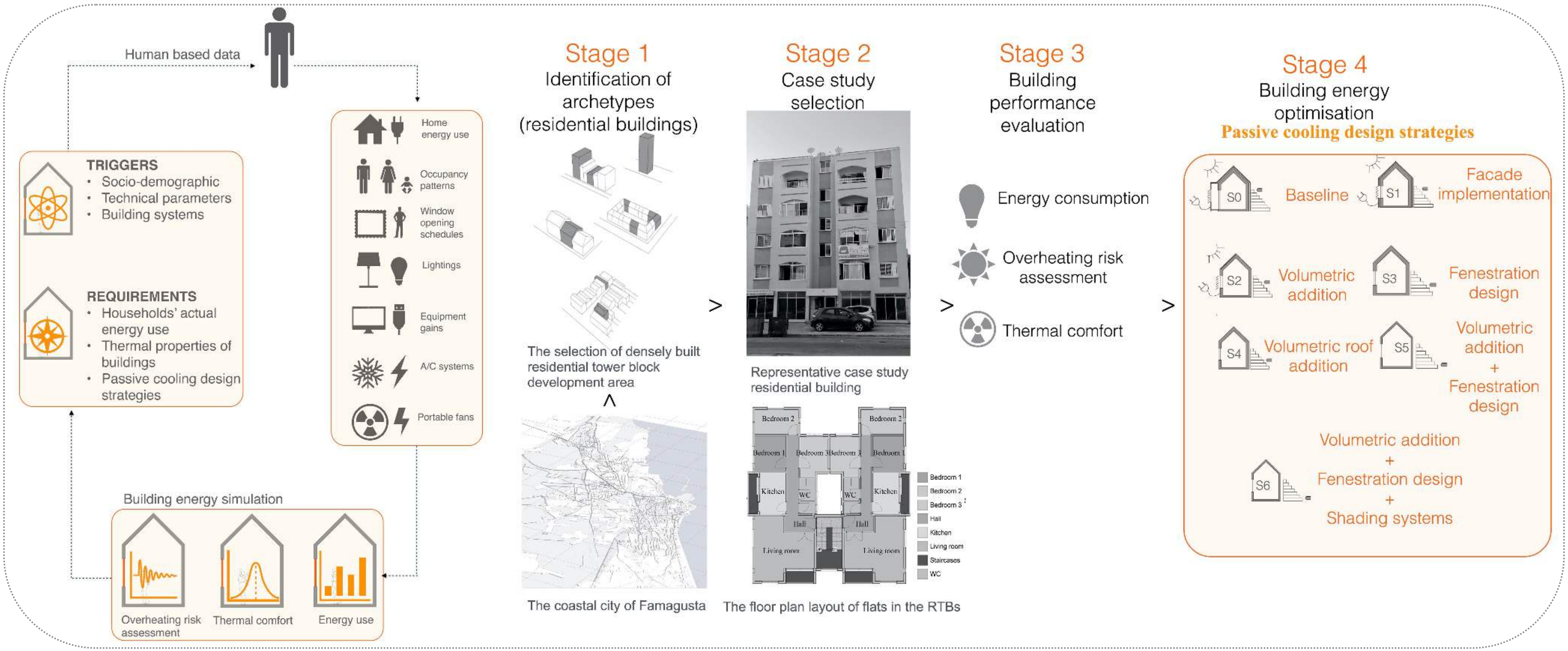


Figure 17: Flow diagram demonstrating novelty of STS approach.

3. Methodology: Questionnaire survey design and Data acquisition

Research data triangulation method: Stages of development to validate questionnaire survey findings

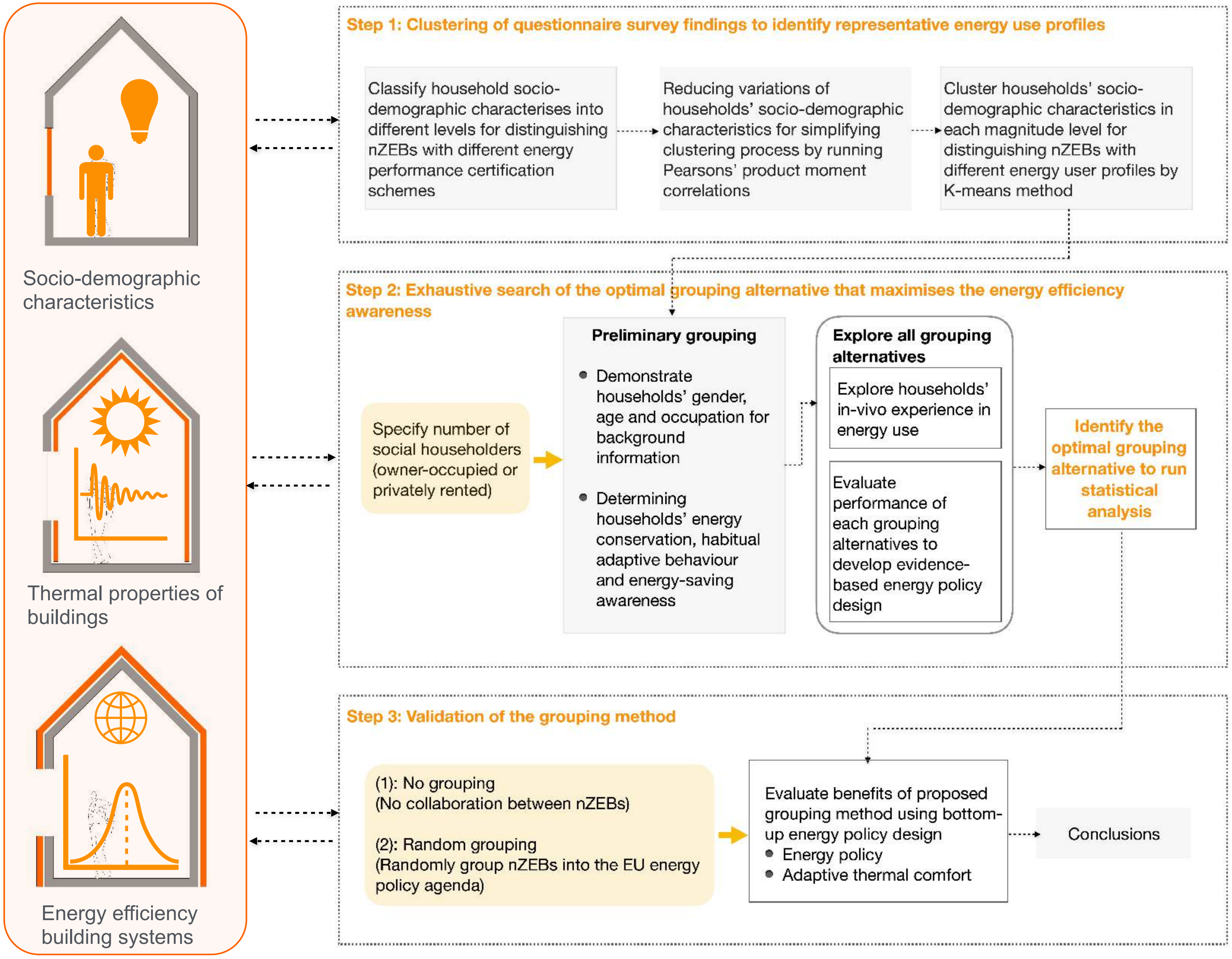


Figure 18: Development stages of evidence-based energy policy framework.

3. Methodology: Field study investigation to identify ‘neutral’ adaptive thermal comfort

Conduct of the survey and field instruments: Physical measurements and Data acquisition

On-site monitoring

In-situ measurement - I
Indoor air temperature

In-situ measurement - II
Solar masks

>

Data collection and Statistical analysis
Energy consumption, environmental parameters, buildings’ thermal properties

Data preprocessing

Data integration → Clustering-based Outlier Detection ← **Data cleaning**

k-Means clustering

Data analysis

Characteristics analysis

Household socio-demographics
Age, gender, occupation, income etc.

Annual characteristics
Energy consumption distribution

Seasonal characteristics
Cooling/Heating/Transition seasons

Statistical methods

Covariance analysis

Impact factors

- Development of socio-technical-systems approach
- Development of evidence-based energy policy design
- Forecasting of neutral adaptive thermal comfort thresholds
- Forecasting of energy use

Energy performance certificates

- Energy Performance Buildings Directives (EPBD)
- Horizon 2030
- Green Tariffs

- ASHRAE Global Thermal Comfort Database II
- European SCAT database
- EN 15251 benchmark criteria

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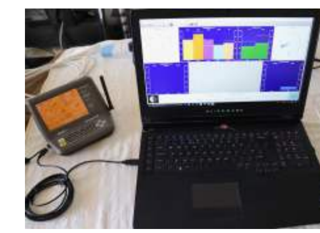

Data recordings and processing

Figure 19: The set-up of the field study investigation and data processing.

3. Methodology: Building performance evaluation

Bridging building-energy-perfomance gap: Overheating risk of European buildings

Figure 20: Validation method flow diagram.

3. Methodology: Building energy simulations

Analytical energy simulation model development: Black-box model construction

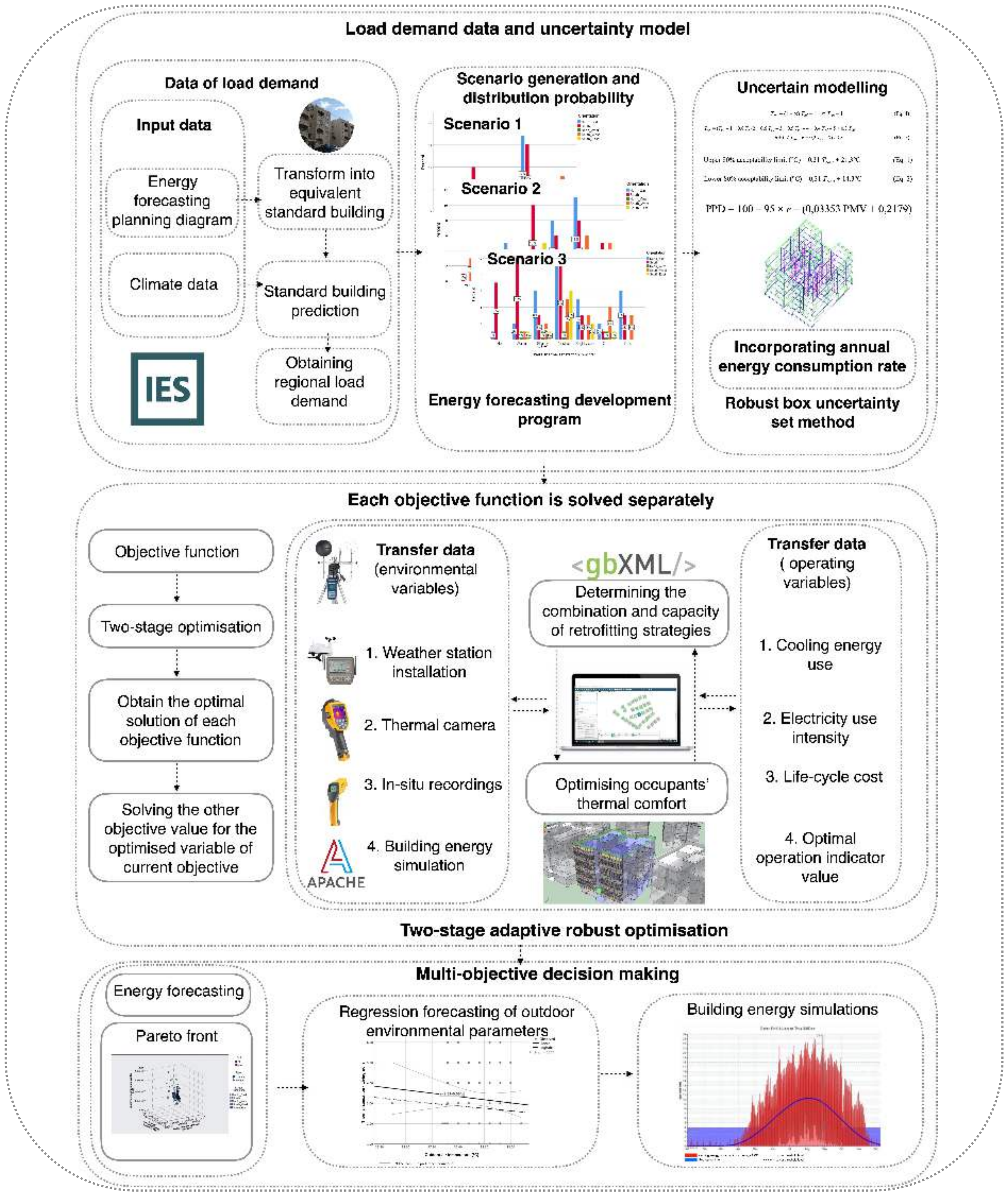

Figure 21: The workflow for the building energy simulations and identification of uncertainty parameters.

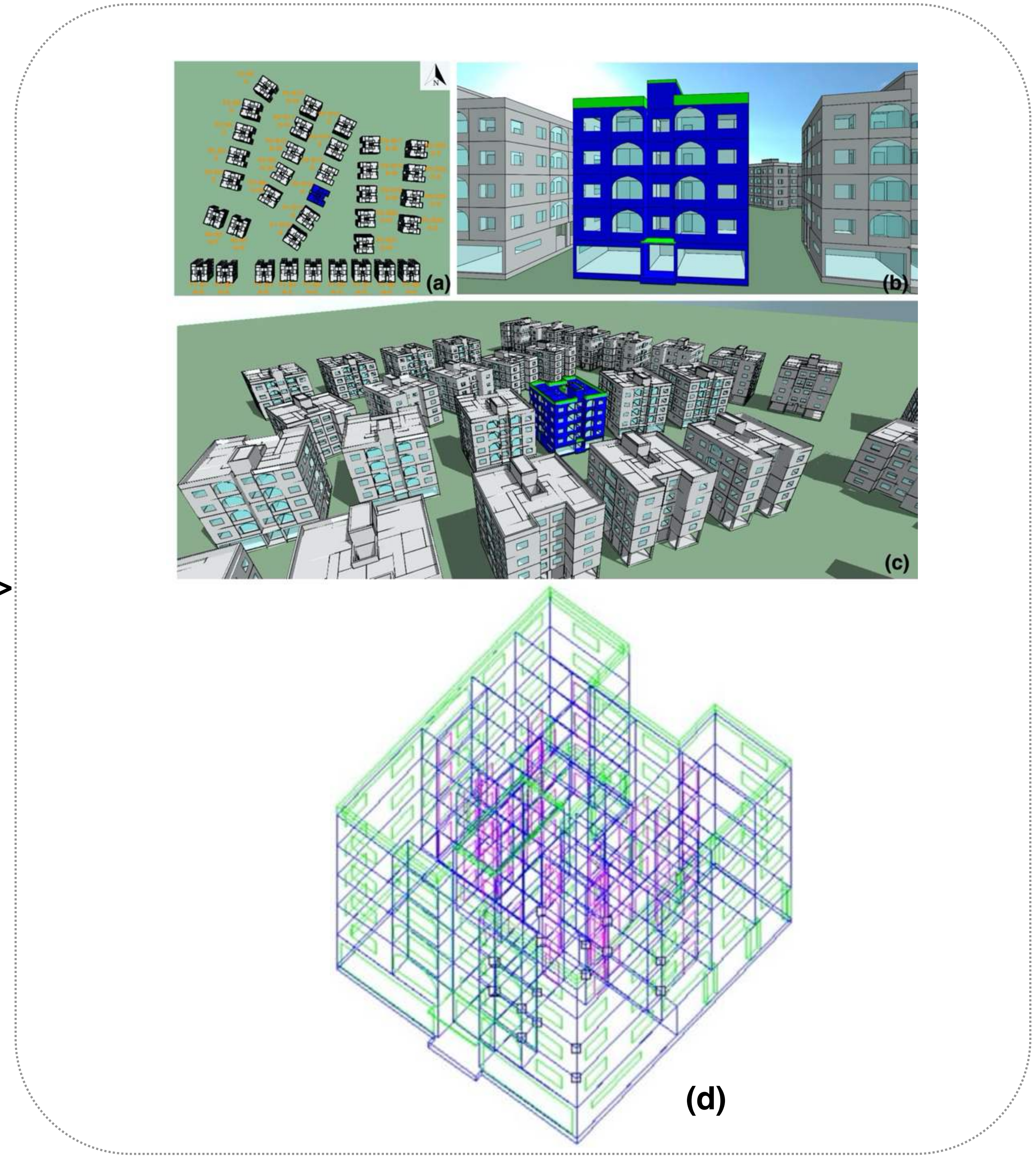

Figure 22: (a) Location map of the RTBs constructed in the ModelIT in the IES software suite; **(b)** Base-case representative energy model of archetype RTBs; **(c)** Analytical energy model of representative RTBs in the social housing development estate viewed from the main road; (d) Black-box energy model of the RTB.

3. Methodology: Building energy simulations

Building energy simulation model calibration: Development of archetype housing stock as base case scenario

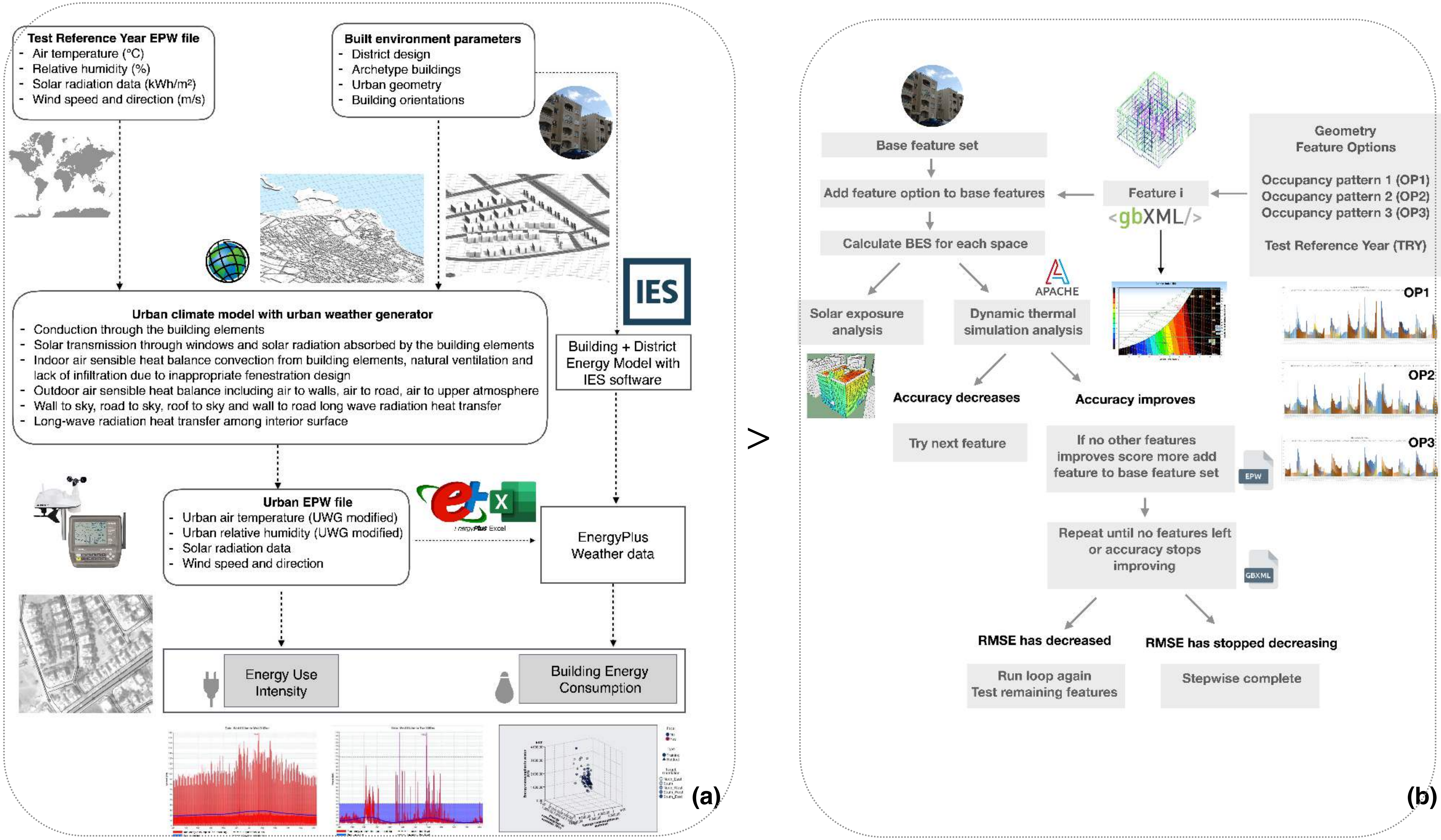

Figure 23: (a) The set-up of the weather files assigned into building energy model for the dynamic thermal simulations; **(b)** Inquiry strategy of DTS analysis using the ApacheSIM software suite.

Building energy simulation model calibration: Integration of longitudinal field study to analyse energy calibration

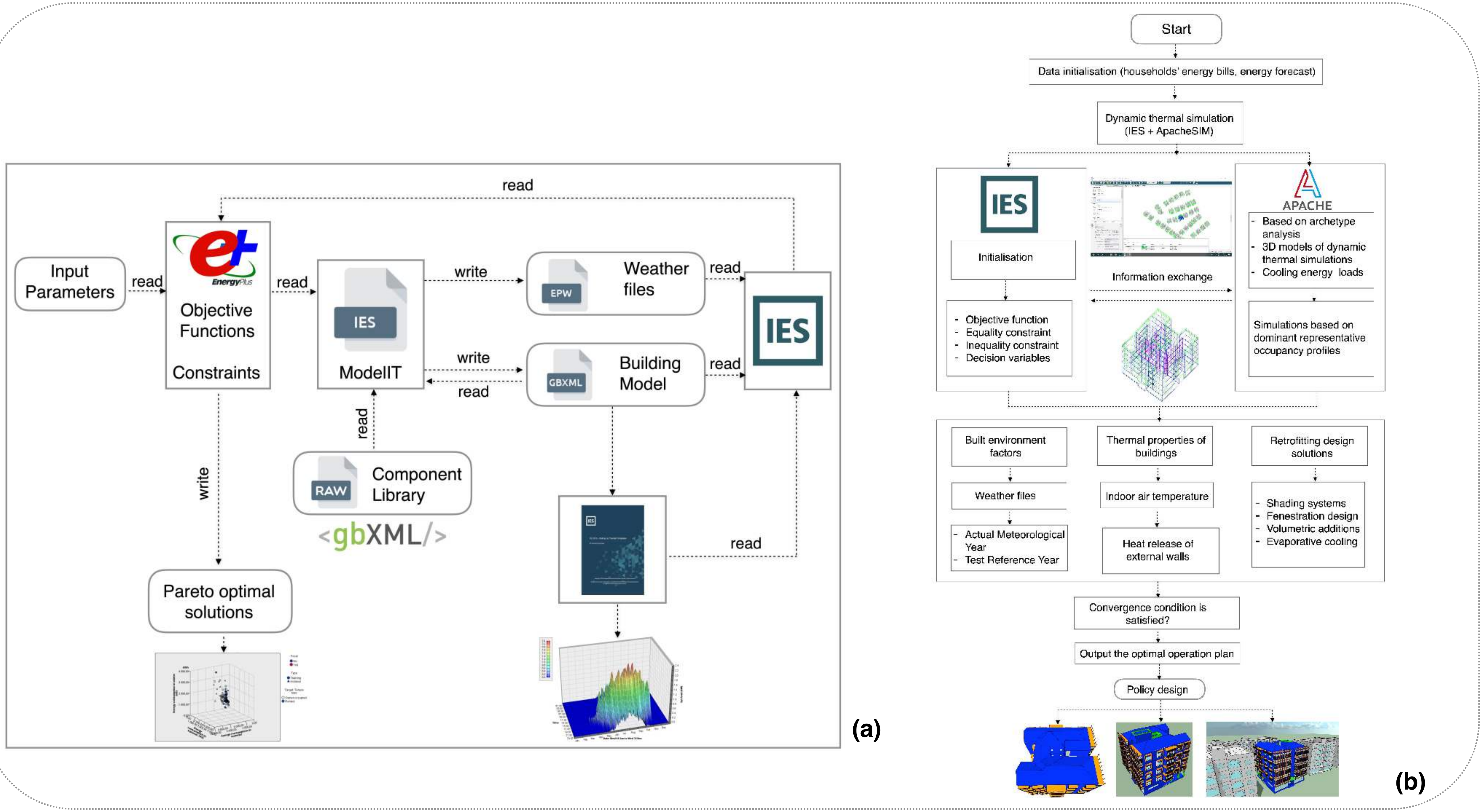

Figure 24: (a) The simulation set input parameters for the dynamic thermal simulations; **(b)** Energy calibration method flow diagram.

4. Results and Discussions (Contribution 1): Feed-forward household interviews

- **Developing an evidence-based energy-policy framework to assess robust energy-performance evaluation and certification schemes in the South-eastern Mediterranean countries**

RQ-1: **Which household socio-demographic characteristics and home-energy performance factors influence household energy use?**

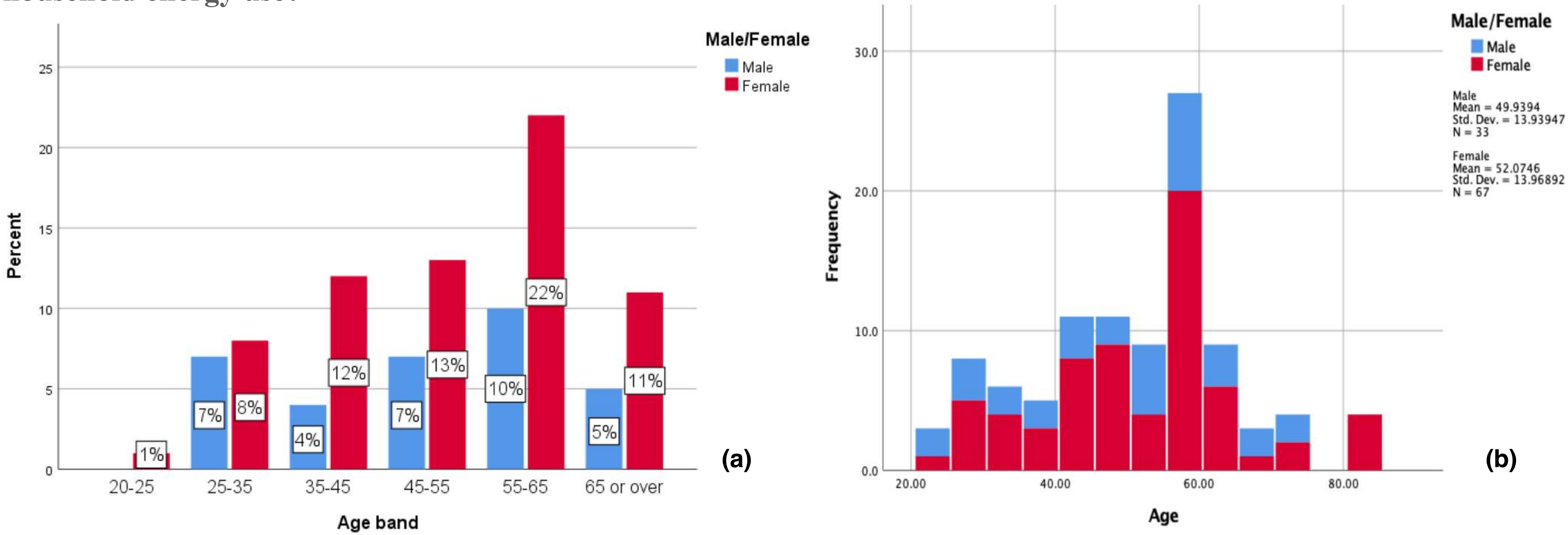

Figure 25: (a) Percentage distribution of age groups by gender; **(b)** Frequency distribution of age groups by gender.

EU-27 countries

European Commission

- 48% of the households were 55-65 and 65-years-of-age and older.
- A moderate negative correlation (r = -0,229, p < 0,05) was found between the occupants' ages and their complaints related to thermal discomfort.
- A moderate positive correlation (r = 0,218, p < 0,01) was confirmed between age and the different floor levels of the flats.

EPCs of buildings

EPBD

- A moderate negative correlation (r = -0,229, p < 0,01) was observed between age group and level of education.
- A moderate negative correlation (r = -0,355, p < 0,01) was found between age group and tenancy status.
- A moderate positive correlation (r = 0,286, p < 0,01) was found between age group and energy use in the summer of 2015.

- **Developing an evidence-based energy-policy framework to assess robust energy-performance evaluation and certification schemes in the South-eastern Mediterranean countries**

RQ-1: **Which household socio-demographic characteristics and home-energy performance factors influence household energy use?**

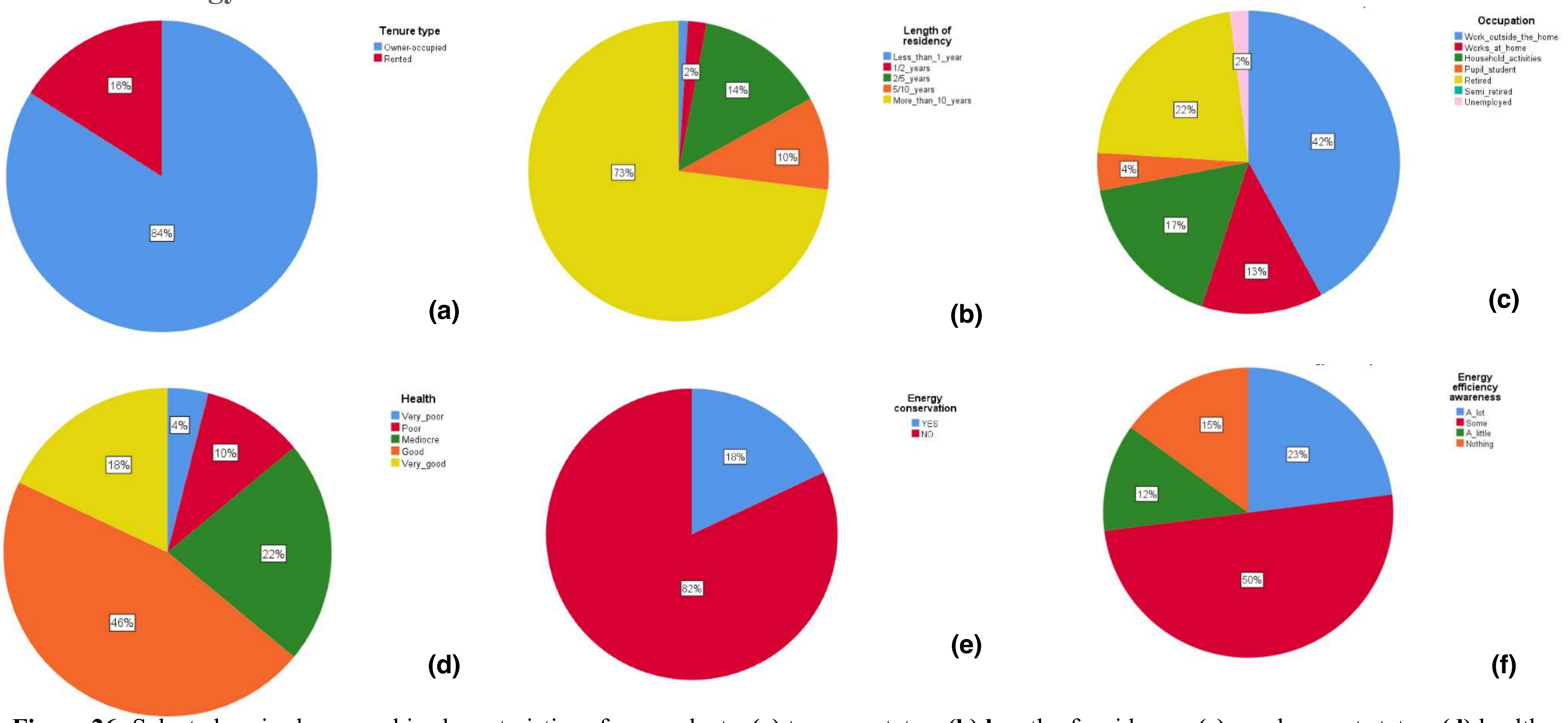

Figure 26: Selected socio-demographic characteristics of respondents; **(a)** tenancy status; **(b) l**ength of residency; **(c)** employment status; **(d)** health conditions; **(e)** energy conservation; **and (f)** energy-saving awareness.

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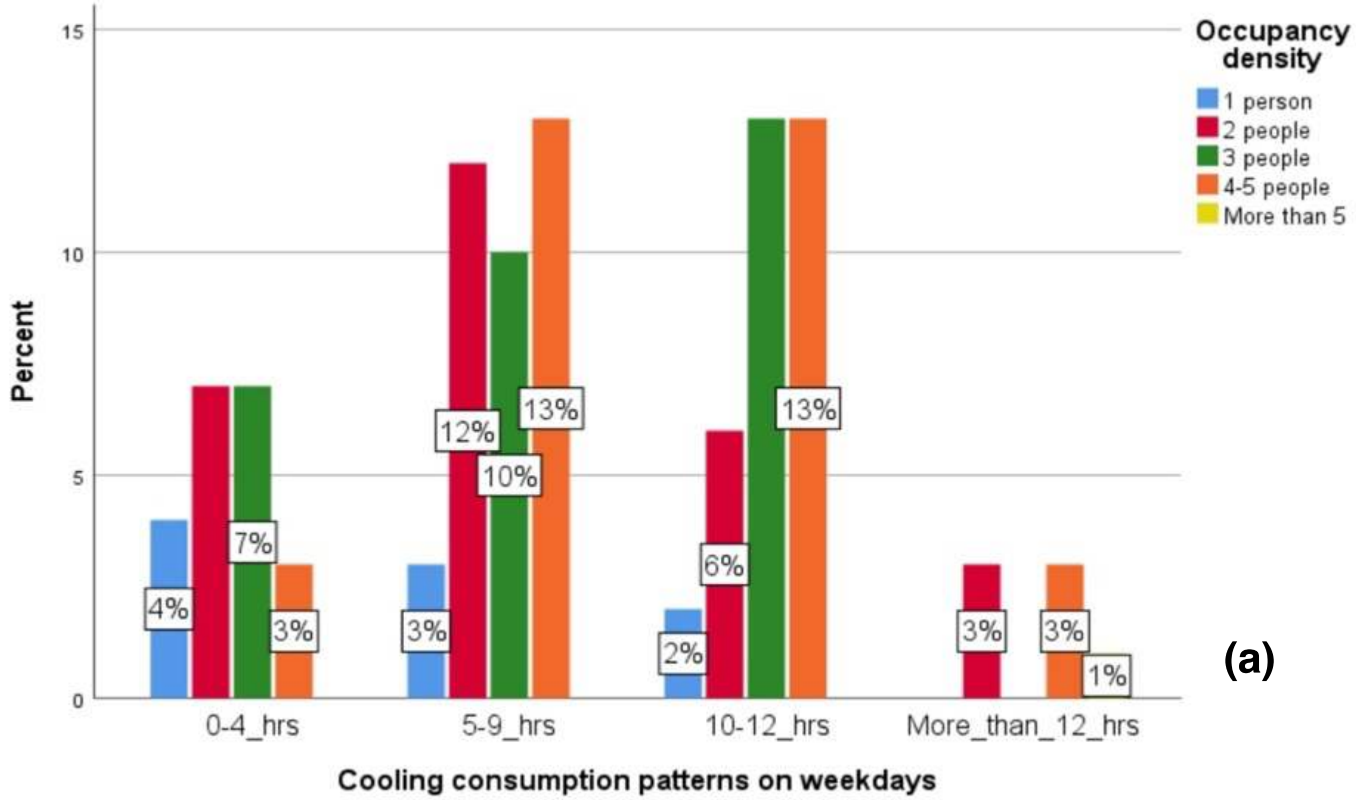
- **Significance of occupancy patterns and habitual household adaptive behaviour on home-energy performance of post-war social housing estate in the South-eastern Mediterranean climate**

RQ-2: **Which occupant energy-consumption behaviours have an impact on the energy performance of social-housing estates?**



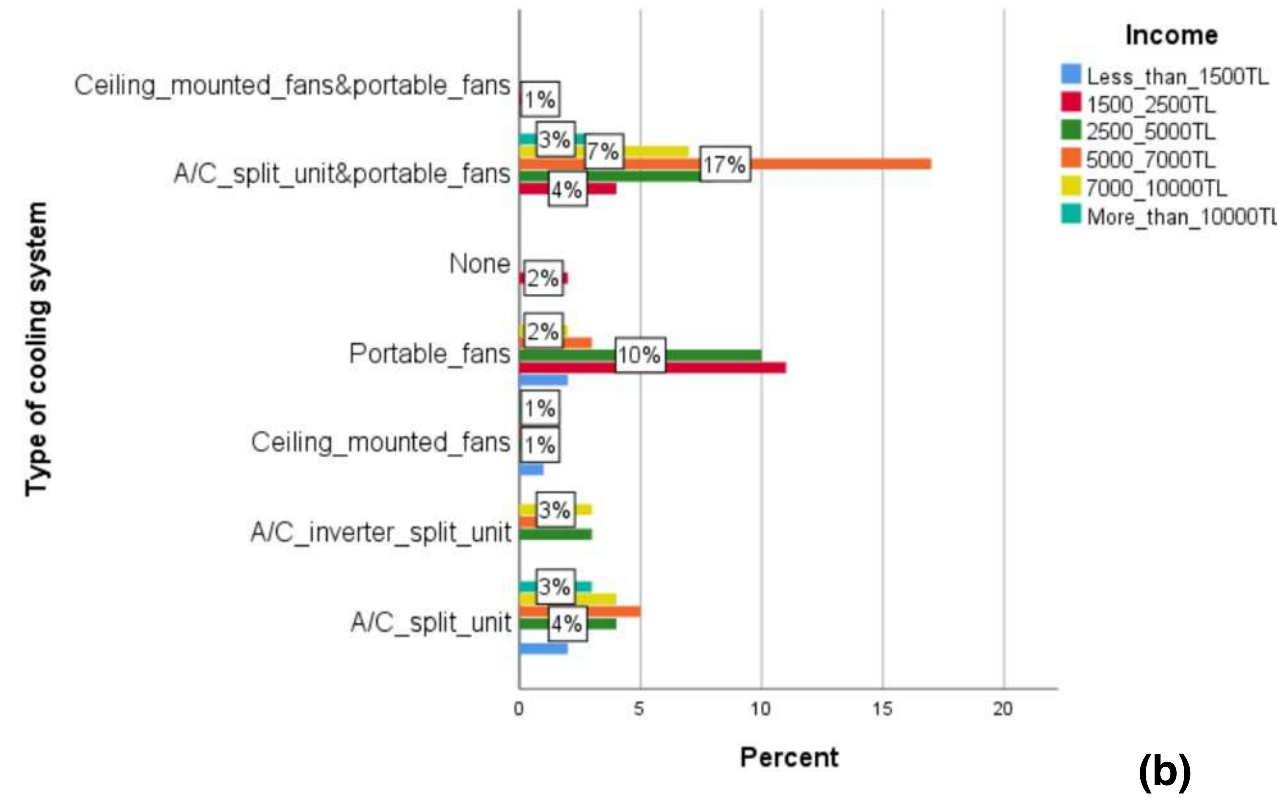
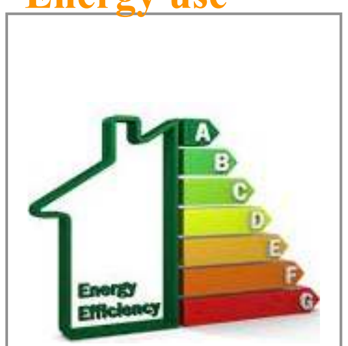


Figure 27: (a) Percentage distribution of cooling-consumption patterns taking occupancy density type into account on weekdays; **(b)** Percentage distribution of the households' types of cooling systems, taking income level into account.

Note: The Turkish Lira (TL) is the currency of Turkey and the self-declared republic of Northern Cyprus, As of April of 2021, 1TL was equivalent to 11,21 GBP, and the minimum wage in NC was a 4.400 TL monthly stipend.

Energy use



- A moderate negative correlation ($r = -0{,}212$, $p < 0{,}05$) was found between occupancy and cooling patterns.
- A strong positive correlation ($r = 0{,}588$, $p < 0{,}01$) was found between weekday heating- and cooling-consumption patterns.

SDG - Call #7

- A weak positive correlation was found between household size ($r = 0{,}058$, $p < 0{,}01$) and the type of cooling system used.
- The presence of heating- or cooling-control systems was found to have partially correlated with income ($r = 0{,}138$, $p < 0{,}01$).

6. Results and Discussions (Contribution 3): Regression forecasting of neutral adaptive thermal comfort

Universal design approach: Contribution to the development of the ASHRAE Global Thermal Comfort Database II

RQ-3: **How do environmental factors affect occupants' thermal comfort?**

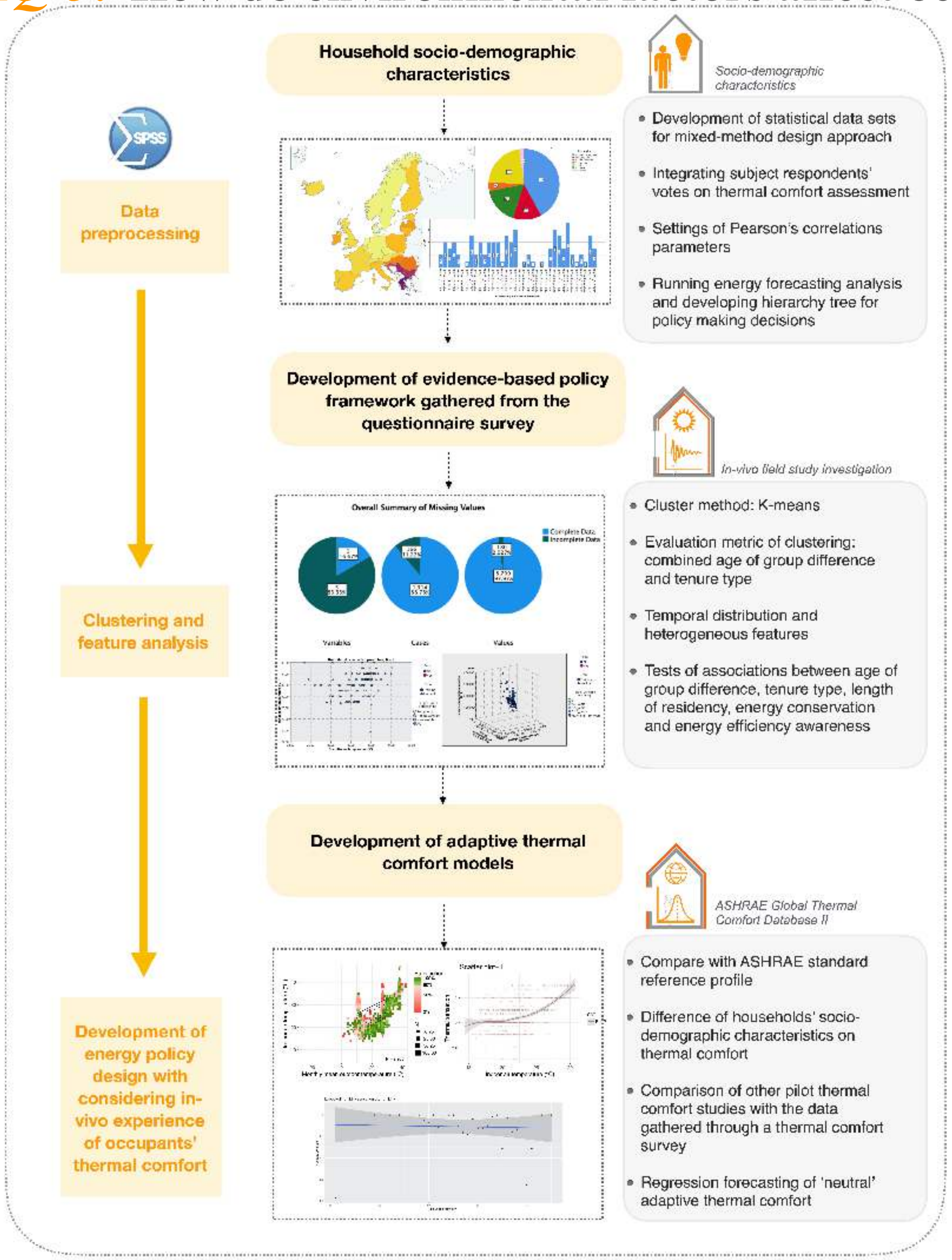


Figure 28: The novel methodological workflow developed for the identification of 'neutral' adaptive thermal comfort.

>

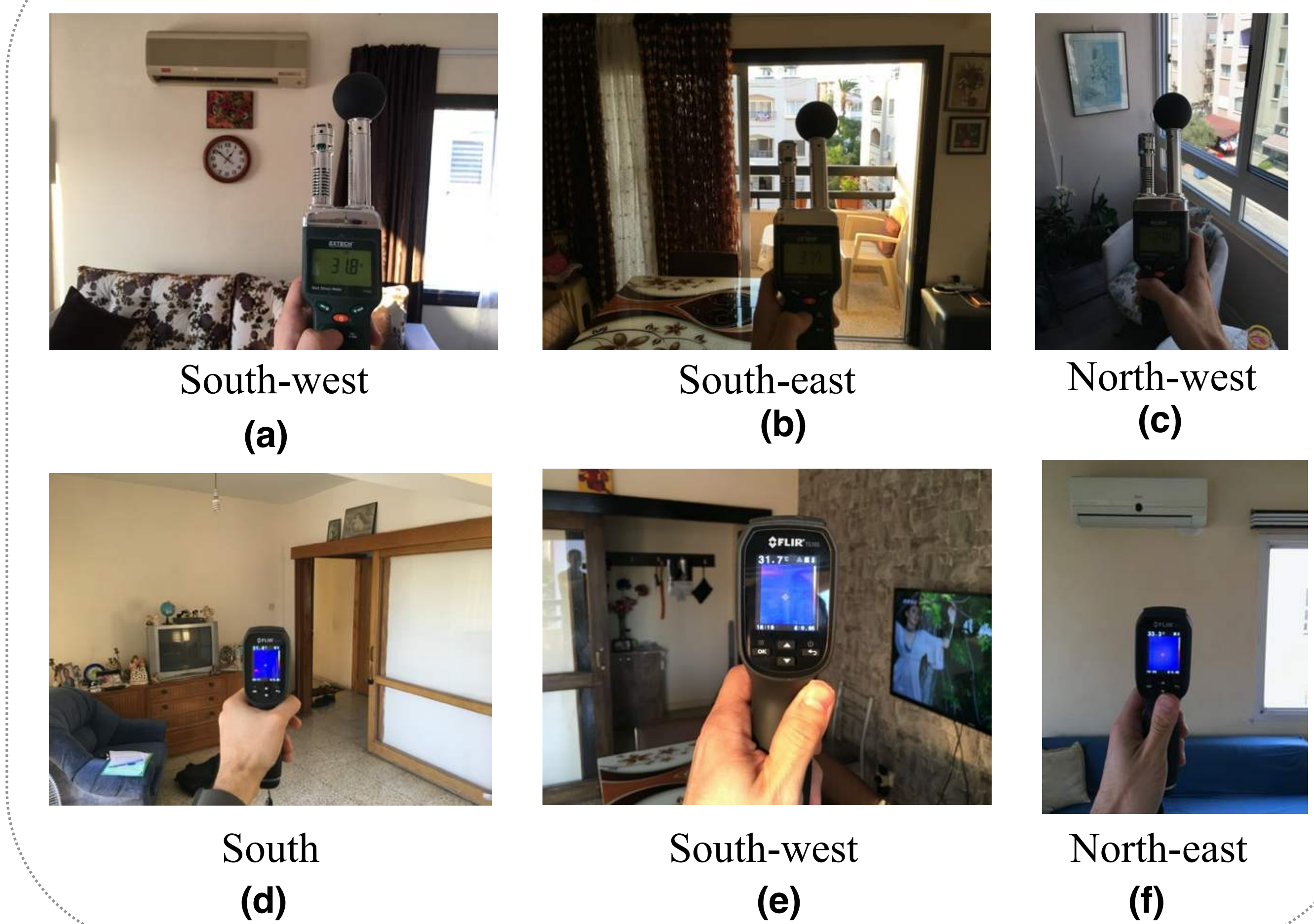


Figure 29: *In-situ* measurements recorded while **(a)** wall-mounted A/C system was in use in late afternoon; **(b)** single glazed aluminium-framed window was open in late afternoon; **(c)** double-glazed window was open in early morning (participant was interviewed in balcony); **(d)** internal doors were open in early morning (participant was interviewed in balcony, and portable fan was in use during survey); **(e)** windows were open; and **(f)** inverter A/C system was in use.

On-site monitoring of environmental conditions to develop benchmarking criterion

RQ-3: How do environmental factors affect occupants' thermal comfort?

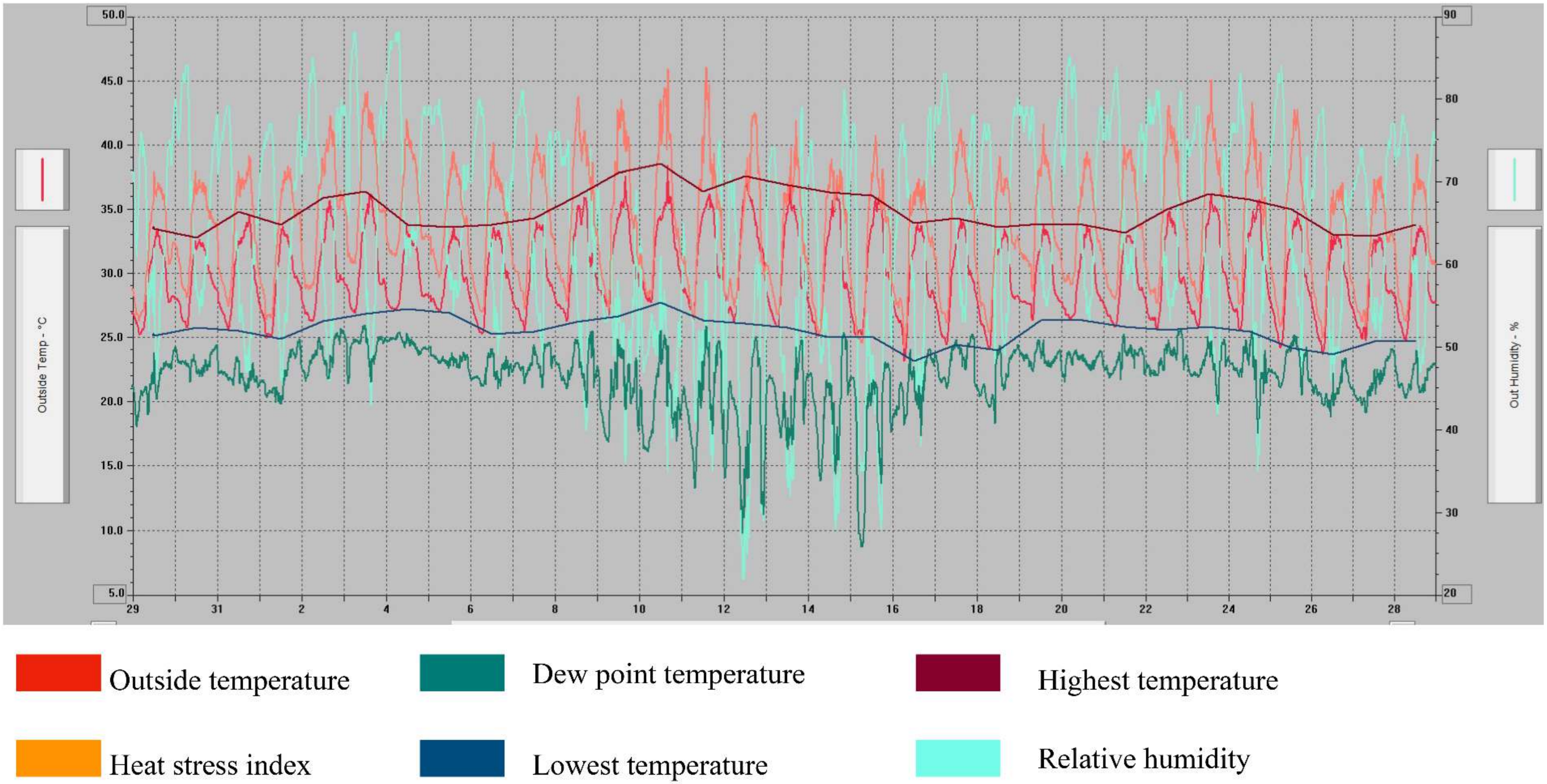
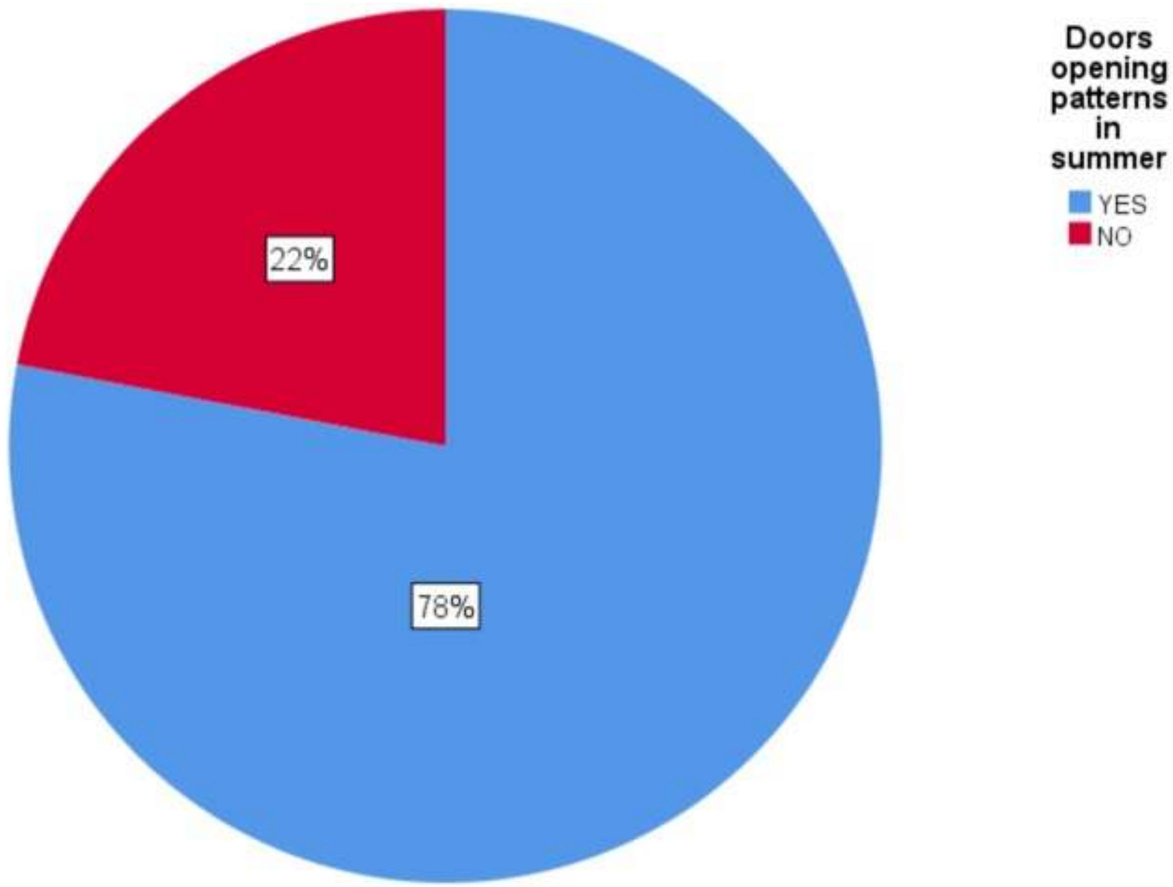


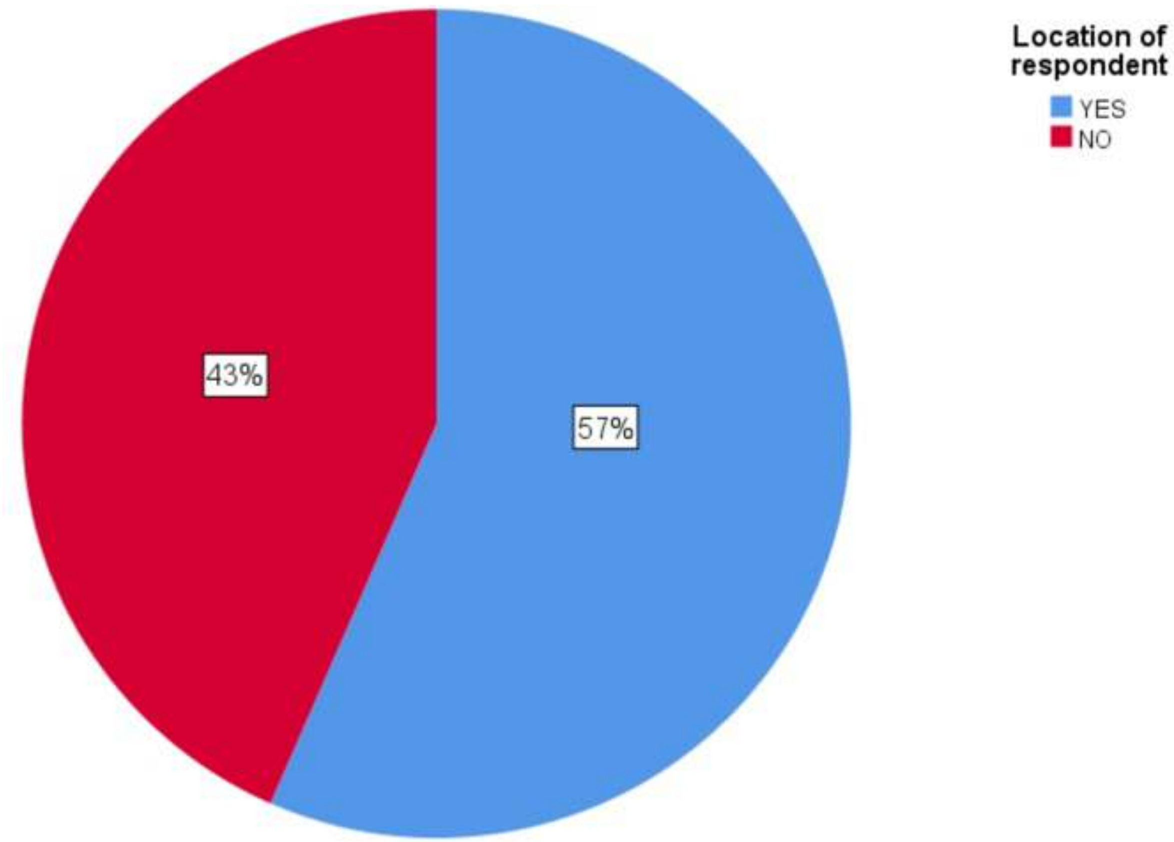
Figure 30: *On-site* environmental monitoring readings between July 29 and August 29, 2018.

Adaptive Thermal Comfort - I: Physiological thermal adaptation

RQ-3: How do environmental factors affect occupants' thermal comfort?



(a)



(b)

Figure 31: (a) Distribution of household internal door-opening patterns in summer; (b) participant location in living rooms during survey.

Benchmark criteria - I

EUROPEAN NORM EN

- 31% of households kept their living room windows open for 6-8 hours per day.
- 55% of households kept their living room windows open for more than eight hours each summer day.

Benchmark criteria - II

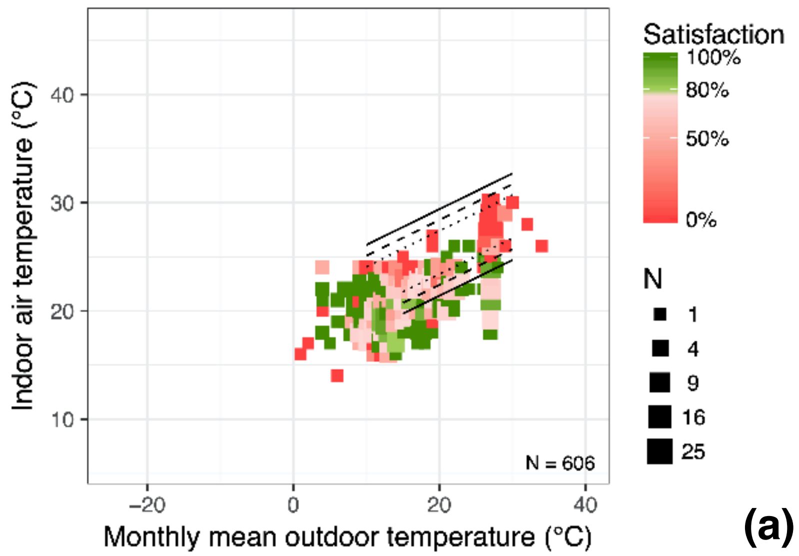
cen

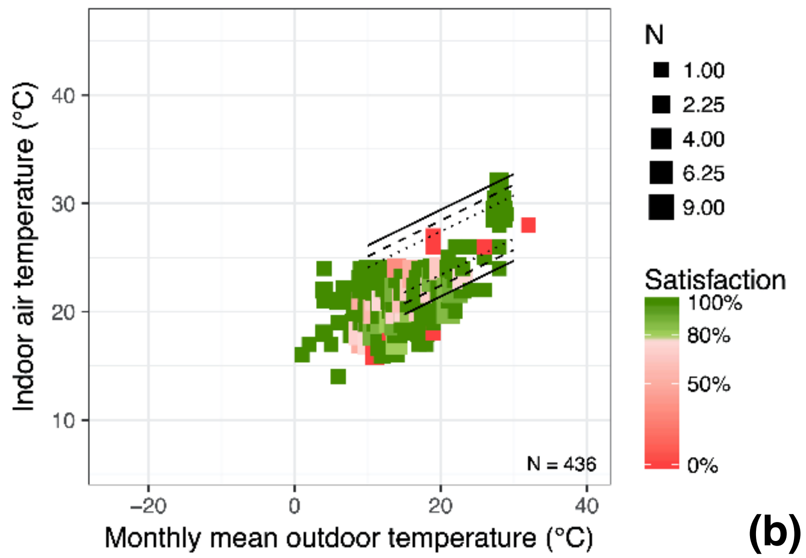
- When the heating and cooling systems were not in use, there was a moderate positive correlation (r = 0,368, p < 0,01) with the widows being kept open.
- 39% of the female and 17% of the male respondents were surveyed near an open window.

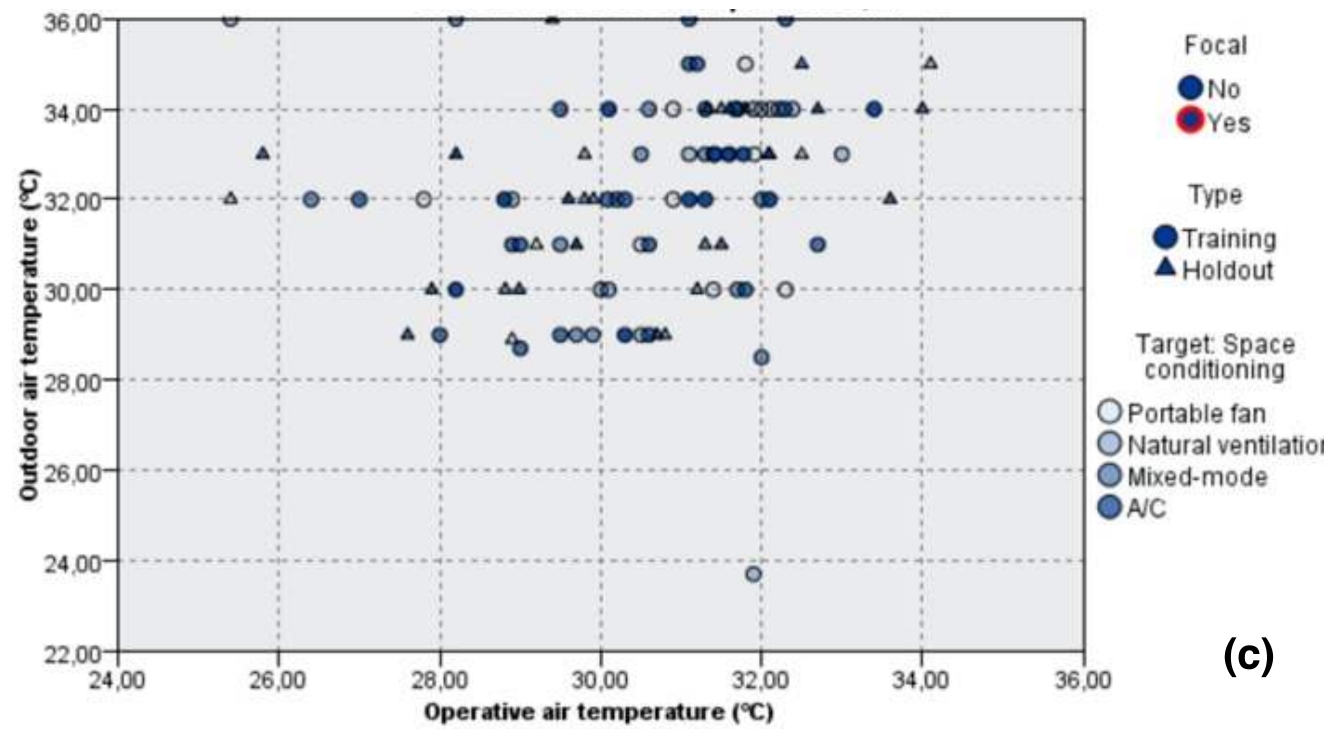
6. Results and Discussions (Contribution 3): Regression forecasting of neutral adaptive thermal comfort

Adaptive Thermal Comfort - II: Psychological thermal adaptation and Cluster analysis of type of cooling systems

RQ-3: How do environmental factors affect occupants' thermal comfort?







Thermal Comfort

Benchmarking criterion to the ASHRAE Global Thermal Comfort Database II

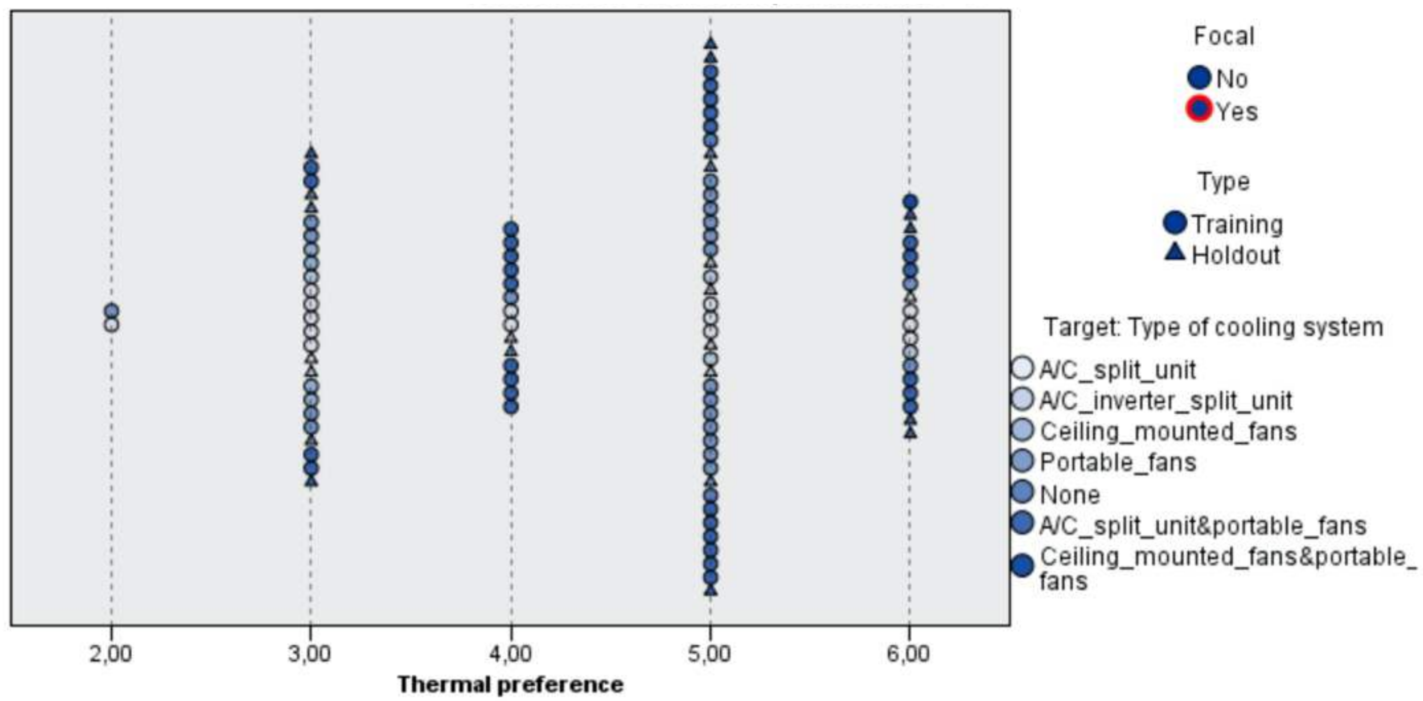
- 80% of the study respondents were slightly comfortable in a temperature ranging from 28,5 °C to 31,5 °C.
- A moderate correlation was found between the occupants' thermal sensation and the indoor air temperature ($r = 0{,}215$, $p < 0{,}05$).
- A negative moderate correlation was found between the occupants' thermal sensation and the outdoor air temperature ($r = -0{,}325$, $p < 0.01$).

Figure 32: Scatter-plot distribution of thermal sensation by **(a)** building typology and **(b)**; climate type; **(c)** cluster analysis of outdoor air temperature and operative air temperatures (OTs) for different types of space conditioning.
Sources: (a)-(b) Graphs were extracted from an open-access thermal-comfort visualisation tool that utilised the satisfaction metric (i.e., Acceptability [TSV±2]), which is available at https://cbe-berkeley.shinyapps.io/comfortdatabase/

6. Results and Discussions (Contribution 3): Regression forecasting of neutral adaptive thermal comfort

Adaptive Thermal Comfort - II: Household Predicted Mean Vote and Cluster analysis of type of cooling systems

RQ-3: **How do environmental factors affect occupants' thermal comfort?**



a)

Thermal preference

- Slightly_warm
- Neutral
- Slightly_cool
- Cool
- Cold

Node 0		
Category	%	n
Slightly_warm	2,0	2
Neutral	25,0	25
Slightly_cool	14,0	14
Cool	41,0	41
Cold	18,0	18
Total	100,0	100

Figure 33: Cluster analysis of household TSVs, taking different types of space conditioning into account.

Representativeness of adaptive thermal comfort thresholds developed for the South-eastern Mediterranean climate

RQ-3: How do environmental factors affect occupants' thermal comfort?

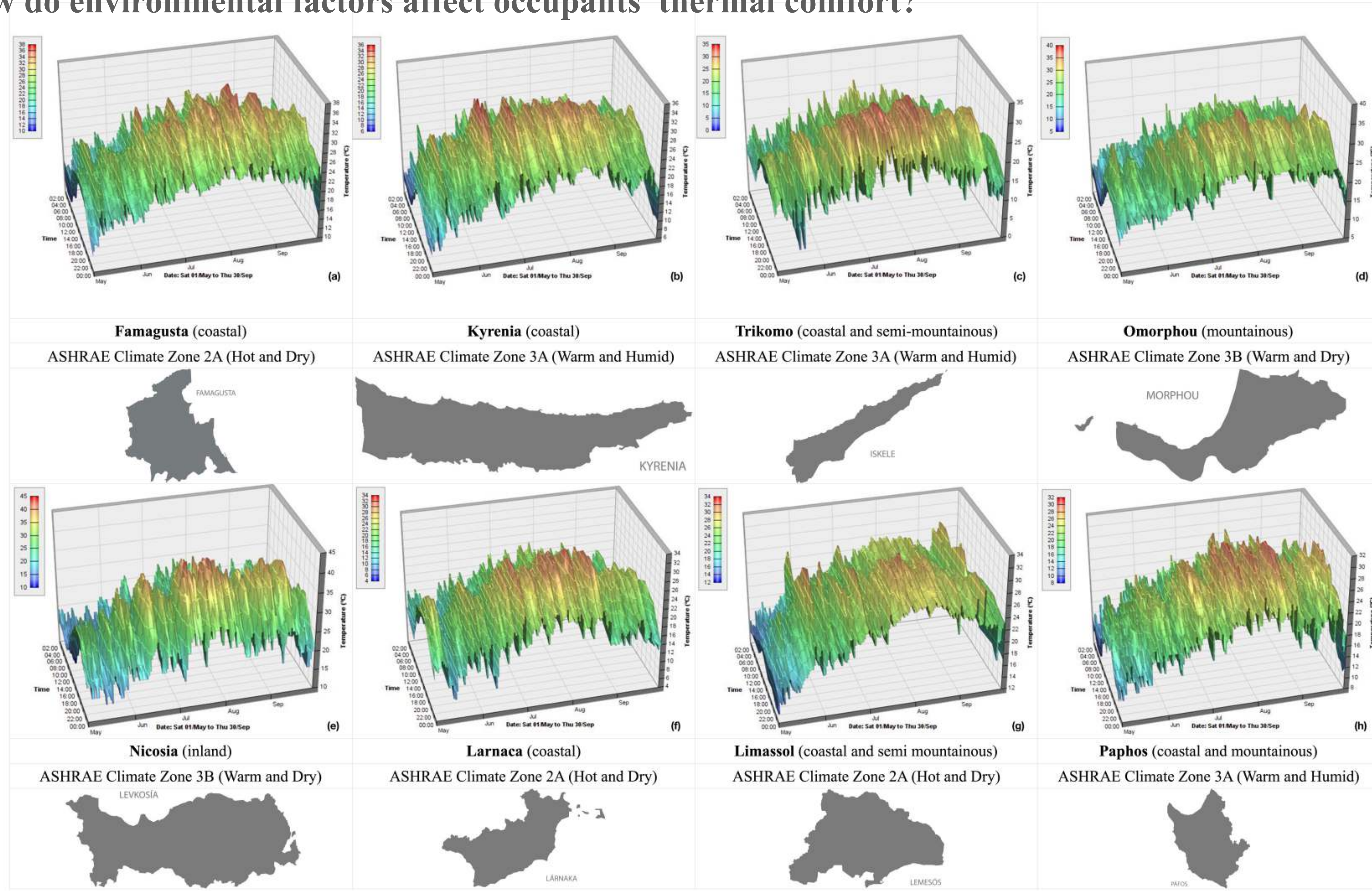


Figure 34: (a) through **(h)** Mapping of climate variations of eight cities in Cyprus.

7. Results and Discussions (Contribution 4): Building-performance evaluation and Energy-model calibration

Universal design approach: Contribution to Energy-calibration studies

RQ-4: How will this study contribute to and inform the design of nZEBs in the EU countries?

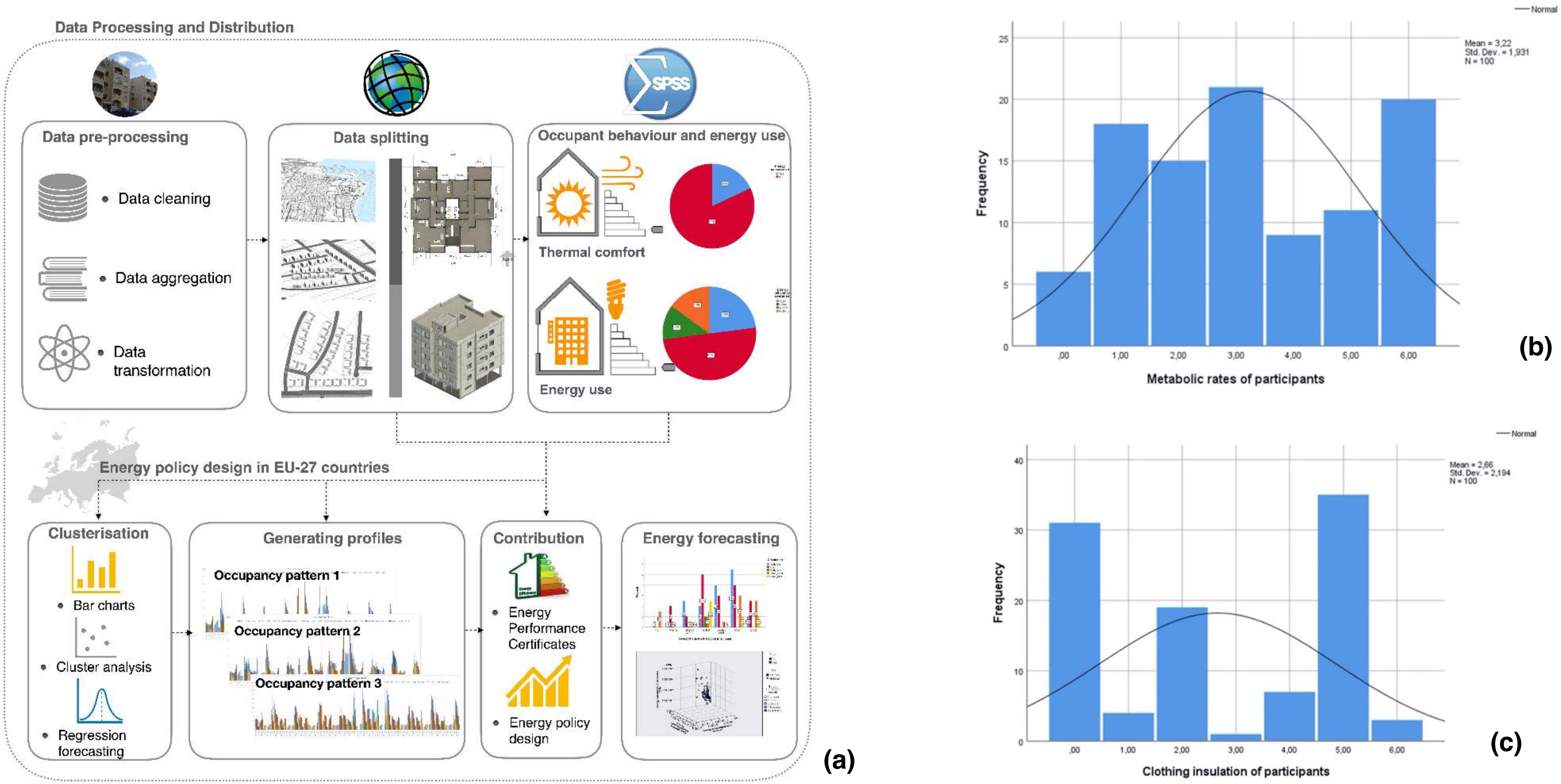


Figure 35: (a) Flow diagram of methodological framework for energy policy design; **(b)** Average participant metabolic rate; **(c)** Distribution of household clothing-insulation values.

7. Results and Discussions (Contribution 4): Building-performance evaluation and Energy-model calibration

Building-fabric thermal performance - I: *On-site* walk through survey in winter

RQ-4: **How will this study contribute to and inform the design of nZEBs in the EU countries?**

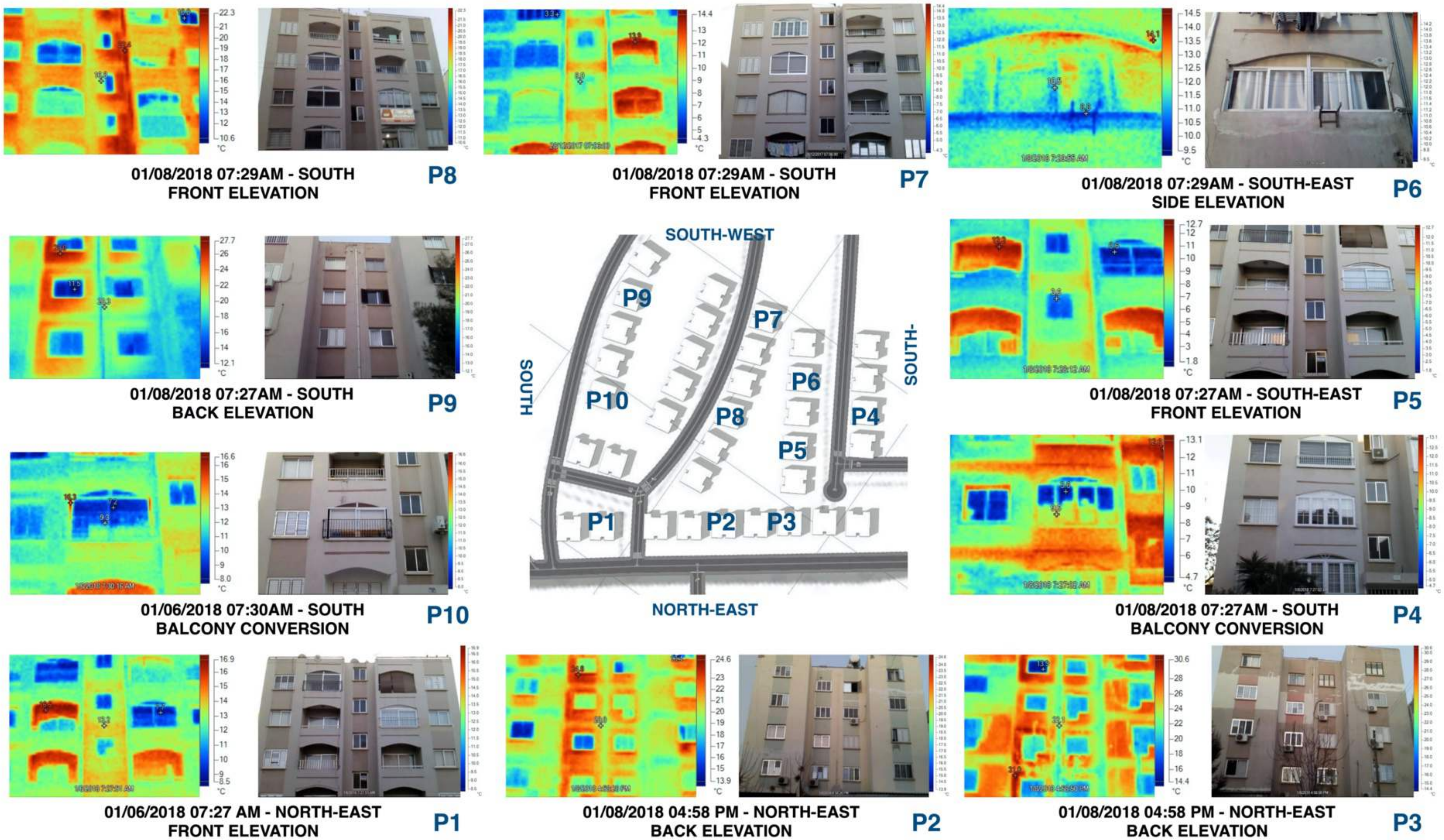


Figure 36: Point-by-point mapping of walk-through thermal-imaging survey conducted in winter 2017-2018, taking RTB orientation and impact of different time of day on overheating risk assessment into account.

Building-fabric thermal performance - I: *On-site* walk through survey in summer

RQ-4: **How will this study contribute to and inform the design of nZEBs in the EU countries?**

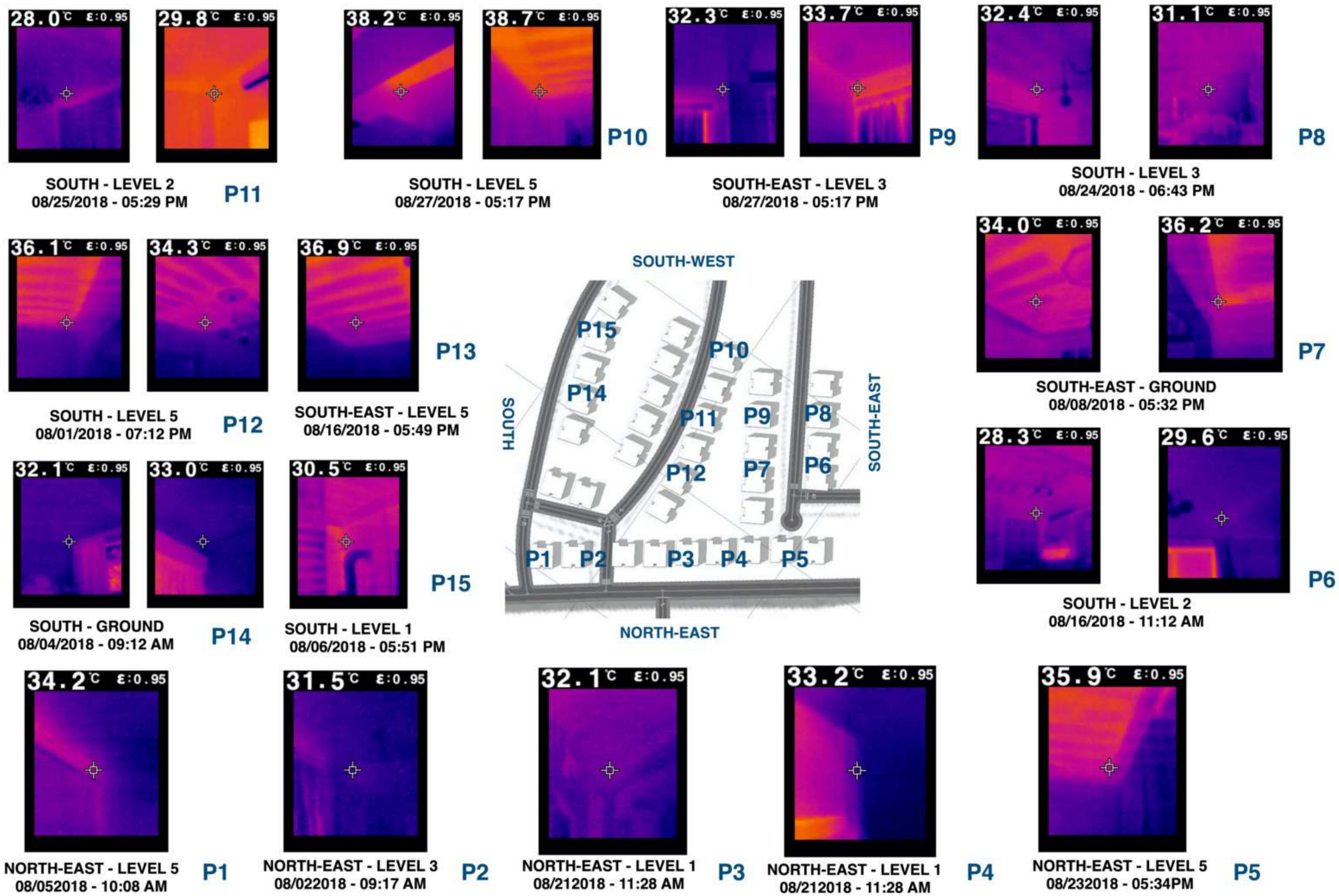


Figure 37: Point-by-point mapping of walk-through thermal-imaging survey conducted while questionnaire survey was administrated, taking different floor levels and impact of different time of day on overheating risk assessment into account.

7. Results and Discussions (Contribution 4): Building-performance evaluation and Energy-model calibration

Building-fabric thermal performance - III: Solar-exposure analysis to validate *on-site* walk through survey

RQ-4: **How will this study contribute to and inform the design of nZEBs in the EU countries?**

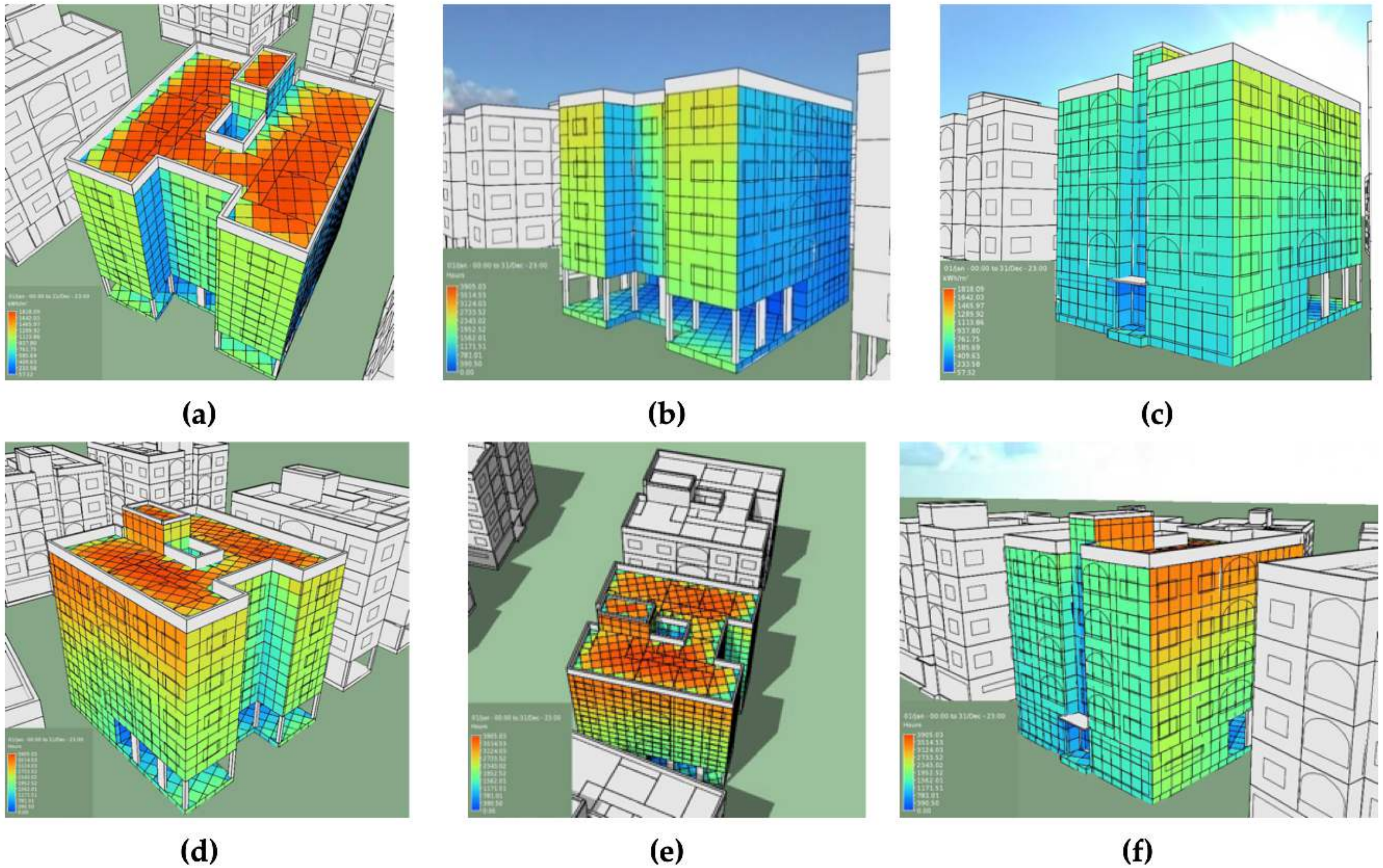


Figure 38: (a) through **(f)** Step-by-step solar exposure analysis of the southwest-facing prototype RTB for the worst-case scenario.

BPE studies

- The internal temperatures of the simulated condominiums remained high throughout the day and night, ranging from a minimum 28,5 °C to a maximum 36,5 °C.
- The high transmittance U-values of the building surfaces absorbed 1.818,09 kWh/m²K between January and December

Overheating risk

ISES International Solar Energy Society

- Outdoor-air temperatures ranged from 25,3 °C- 38,7 °C with a mean temperature of 28,7 °C.
- Indoor temperatures above 34,4 °C in all rooms for the entire year and only exceeded this temperature when it reached 36,4 °C.

7. Results and Discussions (Contribution 4): Building-performance evaluation and Energy-model calibration

Forecasting household energy use to validate survey findings with household energy bills

RQ-4: **How will this study contribute to and inform the design of nZEBs in the EU countries?**

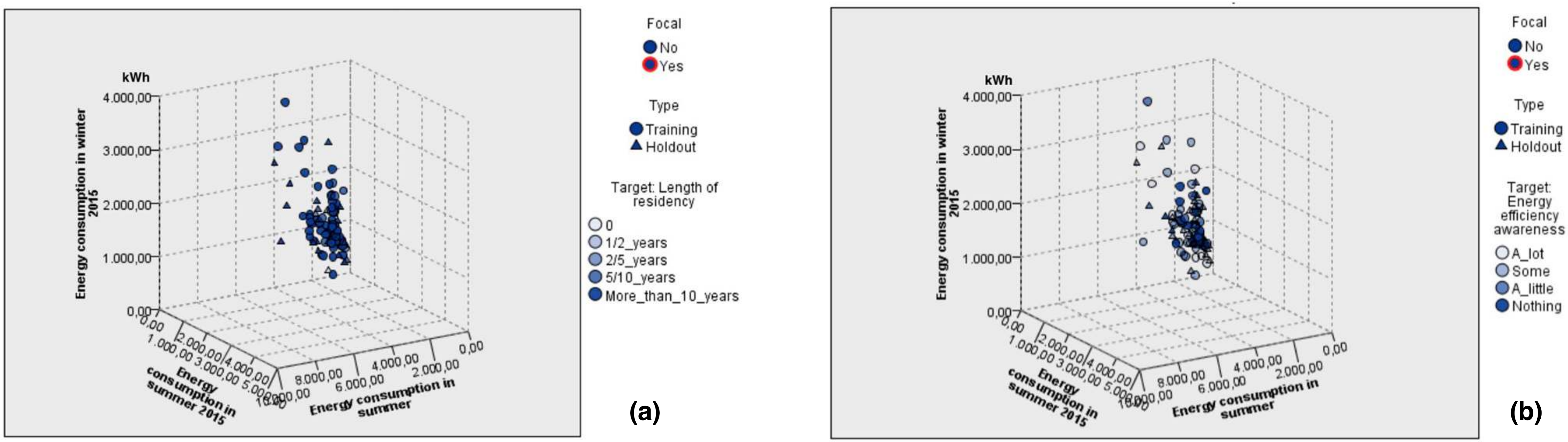


Figure 39: Distribution of energy consumption by **(a)** household density; **(b)** energy-efficiency awareness.

Energy use

International Energy Agency

- Energy consumption of households who had lived in their flats for more than 10 years ranged between 400 - 3.800 kWh.
- Energy consumption of residents who had lived in their units for 5-10 years, who comprised 10% of the sampling size, ranged between 900-1.600 kWh.

Energy policy

Fit for 55

- 15% of the households reported that they had no knowledge of energy efficiency and consumed between 900 - 1.800 kWh of energy.
- 12% claimed to have ‘a little’ awareness of this topic and utilised between 2.000 - 2.800 kWh.
- 50% stated that they had ‘some’ knowledge of energy efficiency and consumed between 900 - 2.100 kWh.

8. Results and Discussions (Contribution 5): Building energy simulation and Retrofitting strategies

- **A novel methodological framework for the optimisation of post-war social housing developments in the South-eastern Mediterranean climate: Policy design and life-cycle cost impact analysis of retrofitting strategies**

RQ-M: **What is the most effective and universally applicable energy-policy framework to implement the EPBD mandates recommended by EU and improve the energy efficiency of existing post-war social housing stock?**

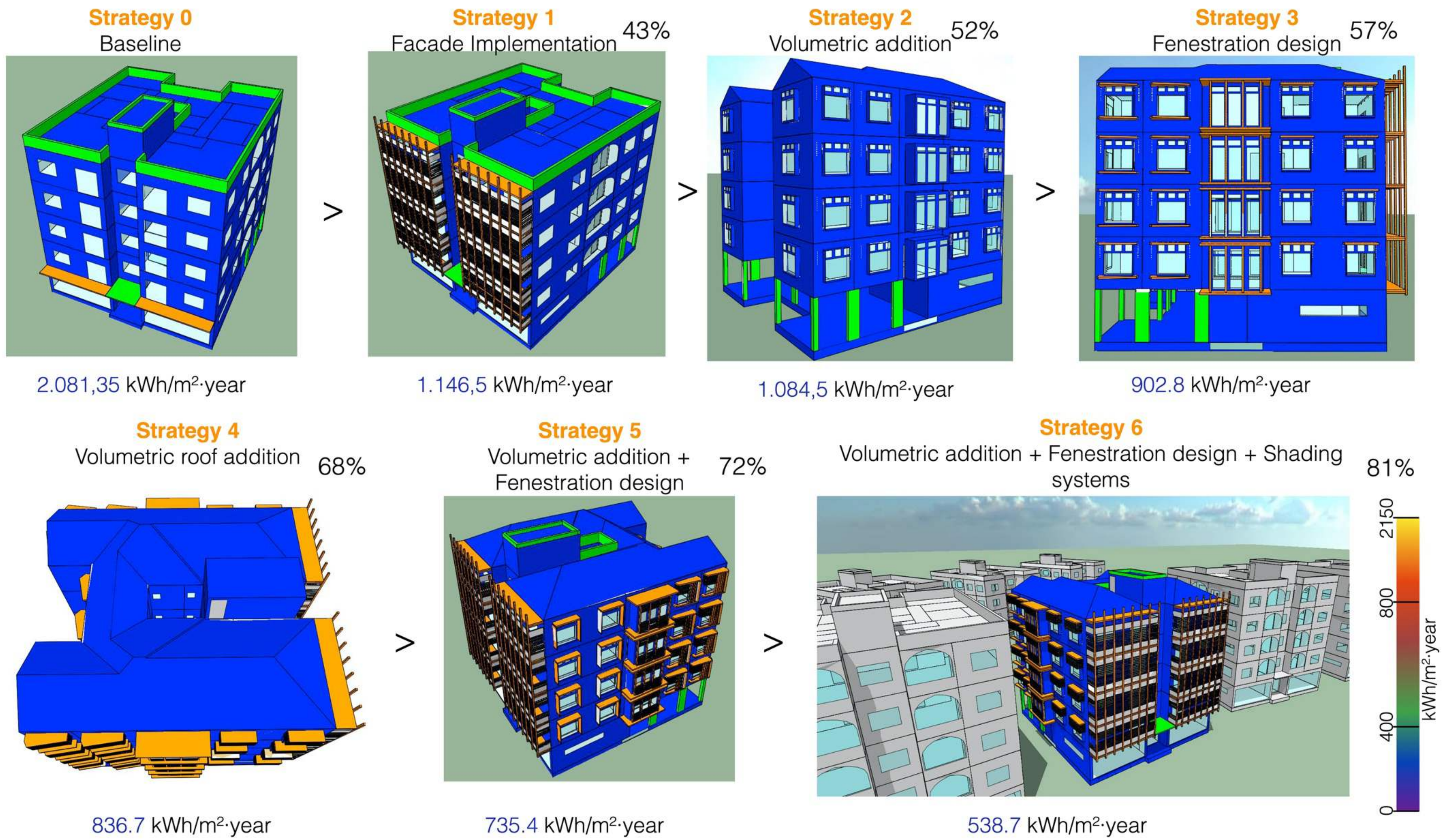


Figure 40: Schematic illustration of six passive cooling strategies implemented to test design-strategy effectiveness.

8. Results and Discussions (Contribution 5): Building energy simulation and Retrofitting strategies

Implementation of passive cooling design strategies: Retrofitting EU domestic-built environment

RQ-M: **What is the most effective and universally applicable energy-policy framework to implement the EPBD mandates recommended by EU and improve the energy efficiency of existing post-war social housing stock?**

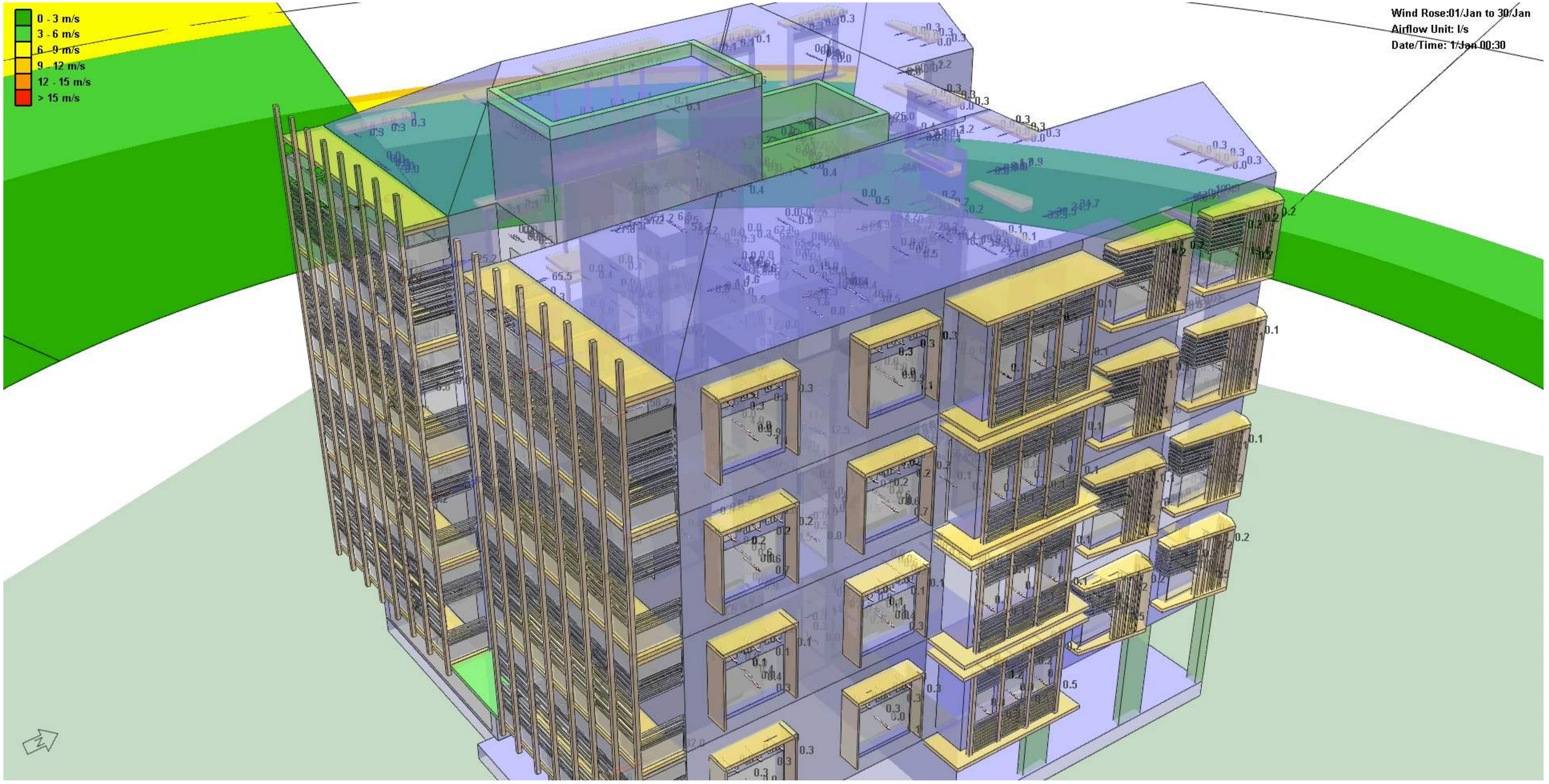


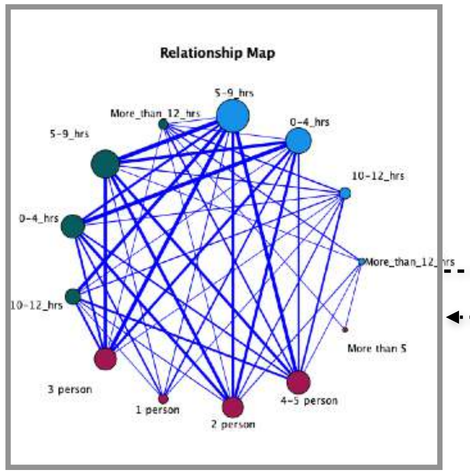
Figure 41: 3D rendering of RTB prototype after all six passive-cooling design strategies implemented. Bird's-eye view shows that shading systems designed with fenestration strategies to acclimatise indoor-air environment, balcony projections show that spatial layout of each flat was re-configured to increase liveability in condominiums.

9. Conclusions: Roadmap to EU Energy-policy framework

Outcomes: Implications for energy-policy design

RQ-M: **What is the most effective and universally applicable energy-policy framework to implement the EPBD mandates recommended by EU and improve the energy efficiency of existing post-war social housing stock?**

Energy policy - I



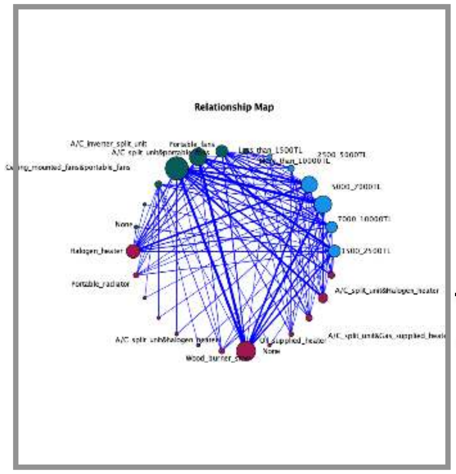
Developing an evidence-based energy-policy framework to assess robust energy-performance evaluation and certification schemes in the South-eastern Mediterranean countries

- Socio-technical associations between building energy use and occupants' thermal comfort were examined.
- A moderate negative correlation ($r = -0{,}329$, $p < 0{,}01$) was found between household income and type of tenancy.
- A moderate negative correlation ($r = -0{,}229$, $p < 0{,}05$) was found between the occupants' age and their complaints related to thermal discomfort.

(Contribution 1)

European Commission

Energy policy - II



Significance of occupancy patterns and habitual household adaptive behaviour on home-energy performance of post-war social-housing estate in the South-eastern Mediterranean climate

- Human-based inclusive approach for residential buildings was developed.
- A strong positive correlation ($r = -0{,}588$, $p < 0{,}01$) between weekday heating-and cooling-consumption patterns, which confirms that household income is a key factor.
- Energy-efficiency measures are recommended at the local and nationwide levels.

(Contribution 2)

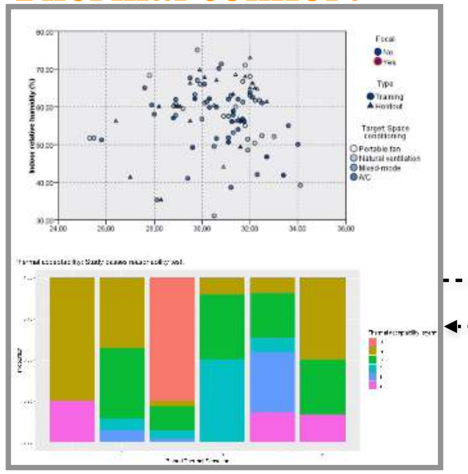
REHVA

Federation of European Heating, Ventilation and Air-conditioning Associations

Figure 42: The developed STS conceptual framework for the retrofit energy policy design.

9. Conclusions: Roadmap to EU Energy-policy framework

Thermal comfort



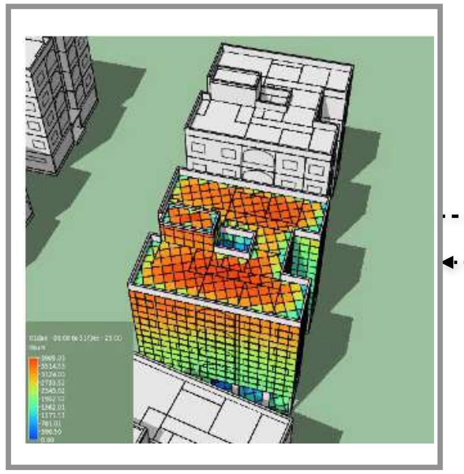
Regression forecasting of 'neutral' adaptive thermal: A field study investigation in the South-eastern Mediterranean climate of Cyprus

- A novel framework combining assessment methodology with existing benchmark criterion of thermal comfort was developed.
- A moderate correlation was found between the occupants' thermal sensation and the indoor air temperature ($r = 0{,}215$, $p < 0{,}05$).
- The 'neutral' temperature was 28,5 °C, and the upper limit of the comfort range in warm indoor air temperature conditions was 31,5 °C.

(Contribution 3)

ASHRAE

Building energy simulation

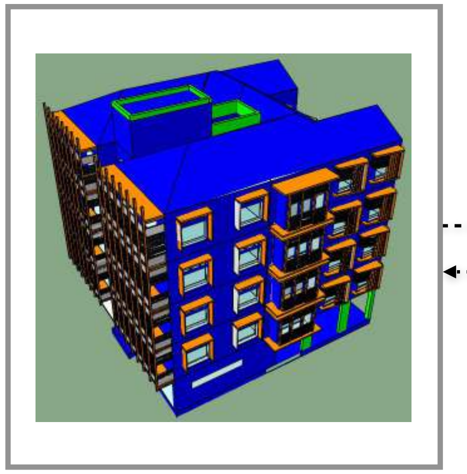


Bridging energy performance gap of a social housing stock in South-eastern Mediterranean Europe: Climate change and mitigation

- A novel building diagnostic and thermal performance-oriented approach was proposed.
- There was a difference of +5 °C between the actual and the simulated-and-predicted operative-air temperatures.
- The 36,5 °C upper thermal-comfort threshold identified in the building-energy-simulation analysis +3,5 °C higher than the recommended thermally acceptable threshold for hot Mediterranean climates in the summer.

(Contribution 4)

Retrofit design policy

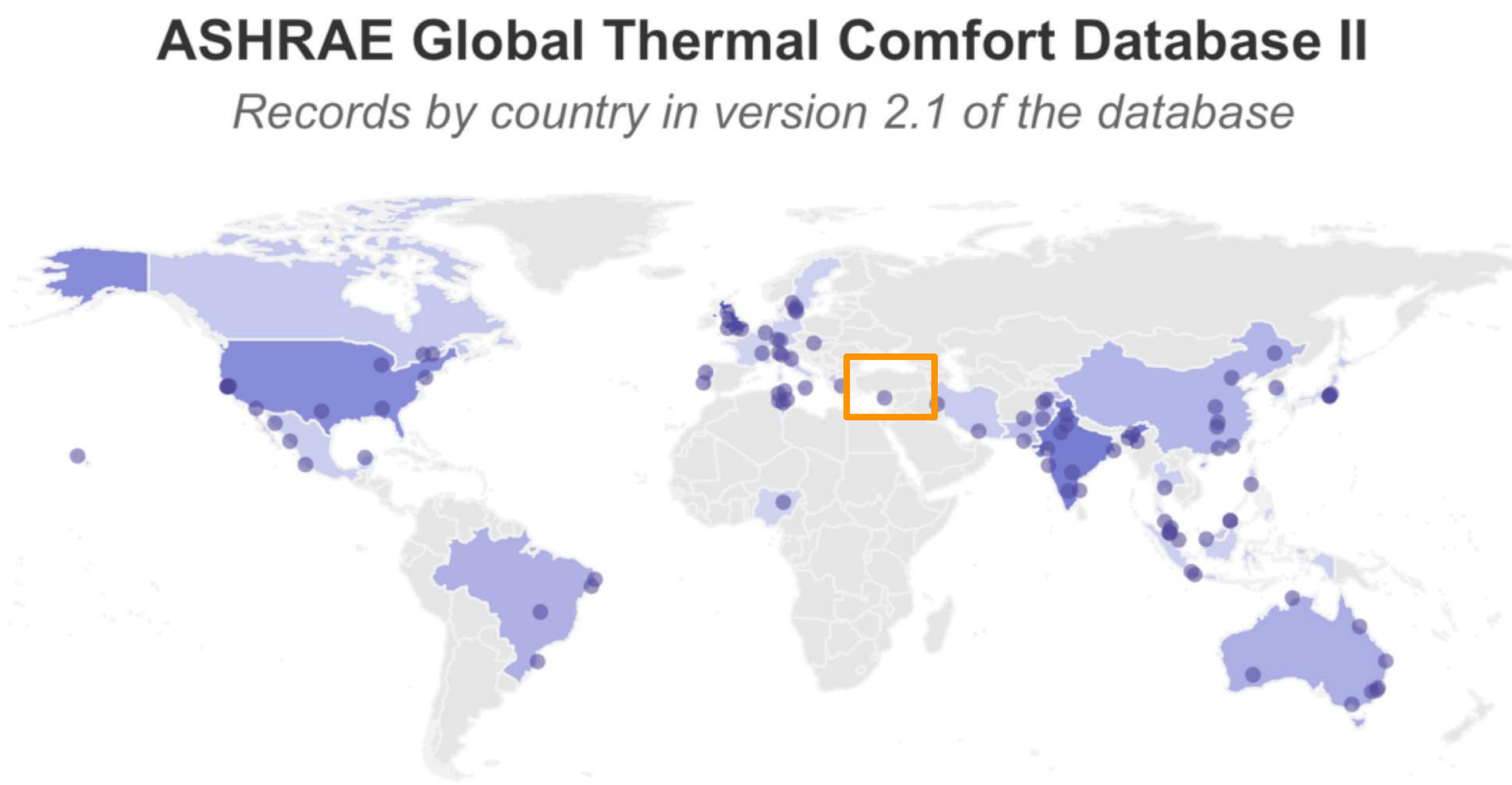


A novel methodological framework for the optimisation of post-war social housing developments in the South-eastern Mediterranean climate: Policy design and life-cycle cost impact analysis of retrofitting strategies

- An energy calibration framework was developed.
- 81% of savings related to cooling consumptions was achieved.
- Recommendations for the development of passive cooling design strategies for buildings' retrofitting were presented.
- Energy effectiveness of passive cooling design strategies to reduce the impact of long-term heatwaves on occupants' thermal comfort were presented.

(Contribution 5)

ISES
International Solar Energy Society



An update to the ASHRAE Global Thermal Comfort Database II ...

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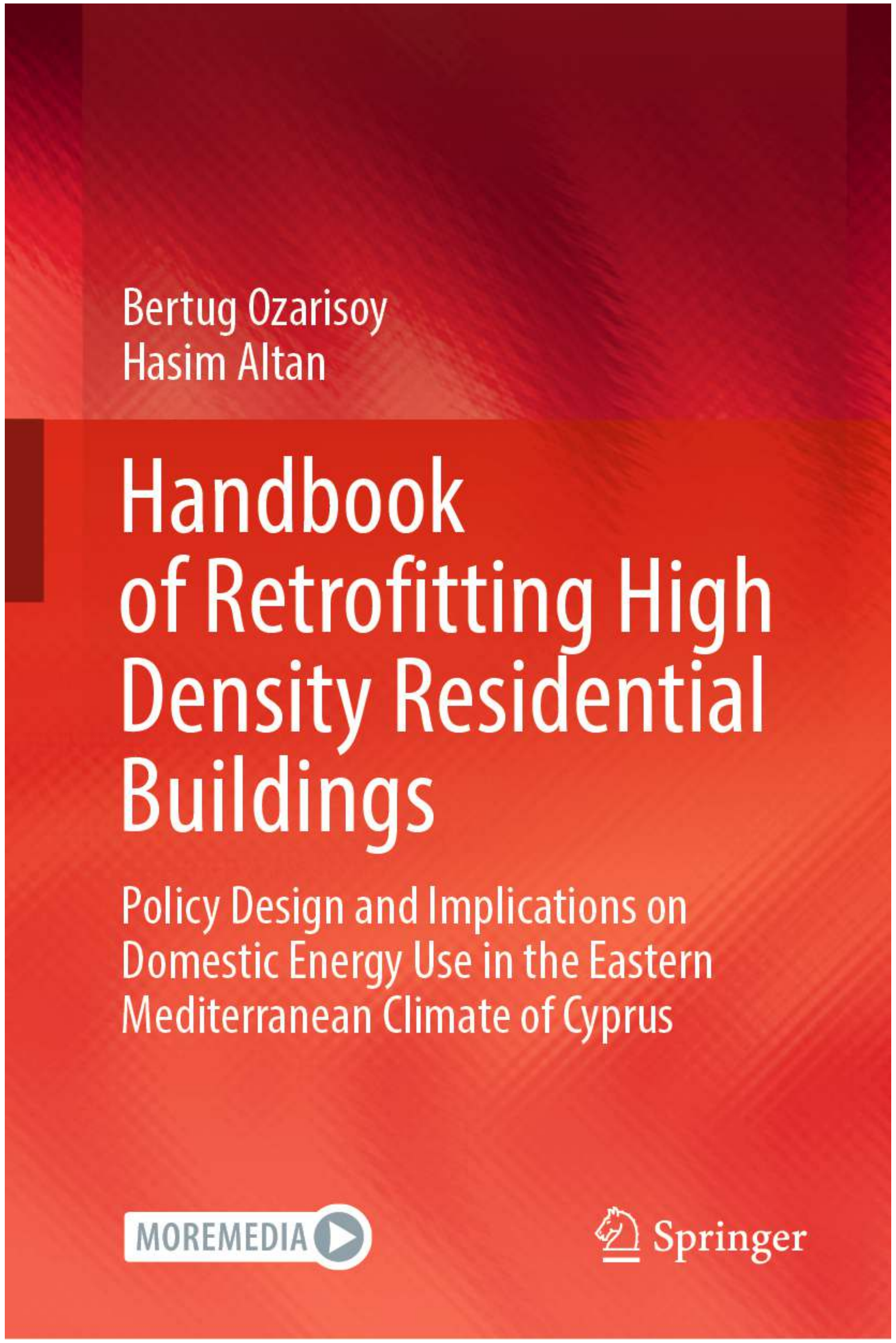
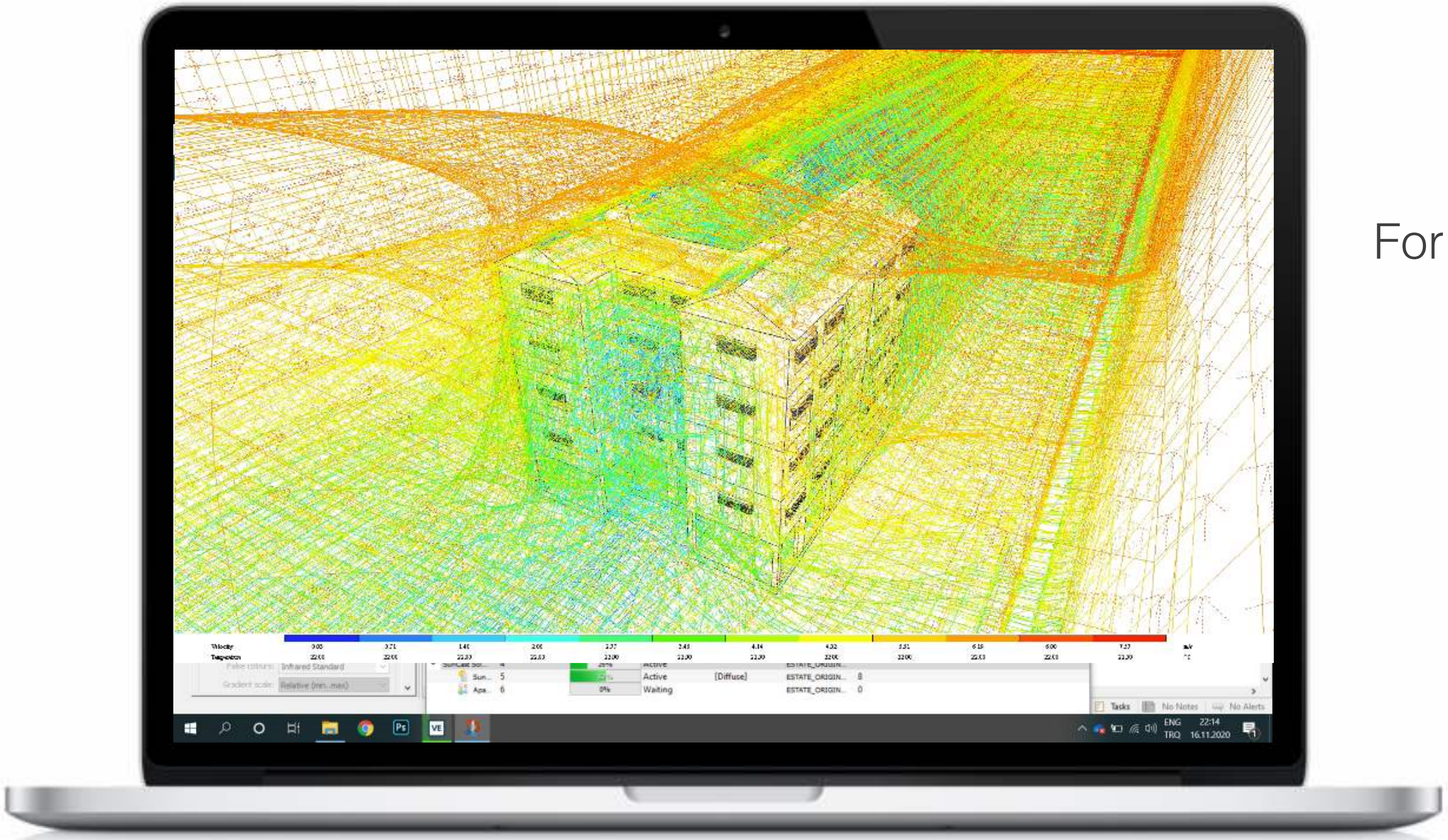
Thesis Title: Assessing the Domestic Energy Use and Thermal Comfort of Occupants in a Post-war Social Housing Development Estate in Famagusta, Northern Cyprus



Source: Ozarisoy, B., & Altan, H. (2022). Handbook of Retrofitting High Density Residential Buildings: Policy design and implications on domestic energy use in the Eastern Mediterranean climate of Cyprus, Springer, https://link.springer.com/book/9783031118531



The Integrated Environmental Solutions software was used to assess overheating risk of the RTBs and optimise efficiency of passive cooling design systems implemented onto the existing building envelopes.

For further discussions and possible networking opportunities
Please do not hesitate to contact with me

Dr. Bertug Ozarisoy
bertug.ozarisoy@lsbu.ac.uk