Themes in Sustainable Development

Energy Poverty

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Energy poverty – a global issue

Energy is a fundamental and essential requirement for meeting basic human needs. The inability to access sufficient, clean, and affordable household energy describes energy poverty phenomenon; a complex and multidimensional problem, affecting societies globally.

Energy poverty globally	
Having no access to electricity	760 million people
Depending on traditional fuels for cooking	2.3 billion people
Indoor air pollution from cooking smoke	3.7 million premature deaths annually

International organizations focus on alleviating energy poverty:

World Health Organization

WORLD BANK

(IEA, 2023)

Energy poverty – a global issue

Sustainable Development Goal 7 (Agenda 2030), a stand-alone goal dedicated to energy, calls to "ensure access to affordable, reliable, sustainable and modern energy for all".

Energy is a central issue to both the 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change.

- ✓ Developing countries struggle for sufficient access to modern energy.
- ✓ Developed nations cannot mitigate energy costs.
- ✓ Energy poverty refers to the inability to have socially and materially required levels of domestic energy services. It is the situation that sufficient domestic warmth and other households' energy needs cannot be satisfied.

(Che et al., 2021; Faiella & Lavecchia, 2021)

Energy poverty drivers

Economic growth is a critical driver of energy poverty. Regional economic levels are consistently associated with the phenomenon; higher income regions (i.e. Europe, Oceania and North America) are less affected by energy poverty compared with low-income regions like Sub-Saharan Africa, South Asia and Central America.

According to International Renewable Energy Agency significant improvements have been observed worldwide from 2010 to 2019:

	2010	2019
People without access to electricity	1.2 billion	759 million
Access to clean cooking	3 billion	2.6 billion

Energy poverty is still a challenging problem in developed countries.
In the USA approximately 30% of households are classified as energy poor.
In Europe more than 54 million (almost 11% of its population) struggle with keeping their homes adequately warm or have arrears in utility bills.

(IRENA, 2021)

Energy poverty drivers

Developing countries			
Low income	Income inequality	Lack in modern energy infrastructure	Urbanization

Income poverty is a significant driver, increasing energy poverty.

Countries with improved access to energy do not foster universal electricity accessibility, using traditional biofuels, even in nations that are major energy suppliers (i.e. MENA).

Income inequality leads to uneven access. In higher-income cases, infrastructure and energy supply have led to growth. On the other hand, in cases like Yemen, energy poverty is a significant and persistent phenomenon, indicating that energy sources and the wealth deriving from them cannot guarantee universal country benefits.

Urbanization is a key factor influencing energy poverty occurrence (urban areas have better progress in electrification compared to rural regions). Rural areas present high disparities compared to urban regions, classifying less densely populated areas as more vulnerable, with lower income and infrastructure access.

(El-Katiri, 2014; Ben Cheikh et al. 2023)

Energy poverty drivers

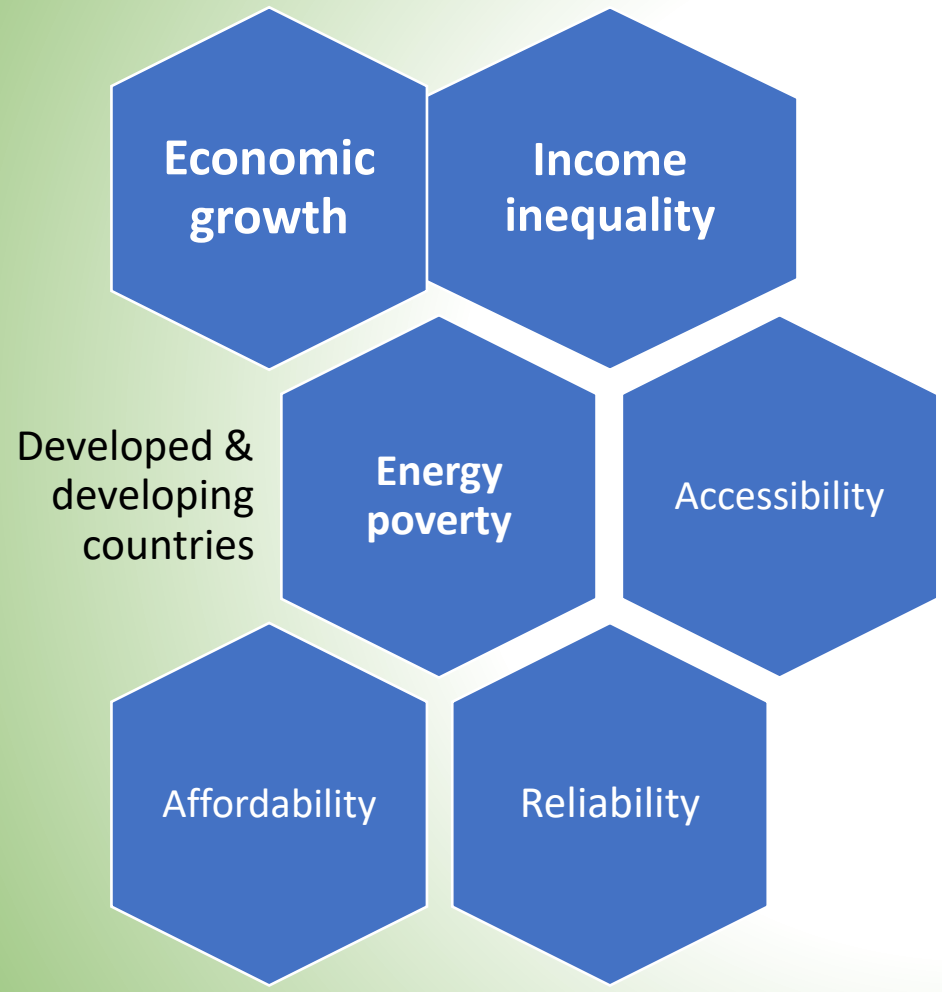
Modern energy infrastructure requires advanced technologies and high upfront costs, which are beyond developing nations' financial and technological capabilities.

Access to modern technologies for cooking and clean energy is the major issue primarily because of: limited power generation capacity, inadequate infrastructure for transmission and distribution, high costs of supplying electricity to remote regions, electricity affordability challenges, ineffective policies and regulations, insufficient planning and institutional support, and a lack of financing options for off-grid entrepreneurial ventures.

- Nations in Middle Eastern European countries, South America and Caribbean, and Southeast Asia seem to improve in energy poverty alleviation. *Transitioning economic structures*, *shifting towards cleaner energy consumption*, and noticeable *technological advancements* contribute significantly.
- Central Asia, South Asia, and Sub-Saharan Africa present less improvement. In Africa, more than 700 million people were left without access to electricity in 2019.

(Salman et al., 2022)

Energy poverty drivers



Accessibility and reliability impact stronger energy poverty in cases of low-income countries.

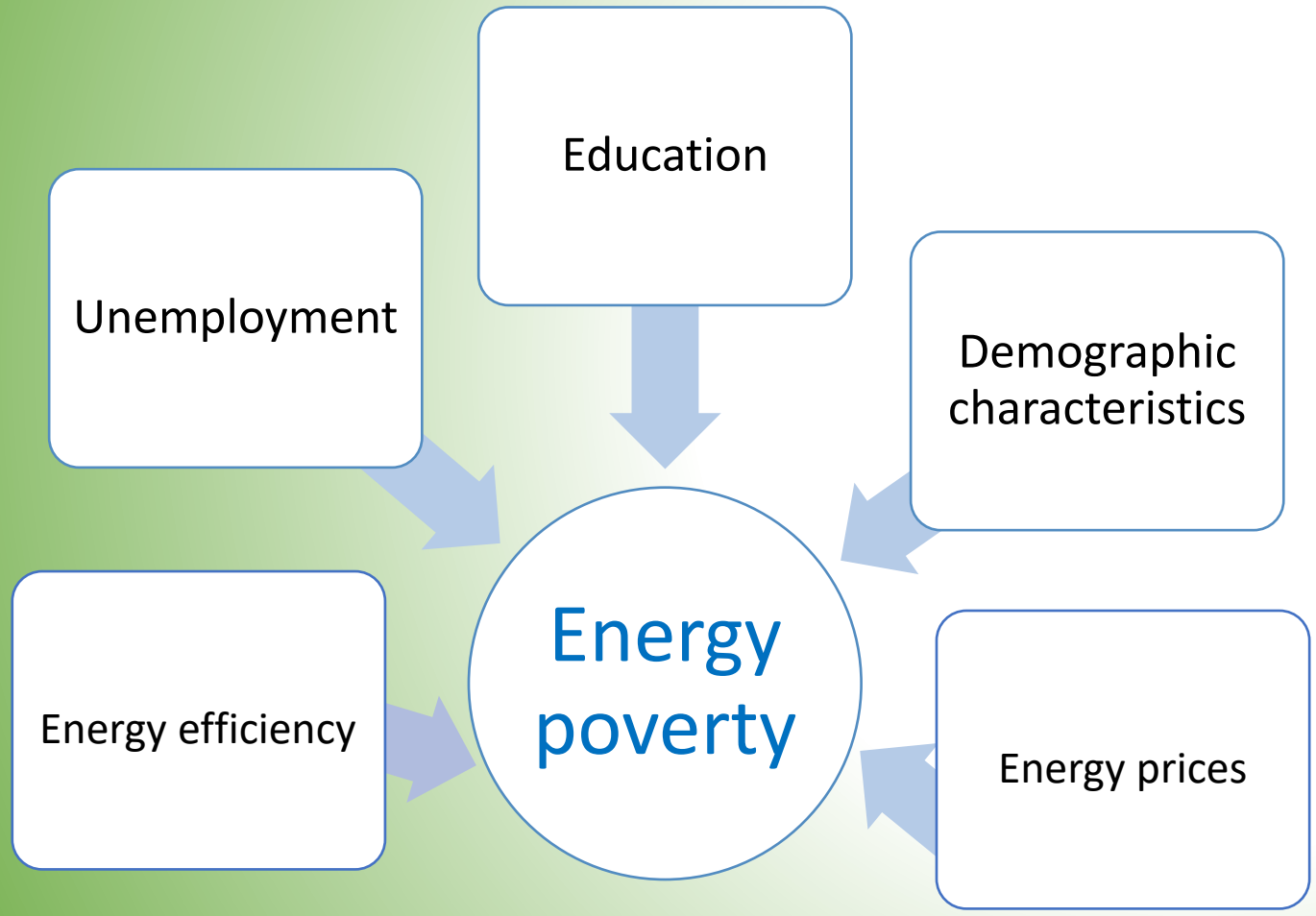
The effect of affordability worsens energy poverty in middle-income countries with high income inequality.

As economic growth improves, households with lower income experience less energy poverty under the accessibility dimension.

On the other hand, as economic growth and income inequality increase, lower income households suffer deeper from energy poverty under the affordability dimension

(Igawa & Managi, 2022)

Energy poverty drivers



Low energy efficiency: old building stock with low energy performance contributes to energy poverty.

Economically inactive people i.e., unemployed or older people, are considered more vulnerable to energy poverty.

Lack of education or low educational levels and limited awareness increase energy poverty.

Demographic factors: gender, age household size, tenure status, occupation, geographical dimension.

(Lyra et al. 2022; Papada & Kaliampakos, 2018; Damigos et al. 2021; Halkos & Kostakis, 2023; Atsalis et al. 2016)

Energy poverty impacts

Health risks	Air pollution, premature deaths, reduced life expectance at birth, increased maternal and child mortality, asthma & respiratory diseases, injuries, reduced life expectance at birth, increased maternal and child mortality, malnutrition, regular hospital visits.
Prosperity and development	Economic progress is threatened (short and long run), impacts on all production sectors, HDI, GDP.
Education	Impacts on years of school attendance, school outcomes and dropouts.
Environmental quality	Greenhouse gas emission increase.
Inequality	Making choices and achieving overall prosperity are undermined, social injustice is generated.

(IEA, 2023; González-Eguino, 2015; Katoch et al. 2024; Nawaz, 2021; Oliveras et al. 2021; Lee & Yuan, 2024; Betto et al. 2020; Tundys et al. 2021; Nguyen & Nasir, 2021)

Energy poverty indicators

Objective approach

- Income and energy expenditure oriented
- Energy expenses against absolute or relative thresholds

Subjective approach

- Ability to keep home adequately warm
- Arrears in utility bills
- Dwellings with leakages, damp, or rot

Direct approach

- Direct measurement of heating and lighting

→

- 10% rule
- Low Income – High Cost indicator
- Low Income-Low Energy Efficiency
- 2M
- M/2

(Herrero, 2017; EPAH)

Energy is a fundamental and essential requirement for meeting basic human needs.

Energy poverty in Europe	2024
Inability to keep home adequately warm	9%
Household electricity prices	0.32€/KWh→ increasing trend
Arrears on utility bills	6.9% of the total households
USA	30% of households are energy poor
Europe	54 million are energy poor
Globally	Heat-related deaths are running at an annual average close to 500,000 globally

An empirical investigation

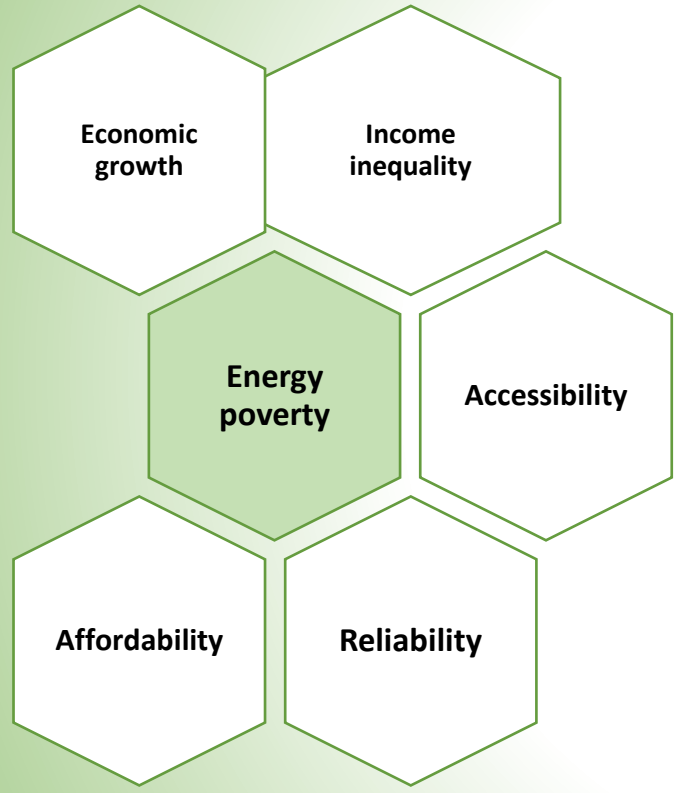
Objective of the study:

- Investigate energy poverty within Southern European countries (Greece, Italy, Spain, Portugal) examining the impact of socioeconomic, dwelling, and climatic determinants on household energy poverty.

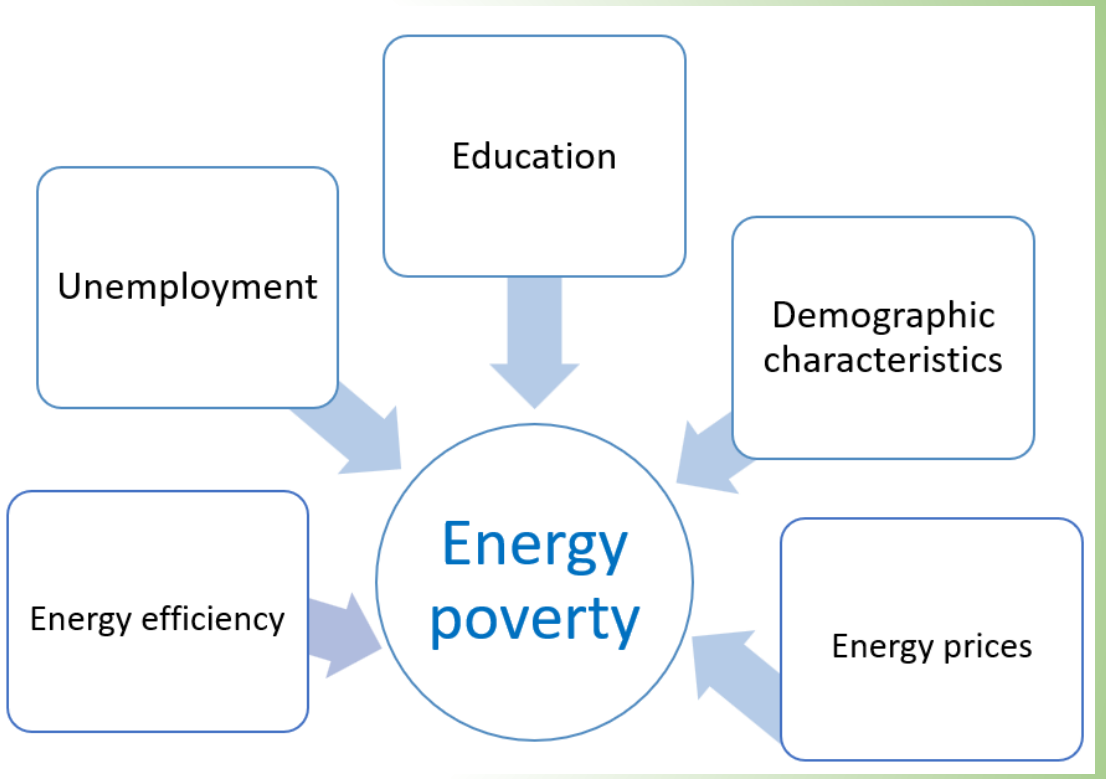
- Micro-data

- EU-SILC dataset

Drivers



(Igawa & Managi, 2022)



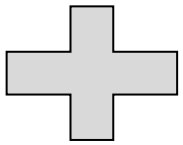
os, 2018; Damigos et al. 2021; Halkos & Kostakis, 2023;

Ways of measuring energy poverty

Objective approach

Subjective approach

Direct approach

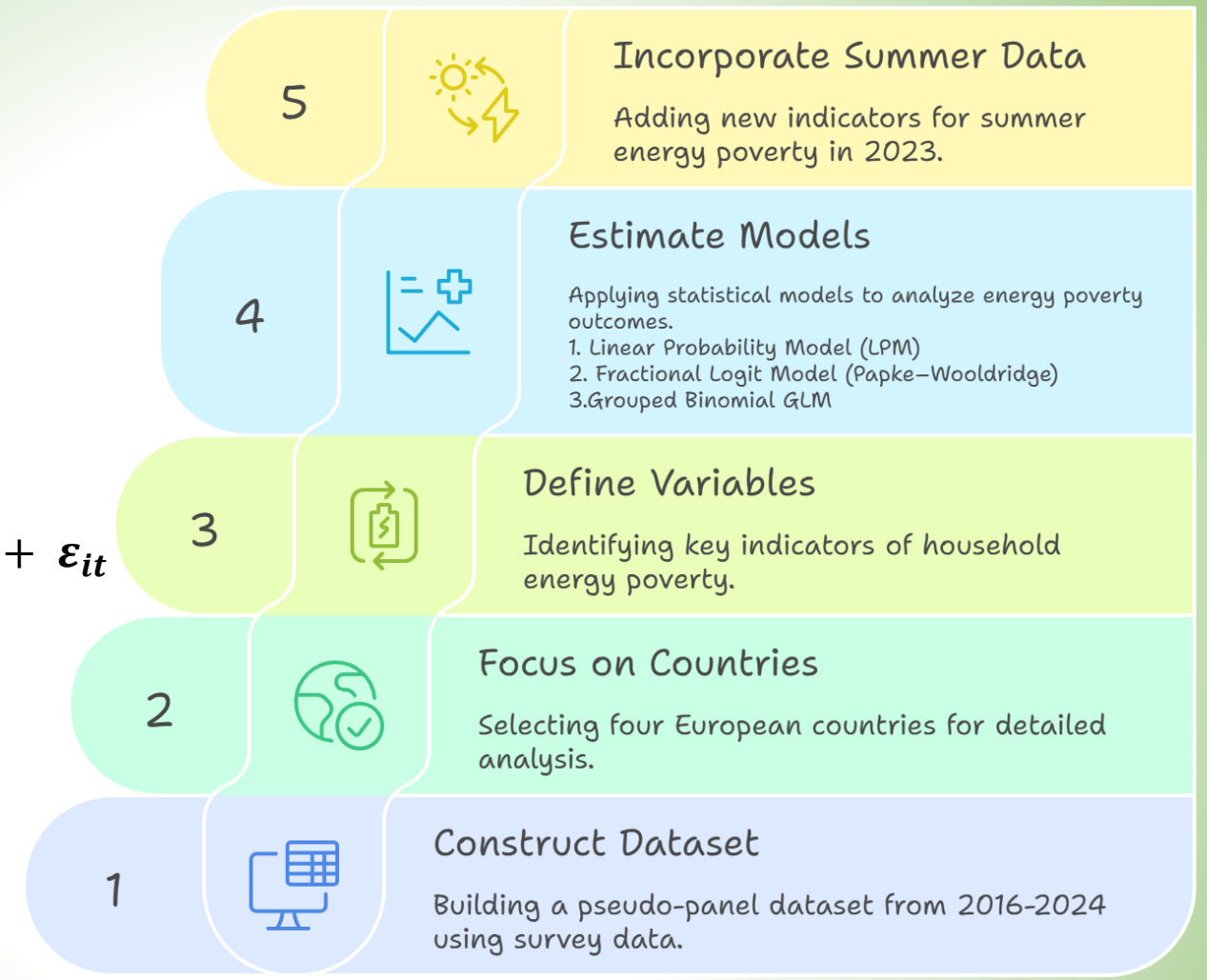


Severe deprivation

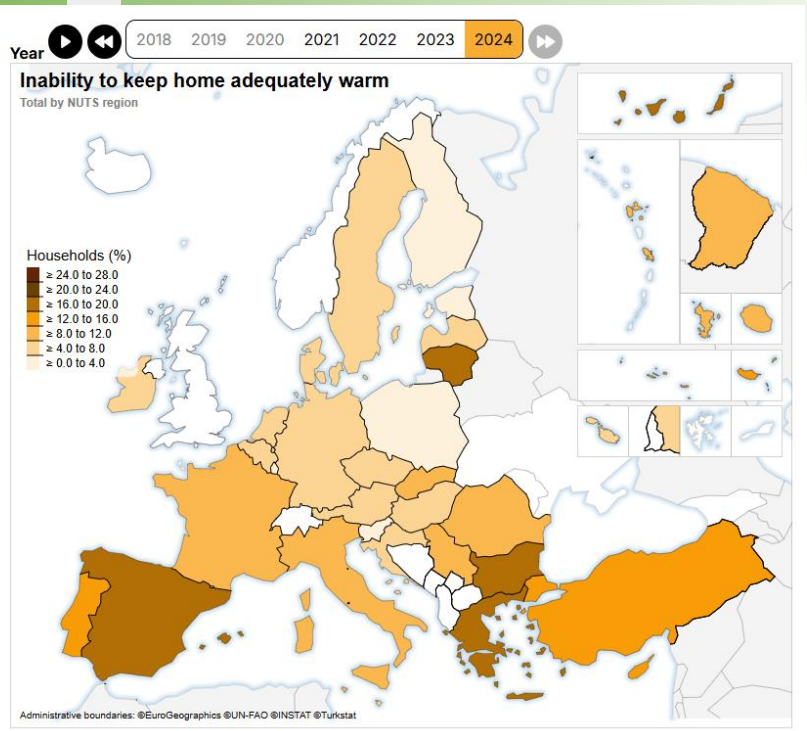
(Herrero, 2017; EPAH)

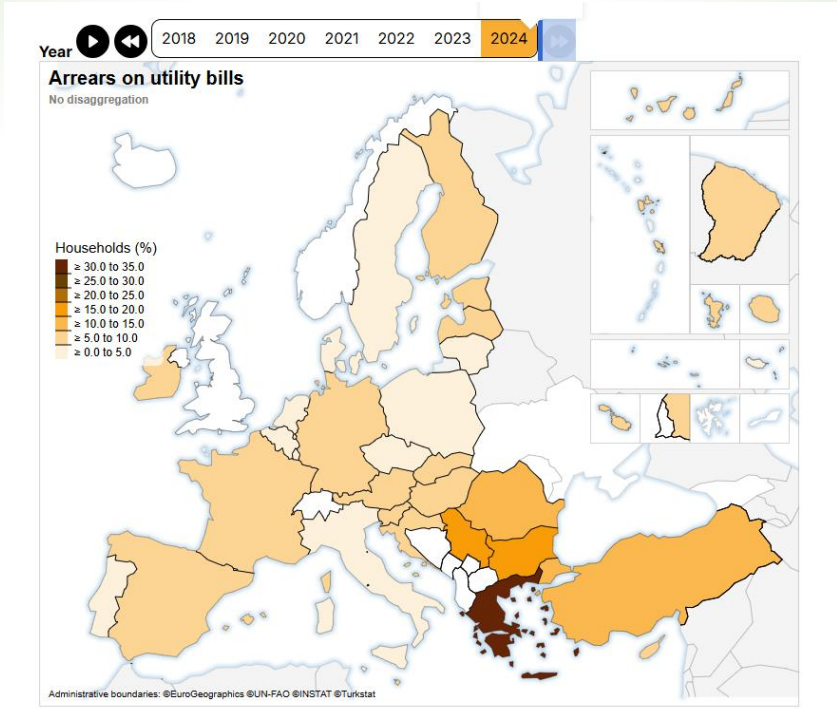
Methodology

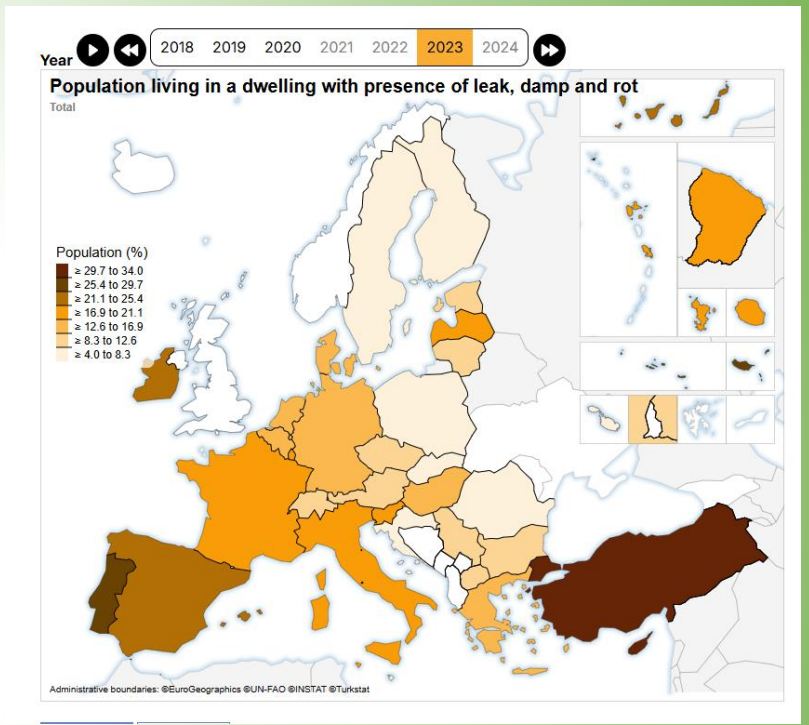
$$EP_{it} = \beta_0 + \beta_1 X_{it} + cohort_{it} + time_{it} + \varepsilon_{it}$$



Some figures on our dependent variables







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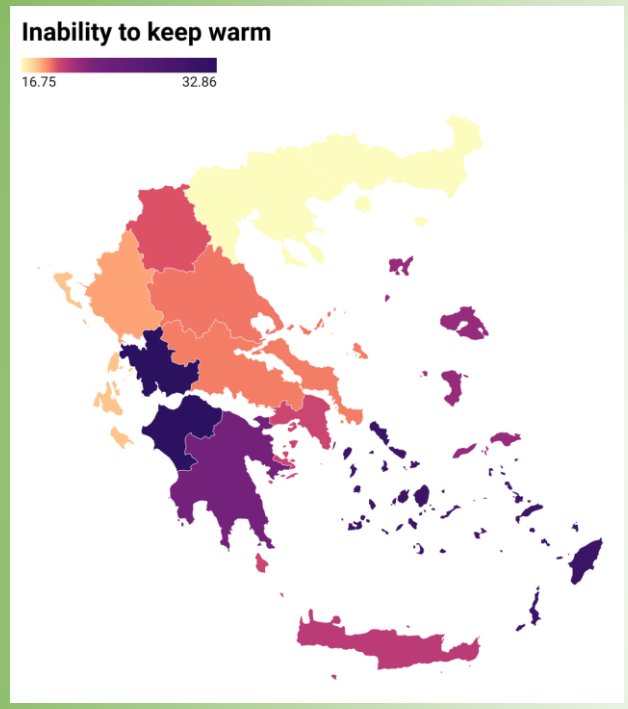

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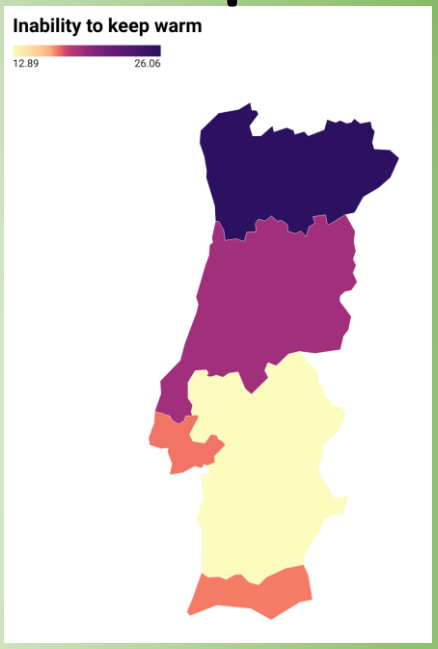
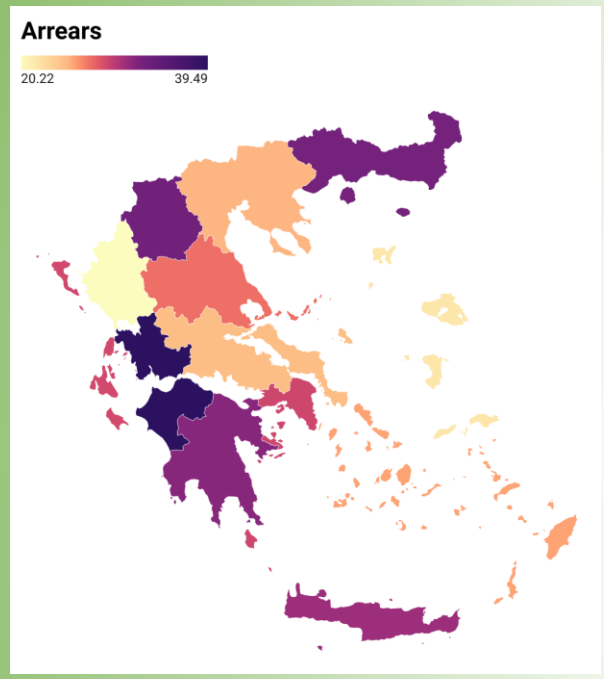
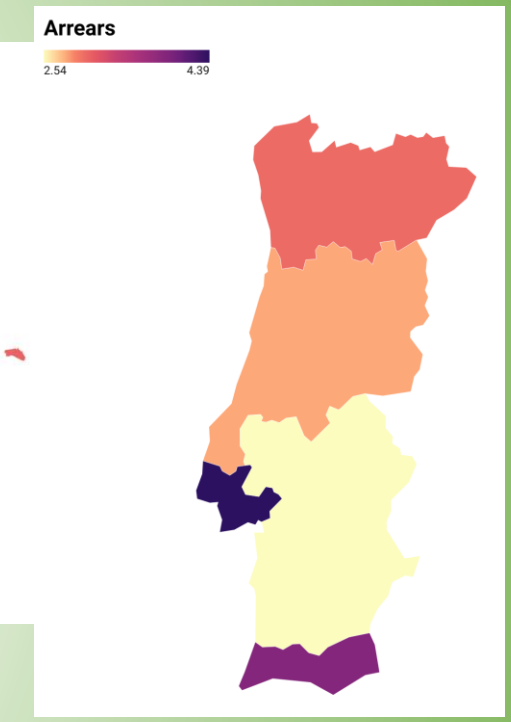
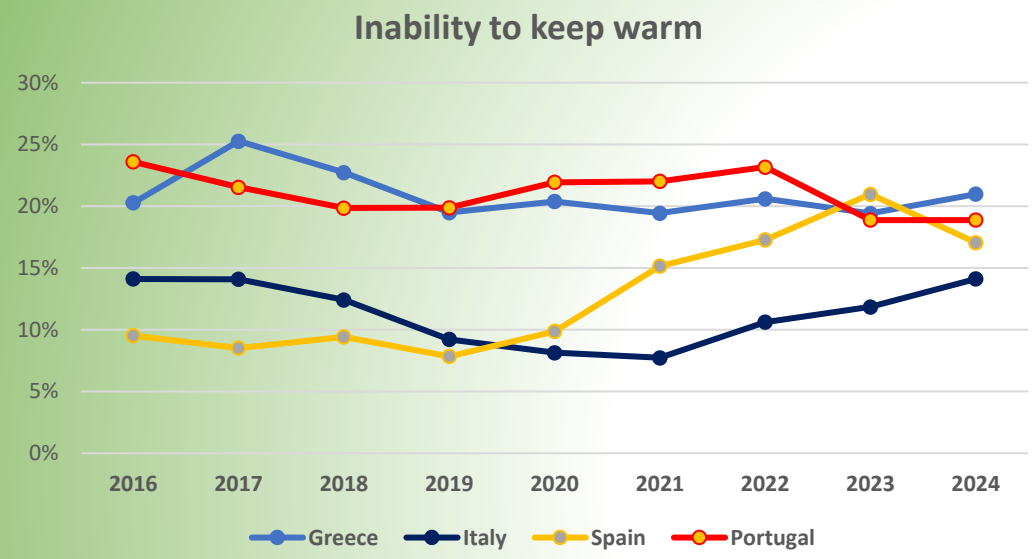


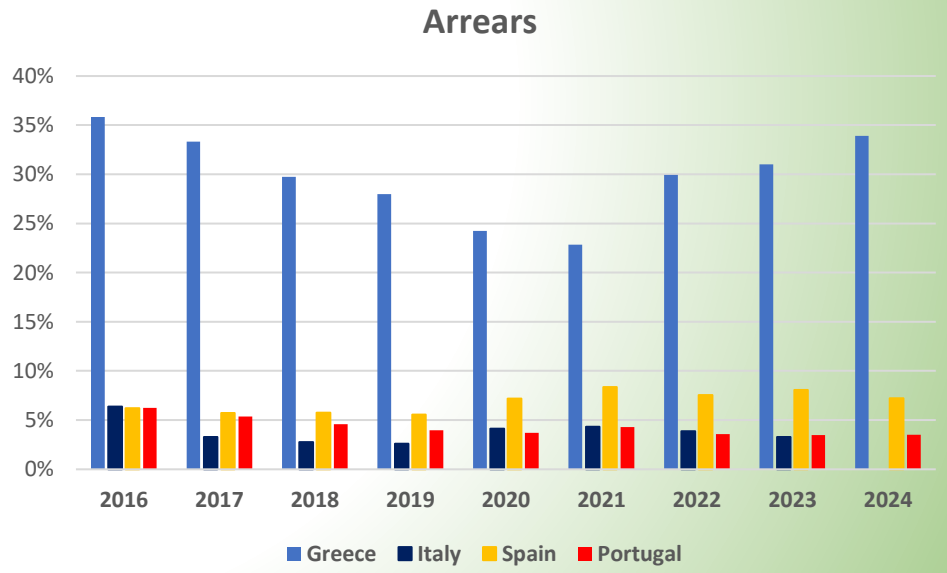
More specifically…(2)



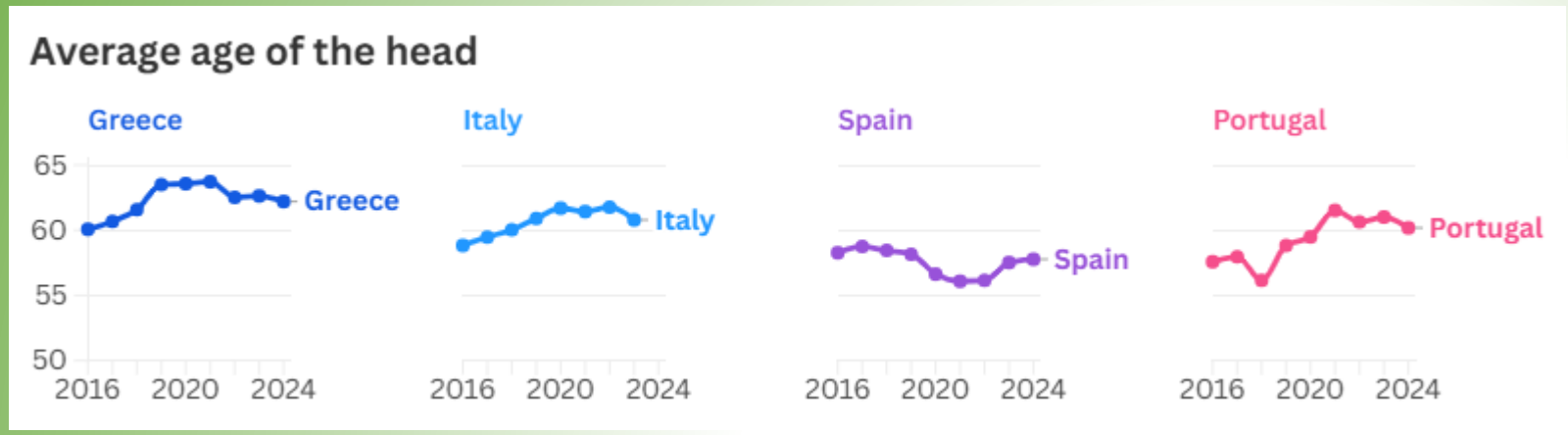


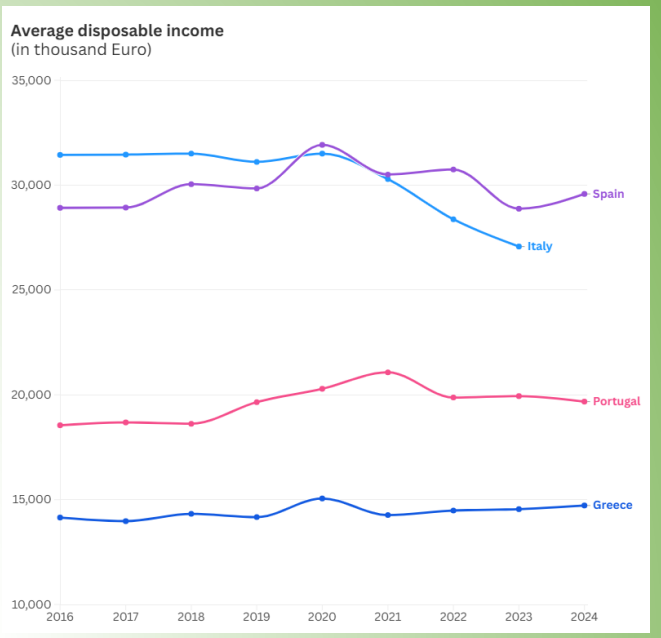
Chronologically…

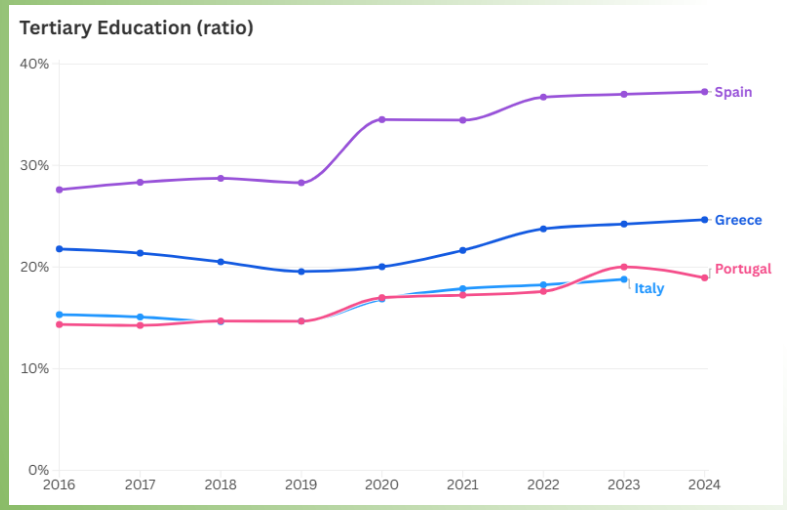


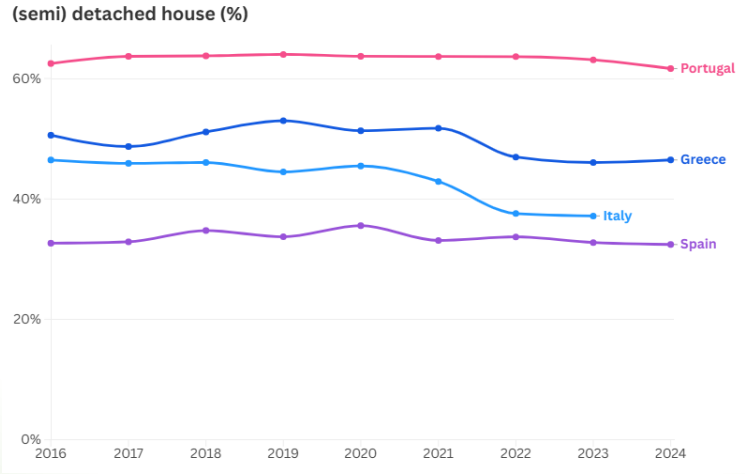


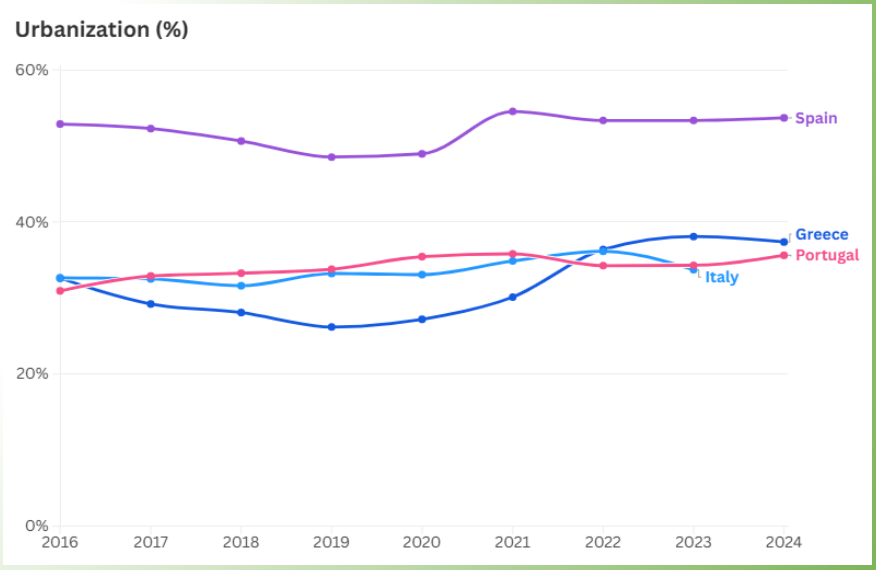
Independent variables…





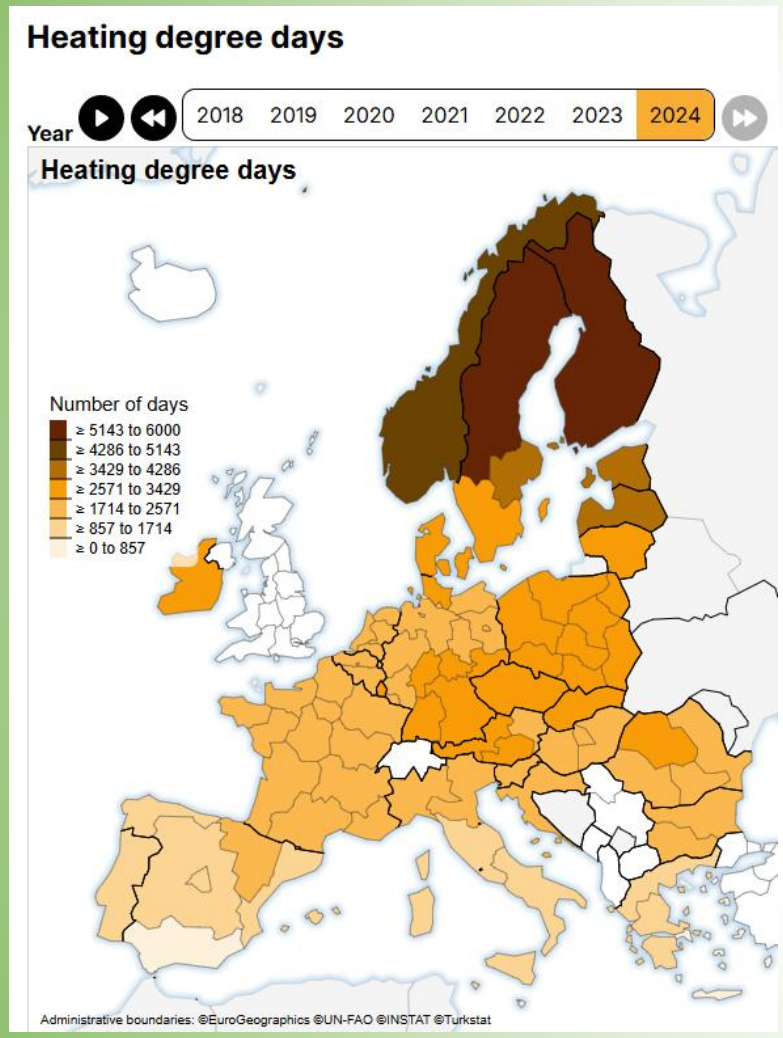


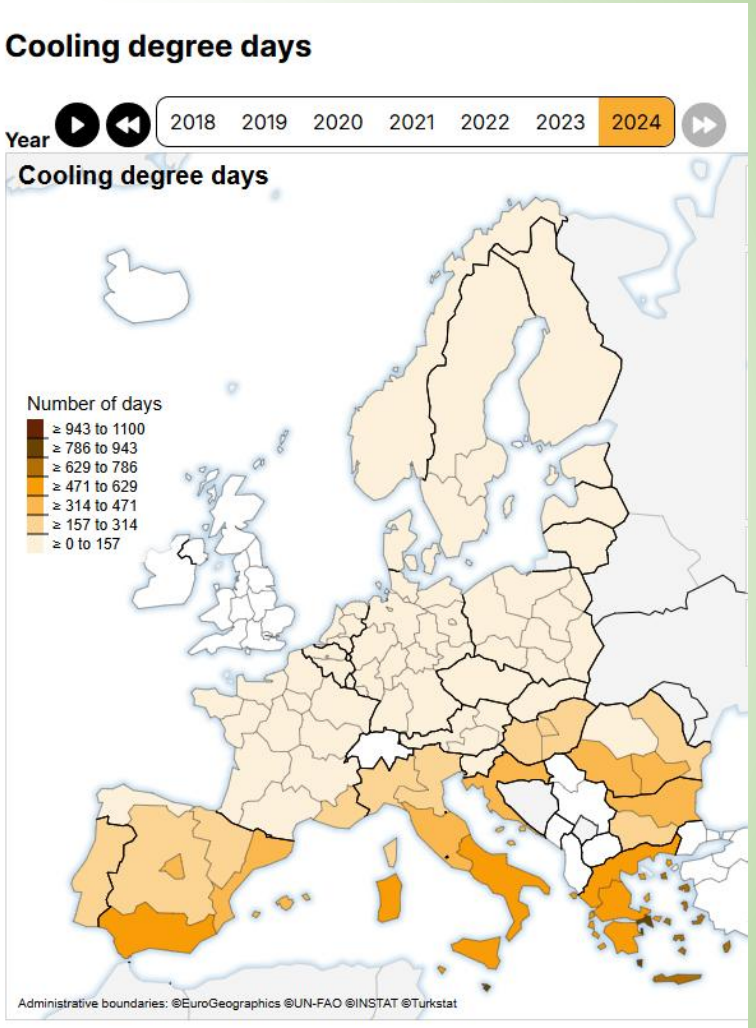




Climatic factors…

City	HDD	CDD
Helsinki	~4500	~50
Berlin	~3000	~150
Athens	~1100	~600





Higher HDD values → colder climate → more heating demand. Higher CDD values → hotter climate → more cooling demand.

Econometric findings…

Greece: Inability to keep home adequately warm (NUTS 1)

Models	LPM	LPM	LPM	Fraction Logit	Fraction Logit	Fraction Logit	Group binomial GLM	Group binomial GLM	Group binomial GLM
Disposable income	-0.138***	-0.165***	-0.115***	-0.949***	-1.081***	-0.882***	-0.796***	-1.105***	-0.876***
	(0.035)	(0.047)	(0.040)	(0.192)	(0.232)	(0.265)	(0.273)	(0.357)	(0.280)
Household size	0.030	0.021	-0.011	0.320	0.353	0.059	0.172	0.108	-0.022
	(0.042)	(0.049)	(0.047)	(0.244)	(0.279)	(0.319)	(0.334)	(0.362)	(0.349)
Urban area	-0.116*	-0.096	-0.025	-0.513	0.084	0.175	-0.834*	-1.216**	-0.666
	(0.067)	(0.073)	(0.067)	(0.402)	(0.538)	(0.462)	(0.453)	(0.516)	(0.457)
Detached house	-0.065	0.111	0.092	-0.252	0.751	0.558	-0.548	0.704	0.567
	(0.053)	(0.075)	(0.072)	(0.341)	(0.464)	(0.470)	(0.340)	(0.566)	(0.525)
Employment status	-0.040*	-0.041	-0.061	-0.216	-0.116	-0.140	-0.198	-0.758	-0.682
	(0.023)	(0.090)	(0.085)	(0.144)	(0.723)	(0.691)	(0.172)	(0.688)	(0.638)
Tertiary ratio	-0.206***	-0.162**	-0.138*	-1.171***	-0.971*	-0.811	-1.370***	-1.186**	-0.976*
	(0.049)	(0.077)	(0.078)	(0.326)	(0.540)	(0.531)	(0.329)	(0.550)	(0.544)
HDD/CDD	-0.164***	-0.101**	-0.300***	-0.901**	-0.302	-1.500***	-0.876**	-1.016***	-2.333***
	(0.052)	(0.047)	(0.069)	(0.378)	(0.371)	(0.479)	(0.342)	(0.351)	(0.574)
Constant	1.244***	1.186***	1.165***	5.036***	3.949***	4.701***	4.759***	5.658***	6.154***
	(0.172)	(0.273)	(0.229)	(1.050)	(1.330)	(1.392)	(1.324)	(2.030)	(1.627)
Cohort effects (NUTS 1)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	392	392	392	392	392	392	392	392	392

Econometric findings…Greece

Greece: Arrears on utility bills (NUTS 1)

Models	LPM	LPM	LPM	Fraction Logit	Fraction Logit	Fraction Logit	Group binomial GLM	Group binomial GLM	Group binomial GLM
Disposable income	-0.181***	-0.287***	-0.238***	-0.982***	-1.355***	-1.317***	-0.877***	-1.439***	-1.277***
	(0.045)	(0.080)	(0.074)	(0.260)	(0.263)	(0.288)	(0.210)	(0.390)	(0.373)
Household size	0.129**	0.081	0.120	0.771***	0.380	0.697*	0.636***	0.437	0.425
	(0.050)	(0.084)	(0.090)	(0.296)	(0.310)	(0.379)	(0.234)	(0.413)	(0.434)
Urban area	-0.125	-0.120	0.078	-0.354	-0.523	0.199	-0.808**	-0.709	0.070
	(0.094)	(0.108)	(0.116)	(0.493)	(0.490)	(0.579)	(0.408)	(0.476)	(0.552)
Detached house	-0.071	0.042	0.062	-0.144	0.046	0.288	-0.512	0.047	0.077
	(0.073)	(0.113)	(0.110)	(0.385)	(0.561)	(0.509)	(0.314)	(0.612)	(0.616)
Employment status	-0.095***	0.011	0.078	-0.416***	0.196	0.540	-0.418***	-0.455	-0.097
	(0.025)	(0.122)	(0.138)	(0.158)	(0.463)	(0.509)	(0.115)	(0.592)	(0.701)
Tertiary ratio	-0.059	-0.073	-0.052	-0.113	-0.200	-0.069	-0.486*	-0.578	-0.204
	(0.057)	(0.107)	(0.110)	(0.290)	(0.499)	(0.508)	(0.254)	(0.545)	(0.589)
HDD/CDD	-0.138*	-0.350***	-0.165	-0.844**	-2.400***	0.093	-0.600	-1.643***	-1.760***
	(0.080)	(0.117)	(0.136)	(0.417)	(0.643)	(0.776)	(0.395)	(0.611)	(0.658)
Constant	1.454***	2.148***	1.485***	4.987***	8.445***	4.842***	4.894***	8.345***	7.365***
	(0.239)	(0.460)	(0.431)	(1.417)	(1.359)	(1.481)	(1.151)	(2.118)	(2.007)
Cohort effects (NUTS 1)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	392	392	392	392	392	392	392	392	392

Notes: Standard errors in parentheses. SEs clustered at cohort. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Greece: Inability to keep home adequately warm, Arrears on utility bills, Leaking roof, damp walls/floors/foundation, or rot in window frames or floor (NUTS 2)

	Inability to keep home adequately warm (NUTS 2)			Arrears on utility bills (NUTS 2)			Leaking roof, damp walls/floors/foundation, or rot in window frames or floor (NUTS 2)		
	LPM	Fraction Logit	Group binomial GLM	LPM	Fraction Logit	Group binomial GLM	LPM	Fraction Logit	Group binomial GLM
Disposable income	-0.154***	-0.149***	-0.132***	-0.172***	-0.218***	-0.210***	-0.039**	-0.008	0.014
	(0.029)	(0.034)	(0.033)	(0.031)	(0.049)	(0.044)	(0.018)	(0.028)	(0.033)
Household size	0.060	0.057	0.055	0.128***	0.143***	0.201***	-0.005	-0.011	-0.076*
	(0.037)	(0.038)	(0.037)	(0.037)	(0.049)	(0.052)	(0.021)	(0.040)	(0.041)
Urban area	-0.053*	-0.073	-0.029	-0.063	-0.081	0.015	0.050**	-0.072	-0.112*
	(0.031)	(0.050)	(0.050)	(0.042)	(0.070)	(0.073)	(0.022)	(0.057)	(0.058)
Detached house	-0.009	-0.001	0.001	-0.014	-0.102*	-0.069	0.040	0.001	-0.035
	(0.029)	(0.044)	(0.044)	(0.040)	(0.058)	(0.058)	(0.024)	(0.051)	(0.052)
Employment status	-0.011	0.084	0.084	-0.094***	0.043	0.077	-0.003	0.008	-0.018
	(0.019)	(0.055)	(0.053)	(0.021)	(0.073)	(0.078)	(0.016)	(0.048)	(0.047)
Tertiary ratio	-0.174***	-0.087	-0.082	-0.104**	-0.116*	-0.103*	-0.093**	-0.104*	-0.093
	(0.038)	(0.055)	(0.054)	(0.045)	(0.063)	(0.061)	(0.039)	(0.061)	(0.062)
HDD/CDD	-0.035***	-0.025***	-0.033**	-0.026***	-0.061***	0.030	-0.037***	0.018	-0.017
	(0.007)	(0.008)	(0.014)	(0.010)	(0.017)	(0.023)	(0.005)	(0.013)	(0.012)
Constant	1.048***	0.949***	0.846***	1.212***	1.458***	1.186***	0.337***	0.223*	0.259*
	(0.136)	(0.179)	(0.173)	(0.140)	(0.264)	(0.243)	(0.080)	(0.134)	(0.156)
Cohort effects (NUTS 2)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	1273	1273	1273	1273	1273	1273	728	728	728

Notes: Standard errors in parentheses. SEs clustered at cohort. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Greece: Leaking roof, damp walls/floors/foundation, or rot in window frames or floor (NUTS 1)

Models	LPM	LPM	LPM	Fraction Logit	Fraction Logit	Fraction Logit	Group binomial GLM	Group binomial GLM	Group binomial GLM
Disposable income	-0.032	0.001	0.060	-0.657***	-0.553	-0.323	-0.016	0.386	0.775
	(0.025)	(0.045)	(0.057)	(0.236)	(0.376)	(0.502)	(0.234)	(0.478)	(0.628)
Household size	-0.017	-0.036	-0.168**	0.411	0.590	-0.294	-0.396	-1.032*	-1.885***
	(0.028)	(0.064)	(0.070)	(0.276)	(0.596)	(0.675)	(0.284)	(0.612)	(0.665)
Urban area	-0.040	-0.037	-0.139*	-0.298	0.159	-0.721	-0.516	-0.614	-1.436*
	(0.040)	(0.086)	(0.082)	(0.367)	(0.669)	(0.632)	(0.357)	(0.743)	(0.736)
Detached house	-0.023	-0.049	-0.141	-0.091	-0.347	-1.098*	-0.343	-0.877	-1.589*
	(0.035)	(0.091)	(0.093)	(0.310)	(0.630)	(0.610)	(0.303)	(0.879)	(0.854)
Employment status	-0.010	-0.007	-0.050	0.164	0.499	0.127	-0.279*	-0.158	-0.498
	(0.015)	(0.082)	(0.071)	(0.138)	(0.693)	(0.605)	(0.148)	(0.894)	(0.774)
Tertiary ratio	-0.067	-0.124	-0.083	-0.534	-0.311	-0.128	-0.728	-1.142	-0.828
	(0.046)	(0.098)	(0.094)	(0.422)	(0.739)	(0.710)	(0.458)	(0.970)	(0.938)
HDD/CDD	-0.069**	0.146	-0.138*	-0.917***	2.616***	0.520	-0.370	1.470	-1.415*
	(0.027)	(0.093)	(0.081)	(0.264)	(0.828)	(0.869)	(0.278)	(1.072)	(0.784)
Constant	0.443***	0.070	0.346	2.427**	-1.940	0.825	-0.241	-2.975	-0.191
	(0.125)	(0.242)	(0.273)	(1.076)	(1.862)	(2.315)	(1.177)	(2.655)	(2.974)
Cohort effects (NUTS 1)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	224	224	224	224	224	224	224	224	224

Notes: Standard errors in parentheses. SEs clustered at cohort. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Econometric findings…Italy

Italy: Inability to keep home adequately warm (NUTS 1)

Models	LPM	LPM	LPM	Fraction Logit	Fraction Logit	Fraction Logit	Group binomial GLM	Group binomial GLM	Group binomial GLM
Disposable income	-0.141***	-0.135***	-0.089**	-1.079***	-1.445***	-0.768**	-1.187***	-1.189***	-0.573*
	(0.015)	(0.048)	(0.037)	(0.192)	(0.532)	(0.359)	(0.141)	(0.420)	(0.337)
Household size	0.085***	0.041***	0.044**	0.473***	0.226	0.073	0.549***	0.250	0.067
	(0.012)	(0.012)	(0.017)	(0.143)	(0.178)	(0.165)	(0.143)	(0.183)	(0.167)
Urban area	-0.087*	0.214**	0.091	-1.031**	1.123	-0.571	-1.103**	1.480**	-0.025
	(0.049)	(0.090)	(0.072)	(0.454)	(0.743)	(0.649)	(0.479)	(0.748)	(0.564)
Detached house	-0.016*	-0.007	0.112*	-0.174**	-0.201**	-0.414	-0.321***	-0.228***	-0.368
	(0.009)	(0.009)	(0.058)	(0.083)	(0.079)	(0.441)	(0.090)	(0.087)	(0.553)
Employment status	-0.025***	-0.030***	-0.013	-0.246***	-0.311***	-0.002	-0.233***	-0.347***	-0.016
	(0.008)	(0.007)	(0.010)	(0.084)	(0.078)	(0.118)	(0.079)	(0.060)	(0.105)
Tertiary ratio	-0.252***	-0.244***	-0.050	-2.214***	-1.015	-0.828	-2.220***	-1.971**	-1.331*
	(0.042)	(0.086)	(0.072)	(0.411)	(0.826)	(0.520)	(0.396)	(0.977)	(0.706)
HDD/CDD	-0.182***	0.126***	0.123**	-1.839***	2.202***	0.179	-1.535***	1.963***	1.395*
	(0.026)	(0.035)	(0.056)	(0.284)	(0.509)	(0.681)	(0.311)	(0.431)	(0.728)
Constant	1.226***	0.609**	0.329	7.436***	2.050	2.829	7.665***	0.942	-0.411
	(0.091)	(0.277)	(0.222)	(0.897)	(3.147)	(2.527)	(0.673)	(2.443)	(2.015)
Cohort effects (NUTS 1)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	480	420	420	480	480	480	480	480	480

Notes: Standard errors in parentheses. SEs clustered at cohort. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Italy: Leaking roof, damp walls/floors/foundation, or rot in window frames or floor (NUTS 1)

Models	LPM	LPM	LPM	Fraction Logit	Fraction Logit	Fraction Logit	Group binomial GLM	Group binomial GLM	Group binomial GLM
Disposable income	-0.023*	0.024	0.002	-0.066	0.472	0.279	-0.161	0.356	0.029
	(0.012)	(0.048)	(0.046)	(0.099)	(0.405)	(0.391)	(0.111)	(0.368)	(0.339)
Household size	0.035***	0.005	-0.016	0.215**	0.025	-0.172	0.356***	0.087	-0.085
	(0.010)	(0.014)	(0.014)	(0.095)	(0.111)	(0.125)	(0.088)	(0.128)	(0.130)
Urban area	0.005	0.024	0.023	-0.138	0.362	0.193	-0.012	-0.070	0.103
	(0.042)	(0.073)	(0.064)	(0.309)	(0.474)	(0.496)	(0.340)	(0.541)	(0.474)
Detached house	0.065***	0.033***	-0.027	0.465***	0.272***	-0.443	0.436***	0.337***	-0.214
	(0.009)	(0.010)	(0.051)	(0.070)	(0.079)	(0.401)	(0.087)	(0.095)	(0.463)
Employment status	0.044***	0.056***	-0.009	0.340***	0.470***	-0.065	0.351***	0.470***	-0.142*
	(0.006)	(0.008)	(0.010)	(0.055)	(0.064)	(0.085)	(0.058)	(0.067)	(0.082)
Tertiary ratio	-0.046	-0.037	0.031	-0.362	0.260	0.346	-0.445	-0.278	0.102
	(0.033)	(0.107)	(0.086)	(0.285)	(0.858)	(0.684)	(0.288)	(0.891)	(0.714)
HDD/CDD	-0.099***	0.473***	0.110	-0.630***	3.637***	1.573**	-0.624***	3.449***	1.384*
	(0.023)	(0.046)	(0.098)	(0.181)	(0.362)	(0.774)	(0.190)	(0.399)	(0.764)
Constant	0.370***	-0.674**	0.011	-0.719	-10.634***	-5.433**	-0.341	-9.531***	-3.978*
	(0.059)	(0.280)	(0.300)	(0.537)	(2.419)	(2.222)	(0.523)	(2.050)	(2.128)
Cohort effects (NUTS 1)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	360	300	300	360	360	360	360	360	360

Notes: Standard errors in parentheses. SEs clustered at cohort. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Italy: Arrears on utility bills (NUTS 1)

Models	LPM	LPM	LPM	Fraction Logit	Fraction Logit	Fraction Logit	Group binomial GLM	Group binomial GLM	Group binomial GLM
Disposable income	-0.045***	-0.041**	-0.026	-0.881***	-1.112*	-1.080*	-0.859***	-0.759*	-0.698
	(0.007)	(0.020)	(0.022)	(0.226)	(0.594)	(0.554)	(0.249)	(0.408)	(0.451)
Household size	0.074***	0.011*	0.010	1.325***	0.276	0.169	1.543***	0.382**	0.256
	(0.008)	(0.006)	(0.008)	(0.159)	(0.195)	(0.219)	(0.188)	(0.182)	(0.203)
Urban area	-0.065**	-0.023	-0.023	-0.758	0.211	0.184	-1.398**	-0.364	-0.322
	(0.030)	(0.028)	(0.028)	(0.558)	(0.659)	(0.707)	(0.584)	(0.467)	(0.445)
Detached house	-0.001	0.012***	0.024	0.438***	0.445***	0.054	0.027	0.305***	0.173
	(0.006)	(0.004)	(0.021)	(0.146)	(0.153)	(0.547)	(0.168)	(0.111)	(0.339)
Employment status	-0.009**	0.014***	-0.011**	-0.191	0.628***	-0.080	-0.237*	0.587***	-0.151
	(0.004)	(0.004)	(0.005)	(0.125)	(0.128)	(0.199)	(0.136)	(0.139)	(0.174)
Tertiary ratio	-0.043*	-0.077	-0.049	-0.482	0.118	0.306	-0.905*	-1.262	-1.109
	(0.024)	(0.049)	(0.050)	(0.451)	(0.883)	(0.983)	(0.499)	(0.970)	(1.033)
HDD/CDD	-0.061***	0.130***	-0.030	-1.542***	3.590***	1.135	-1.241**	3.609***	1.245*
	(0.017)	(0.021)	(0.041)	(0.436)	(0.577)	(0.927)	(0.505)	(0.475)	(0.755)
Constant	0.382***	0.111	0.245*	3.433***	-3.129	1.253	3.469***	-4.579**	-0.716
	(0.037)	(0.112)	(0.140)	(0.929)	(3.114)	(3.623)	(0.902)	(2.107)	(2.557)
Cohort effects (NUTS 1)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	480	420	420	480	480	480	480	480	480

Notes: Standard errors in parentheses. SEs clustered at cohort. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Econometric findings…Spain

Spain: Inability to keep home adequately warm (NUTS 1)

Models	LPM	LPM	LPM	Fraction Logit	Fraction Logit	Fraction Logit	Group binomial GLM	Group binomial GLM	Group binomial GLM
Disposable income	-0.036*	-0.045	-0.057*	-0.059	-0.669*	0.241	-0.377**	0.294	-0.118
	(0.020)	(0.050)	(0.031)	(0.149)	(0.372)	(0.333)	(0.179)	(0.515)	(0.342)
Household size	-0.068**	-0.104*	0.010	-0.631**	-1.655***	-0.855	-0.174	-1.317*	-0.683
	(0.030)	(0.057)	(0.043)	(0.248)	(0.628)	(0.522)	(0.239)	(0.674)	(0.511)
Urban area	-0.088**	-0.246***	-0.004	-0.423	-0.451	0.791*	-0.503	-2.215***	0.245
	(0.034)	(0.054)	(0.035)	(0.313)	(0.627)	(0.459)	(0.312)	(0.569)	(0.403)
Detached house	-0.158***	-0.100	0.045	-1.106***	-0.116	0.787	-0.719*	-1.027	0.632
	(0.038)	(0.062)	(0.042)	(0.359)	(0.585)	(0.479)	(0.408)	(0.665)	(0.521)
Employment status	-0.048**	-0.160*	0.036	-0.552***	0.179	1.252	-0.059	0.683	1.769***
	(0.021)	(0.087)	(0.062)	(0.184)	(1.303)	(0.966)	(0.182)	(1.087)	(0.658)
Tertiary ratio	0.096***	0.205***	-0.102*	0.377	0.479	-1.293**	0.518	0.446	-1.693**
	(0.036)	(0.068)	(0.053)	(0.345)	(0.653)	(0.657)	(0.381)	(0.896)	(0.684)
HDD/CDD	-0.027***	-0.068***	-0.013	-0.231***	-0.837***	-0.273***	-0.284***	-1.119***	-0.192*
	(0.007)	(0.015)	(0.009)	(0.074)	(0.187)	(0.093)	(0.085)	(0.297)	(0.114)
Constant	0.565***	0.756***	0.452***	0.317	-2.126	-3.058*	1.217	1.576	-1.126
	(0.103)	(0.274)	(0.169)	(0.832)	(2.106)	(1.719)	(0.970)	(2.575)	(1.629)
Cohort effects (NUTS 1)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	882	882	882	882	882	882	882	882	882

Notes: Standard errors in parentheses. SEs clustered at cohort. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Spain: Leaking roof, damp walls/floors/foundation, or rot in window frames or floor (NUTS 1)

Models	LPM	LPM	LPM	Fraction Logit	Fraction Logit	Fraction Logit	Group binomial GLM	Group binomial GLM	Group binomial GLM
Disposable income	-0.114***	0.004	-0.051	-0.815***	0.550**	0.175	-0.950***	0.163	-0.445*
	(0.019)	(0.041)	(0.034)	(0.167)	(0.237)	(0.256)	(0.219)	(0.269)	(0.232)
Household size	0.040	0.019	0.087*	0.307	-0.936**	-0.333	0.636***	0.198	0.480
	(0.025)	(0.050)	(0.046)	(0.259)	(0.397)	(0.425)	(0.217)	(0.351)	(0.353)
Urban area	-0.019	-0.079	-0.026	-0.499	-0.073	0.233	-0.031	-0.640	-0.637
	(0.030)	(0.068)	(0.060)	(0.327)	(0.472)	(0.506)	(0.312)	(0.558)	(0.487)
Detached house	-0.175***	-0.152**	-0.074	-1.639***	0.072	0.344	-0.845***	-0.895*	-0.443
	(0.026)	(0.067)	(0.059)	(0.294)	(0.499)	(0.526)	(0.250)	(0.539)	(0.435)
Employment status	-0.028	0.091	0.154**	-0.321	0.986*	0.926	-0.012	1.533***	1.324***
	(0.019)	(0.076)	(0.068)	(0.214)	(0.578)	(0.600)	(0.151)	(0.522)	(0.456)
Tertiary ratio	0.125***	0.172***	-0.067	0.468	-0.468	-1.317**	0.647**	0.673	-0.505
	(0.033)	(0.064)	(0.051)	(0.403)	(0.562)	(0.571)	(0.287)	(0.491)	(0.393)
HDD/CDD	0.001	-0.145***	-0.087***	-0.070	-1.124***	-0.432**	-0.063	-1.194***	-0.701***
	(0.007)	(0.028)	(0.025)	(0.076)	(0.241)	(0.185)	(0.071)	(0.270)	(0.218)
Constant	0.868***	0.362*	0.504**	4.152***	-0.985	-1.096	3.587***	0.798	2.626*
	(0.102)	(0.210)	(0.193)	(0.838)	(1.439)	(1.614)	(1.220)	(1.534)	(1.349)
Cohort effects (NUTS 1)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	588	588	588	588	588	588	588	588	588

Notes: Standard errors in parentheses. SEs clustered at cohort. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Spain: Inability to keep home adequately warm, Arrears on utility bills, Leaking roof, damp walls/floors/foundation, or rot in window frames or floor (NUTS 2)

	Inability to keep home adequately warm (NUTS 2)			Arrears on utility bills (NUTS 2)			Leaking roof, damp walls/floors/foundation, or rot in window frames or floor (NUTS 2)		
	LPM	Fraction Logit	Group binomial GLM	LPM	Fraction Logit	Group binomial GLM	LPM	Fraction Logit	Group binomial GLM
Disposable income	-0.066***	-0.049	-0.068***	-0.104***	-0.050***	-0.066***	-0.099***	0.003	-0.038
	(0.014)	(0.030)	(0.021)	(0.015)	(0.016)	(0.016)	(0.017)	(0.029)	(0.028)
Household size	-0.014	-0.096**	0.008	0.160***	0.067***	0.101***	0.038*	-0.007	0.062*
	(0.020)	(0.039)	(0.031)	(0.017)	(0.020)	(0.021)	(0.021)	(0.037)	(0.035)
Urban area	-0.055**	-0.099***	0.010	-0.058***	-0.038**	-0.015	-0.033	-0.053	-0.031
	(0.022)	(0.037)	(0.022)	(0.016)	(0.015)	(0.014)	(0.023)	(0.042)	(0.038)
Detached house	-0.086***	0.001	0.058**	-0.019	-0.022	-0.012	-0.186***	-0.126***	-0.093**
	(0.027)	(0.039)	(0.028)	(0.017)	(0.016)	(0.016)	(0.022)	(0.045)	(0.041)
Employment status	-0.028*	-0.123**	0.035	-0.006	0.034	0.062**	-0.031*	0.027	0.075
	(0.016)	(0.059)	(0.041)	(0.012)	(0.028)	(0.027)	(0.017)	(0.053)	(0.051)
Tertiary ratio	0.066**	0.149***	-0.079**	0.051**	0.030	-0.031	0.109***	0.105**	-0.062
	(0.028)	(0.046)	(0.036)	(0.021)	(0.021)	(0.020)	(0.029)	(0.049)	(0.044)
HDD/CDD	-0.008***	-0.007***	-0.002	-0.006***	-0.001	-0.000	0.004	-0.022**	-0.006
	(0.003)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.004)	(0.010)	(0.008)
Constant	0.602***	0.556***	0.474***	0.559***	0.303***	0.356***	0.799***	0.244	0.393**
	(0.074)	(0.168)	(0.112)	(0.065)	(0.074)	(0.075)	(0.090)	(0.158)	(0.154)
Cohort effects (NUTS 2)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	2388	2388	2388	2388	2388	2388	1591	1591	1591

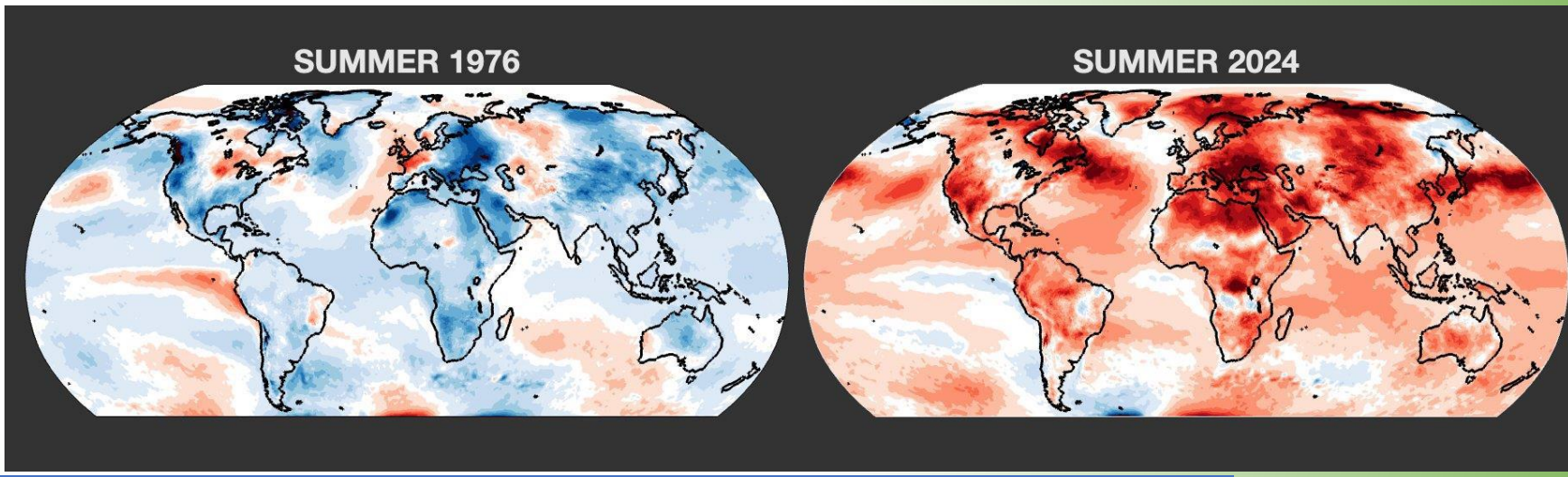
Notes: Standard errors in parentheses. SEs clustered at cohort. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Spain: Arrears on utility bills (NUTS 1)

Models	LPM	LPM	LPM	Fraction Logit	Fraction Logit	Fraction Logit	Group binomial GLM	Group binomial GLM	Group binomial GLM
Disposable income	-0.109***	-0.060**	-0.084***	-1.606***	-0.776*	-1.176**	-1.517***	-0.335	-0.758***
	(0.019)	(0.023)	(0.024)	(0.326)	(0.436)	(0.489)	(0.342)	(0.254)	(0.276)
Household size	0.164***	0.083***	0.125***	2.538***	1.826***	2.301***	2.570***	1.155***	1.564***
	(0.022)	(0.026)	(0.029)	(0.299)	(0.457)	(0.466)	(0.251)	(0.274)	(0.340)
Urban area	-0.048**	-0.088***	-0.040	-1.489***	-1.740**	-1.373	-0.491	-1.271***	-0.525
	(0.023)	(0.023)	(0.024)	(0.481)	(0.824)	(0.873)	(0.432)	(0.454)	(0.439)
Detached house	-0.016	-0.027	0.000	-0.656	-0.184	0.161	0.105	-0.155	0.487
	(0.023)	(0.028)	(0.027)	(0.479)	(0.454)	(0.475)	(0.438)	(0.516)	(0.544)
Employment status	-0.000	0.038	0.070*	-0.704***	0.042	0.420	0.049	0.596	0.489
	(0.016)	(0.039)	(0.035)	(0.238)	(0.520)	(0.449)	(0.208)	(0.492)	(0.430)
Tertiary ratio	0.065**	0.058**	-0.028	0.337	0.068	-0.646**	0.895**	0.081	-0.816**
	(0.029)	(0.028)	(0.026)	(0.328)	(0.342)	(0.286)	(0.363)	(0.369)	(0.374)
HDD/CDD	-0.023***	-0.015***	-0.004	-0.377***	-0.443*	0.026	-0.536***	-0.554*	-0.052
	(0.005)	(0.006)	(0.005)	(0.137)	(0.259)	(0.172)	(0.195)	(0.319)	(0.208)
Constant	0.588***	0.384***	0.437***	6.021***	2.572	2.706	4.217**	0.811	0.833
	(0.082)	(0.103)	(0.110)	(1.543)	(1.973)	(2.094)	(1.855)	(1.554)	(1.580)
Cohort effects (NUTS 1)	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Time effects	No	No	Yes	No	No	Yes	No	No	Yes
Observations	882	882	882	882	882	882	882	882	882

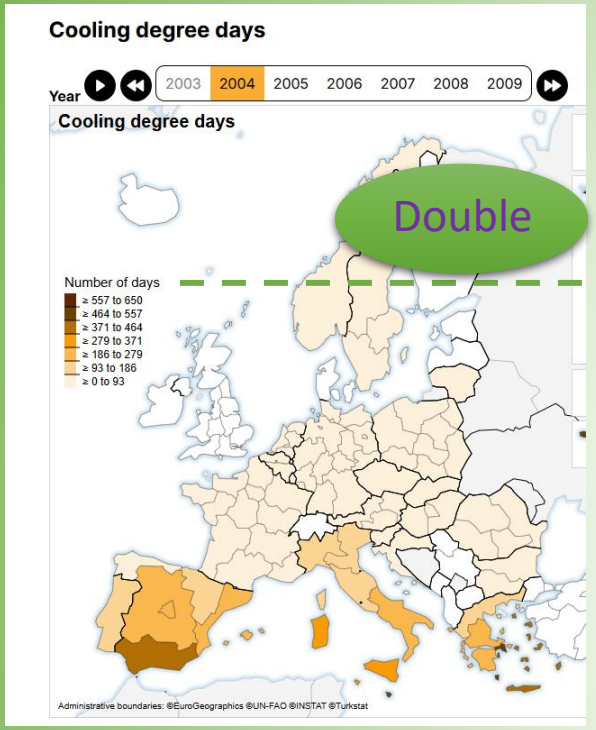
Notes: Standard errors in parentheses. SEs clustered at cohort. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Now, why summer energy poverty?



As shown in the temperature maps, global and European temperatures have increased significantly since the 1970s, with recent summers experiencing much higher temperature anomalies. This means that households are increasingly exposed to extreme heat during the summer months. For many vulnerable households, the problem is not only heating in winter but also the inability to afford cooling in summer. Limited access to air conditioning, inefficient buildings, and high electricity prices can lead to dangerous indoor temperatures.

CDD 2004 vs 2024



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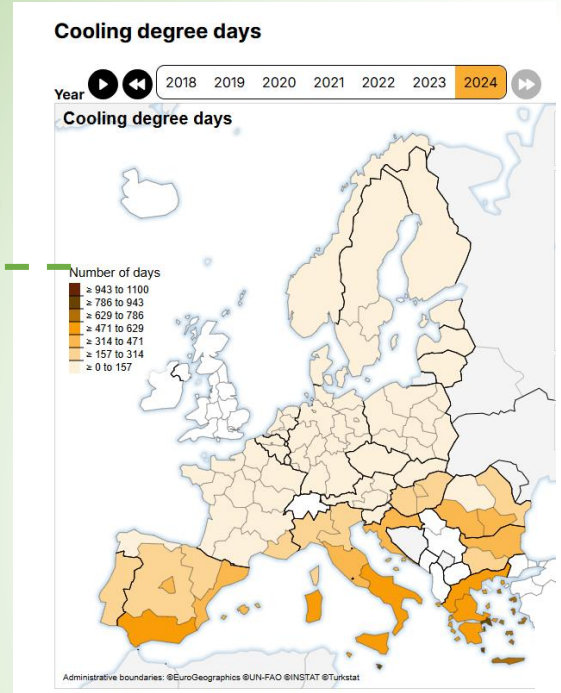

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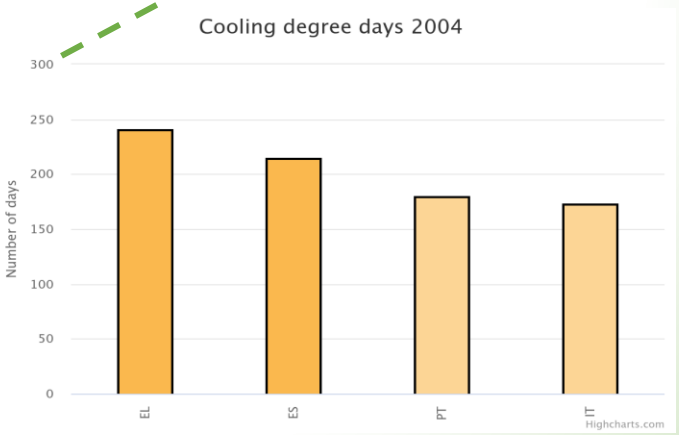
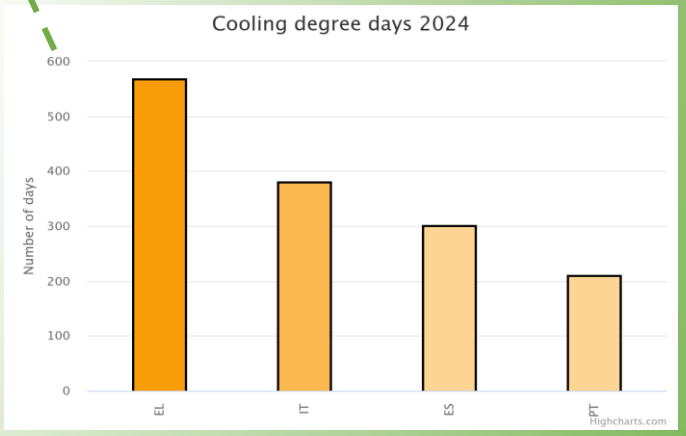
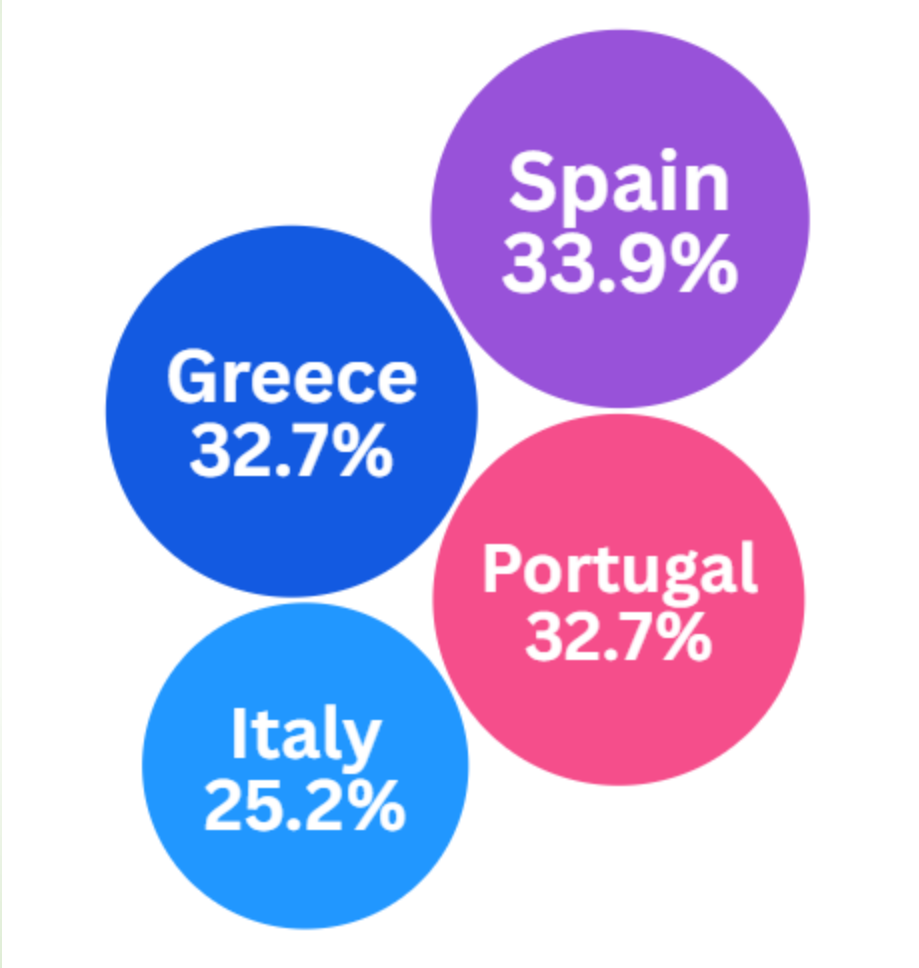
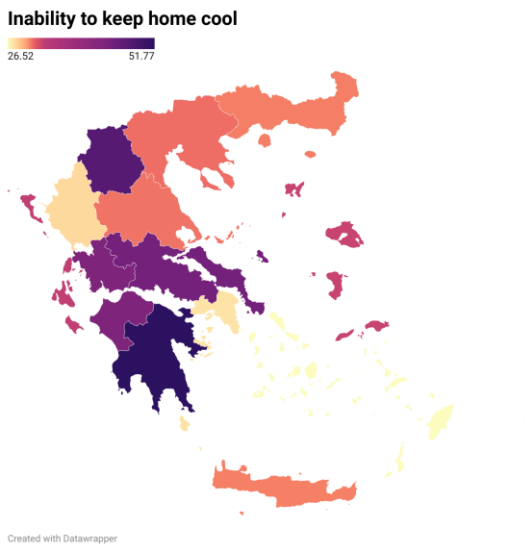


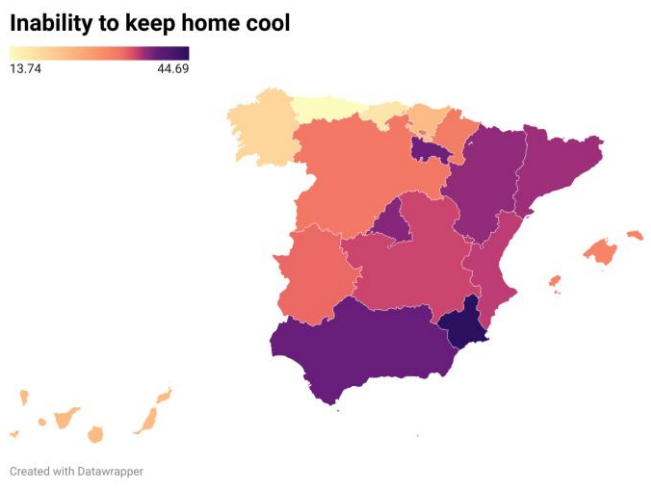


Inability of existing cooling and insulation to keep homes cool



Inability of existing cooling and insulation to keep homes cool





Variables	Inability to keep home adequately cool
1946 – 1960	0.140
	(0.197)
1961-1980	-0.234
	(0.184)
1981 – 2000	-0.694***
	(0.185)
2001 – 2020	-1.186***
	(0.195)
After 2021	-1.519***
	(0.435)
Household size	0.045
	(0.030)
Semi-rural area	0.275***
	(0.070)
Rural area	0.406***
	(0.074)
Age	-0.002
	(0.002)
Tertiary education	-0.301***
	(0.072)
Income	-0.000***
	(0.000)
Region effects	Yes

Conclusions

- Income
- Urban area
- Detached houses
- Employment
- Higher educational level
- Heating demand

Decrease energy poverty

- Household size

Increase energy poverty

Hot to ignore: Summer Energy Poverty in Southern Europe

Policy implications - Limitations

✓ Policies

- ✓ Strengthen income support and social welfare measures (especially within large families)
- ✓ Promote employment and economic inclusion (especially in rural areas)
- ✓ Enhance educational opportunities and awareness
- ✓ Address high heating demand with energy efficiency and renewable solutions

✓ Limitations

- ✓ Measurement of energy poverty
- ✓ Limited set of variables
- ✓ Self reported data (EU-SILC)
- ✓ Causality vs. Correlation

To sum up…

ENERGY POVERTY

& Summer Energy Poverty

A Global and European Perspective

Ioannis Kostakis | Harokopio University of Athens

WHAT IS ENERGY POVERTY?

Definition

The inability to access sufficient, clean, and affordable household energy.

A complex, multidimensional phenomenon affecting societies globally — from developing nations lacking basic electricity to developed countries unable to meet rising energy costs.

760M

People without electricity access

2.3B

People relying on traditional fuels for cooking

54M

Europeans struggling with energy bills

SDG 7 (Agenda 2030): Ensure access to affordable, reliable, sustainable and modern energy for all

THE GLOBAL SCALE

Energy poverty affects billions worldwide — progress is uneven

760M

without electricity

World, 2023

2.3B

use traditional cooking fuels

World, 2023

3.7M

premature deaths from cooking smoke

Annually

30%

of US households energy poor

USA

11%

of Europeans struggle to stay warm

Europe

500K

heat-related deaths annually

Globally

KEY DRIVERS OF ENERGY POVERTY

Low Income & Inequality

Higher income regions (Europe, N. America, Oceania) are less affected. In Sub-Saharan Africa and South Asia, income poverty directly drives energy poverty.

Poor Energy Efficiency

Old building stock with low thermal performance forces households to spend more on heating and cooling to achieve basic comfort standards.

Energy Prices & Infrastructure

High upfront technology costs, limited grid infrastructure, and unaffordable electricity tariffs trap vulnerable households in energy poverty.

Urbanization & Geography

Rural areas have higher disparities in electrification vs. urban regions. Remote locations face high supply costs and lower incomes.

Demographic Vulnerability

Elderly, unemployed, and larger households face elevated risk. Gender, age, tenure status and occupation are significant determinants.

Education & Awareness

Low educational attainment and limited awareness of energy efficiency programs increase both the incidence and depth of energy poverty.

THE IMPACTS OF ENERGY POVERTY

Health Risks

- Air pollution & premature deaths
- Respiratory diseases & asthma
- Increased maternal/child mortality
- Malnutrition & reduced life expectancy

Economic Harm

- Threatens GDP and HDI growth
- Impacts all production sectors
- Short and long-run drag on prosperity
- Disproportionate burden on poor

Education

- Fewer years of school attendance
- Higher dropout rates
- Poor study conditions at home
- Intergenerational poverty cycles

Environment

- Increased greenhouse gas emissions
- Continued use of biomass fuels
- Deforestation in developing regions
- Air and indoor pollution

Social Inequality

- Restricts personal choices & mobility
- Deepens social injustice
- Undermines gender equality
- Vulnerable groups most affected

PART II

Summer Energy Poverty

The overlooked dimension of a growing crisis

Southern Europe & Beyond | A climate-driven challenge

WHY SUMMER ENERGY POVERTY?

2×

Cooling Degree Days

(CDD) have doubled across Southern Europe between 2004 and 2024

Sources: Kostakis et al., EU-SILC data

Heat Kills

Heat-related deaths run at ~500,000 annually worldwide. In Southern Europe, extreme summers are becoming the new normal.

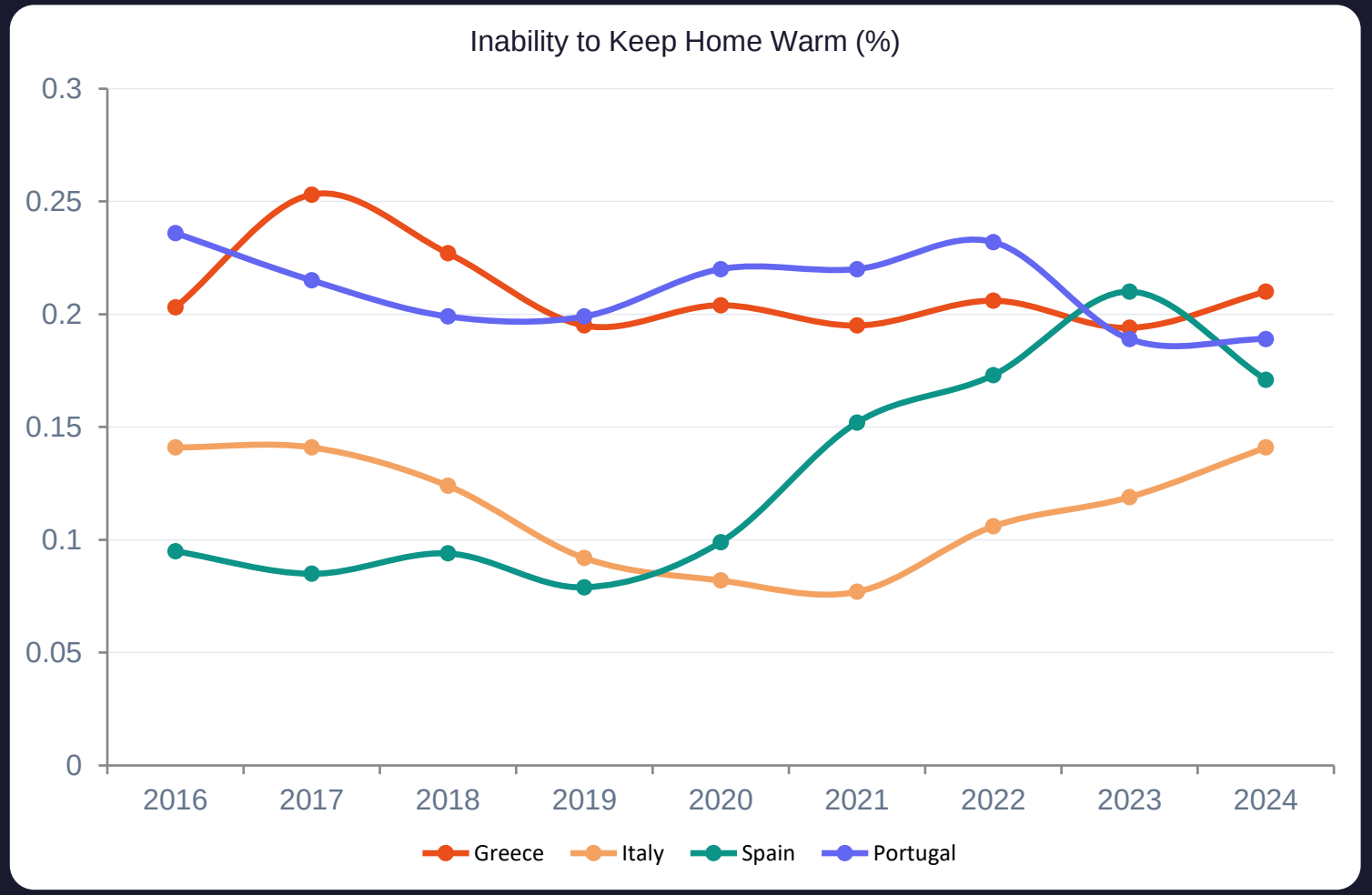
Cooling is the New Heating

Just as winter heating was once the dominant concern, summer cooling is now equally critical — yet poorly addressed by policy.

Inadequate Building Stock

Most European housing was designed for heating, not cooling. Buildings built before 1980 lack insulation adequate for extreme heat.

SOUTHERN EUROPE: INABILITY TO KEEP COOL



Key Findings

GR

PT

ES

IT

Source: EU-SILC dataset, 2016–2024

DETERMINANTS OF SUMMER ENERGY POVERTY

▲ INCREASES Energy Poverty

Household Size

Larger families face compounded cooling needs and costs

Rural / Semi-rural Location

+40% higher risk in rural vs. urban areas

Pre-1980 Buildings

Old construction with no cooling or insulation

Low Income

Cannot afford air conditioning or efficient cooling

▼ DECREASES Energy Poverty

Newer Buildings (post-2001)

Modern construction reduces risk by up to 67% vs. pre-war stock

Urban Location

Better infrastructure and access to cooling solutions

Higher Education

Tertiary education significantly reduces probability of poverty

Higher Income

Each income unit increase reduces summer energy poverty significantly

MEASURING ENERGY POVERTY

Key indicators used in research and policy

10% Rule

A household is energy poor if it spends more than 10% of income on energy.

Simple but criticized for ignoring actual consumption needs

2M Rule

Energy poor if spending is more than twice the median household energy expenditure.

Accounts for relative energy burden in national contexts

Low Income - High Cost (LIHC)

Households below median income after housing energy costs are energy poor.

Better captures affordability across income spectrum

M/2 Rule

Energy poor if spending is less than half the median (under-consumption).

Captures hidden deprivation — people going without adequate energy

Low Income - Low Energy Efficiency (LILEE)

Combines low income with poor dwelling energy performance rating.

Focuses on structural/physical drivers of energy poverty

OBJECTIVE INDICATORS OF ENERGY POVERTY

Expenditure-based indicators: 10% Rule · LIHC · LILEE

1 10% Rule

Earliest and most widely used indicator.

Definition: A household is energy poor if it spends more than **10% of its income** on energy.

Example
Income: EUR 15,000 | Energy: EUR 1,800
Share = 1,800 / 15,000 = **12%**

Energy share > 10% => Classified as energy poor

Limitation: Ignores income distribution. A wealthy household with a large home may be misclassified.

2 LIHC

Low Income – High Cost

Developed in the UK to improve the 10% rule.

Both conditions must apply:

1. Energy costs are above the national median
2. After paying bills, income falls below poverty line

Example
Income before energy: EUR 14,000
Energy costs: EUR 2,000 =>
Remaining: EUR 12,000
Poverty threshold: EUR 13,000

Better captures real affordability problems across income groups.

3 LILEE

Low Income – Low Energy Efficiency

A newer approach focusing on housing quality.

Both conditions must apply:

1. Household income is below the poverty threshold
2. The home has a poor energy efficiency rating (EPC: E or F)

Example
Income: EUR 13,000 (below threshold)
Home energy rating: E or F

Focuses on structural housing problems, not just energy costs.

OBJECTIVE INDICATORS OF ENERGY POVERTY

Relative expenditure indicators: 2M Rule · M/2 Rule · Summary Comparison

4 2M Indicator

Twice the Median

Definition: Energy poor if energy expenditure share is more than **twice the national median.**

Example
National median energy share: 4% of income
Poverty threshold = 2 x 4% = 8%

Household spends 9% => Energy Poor

Adapts to national consumption patterns.

5 M/2 Indicator

Half the Median — Hidden Poverty

Definition: Energy poor if spending is **less than half the national median** — cannot afford adequate energy use.

Example
Median energy spending: EUR 1,200/year
Threshold (M/2): EUR 600/year

Household spends EUR 450 => Energy Poor

Captures hidden deprivation: under-heating, self-rationing, energy deprivation.

POLICY RECOMMENDATIONS

01 Strengthen Social Protection

Expand income support for vulnerable households. Target large families and those with arrears on utility bills. Design energy voucher schemes for summer cooling.

02 Retrofit Building Stock

Incentivize deep renovation of pre-1980 buildings with both cooling and heating insulation. Prioritize rural and low-income areas with grants.

03 Renewable Energy Solutions

Subsidize solar PV and efficient air conditioning for energy-poor households. Community energy projects to lower costs in remote areas.

04 Expand Education & Awareness

Energy literacy campaigns targeting low-education, elderly and rural groups. Include energy poverty in national school curricula.

05 Improve Summer Policy Coverage

Explicitly include cooling needs in national energy poverty action plans. Update indicators to capture summer dimension. Climate-proof social housing.

06 Better Measurement

Adopt multidimensional indicators beyond the 10% rule. Integrate EU-SILC data on cooling deprivation systematically across all member states.

KEY TAKEAWAYS

1. Energy poverty is a complex, multidimensional crisis affecting billions — from lack of electricity access in the Global South to unaffordable bills in developed nations.

2. Summer energy poverty is the overlooked dimension: rising temperatures, doubling CDD, and aging building stock are creating a new wave of thermal vulnerability.

3. Southern Europe is at the frontline — Greece, Spain, Portugal and Italy all show significant inability to keep homes cool, with Spain worsening dramatically.

4. Key risk factors: rural location, old buildings, low income, large households. Protective: newer construction, higher education, urban living.

5. Policy must explicitly address the cooling dimension: income support, building retrofits, renewable energy access, and updated measurement frameworks.

Thank you a lot for your attention!