POBRESA ENERGÈTICA I SALUT

Una aproximació des de les desigualtats socials

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TESI DOCTORAL UPF / 2021

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“The reason to study how injustice harms health is not to prove that injustice is wrong, since it is, by definition. Instead, the reasons are to deepen understanding of how injustice shapes population health, for whose benefit at whose expense; to contest narratives that naturalize inequities; and to generate evidence for accountability. After all, if people have created unjust societal systems and structures, so too can people challenge these systems and structures and advocate instead for human rights, health equity, and ecological sustainability.”

Nancy Krieger, 2019

Amb l’esperança que els resultats d’aquest treball constitueixin un petit gra de sorra de la tempesta necessària per capgirar el món.

AGRAÏMENTS

Aquesta tesi ha estat possible gràcies a la il·lusió, el coneixement, el temps i l'esforç de moltes persones. A totes les persones que m'heu acompanyat en aquest procés i hi heu contribuït de forma directa o indirecta, moltes gràcies!

Gràcies en especial al Marc. Impossible descriure en un parell de línies lo feliç que estic de què hagis estat el meu director de tesi, no em puc imaginar una millor direcció. Gràcies per la teva implicació, el teu entusiasme i la teva disposició. I que aquestes paraules no sonin buides i estàndards, és genial que tot et motivi tan ràpid i que sempre estiguis allà quan ho necessito. Gràcies també pel tracte, és un luxe poder treballar des d'aquesta horitzontalitat. I, sobretot, gràcies per ensenyar-me tant (i fer-me tornar encara més friki, rigorosa i perfeccionista!). S'acaba el PENSA i la tesi, però sembla que de moment no et deslliures de mi, així que espero seguir aprenent i passant-ho bé al teu costat!

Moltes gràcies també Carme. Per acceptar la co-direcció d'aquesta tesi i per trobar sempre el temps per reunir-te amb nosaltres i llegir (i rellegir) els articles i la tesi. Gràcies per les teves reflexions i comentaris sempre tan encertats, i per tot el teu suport aquests anys. Entre els dos heu aconseguit, que sense adonar-me'n, estigui acabant un doctorat.

Un gràcies especial també a tot l'equip PENSA (Andrés, Carme, Laia, Lucia, Marc, Maria José, Martina i Mercè). Ha estat molt enriquidor poder treballar amb totes vosaltres. Les vostres

aportacions són clau en tots els estudis que conformen aquesta tesi.

Gràcies també a la resta de coautores i coautors. Gràcies Irene, per ampliar la mirada, i per compartir les alegries i les angoixes que acompanyen el doctorat. Gracias Migue y gracias Carlos por introducirme al mundo Bayesiano y por vuestra paciencia y disponibilidad. Ha sido un gusto colaborar con vosotros.

Gracias también al equipo PENSA de la Escuela Andaluza de Salud Pública. En especial a Virginia, con quien hemos sufrido (y también disfrutado) el nunca acabar de hacer una scoping review de un tema tan amplio y complejo.

Gràcies també al Pau i al Cristian, per ajudar-nos a difondre els resultats d'aquest treball més enllà del món de l'acadèmia, amb la programació del shiny.

Vull agrair també a totes les persones que formen i participen de l'Aliança contra la Pobresa Energètica. Potser sense saber-ho, vosaltres també heu estat clau en aquest procés. M'heu ajudat a contextualitzar què és la pobresa energètica, més enllà de les definicions acadèmiques, a ampliar i polititzar la mirada i, sobretot, a entendre realment què vol dir que la pobresa energètica afecta la salut. Gràcies per les experiències compartides i per l'espai de confiança i lluita col·lectiva.

Gràcies també a totes les persones que de manera anònima i generosa han contestat les enquestes que s'han utilitzat en aquests estudis i que, per tant, els han fet possibles. Tant de bo serveixin per millorar les condicions de vida de les persones que viuen en situació de pobresa energètica.

Al llarg d'aquests anys que he passat a l'ASPB fent la tesi, he compartit moltes estones de treball i reflexió, però també cafès, dinars, sortides i festes, amb moltes persones que hi treballen o que hi han passat alguna temporada. Gràcies a totes les persones del SEQUIA per acollir-me al servei quan vaig entrar a fer recerca i ara ja com a una treballadora més! Gràcies al grup d'habitatge, per les discussions i per l'oportunitat de participar en altres projectes relacionats amb l'habitatge i la salut. I gràcies també Ana, Andrés, Amaia, Brenda, Cate, Constanza, Eli, Hugo, Irene, Juli, María, Marta, Mercè, Naty, Oleguer, Patri, Vanessa, Vero i moltes més per compartir i alegrar-me el dia a dia! I un gràcies especial per l'Esther, perquè sense els teus dots de recursos humans potser mai hauria acabat fent aquest doctorat! Moltes gràcies també per la curosa revisió final del text.

Per acabar, també vull agrair a la meva família, amigues i amics els ànims, les cures, i, sobretot, el dia a dia i tots els espais que tant m'han ajudat a desconnectar i oblidar-me de la tesi per una bona estona! També, gràcies mama per aquesta última lectura de la tesi, gràcies Matt per no cansar-te mai de corregir-me textos en anglès i mil gràcies Alex (i Nuri) per aquesta portada tan preciosa. I, sobretot, gràcies Pol, per aguantar les meves reflexions en alt, per fer la lectura final i per tot el que tu i jo ja ens sabem.

RESUM

Aquesta tesi té per objectiu ampliar el coneixement sobre la pobresa energètica i la seva relació amb la salut a la Unió Europea i a Barcelona, tenint en compte les desigualtats socials. Per tal d'assolir aquest objectiu s'han dut a terme quatre estudis.

El primer estudi analitza l'evolució temporal de la pobresa energètica, la seva associació amb la salut i l'impacte en salut que comporta, als països de la Unió Europea abans i durant la crisi econòmica del 2008. Es mostra un increment generalitzat de la pobresa energètica i del seu impacte en salut. Aquesta evolució va ser pitjor en els països amb major vulnerabilitat estructural a la pobresa energètica (sud i est de la Unió Europea) i en les dones, ampliant-se així les desigualtats territorials i de gènere.

Els altres estudis analitzen la distribució de la pobresa energètica a la ciutat de Barcelona, així com la seva relació amb la salut. Els resultats revelen fortes desigualtats socials en l'exposició a la pobresa energètica. Els col·lectius més afectats són les persones de classes socials més desafavorides, les persones nascudes en països de renda baixa i mitjana i les dones grans. S'identifiquen també tres agrupacions de barris amb nivells de pobresa energètica significativament superiors a la mitjana de la ciutat. Els resultats també confirmen l'associació entre la pobresa energètica i diversos problemes de salut física i mental així com amb un major ús de serveis de salut i consum de fàrmacs. En la població infantil, la pobresa energètica també s'associa amb un pitjor estat de salut general, una pitjor salut mental i una major prevalença d'asma i sobrepès. La pobresa energètica actuaria, per tant, com un amplificador de les desigualtats socials en salut.

ABSTRACT

The aim of this doctoral thesis is to broaden knowledge about energy poverty and its relationship with health in the European Union and in Barcelona, taking into account social inequalities. In order to achieve this objective, four studies have been carried out.

The first study analyses time trends in energy poverty, its association with health and its impacts on health, in the European Union countries before and during the economic crisis of 2008. The results show a generalised increase in energy poverty and its impact on health following the economic crisis. The figures are worse in countries with higher structural vulnerability to energy poverty (south and east of the European Union) and for women, thus widening territorial and gender inequalities.

The other studies analyse the distribution of energy poverty in the city of Barcelona, as well as its relationship with health. The results reveal strong social inequalities in exposure to energy poverty. The most affected groups are people from the most disadvantaged social classes, people born in low- and middle-income countries and older women. Three clusters of neighbourhoods with significantly higher levels of energy poverty than the city average are also identified. The findings also confirm the association between energy poverty and various physical and mental health conditions, as well as with a higher use of health services and medication. In children, energy poverty is also associated with poorer general health, poorer mental health and a higher prevalence of asthma and overweight. Energy poverty therefore acts as an amplifier of social inequalities in health.

PREFACI

Aquesta tesi doctoral s’ha realitzat a l’Agència de Salut Pública de Barcelona durant els anys 2018-2021 i sota la direcció del Dr. Marc Marí Dell’Olmo i la Dra. Carme Borrell Thió.

La tesi s’emmarca en el projecte *PENSA (Pobresa energètica i salut: de l’evidència a l’acció).* El projecte PENSA, neix l’any 2016, en plena expansió del reconeixement de la pobresa energètica com un problema social important a la Unió Europea[1]. Té per objectiu generar evidència científica sobre la relació de la pobresa energètica amb la salut a la Unió Europea i, en particular, a l’Estat espanyol i a la ciutat de Barcelona. Es tracta d’un projecte coordinat, liderat per l’Agència de Salut Pública de Barcelona, amb un subprojecte que s’ha dut a terme a l’Escuela Andaluza de Salud Pública i dos subprojectes realitzats a l’Agència de Salut Pública de Barcelona.

En particular, els estudis que conformen aquesta tesi s’emmarquen en el subprojecte *Pobresa energètica i salut des de múltiples perspectives: anàlisi individual, geogràfic i temporal*, del qual Marc Marí Dell’Olmo n’és l’investigador principal i el qual ha estat finançat pel Fondo de Investigación en Salud del Instituto Carlos III (PI15/02006). Aquesta tesi, també ha comptat amb el suport econòmic de l’ajuda per a la contractació Río Hortega

[1] En el transcurs d’aquesta tesi s’han produït canvis en la composició dels Estats membres de la Unió Europea. En aquest treball, quan parlem de la Unió Europea incloem als 27 països que la conformaven durant el període 2007-2013

(CM19/00184) de l'Instituto Carlos III i del subprograma de pobresa energètica del CIBER d'Epidemiologia i Salut Pública (CIBERESP).

La tesi es presenta com un recull d'articles, d'acord amb la normativa del Programa de Doctorat en Biomedicina del Departament de Ciències Experimentals i de la Salut de la Universitat Pompeu Fabra. El present document s'estructura en deu apartats: introducció, justificació, objectius, hipòtesis, mètodes i resultats, discussió, recomanacions i implicacions, conclusions, bibliografia i annexos. A l'apartat de mètodes i resultats s'inclouen els quatre articles científics que conformen aquesta tesi. Els tres primers articles han estat publicats a les revistes "Health and Place", "SSM - Population Health" i "International Journal of Environmental Research and Public Health" respectivament. El quart article s'ha enviat a una revista científica per a la seva publicació i està actualment en procés de revisió. En els annexos I i II s'inclouen dos articles més del projecte PENSA en els quals he participat de manera significativa i que són cabdals per entendre la història que intenta explicar aquesta tesi. El primer ha estat publicat a la revista "Energy policy" i el segon s'ha enviat a una revista científica per a la seva publicació i està actualment en revisió. Els annexos III, IV i V contenen el material suplementari dels articles 1, 2 i 4 de la tesi, respectivament.

Per últim, per tal de compartir i difondre els resultats obtinguts en aquesta tesi més enllà de l'àmbit acadèmic i com a part del projecte PENSA, tota la informació generada en relació amb la ciutat de Barcelona pot trobar-se a la següent pàgina web: https://aspb.shinyapps.io/PENSA/

ÍNDEX

1. INTRODUCCIÓ

Aquesta tesi aprofundeix en l'estudi de la pobresa energètica i la seva relació amb la salut, tenint en compte les desigualtats socials associades. Amb la finalitat d'introduir alguns antecedents rellevants pels quatre estudis que la conformen, aquesta primera secció s'estructura en tres apartats. El primer apartat subratlla el paper central que juga avui dia l'energia en la nostra societat. El segon apartat revisa alguns punts claus sobre la problemàtica de la pobresa energètica. Per últim, el tercer apartat se centra en la relació entre la pobresa energètica i la salut.

1.1. La complexitat de la relació energia-societat

L'energia juga un paper central en les vides humanes. Històricament, el descobriment de noves fonts d'energia i els avenços en les seves tecnologies i usos, han marcat el desenvolupament social i econòmic de la humanitat, canviant progressivament els nostres modes de vida. L'energia configura el ritme i la manera com una societat viu, treballa, aprèn, es relaciona i s'organitza, es comunica i s'informa, es cuida i es protegeix, produeix i consumeix. En les societats modernes, disposar d'un subministrament adequat i suficient d'energia es relaciona amb un major benestar,[1] ja que aquesta és el motor del sistema productiu que ens permet generar béns i serveis, però també és essencial per al treball reproductiu, facilitant les tasques de cura i sosteniment de la vida.

Tanmateix, l’actual model de generació, distribució i consum d'energia també té fortes conseqüències negatives per al medi ambient i les persones. Alguns exemples són: la contaminació de l'aire i l'aigua i els seus respectius efectes sobre la salut de les persones i el planeta; l'impacte dels megaprojectes d'energia sobre el territori que sovint impliquen desplaçaments forçats de comunitats senceres; o la importantíssima contribució del sector energètic en l'emissió de gasos amb efecte d'hivernacle, que correspon al voltant de dos terços de les fonts antropogèniques responsables de l'escalfament global.[2,3]

A més, és important destacar que tant els beneficis com les conseqüències negatives de l'ús d'energia es distribueixen de manera molt desigual i no repercuteixen a totes les persones ni territoris per igual. Aquesta distribució desigual està íntimament relacionada amb la distribució de poder en les societats i condiciona les oportunitats de present i futur.[4]

La complexa interacció entre l'energia i el benestar social i econòmic, la sostenibilitat del medi ambient i l'equitat social, posa en qüestió l'actual model energètic. Garantir l'accés universal a una energia assequible, segura, sostenible i moderna és un dels majors reptes del segle XXI. Així es recull també en els Objectius de Desenvolupament Sostenible de les Nacions Unides (ODS) per a posar fi a la pobresa, protegir el planeta i millorar les vides i perspectives de les persones a tot el món. Els ODS dediquen un dels disset objectius exclusivament a la provisió d'energia assequible i no contaminant, però reconeixen també el paper central de l'energia en gairebé tots els reptes i oportunitats que afronta el planeta, ja sigui en relació amb la seguretat, el canvi climàtic, la producció d'aliments, l'ocupació o l'augment dels ingressos.[5]

Aconseguir aquest objectiu no és fàcil, ja que confronta demandes socials i interessos divergents, i requereix una transformació de l'actual model energètic. En l'actualitat, tot i el creixent reclam per a la recuperació de l'energia com un bé comú essencial, predomina una visió fortament mercantilista. El sector energètic és una peça cabdal del sistema econòmic capitalista i la formulació de polítiques energètiques està dominada per actors econòmics, la indústria i els diferents grups de pressió (lobbies energètics). Aquests promouen polítiques basades en els costos i beneficis econòmics i que mantenen el *statu quo* del sector.[6]

Una de les principals xarxes internacionals de caràcter econòmic amb forta influència sobre el sector energètic és el Consell Mundial de l'Energia. Aquesta, per exemple, apunta que el principal desafiament de les futures polítiques energètiques és balancejar tres dimensions suposadament contraposades: la seguretat energètica, l'equitat energètica i la sostenibilitat ambiental. Aquestes tres dimensions conformen el que es defineix com el trilema energètic.[7] Tot i que a primera vista pot semblar un abordatge força integral, les visions més crítiques de l'acadèmia evidencien com es tracta d'una proposta amb un enfocament predominantment econòmic. Així, cal fer palès que quan el Consell Mundial de l'Energia parla d'equitat energètica, es refereix tan sols a promoure l'accessibilitat i l'assequibilitat dels subministraments, assumint acríticament el mercat com a mecanisme ideal de distribució de l’energia i sense qüestionar un punt clau: la governança de l’actual model energètic i la distribució del poder econòmic i polític associada.[4,6,8]

Per això, diverses veus insisteixen en la necessitat d’incloure una quarta dimensió central i transversal a la resta del trilema energètic: la justícia social[4] o energètica[6]. D’aquesta manera, també s’incorpora en l’anàlisi del futur de l’energia qui controla i com es controlen els models energètics, així com les estructures socials i el context sociohistòric on s’incrusten les altres dimensions del trilema. Aquesta aproximació, obre també la possibilitat d’avançar cap a paradigmes alternatius que fomentin, per exemple, la sobirania i la democràcia energètica.

Un clar exemple de la necessitat d’ampliar el debat del trilema energètic és el cas de l’Estat espanyol. No és possible promoure una equitat energètica real, sense abordar l’oligopoli que domina el mercat energètic espanyol, així com l’important vincle entre el negoci del sector elèctric i el poder polític. Aquest vincle, suposa una relació bidireccional on els alts directius de les grans companyies energètiques condicionen les decisions polítiques del sector (com ara projectes i proposicions de llei, normes governamentals o les decisions de la Comissió Nacional dels Mercats i la Competència), i, alhora, els ex-alts càrrecs públics es beneficien de les freqüents portes giratòries del sector.[9,10]

Per tant, per avançar cap a un model energètic que no confronti les diferents dimensions esmentades i es regeixi per la justícia social, cal un replantejament integral que tingui en compte, entre d’altres, la necessitat de rematerialitzar les pràctiques de producció i consum d'energia, identificant d'on ve l'energia i per a quines pràctiques socials s'utilitza, però també qui posseeix i controla les diferents peces i processos del model energètic. La complexitat d’aquest repte requereix un abordatge interdisciplinari. Així, en la discussió sobre el futur de l’energia és important afegir a la perspectiva tècnica i predominantment des de les ciències naturals, la visió de les ciències socials i de la salut.[4]

Aquesta tesi anhela ser una contribució en aquesta direcció. Se centra en la privació dels serveis energètics a la llar i en les conseqüències que això té per a la salut i el benestar de les persones. S’intenta, però, abordar la problemàtica des de la consciència del complex entramat del qual forma part l’objecte d’estudi. Així mateix, es parteix de la comprensió de l'energia com un bé essencial i s’assumeix, per tant, que és necessari repensar l'actual model energètic i exigir un canvi de paradigma que posi la vida en el centre.

1.2. La pobresa energètica

1.2.1. Orígens, terminologia, definicions i enfocaments

No existeix un terme únic, ni una definició única, per a referir-nos a la privació d'energia a la llar. Aquesta heterogeneïtat pot relacionar-se amb la complexitat i multidimensionalitat de la problemàtica, la seva evolució en el temps o el context i la perspectiva des d'on es denomina i es defineix el fenomen. És important saber quines situacions concretes estem reconeixent quan parlem de pobresa energètica, ja que això determina com mesurem el fenomen, quines causes i conseqüències identifiquem i com abordem la problemàtica. A continuació, es presenta una breu revisió dels diferents orígens, termes, definicions i enfocaments de la pobresa energètica, per tal de posar en relleu les seves particularitats.

Els primers esments als problemes de privació d'energia a la llar es remunten als anys 70.[11] En el Sud global, es va començar a utilitzar el terme de "pobresa energètica" per referir-se als problemes d'accés a serveis d'energia domèstica. En aquest context, el debat s'ha centrat principalment en la persistent deficiència de les infraestructures energètiques, que continuen impedint tenir accés a serveis energètics moderns a milions de persones. Avui dia, s'estima que 770 milions de persones encara no tenen accés a l'electricitat[12] i que més de 2600 milions de persones depenen principalment de la fusta, el carbó, el carbó vegetal o les deixalles d'origen animal com a principal font d'energia per a cuinar.[13] Com a principals conseqüències de la falta d'accés a l'electricitat i a fonts alternatives a la biomassa per a cuinar i escalfar la llar, s'identifiquen la contaminació de l'aire dins de les llars i els seus efectes negatius sobre la salut. També es reconeixen altres impactes significatius en qüestions com: la seguretat personal, els usos del temps, l'educació, la productivitat laboral i els ingressos, amb un major impacte en les dones i nenes.[14]

En el Nord global, la privació d'energia a la llar es va reconèixer per primera vegada com un problema social amb entitat pròpia, i no com un aspecte marginal de la pobresa, al Regne Unit. [15] Arran de la crisi energètica de 1973, l'augment dels preus de l'energia va provocar que moltes llars no poguessin escalfar els seus habitatges adequadament, fenomen que es va identificar amb el terme de "*fuel poverty*". És també en aquest context que va emergir la lluita pel dret a l'energia.[16] Però no va ser fins a principis dels anys 90 que el terme "fuel poverty" es va popularitzar i va entrar en els debats acadèmics i polítics. L'any 1991, Brenda Boardman va proposar la primera definició quantificable de "fuel poverty" referint-se a aquelles llars incapaces d'aconseguir un nivell adequat de serveis energètics, en particular de calefacció, amb el 10% dels seus ingressos.[17] El llindar del 10% representava el doble de la mitjana de la despesa energètica de les llars angleses, que en aquell moment se situava en el 5%. Aquesta definició, així com el llindar del 10%, ha estat la predominant al Regne Unit durant dècades, sent la base per a l'estratègia nacional contra la pobresa energètica del 2001, i encara és la definició de referència en alguns països europeus.

Amb la publicació de Boardman, al Regne Unit va aflorar una problemàtica gairebé ignorada fins al moment. El debat es va centrar, principalment, en l'assequibilitat dels serveis energètics per a escalfar la llar i l'impacte de les cases fredes en termes de salut pública, principalment sobre: l'excés de mortalitat hivernal i les malalties cardiovasculars i respiratòries.[18–22] Es va establir un ampli consens sobre la principal causa de la "fuel poverty": la interacció entre uns elevats preus de l'energia, uns baixos ingressos en les llars i una baixa eficiència dels habitatges i dels seus equipaments per a escalfar-los.[23] Aquesta aproximació, ha tingut una forta influència sobre la recerca i l’agenda política d'altres països del Nord global, com Irlanda i Nova Zelanda[24,25], així com en el desenvolupament d'indicadors per a mesurar la pobresa energètica, com es veurà en el pròxim subapartat.

Durant la segona dècada dels 2000, la problemàtica de la privació d’energia a la llar va experimentar una forta irrupció en els debats socials, acadèmics i polítics de molts altres països del Nord global. L'augment constant dels preus de l'energia i les conseqüències socioeconòmiques de la crisi del 2008, van deixar a moltes llars sense poder fer front a les seves factures de subministraments d'energia. El terme “pobresa energètica” va deixar d'utilitzar-se només al Sud global i va passar a ser el terme de referència per a molts països europeus, així com per a la Unió Europea.

Va ser en aquest context, que Bouzarovski va proposar una definició que ha aconseguit un ampli consens en el món acadèmic i que persegueix integrar les visions predominants al Sud (accés) i al Nord (assequibilitat) globals en un mateix marc conceptual. Es defineix, així, la *pobresa energètica* com la incapacitat d'una llar per a assegurar un nivell social i materialment necessari de serveis energètics a l'habitatge.[26] Aquesta definició parteix de l'argument que les persones no demanden energia, sinó serveis energètics. És a dir, els serveis que faciliten el subministrament d'energia, com: la il·luminació, la calefacció, la refrigeració, l'aigua calenta per a rentar i rentar-se, la cuina o l'ús d'altres electrodomèstics i dispositius electrònics. El fet de centrar-se en els serveis energètics permet reconèixer la multidimensionalitat de les causes de la pobresa energètica, així com de les seves conseqüències. Aquesta definició també evoca la relativitat del fenomen, en reconèixer que les necessitats estan culturalment i socialment condicionades, permetent o no la participació en els modes de vida, els costums i les activitats que defineixen la pertinença a una societat.[15,27]

Un concepte més ampli i dinàmic que parteix d'aquesta definició és la *vulnerabilitat energètica*. Pensar en termes de vulnerabilitat permet anar més enllà de la tríada clàssica de la pobresa energètica (elevats preus de l'energia, baixos ingressos i baixa eficiència de l'habitatge i els electrodomèstics). A la Taula 1, es defineixen els sis principals factors determinants de la vulnerabilitat energètica: l'accés, l'assequibilitat, la flexibilitat, l'eficiència energètica, les necessitats i les pràctiques. Aquests sis factors permeten identificar un conjunt de condicions, tant internes com externes a la llar, que poden conduir a la pobresa energètica en un moment donat. Així, la vulnerabilitat energètica es pot definir com la susceptibilitat d'una llar de patir pobresa energètica quan es produeix un canvi en les seves condicions internes (com la pèrdua d'ocupació, l'augment del preu del lloguer o un augment de necessitat de serveis energètics per malaltia) o en les condicions externes (com una crisi econòmica o canvis en la regulació dels preus de l'energia). Les principals aportacions d'aquesta aproximació són: a) té en compte les necessitats de la llar; b) possibilita la identificació de llars que podrien estar en risc d'experimentar pobresa energètica; i c) reconeix la contribució de la combinació de factors socials, econòmics, polítics i infraestructurals a aquesta situació.[11]

Taula 1. Factors de vulnerabilitat energètica. Bouzarovski i Petrova, 2015.

Factor	Força motriu
Accés	Baixa disponibilitat de vectors energètics adequats per cobrir les necessitats de la llar.
Assequibilitat	Desproporció entre el cost de l’energia i els ingressos de la llar, inclosos el paper dels impostos i dels mecanismes d’assistència. Incapacitat d’invertir en la construcció d’infraestructures energètiques noves.
Flexibilitat	Incapacitat de canviar d’un mode de proveïment d’energia que sigui apropiat per a les necessitats de la llar.
Eficiència energètica	Pèrdua desproporcionada d’energia útil en la conversió d’energia a serveis de l’energia a la llar.
Necessitats	Desajust entre els requeriments energètics de la llar i els serveis de l’energia disponible per raons socials, culturals, econòmiques o de la salut.
Pràctiques	Manca de coneixement sobre programes de suport o formes d’ús eficient d’energia a la llar.

En aquesta línia, la idea de *vulnerabilitat estructural a la pobresa energètica* escala el concepte de vulnerabilitat energètica a nivell de país. S'aparta així el focus de les llars, per a emfatitzar el paper dels determinants més estructurals de la pobresa energètica. Aquest enfocament considera la tríada clàssica de la pobresa energètica com els determinants intermedis de la pobresa energètica, que a la vegada són el resultat de determinants contextuals estructurals. D'aquesta manera, els preus de l'energia serien el resultat del mercat i les polítiques d'energia, els ingressos estarien determinats per la configuració del mercat laboral i l'estat del benestar i l'eficiència energètica dels habitatges estaria condicionada al mercat i les polítiques d'habitatge.[28] La vulnerabilitat estructural a la pobresa energètica es refereix, per tant, a com la configuració dels determinants estructurals de la pobresa energètica, en cada context, determinen la capacitat d'un país de protegir la seva població, en major o menor mesura, de les condicions internes i externes que poden conduir a la pobresa energètica.[29] Aquest concepte és útil per a abordar la probabilitat d'un país d'experimentar un alt percentatge de pobresa energètica, considerant aquesta com una condició de privació temporal i identificant aquelles causes més macro, que no acostumen a ser el principal objectiu de les polítiques d'aquest àmbit, però que tenen un major potencial de benefici a llarg termini. Aquest enfocament s'ha desenvolupat en el marc del projecte PENSA i s'aprofundeix en l'Annex I.

Una altra perspectiva interessant és l'enfocament de les *capacitats*. Aquesta aproximació sorgeix com a crítica al mesurament del progrés a través del producte interior brut. Reivindica que, per a entendre realment el desenvolupament social i econòmic, hem d'analitzar com s'amplien les capacitats de les persones per a aconseguir benestar i no basar-nos en mesures econòmiques agregades que invisibilitzen la posició dels col·lectius més desafavorits. Per tant, la pobresa i el menor desenvolupament es conceptualitzen com la privació de capacitats per a exercir funcions crucials i socialment valorades com per exemple: tenir bona salut, educar-se, tenir un treball remunerat o mantenir relacions socials significatives.[30] Per tant, des d'aquesta perspectiva, la pobresa energètica s'entén com la incapacitat de desenvolupar capacitats essencials com a resultat, directe o indirecte, d'un accés insuficient a serveis energètics assequibles, fiables i segurs, tenint en compte els mitjans alternatius raonables per a assolir aquestes capacitats.[31] Aquest enfocament també es caracteritza per reconèixer la multidimensionalitat del problema, les diferències en les necessitats energètiques i per ser sensible a diferents contextos. A més, se singularitza per la forta valoració de la llibertat de triar dels individus entenent que, promovent les capacitats es maximitzen les oportunitats, però deixant a les persones que triïn lliurement quin tipus de vida valoren. Per últim, aquest enfocament també realça la possibilitat de vies alternatives per a proveir serveis energètics i l'efecte de l'evolució de les normes socials en la constitució de la demanda d'energia. Es dona pas així a abordatges alternatius com per exemple: solucions comunitàries o intervencions entorn de les normes socials.

En darrer lloc, més recentment està emergint amb força una aproximació a la pobresa energètica des de la *justícia energètica*. D'acord amb els conceptes de justícia social i justícia ambiental o climàtica, la justícia energètica persegueix aplicar els principis de justícia als models energètics. Facilita, per tant, avaluar on emergeixen les injustícies, quins grups afectats de la societat són ignorats i quins processos existeixen per a rectificar-les, amb la finalitat de revelar i reduir aquestes injustícies.[32] Aquest enfocament argumenta que la pobresa energètica integra tres formes d'injustícia. D'una banda, la injustícia distributiva, que es refereix a les desigualtats en l'accés als serveis d'energia, reconeixent aquests serveis com un bé essencial, així com la seva estreta relació amb la desigual distribució d'altres béns (ingressos, habitatges energèticament eficients, etc.). D'altra banda, la injustícia en el reconeixement, és a dir, en la falta o l'incorrecte reconeixement dels drets i les necessitats de certs grups socials políticament marginalitzats. I, finalment, la injustícia processal, que abasta aspectes com: l'accés inadequat a la informació, la falta de participació i d'influència efectiva en la presa de decisions o l'accés restringit a drets i requisits legals, així com les barreres en la capacitat per desafiar-los.[33]

En aquesta tesi s'utilitza la definició de pobresa energètica proposada per Bouzarovski, juntament amb les conceptualitzacions més àmplies i dinàmiques de vulnerabilitat energètica i de vulnerabilitat estructural a la pobresa energètica. S'inclouen també elements de l'enfocament de la justícia energètica, principalment la desigual distribució del fenomen, així com la falta de reconeixement de certs grups socials.

1.2.2. La mesura de la pobresa energètica

La identificació i mesura de la pobresa energètica no és una tasca senzilla. El fet que sigui un fenomen multidimensional, culturalment sensible i que variï en funció del temps i el lloc, fa que no sigui fàcil de captar amb un únic indicador.[34] A la pràctica, s'han desenvolupat una sèrie d'indicadors, simples i compostos, que permeten captar diferents aspectes de la pobresa energètica. Cadascun d'ells té els seus avantatges i inconvenients i poden ser més o menys adequats, depenent del focus d'interès i de l'escala d'anàlisi. És important tenir present que la disponibilitat de certes dades i indicadors pot orientar l'anàlisi cap als símptomes de la pobresa energètica més fàcils de reconèixer, a costa de silenciar altres aspectes significatius, però difícils de mesurar.[35] La literatura identifica tres enfocaments principals en la mesura de la pobresa energètica: la mesura directa, els indicadors basats en els ingressos i les despeses de la llar i els indicadors basats en les percepcions i declaracions de la llar.[36,37]

La *mesura directa* consisteix a comprovar si s'aconsegueixen nivells adequats de serveis energètics en la llar. Fins al moment, s'ha utilitzat fonamentalment en estudis que comparaven la temperatura a l'interior de les cases amb uns valors de referència.[38] Les principals limitacions d'aquest mètode recauen en: les dificultats tècniques de la valoració dels serveis energètics, la determinació d'estàndards adequats de comparació i les implicacions ètiques que comporta entrar a les llars i monitorar paràmetres.[36]

L'enfocament d'*ingressos i despeses* examina els costos energètics de les llars amb relació a llindars absoluts o relatius. És dels enfocaments tradicionalment més emprats, sobretot el llindar del 10% de Boardman que identifica, en situació pobresa energètica, aquelles llars que dediquen més d'un 10% dels seus ingressos als serveis energètics.[23] Altres indicadors, àmpliament utilitzats, són la baixa despesa energètica absoluta (M/2) i l'alt percentatge de despesa energètica sobre els ingressos (2M). El primer (M/2), identifica aquelles llars on la despesa energètica absoluta és inferior a la meitat de la mitjana nacional i el segon (2M), aquelles llars on la càrrega de la despesa energètica sobre els ingressos és més del doble de la mitjana nacional.[39] Un avantatge dels indicadors basats en despeses i ingressos és que, normalment, permeten considerar tots els serveis energètics en la mesura en què aquests es reflecteixen en el pressupost de les llars.[40] En canvi, les seves principals limitacions recauen en la falta de reconeixement de les diferents necessitats de les llars i en la poca disponibilitat d'aquesta informació en molts contextos.[36]

Finalment, l'enfocament de *percepcions i declaracions*, també conegut com a consensual, es basa en les valoracions subjectives de les persones sobre les condicions de l'habitatge i sobre la capacitat de satisfer certes necessitats bàsiques. Aquesta aproximació parteix del plantejament de pobresa relativa de Townsend[41] i es basa en la incapacitat de permetre's qüestions que la societat considera necessitats bàsiques de la vida.[42] Els tres indicadors més utilitzats des d'aquest enfocament són: a) no poder permetre's mantenir la llar a una temperatura adequada durant els mesos freds; b) haver-se endarrerit en el pagament de rebuts de serveis (gas, electricitat, calefacció…) almenys una vegada en els últims 12 mesos; i c) la presència de deficiències en l'habitatge, com ara goteres, humitats i floridura. La recollida d'aquests indicadors és més senzilla i s'inclouen en les diferents enquestes nacionals que alimenten les estadístiques d'ingressos i condicions de vida de la Unió Europea (EU-SILC). A més, es considera que aquests indicadors autodeclarats tenen la capacitat de captar elements més amplis de la pobresa energètica, com l'exclusió social i la privació material, i s'argumenta que es tracta d'una valoració de baix a dalt, ja que són les mateixes persones les que avaluen, per exemple, si el confort tèrmic és adequat.[43] Cal destacar que la influència, durant dècades, de l'aproximació de la “fuel poverty” ha comportat que els indicadors més utilitzats estiguin enfocats a identificar temperatures inadequades durant els mesos freds i no durant els mesos càlids.

Últimament, i amb l'objectiu de resumir en un únic indicador diferents dimensions de la pobresa energètica, s'han desenvolupat diversos indicadors compostos (índexs).[44] Aquests van des de la suma ponderada d'indicadors simples, fins a complexes metodologies que inclouen diversos indicadors de pobresa energètica i/o altres indicadors de condicions de vulnerabilitat. Varia també el context i l'escala (individual i geogràfica) on són aplicables. Un exemple, que es desenvolupa amb més profunditat en l’Annex I d'aquesta tesi, és l'índex de vulnerabilitat estructural a la pobresa energètica. Aquest índex està format per 13 indicadors a escala de país que informen sobre tres dimensions estructurals clau de la pobresa energètica: el mercat i les polítiques d'energia, el mercat laboral i l'estat del benestar i el mercat i les polítiques d'habitatge.[29]

Finalment, cal destacar les recents recomanacions de l'Observatori de la Pobresa Energètica de la Unió Europea (EPOV per a les seves sigles en anglès), sobre quins indicadors són els més adequats per a entendre, monitorar i guiar les polítiques públiques relacionades amb la pobresa energètica dels Estats membres. La proposta inclou una sèrie d'indicadors primaris i secundaris, fàcilment disponibles, que han de ser utilitzats de forma combinada per a aconseguir una millor fotografia de la situació. Els quatre indicadors primaris inclouen els d'ingressos i despeses M/2 i 2M i els autodeclarats de temperatura adequada a la llar durant els mesos freds i endarreriments en el pagament de rebuts de serveis. Alguns exemples d'indicadors secundaris són: els preus dels combustibles, el nivell energètic dels habitatges, la presència d'equips d'aire condicionat i calefacció o si l'habitatge és confortablement fresc durant l'estiu.[45]

En aquesta tesi s'utilitzen els dos indicadors primaris autodeclarats recomanats per l'EPOV i l'adaptació de l'indicador d'assequibilitat de confort tèrmic per als mesos d'estiu, a causa de la rellevància dels efectes de les altes temperatures en el nostre context i en l'actual escenari d'emergència climàtica. També, es fa servir l'índex de vulnerabilitat estructural a la pobresa energètica i es desenvolupa una proposta d'índex de pobresa energètica per a àrees petites.

1.2.3. Contextualització i magnitud del problema a diferents escales

La Unió Europea

La pobresa energètica és un problema important a *Europa*, on s'estima que entre 50 i 125 milions de persones viuen en situació de pobresa energètica.[46] A més, en l'actual context de crisi social i climàtica, és esperable que augmenti el nombre de llars afectades a causa de: les contínues dificultats econòmiques, l'augment de les desigualtats, l'augment dels preus de l'energia i la major variabilitat climàtica i el conseqüent canvi en les necessitats energètiques.[26,46–49]

Tot i que la problemàtica s'estén per tot el continent, la pobresa energètica es distribueix de manera molt desigual, socialment i geogràficament. Socialment, es veuen més afectats per la pobresa energètica aquells col·lectius amb majors necessitats energètiques, com les persones grans, les llars amb criatures o les persones amb algunes malalties o condicions cròniques específiques.[47,50–52] També, es relacionen amb una major vulnerabilitat energètica altres característiques sociodemogràfiques, socioeconòmiques i de l'habitatge. Alguns exemples descrits en la literatura són: les persones amb menys estudis, les persones migrades, les famílies monoparentals o les persones que viuen de lloguer a preu de mercat.[53–56]

Geogràficament, el nombre de persones que viuen en situació de pobresa energètica varia dràsticament entre els països de la *Unió Europea*. Concretament, segons dades de l'EU-SILC, l'any 2016 el percentatge de llars que no podien permetre's mantenir la llar a una temperatura adequada durant els mesos freds oscil·lava entre l'1,7% a Luxemburg i el 39,2% a Bulgària, situant-se el valor mitjà de la Unió Europea en el 8,7%.[45] A pesar que, tradicionalment, la pobresa energètica s'ha abordat gairebé en exclusiva al Regne Unit i Irlanda, recentment diversos estudis han mostrat que els Estats membres més afectats per la pobresa energètica són els del sud i est de la Unió Europea.

A través de l'anàlisi de les tendències espacials i temporals de la pobresa energètica, així com dels preus del gas i l'electricitat, Bouzarovski i Tirado-Herrero (2017) van mostrar l'existència d'una clara divisió geogràfica a la Unió Europea. Aquests autors argumenten que la clàssica estructura centre-perifèria, utilitzada en l'anàlisi del desenvolupament econòmic,[57] també és aplicable en el cas de la pobresa energètica. Es diferencien així, dues grans regions a la Unió Europea: a) el *centre*, compost pels països del nord i oest de la Unió Europea i on les taxes de pobresa energètica són menors, i b) la *perifèria*, composta pels països del sud i est de la Unió Europea i on les taxes de pobresa energètica són majors. Les principals diferències entre totes dues macro regions estarien en: el grau de reconeixement públic que rep la pobresa energètica, el seu abast sociodemogràfic i la configuració dels seus determinants més estructurals.[58]

Com a part del projecte PENSA (Annex I), es va analitzar la configuració dels determinants estructurals de la pobresa energètica a escala de país a la Unió Europea, a través de l'índex de vulnerabilitat estructural a la pobresa energètica. Consistentment, aquest índex identifica exactament les dues mateixes macro regions, corresponent: a) el centre als països amb menor vulnerabilitat estructural a la pobresa energètica (Irlanda, el Regne Unit, França, Bèlgica, Luxemburg, Àustria, Finlàndia, Alemanya, Suècia, Holanda i Dinamarca – per ordre de més a menys vulnerabilitat estructural) i b) la perifèria als països amb major vulnerabilitat estructural a la pobresa energètica (Romania, Bulgària, Grècia, Letònia, Lituània, Itàlia, Eslovàquia, Hongria, Estònia, Xipre, Polònia, Espanya, Portugal, Eslovènia, Malta i República Txeca – per ordre de més a menys vulnerabilitat estructural).[29]

Al mateix temps, però, dins de les dues macro regions existeixen diferències considerables en la incidència i les característiques de la pobresa energètica. En el cas dels *països amb menor vulnerabilitat estructural a la pobresa energètica*, la problemàtica és significativament major a: Irlanda, el Regne Unit, França i Bèlgica.[58] En aquests països, la pobresa energètica acostuma a concentrar-se en grups demogràfics específics i està vinculada, principalment, a la impossibilitat d'adquirir calor a un preu assequible entre les llars amb baixos ingressos que viuen en habitatges energèticament ineficients.[23]

Els *països amb major vulnerabilitat estructural a la pobresa energètica* comparteixen importants similituds en les causes més sistèmiques de la pobresa energètica, que justifiquen aquesta categoria única. Un exemple és l'increment dels preus de l'energia en els últims anys, que ha estat superior a la mitjana de la Unió Europea en aquesta macro regió. Així i tot, s'observen dues casuístiques específiques: la dels països postsoviètics i la dels països mediterranis o del sud d'Europa. Els *països postsoviètics* es caracteritzen per tenir climes freds, un parc d'habitatges ineficient i infraestructures decadents i/o poc desenvolupades. Pateixen també altes taxes de desigualtat d'ingressos i problemes sistèmics en la governança dels sectors de l'energia i l'habitatge i de la xarxa del benestar social. A més, la transició d'una economia de planificació central a una economia de mercat, en la dècada dels 90, va obligar a reajustar a l'alça les tarifes energètiques, sense el previ desenvolupament de mecanismes adequats de benestar social i de millora de l'eficiència energètica dels edificis.[26]

En canvi, els *països del sud d'Europa* es caracteritzen per climes més temperats, amb hiverns més suaus, però estius més calorosos. Els seus mercats energètics són poc flexibles i els seus parcs d'habitatge són de baixa qualitat, no hi ha sistemes de calefacció adequats i el lloguer social és insignificant. En aquests països, també s'observen altes taxes de desocupació i de pobresa laboral i els sistemes de protecció social estan poc desenvolupats.[29,47,58,59] Cal remarcar que el predominant focus sobre el fred, en els estudis de pobresa energètica realitzats fins al moment, podria estar infraestimant les ja altes taxes de pobresa energètica trobades en el sud d'Europa.

L'Estat espanyol

Centrant-nos en l'*Estat espanyol*, s'estima que, l'any 2016, un 10,1% de la població no podia permetre's mantenir la llar a una temperatura adequada durant els mesos freds, un valor superior a la mitjana de la Unió Europea.[45] A l'Estat espanyol, però, la pobresa energètica no es va reconèixer com un problema social rellevant fins a finals de la primera dècada dels anys 2000. Entre l'any 2008 i el 2014, el percentatge de llars que no podien permetre's mantenir la llar a una temperatura adequada durant els mesos freds va incrementar un 88%.[45]

Les causes d'aquesta dramàtica situació a l'Estat espanyol són múltiples. D'una banda, els preus de l'electricitat i del gas natural no han parat de pujar des del 2008, a un ritme molt superior a la mitjana de la Unió Europea. Partint de valors inferiors a la mitjana de la Unió Europea, el preu de l'electricitat de l'Estat espanyol ha passat a ser un dels més cars de la Unió Europea, concretament el cinquè més car segons dades de l'Eurostat del primer semestre de 2021.[60] Aquest increment no s'ha vist acompanyat d'un augment del poder adquisitiu de les llars, sinó al contrari, coincidint el període amb un fort episodi de crisi econòmica que va provocar un greu augment de la desocupació i de la precarietat laboral. La gran recessió que va iniciar l'any 2008, va tenir una importantíssima repercussió en les dificultats de les llars per a fer front als pagaments de l'habitatge i dels serveis associats, com els subministraments d'energia.[61]

No obstant això, la crisi econòmica del 2008 no sols va crear noves vulnerabilitats a la pobresa energètica, també va destapar i reforçar altres vulnerabilitats estructurals ja existents. En primer lloc, la deficient regulació de l'accés a l'habitatge i de la construcció d'aquest. L'Estat espanyol té un important problema d'accés, assequibilitat i estabilitat de l'habitatge.[62] Tot i la sobredimensió del seu parc d'habitatges, aquest està infrautilitzat, amb molts habitatges buits. La principal via d'accés a l'habitatge és la propietat, sent el lloguer a preu de mercat la via residual per a aquelles persones que no tenen prou recursos per comprar, ja que el lloguer social, o altres vies alternatives com l'habitatge cooperatiu, són insignificants.[63] El creixent ús de l'habitatge com a mercaderia i com a instrument d'inversió es tradueix en una forta inseguretat residencial. Entre 2007 i 2012 es van registrar més de 350.000 execucions hipotecàries, deixant centenars de milers de famílies endeutades i sense habitatge.[64] En l'actualitat, la problemàtica dels desnonaments s'ha desplaçat cap a les llars que viuen de lloguer, representant ja el 65% dels desnonaments registrats per les estadístiques del Consell General del Poder Judicial. Aquestes xifres, però, no tenen en compte l'emergent problema dels desnonaments silenciosos. És a dir, aquelles llars que es veuen obligades a abandonar el seu habitatge per no poder assumir el preu del lloguer.[65] A més, més del 50% del parc d'habitatge espanyol es va construir abans de 1980, és a dir, abans que entressin en vigor les primeres mesures energètiques del codi tècnic de l'edificació (CTE). No obstant això, els estàndards energètics no van millorar de manera significativa fins a la implementació del CTE-2007, el que significa que prop del 80% dels habitatges es van construir sense cap o amb un baixíssim requisit d'aïllament.[66]

En segon lloc, les deficiències del mercat laboral espanyol i de l'estat del benestar aboquen moltes llars a una important vulnerabilitat econòmica. El mercat de treball espanyol es caracteritza per una alta taxa de desocupació i una progressiva precarització de les condicions laborals, facilitada per la Reforma Laboral de febrer de 2012 (Reial decret 3/2012 de 10 de febrer). L'augment de la temporalitat i de la parcialitat no voluntària, la disminució de la capacitat de negociació col·lectiva i l'augment de les desigualtats salarials han jugat un paper crucial en l'exacerbació de les desigualtats socials i econòmiques. Així mateix, el model d'estat del benestar espanyol, poc desenvolupat i poc orientat a la redistribució i a l'equitat social, no aconsegueix revertir les condicions de vida injustes i continua relegant en la família un paper clau a l'hora de proveir benestar i esmorteir situacions de crisis.[67]

Finalment, el fracàs de la implementació de les polítiques de la Unió Europea per a l'alliberament del sector de l'energia, han deixat el control del sector energètic en mans d'un oligopoli format per 5 empreses. Aquestes gaudeixen d'una situació privilegiada en el mercat, entre d'altres raons, per a la pràctica no respectar l'obligació de mantenir separades les activitats de generació, distribució i comercialització de l'energia. La concentració del poder del sector es tradueix en un model de gestió abusiu i opac, que prioritza el benefici econòmic d'aquestes poques empreses a costa dels drets energètics de la ciutadania.[68]

La ciutat de Barcelona

Una altra escala on la pobresa energètica cada vegada és més rellevant són els contextos urbans. La pobresa energètica és un problema global amb afectacions locals i, sovint, són les administracions i les entitats locals les que detecten i intenten donar resposta a aquesta problemàtica. La densitat i complexitat sociodemogràfica de les ciutats desencadena una alta concentració de llars amb dificultats de satisfer les seves necessitats energètiques i, a més, s'hi identifiquen factors específicament urbans.[69]

D'una banda, tot i que a les ciutats l'oferta de treball és major i es concentren els treballs més ben pagats, també existeixen majors desigualtats socioeconòmiques.[70] El cost de la vida també és superior en els contextos urbans, degut a uns majors preus dels béns i dels serveis. En particular, el preu de l'habitatge (lloguer o hipoteca) té un especial impacte sobre els pressupostos de la llar, ja que en moltes ciutats l'immoble opera com un bé d'inversió, limitant el dret a l'habitatge de la ciutadania. Un altre factor característic és la configuració urbana i arquitectònica. La concentració d'asfalt, edificis de formigó i d'altres materials absorbents de calor, així com la falta de vegetació, provoca el conegut efecte illa de calor,[71] augmentant la necessitat de serveis d'energia en ciutats de climes càlids. A les ciutats, també predominen els edificis d'apartaments. Aquests, tot i que en general són energèticament més eficients, poden ser més difícils de rehabilitar, a causa de la complexitat de l'estructura social i econòmica de les pròpies comunitats veïnals.[69]

D'altra banda, però, les ciutats també gaudeixen d'una major proximitat a les xarxes de suport institucionals o privades, com: els serveis socials, les associacions de veïns i veïnes o les organitzacions sense ànim de lucre, que poden jugar un paper clau en la mitigació de les situacions de pobresa energètica. La major rotació de població i el major grau d'anonimat poden, però, exacerbar situacions d'aïllament, especialment en persones nouvingudes que poden estar menys vinculades al territori al moment de la seva arribada.[69] Finalment, les ciutats també són importants escenaris generadors de resistència, solidaritat i protesta. La seva grandària, densitat i diversitat, així com la presència de centres de poder on es prenen decisions, promouen el sorgiment de moviments socials que desafien el *statu quo*.[72]

Un bon exemple és la ciutat de *Barcelona*, on conflueixen aspectes com: un alt percentatge de llars en situació de pobresa energètica amb casuístiques particulars, una voluntat explícita de l'Ajuntament per a abordar la problemàtica i una forta mobilització social a favor del dret universal a l'energia. L’any 2016, segons dades de l'Enquesta de Salut de Barcelona, un 9,4% de la població no podia permetre's mantenir la llar a una temperatura adequada durant els mesos freds. Les desigualtats geogràfiques es reprodueixen també a escales menors i en el cas de Barcelona, s'observen notables diferències entre districtes. El percentatge de llars en situació de pobresa energètica oscil·la entre el 2,9% en el districte de les Corts i el 21,1% a Ciutat Vella.[73] No obstant això, no existeixen estimacions per a àrees més petites, com per exemple els barris.

A Barcelona, l'augment del reconeixement de la pobresa energètica, com un important problema social i de salut pública, s'identifica tant a nivell institucional com a nivell de la ciutadania. Entre les iniciatives institucionals destaca la implementació d'11 Punts d'Assessorament Energètic (PAE), que tenen com a objectiu garantir els drets a l'energia i als subministraments bàsics de la ciutadania i millorar l'eficiència energètica de les llars.[74] També, és significativa la inclusió de l'eliminació de la pobresa energètica entre els objectius del Pla Clima de la ciutat per al 2030,[75] així com la inclusió de preguntes sobre pobresa energètica en l'enquesta de salut de la ciutat, que alimenten molts dels resultats d'aquesta tesi. Quant a la ciutadania, Barcelona acull la seu principal de l’Aliança contra la Pobresa Energètica. Com es veurà més endavant, aquest moviment social juga un paper importantíssim en la lluita contra la pobresa energètica i a favor del dret universal als serveis d'aigua i energia a la ciutat, exercint pressió sobre l'administració perquè garanteixi aquests drets i sobre les grans empreses subministradores perquè assumeixin la seva responsabilitat en aquesta problemàtica.[76]

En aquesta tesi es vol estudiar les característiques de la pobresa energètica i les seves conseqüències sobre la salut, en diferents contextos i escales geogràfiques. Per això, la problemàtica s'aborda en els següents àmbits geogràfics: la Unió Europea, les dues macro regions de la Unió Europea, la ciutat de Barcelona i els seus 73 barris.

1.2.4. Marc jurídic de la pobresa energètica

La Declaració Universal dels Drets Humans, aprovada l'any 1948 per l'assemblea general de les Nacions Unides, i el posterior Pacte Internacional dels Drets Econòmics, Socials i Culturals (1966), reconeixen l'habitatge adequat com a part del dret a un nivell de vida adequat. El Comitè dels Drets Econòmics, Socials i Culturals ha desenvolupat el contingut d'aquests drets en diverses Observacions Generals. Dins dels aspectes clau del dret a un habitatge adequat, s'especifica que aquest és més que quatre parets i un sostre i que els subministraments bàsics i la seva habitabilitat són igual de fonamentals. El text precisa que un habitatge no és adequat si no disposa d'energia per a cuinar, escalfar o il·luminar la llar.[77] Tot i que amb menor abast, la Declaració Universal de Drets Humans Emergents, aprovada pel Fòrum Universal de les Cultures de Monterrey l'any 2007, fa referència explícita, com a part del dret a la seguretat vital, al dret de tot ésser humà a disposar d'energia, així com d'aigua potable, sanejament i d’una alimentació adequada.[78]

El fet que l'energia sigui essencial per a la vida, i per a salvaguardar una àmplia gamma de drets humans bàsics, ha impulsat la lluita per la inclusió de l'energia dins d'un conjunt de drets de “segona generació”. Aquests, són drets fonamentals relacionats amb l'equitat i la igualtat i busquen satisfer les necessitats socioeconòmiques i de benestar políticament significatives per a la ciutadania global. Però el dret a l'energia és un dret complex. A diferència de l'aigua, per exemple, l'energia no és una única cosa ni té una única funció primària vital. Les múltiples formes i fonts d'energia existents, així com els diferents serveis que proveeix l'energia, fan necessària l'ampliació del debat. Per a avançar en la garantia del dret a l'energia, és pertinent, per tant, no parlar únicament de l'accés a l'energia, sinó també de l'ús i de l'assequibilitat, de la concreció de les necessitats energètiques i de l'impacte a escala global del seu origen i consum.[68,79]

Aquesta visió de drets confronta amb la visió fins ara dominant en les polítiques energètiques de la *Unió Europea*, segons la qual l'energia és un servei i la seva provisió ha de regir-se per criteris de mercat.[69] En aquesta línia, destaca també la falta de consens respecte a una estratègia política comuna contra la pobresa energètica justificada, principalment, per les particularitats de la problemàtica en cada Estat membre així com per l'exercici de competències d'acord amb el principi de subsidiarietat.[80]

La pobresa energètica no va començar a formar part de la legislació europea fins a l'any 2009. Ho va fer a través del “Third Energy Package”, el qual introduïa les directives 2009/72/EC i 2009/73/EC relatives al mercat intern de l'electricitat i del gas natural respectivament. En elles, s'hi inclou l'obligació legal de protegir les persones consumidores vulnerables en els mercats energètics. Específicament, s'insta els Estats membres a definir el concepte de persona consumidora vulnerable i a prohibir la desconnexió del subministrament d'electricitat i/o gas a aquestes persones en moments crítics. El més recent “Clean Energy for all Europeans Package (2018-2019)” suposa un modest avenç. Aquest nou conjunt de directives obliga els Estats membres a reconèixer i monitorar la prevalença de pobresa energètica en els seus Plans d'Energia i Clima i, si la problemàtica és “significativa”, els exigeix que estableixin mesures concretes per a reduir-la. És criticable la poca concreció en la necessitat d'establir objectius específics per a la reducció de la pobresa energètica. Tanmateix, destaca una comprensió una mica més àmplia de la pobresa energètica introduint en el discurs les polítiques socials i un fort focus sobre l'eficiència energètica de les llars. També és important la creació de l'Observatori de la Pobresa Energètica de la Unió Europea que pretén donar suport als Estats membres en la seva lluita contra la pobresa energètica, a través d'instruments per a la mesura i el monitoratge i la posada en comú de bones pràctiques per a reduir-la.[81] Per últim, és rellevant el recent enfocament adoptat per la Comissió Europea en el “European Green Deal” i en el Pla de recuperació després de la COVID-19. La vinculació de la pobresa energètica a la idea de transicions energètiques i climàtiques justes i equitatives que no deixin a ningú enrere, fa una crida a la coherència entre les polítiques ambientals i socials, així com a una major participació ciutadana.[82]

A l'*Estat espanyol*, la transposició de les directives del “Third Energy Package” es materialitzen a través de: a) el Reial decret llei 6/2009, de 30 d’abril, pel qual s’adopten determinades mesures en el sector energètic i s’aprova el bo social i, en menor mesura, b) la Llei 24/2013, de 26 de desembre, del sector elèctric que prohibeix la suspensió del subministrament d'electricitat domèstica quan a la llar hi viu una persona depenent d'un equip mèdic, alimentat amb electricitat. El bo social elèctric ha experimentat una evolució progressiva des de la seva aprovació pel Reial decret llei 6/2009, que es va traduir en una congelació de la tarifa a pagar per les persones beneficiàries a nivells de 2009, fins a l'actual Reial decret 897/2017, de 6 d’octubre, pel qual es regula la figura de consumidor vulnerable, el bo social i altres mesures de protecció per als consumidors domèstics d'energia elèctrica. En aquesta última actualització del 2017, es van modificar substancialment els criteris d'accés fent-los dependre, per primera vegada, dels ingressos de la llar. Es va diferenciar també entre persona consumidora vulnerable (rebaixa del 25% en la factura elèctrica), vulnerable severa (rebaixa del 40%) i en risc d'exclusió social, a qui no se li pot interrompre el subministrament i la factura de la qual l'assumeix, a parts iguals, el bo social i els serveis socials.

El bo social elèctric és l'actual mesura clau de l'Estat espanyol per a protegir les llars en situació de pobresa energètica, però aquesta presenta moltes limitacions. D'una banda, aplica exclusivament a l'electricitat, per la qual cosa no inclou altres subministraments, com per exemple, el gas natural. D'altra banda, en ser els ingressos de la llar el principal criteri d'assignació, és possible que una part important de llars en situació de pobresa energètica quedin fora del bo social. A més, els límits de renda establerts són exageradament baixos i la protecció enfront dels talls és molt limitada per a l'electricitat i nul·la per a la resta de subministraments. Finalment, el desconeixement, la falta d'informació i les dificultats pràctiques del procediment de sol·licitud, limiten el nombre de potencials beneficiaris penalitzant, encara més, aquelles persones de més edat, amb menys formació o amb barreres idiomàtiques. [65]

El panorama és substancialment diferent a *Catalunya*, on existeix la Llei 24/2015, del 29 de juliol, de mesures urgents per a afrontar l'emergència en l'àmbit de l'habitatge i la pobresa energètica. Aquesta llei neix com una Iniciativa Legislativa Popular (ILP) impulsada per la Plataforma d'Afectats per la Hipoteca, l'Aliança contra la Pobresa Energètica i l'Observatori DESC, i es va acabar aprovant per unanimitat en el parlament de Catalunya, l'any 2015. Es tracta d'una llei pionera, i àmpliament garantista, que prohibeix la interrupció dels subministraments bàsics per motius econòmics a persones en situació de risc d'exclusió residencial. També preveu la corresponsabilitat entre les administracions públiques i les empreses subministradores per a assumir el deute generat que les llars no poden pagar. Alguns punts remarcables d'aquesta llei són: que garanteix l'accés tant a l'electricitat, com al gas i a l'aigua; els límits de renda són més garantistes; i, basant-se en el principi de precaució, obliga les subministradores a comprovar amb serveis socials que no es tracti d'una llar en situació d'exclusió residencial, abans d'efectuar qualsevol tall. A més, el grup promotor de la llei, que ja va participar en el desenvolupament de protocols d'aplicació, continua tenint un paper clau tant en el seguiment i control de l'aplicació de la llei com en les negociacions dels convenis entre les administracions i les empreses. Aquests convenis han donat lloc, entre d'altres, a la possibilitat d'instal·lar comptadors socials temporals d'aigua i electricitat en llars en situació d'ocupació en precari, així com la recent condonació del deute acumulat de més de 35.000 llars amb una de les empreses subministradores.

Des de l'Ajuntament de *Barcelona*, i en sintonia amb la llei 24/2015, també s'ha avançat en la regulació en clau de drets. Un exemple és el servei, anteriorment descrit, que ofereixen els Punts d'Assessorament Energètic el qual es fonamenta en la garantia dels drets energètics, així com de la millora de l'eficiència energètica.[74] També segueix la mateixa línia el Pla pel Dret a l'Habitatge de Barcelona 2016-2025 que inclou, entre els seus principals eixos, la rehabilitació del parc d'habitatges de la ciutat, amb un enfocament més social amb la finalitat de revertir les desigualtats existents.[83] Per últim, i com ja s'ha comentat anteriorment, l'eliminació de la pobresa energètica és un dels objectius que planteja el Pla Clima de la ciutat per a l'any 2030.[75]

1.3. Pobresa energètica, salut i desigualtats en salut

Aquesta tesi aprofundeix en la relació de la pobresa energètica amb la salut i el benestar de les persones i les poblacions. En aquest apartat es repassa el model teòric que subjau a l'aproximació del treball empíric realitzat, per a després revisar, breument, la literatura existent fins al moment i acabar presentant el marc conceptual específic utilitzat en aquesta tesi.

1.3.1. La pobresa energètica com a determinant social de la salut i la seva relació amb les desigualtats en salut

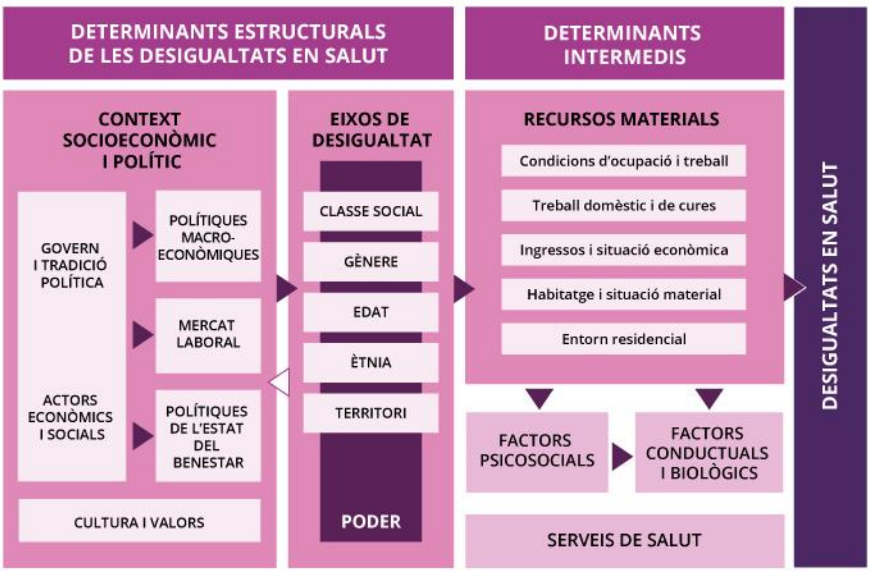
Aquesta tesi s'emmarca en els estudis de l'epidemiologia social, principalment en les teories de la producció social de la malaltia i l'economia política de la salut.[84] És a dir, es reconeix com a clau el paper que juguen els processos polítics, econòmics i sociohistòrics en la (re)producció i distribució dels determinants de la salut.[85] Obrir la discussió sobre com la priorització de l'acumulació de capital, poder i prestigi d'unes poques persones repercuteix en la salut de moltes altres trasllada el focus d'estudi de la salut a les desigualtats en salut. Les desigualtats en salut es defineixen com aquelles diferències en la salut produïdes socialment que són sistemàtiques, evitables i injustes i que es donen entre grups poblacionals definits socialment, econòmicament, demogràficament o geogràficament.[86–88] D’aquesta manera, la salut és també una qüestió de justícia social i, conseqüentment, és necessari que l'equitat en salut regeixi els processos de recerca i l'acció de la salut pública.

Existeixen diferents models que intenten explicar els factors i processos responsables de les desigualtats socials en salut. Si bé és cert que cap marc conceptual és perfecte, i que tots cauen en la fragmentació i simplificació de la realitat, aquests ens ajuden a guiar els treballs empírics i a orientar l'acció, a través de polítiques públiques i altres pràctiques transformadores. Aquesta tesi adopta l’enfocament del marc conceptual desenvolupat per la Comissió per a Reduir les Desigualtats Socials en Salut a l'Estat espanyol de 2010,[89] que, al mateix temps, és una adaptació a partir dels models proposats per Solar i Irwin per a la Comissió de Determinants Socials de la Salut de l'Organització Mundial de la Salut[88] i per Navarro. [90]

Com es pot veure en la Figura 1, aquest marc conceptual considera dos elements principals: els determinants estructurals de les desigualtats en salut i els intermedis. Els determinants estructurals es componen per la interacció entre el context socioeconòmic i polític i els eixos de desigualtat. El context socioeconòmic i polític es defineix de forma àmplia per a donar cabuda a tots aquells mecanismes que generen, configuren i mantenen l'estratificació social i la distribució de poder i recursos segons aquesta. L'estratificació social s'organitza a través de la intersecció de diferents eixos de desigualtat, com són: la classe social, el gènere, l'edat, l'ètnia o el territori de procedència o residència que produeixen, i reprodueixen, jerarquies de poder entre els diferents grups socials.

És aquesta estructura social jeràrquica la que, finalment, repercuteix en les oportunitats de tenir una bona salut a través de la falta de poder i la desigual exposició als anomenats determinants intermedis. Els determinants intermedis fan al·lusió a les condicions de vida de les persones, definides pels recursos materials, així com per altres factors psicosocials, conductuals i biològics. Els recursos materials com: les condicions d'ocupació i treball, el treball domèstic i de cures, el nivell d'ingressos i la situació econòmica i patrimonial, l'habitatge i la situació material o el barri o àrea de residència, tenen, juntament amb la posició de poder, un efecte directe sobre la salut. Al mateix temps, però, els recursos materials i el poder influeixen en processos psicosocials com ara la falta de control, l'autorealització o les situacions d'estrès, que, conjuntament, també poden determinar conductes individuals que poden repercutir en la salut. Per últim, els serveis socials i de salut poden tenir un efecte tant multiplicador com amortidor de les desigualtats en salut.

Figura 1. Marc conceptual dels determinants de les desigualtats socials en salut. Comissió per Reduir les Desigualtats Socials en Salut a l'Estat espanyol, 2010.



En aquest escenari, la pobresa energètica, així com les seves causes més directes (tríada de la pobresa energètica), poden considerar-se com la falta de recursos materials, que s'expressa com la falta de serveis energètics a la llar. Aquesta falta de serveis energètics té un efecte directe sobre la salut a través de, per exemple, unes temperatures inadequades en l'habitatge. Però també pot tenir un efecte indirecte sobre la salut a través de factors psicosocials, com l'estrès que provoca no poder pagar factures i acumular deute, i de la generació de conductes nocives per a la salut, com l'ús de fonts d'energia poc segures o una pitjor dieta a causa de les dificultats per conservar i cuinar aliments. És d'esperar, per tant, que existeixin desigualtats entre l'estat de salut d'aquelles persones que viuen en situació de pobresa energètica i les que no pateixen aquesta problemàtica. A més, en considerar-la un determinant intermedi, la pobresa energètica es distribuirà de manera desigual en la societat afectant més aquells grups socials més desafavorits i amplificant, així, les desigualtats socials en salut.

1.3.2. Els efectes de la pobresa energètica sobre la salut i les desigualtats en salut

Els efectes negatius sobre la salut i el benestar de les persones són un dels principals impactes de la pobresa energètica. Aquests han centrat l'atenció de la problemàtica des de l'inici, tant al Sud global, en relació principalment a la contaminació de l'aire dins de les cases, com al Nord global, en relació sobretot a les cases fredes i altres condicions físiques deficients de les llars.

Centrant-nos en el Nord global, diversos estudis han evidenciat com la pobresa energètica afecta negativament la salut. Fins al moment, els principals estudis s'han realitzat al Regne Unit, Irlanda i Nova Zelanda, amb un fort biaix cap a les conseqüències de la temperatura inadequada en les llars durant els mesos freds.

Com a part del projecte PENSA, s'ha dut a terme una revisió d'abast (scoping review) sobre els efectes de la pobresa energètica sobre la salut i les desigualtats en salut,[91] que s'adjunta en l'Annex II d'aquesta tesi. Aquesta revisió neix amb l'objectiu d'actualitzar i ampliar altres treballs de revisió realitzats fins al moment, com el de l'equip de revisió de Marmot sobre els impactes en salut de les cases fredes i la "fuel poverty",[48] així com per a examinar els estudis realitzats fins ara des d'una perspectiva de desigualtats en salut. La revisió inclou tant estudis observacionals, que analitzen els efectes de la pobresa energètica sobre la salut, com estudis relacionats amb intervencions per a pal·liar la pobresa energètica i que analitzen els beneficis que aquestes suposen per a la salut. A continuació, es fa un breu resum sobre els principals resultats trobats en la revisió d'abast, que pot ampliar-se en l'Annex II.

La revisió inclou 38 estudis, 24 observacionals i 14 relacionats amb intervencions per a alleujar la pobresa energètica. Gairebé la meitat dels estudis (18) es van realitzar al Regne Unit. Per a la síntesi de resultats, les diferents mesures d'exposició a la pobresa energètica es van agrupar en cinc categories: 1) temperatures inadequades, 2) problemes financers, 3) condicions físiques de l'habitatge inadequades, 4) índexs de pobresa energètica i 5) valoració qualitativa. Així mateix, els principals resultats de salut trobats es van classificar en: 1) estat general de salut, 2) salut mental, 3) salut respiratòria, 4) malalties cròniques, 5) mortalitat, 6) ús de serveis sanitaris i 7) altres riscos per a la salut.

Existeix una forta evidència que la pobresa energètica s'associa a un pitjor *estat general de salut.* Aquest es relaciona tant amb l'exposició a temperatures i condicions inadequades en l'habitatge, com amb les dificultats econòmiques de la llar per fer front a les factures i amb diferents indicadors compostos (índexs). Per exemple, l'any 2012, en un estudi realitzat en la població adulta dels dos últims quintils de renda dels països de la Unió Europea, es va trobar que els 4 indicadors de pobresa energètica utilitzats en l'estudi s'associaven a una pitjor salut percebuda. A més, es va constatar que com més gran era el nombre d'indicadors de pobresa energètica reportats, major era la probabilitat de reportar una mala salut percebuda.[92]

Diversos estudis també identifiquen importants efectes sobre la *salut mental*. Aquesta forta afectació pot deure's als múltiples, i sovint més immediats, mecanismes a través dels quals la pobresa energètica afecta la salut mental.[93] Per exemple, s'ha observat que el discomfort tèrmic [94] i la pròpia preocupació que el fred està afectant la salut física[95] tenen un efecte directe sobre la salut mental. Al mateix temps, però, la salut mental es pot veure afectada per les preocupacions sobre com pagar els rebuts d'energia, l'acumulació de deute, la sensació de falta de control sobre el problema i de manca de solucions o l'estigmatització dins de la pròpia comunitat.[95,96]

Un dels efectes més reconeguts de la pobresa energètica són les conseqüències negatives per a la *salut respiratòria*. Aquestes s'han relacionat, principalment, amb les temperatures fredes i la presència d'humitats i floridura en l'habitatge. Les temperatures fredes suprimeixen el sistema immune i afecten la funció protectora normal del tracte respiratori, amb un augment de la broncoconstricció, la producció de moc i la reducció de l'eliminació d'aquest, la qual cosa es tradueix en una major morbiditat respiratòria.[48] La literatura identifica, principalment, un increment d'infeccions respiratòries i de malalties lleus com refredats i, sobretot, una forta relació amb l'asma. La pobresa energètica s'associa amb asma en persones adultes[97,98] i en persones grans,[99] però sobretot durant la infància. A més, el fred i la humitat faciliten l'aparició de floridura en l'habitatge que pot actuar com a desencadenant de respostes al·lèrgiques com ara l'asma.[48] L'Organització Mundial de la Salut estima que, aproximadament, un 12% dels casos de debut d'asma infantil són atribuïbles a la presència de floridura en els seus habitatges i un 15% a la humitat.[100]

La literatura científica també vincula la pobresa energètica a una major prevalença de *malalties cròniques*, així com a un empitjorament o mal control d'aquestes. És especialment rellevant el paper de les temperatures fredes en els problemes circulatoris. El fred augmenta la pressió arterial i la viscositat de la sang, incrementant així el risc d'accidents cerebrovasculars i d'infarts de miocardi.[48] Altres exemples descrits en la literatura són el pitjor control de la diabetis mellitus[101] o de la simptomatologia de l'artritis i altres malalties reumàtiques.[102]

L'impacte més extrem de la pobresa energètica és l'augment de la *mortalitat*, principalment, per causes cardiovasculars i respiratòries. L'excés de mortalitat hivernal va ser un dels primers efectes en salut que es va relacionar amb la pobresa energètica. És difícil quantificar quina part de l'excés de mortalitat hivernal pot atribuir-se a la pobresa energètica, ja que aquesta es veu influenciada tant per la temperatura exterior com per la interior i, a més, existeix un efecte tant agut com acumulatiu del fred. Així i tot, un estudi va mostrar que l'excés de mortalitat hivernal era major en països amb climes més càlids (com Portugal, Espanya i Grècia) i en països amb pitjors estàndards de construcció (el Regne Unit i Irlanda). L'estudi va concloure que la variació en l'excés de mortalitat hivernal entre països es devia, principalment, a les diferències de temperatura a l'interior de les cases i a les circumstàncies socioeconòmiques.[18] Posteriorment, i com a part del projecte PENSA (Annex I), es va evidenciar com la vulnerabilitat estructural a la pobresa energètica s'associava a una major mortalitat hivernal.[29]

Els efectes sobre la salut de la pobresa energètica també poden repercutir en un major ús de *serveis de salut*. Tot i que són pocs els estudis existents al respecte, la literatura suggereix que la pobresa energètica es relaciona amb un augment de visites ambulatòries en persones amb diabetis mellitus[101] i de visites a atenció primària en població general.[97] També s'ha observat una disminució de l'ús de serveis de salut després d'una intervenció duta a terme a Nova Zelanda per a millorar l'eficiència energètica en llars sense aïllament tèrmic, on residia almenys una persona amb problemes respiratoris.[103]

Tanmateix, a aquests efectes més directes de la pobresa energètica sobre la salut, cal afegir les repercussions més indirectes de l'afectació de la pobresa energètica en el dia a dia de les persones. Les llars en situació de pobresa energètica desenvolupen diferents estratègies per a combatre les dificultats per a satisfer les seves necessitats energètiques, que poden suposar situacions de *risc per a la salut*. Les principals respostes de les llars poden resumir-se en quatre estratègies.[104,105] La primera, minimitzar el consum per a reduir al màxim les factures. Per a minimitzar la despesa, hi ha llars que limiten l'espai utilitzable a l'habitatge, la qual cosa pot portar a la confrontació entre els diferents membres per la falta de privacitat i d'espai personal, especialment durant l'adolescència.[106] Minimitzar el consum d'energia també pot provocar mancances en la higiene, una pitjor alimentació, per la restricció de l'ús dels fogons o el forn, o un augment de caigudes a causa d'una il·luminació insuficient.[48] La segona estratègia, és prioritzar els serveis energètics a costa d'endeutar-se amb les companyies subministradores, amb les conseqüències que això suposa per a la salut mental. Aquesta resposta sembla ser més comuna en persones joves i, sobretot, en famílies amb criatures petites.[107] En canvi, és molt poc freqüent en persones grans, en les quals s'ha observat una particular por o aversió al deute, preferint abans sacrificar el seu benestar.[50] La tercera estratègia, té a veure amb disminuir la despesa en altres béns essencials per a poder mantenir un mínim de serveis d'energia, donant lloc, per exemple, al conegut dilema de "heat or eat".[48] En aquest sentit, s'ha descrit una major inseguretat alimentària en les persones en situació de pobresa energètica que, juntament amb un major consum d'aliments calòrics barats, comporta un increment de risc de desnutrició o obesitat.[108,109] La quarta i última estratègia, consisteix a usar fonts d'energia alternatives menys segures o connectar-se de manera irregular a la xarxa de distribució d'energia. Ambdues poden implicar greus conseqüències d'inseguretat incrementant, per exemple, el risc de cremades o d'inhalació de monòxid de carboni[110,111] i comporten un important rebuig social.

Per últim, per a revisar l'evidència existent del paper de la pobresa energètica sobre les *desigualtats en salut*, la revisió d'abast examina si els estudis inclosos consideren o no algun eix de desigualtat. Es diferencia entre els articles que desagreguen dades per almenys un eix de desigualtat i els que estan dirigits a un grup social específic, definit per un o més eixos de desigualtat. Dels 38 articles, 10 (26,3%) no consideren cap eix de desigualtat, 21 (55,3%) se centren en un grup vulnerable específic i 11 (28,9%) presenten dades desagregades per almenys un eix de desigualtat (existeix un solapament de 4 estudis, on s'estudia un grup vulnerable i alhora es proporciona informació desagregada per diferents subgrups).

Molts dels estudis dirigits a grups socials específics són estudis relacionats amb intervencions per a mitigar la pobresa energètica. Aquestes generalment es dirigeixen a grups vulnerabulitzats i els beneficis en salut que generen poden ajudar a reduir les desigualtats en salut. Els eixos de desigualtat més utilitzats per a seleccionar els grups vulnerabilitzats són la classe social o el nivell d'ingressos i l'edat, considerant tant edats primerenques com edats avançades. Un estudi també aborda la problemàtica des d'un punt de vista territorial, dirigint una intervenció a comunitats rurals a Irlanda.[102]

Crida l'atenció els pocs estudis que proporcionen dades desagregades per almenys un eix de desigualtat i la gairebé nul·la anàlisi de la interacció de més d'un eix de desigualtat. L'únic estudi de la revisió d’abast que analitza la intersecció de dos eixos (sexe i territori) és el primer estudi d'aquesta tesi, per la qual cosa els resultats principals no es tenen en compte en aquest subapartat i es comentaran més endavant. L’escassa evidència disponible sobre les desigualtats en salut relacionades amb la pobresa energètica identifica desigualtats per raó de gènere, edat, ètnia i territori. Per exemple, la pobresa energètica s’associa més fortament a la inseguretat alimentària en persones grans que en persones adultes més joves.[112] Pel que fa al territori, s'observa un major excés de mortalitat hivernal en aquells països que presenten una major vulnerabilitat estructural a la pobresa energètica.[18,29] L'impacte sobre l’estat de salut percebut també és major en aquests països, sobretot en els estrats de la societat amb menors ingressos, ja que presenten percentatges de pobresa energètica superiors.[92] Amb relació als estudis d’intervencions per a reduir la pobresa energètica, s’observa un major benefici en salut en les dones[113] i en les persones d'edat avançada.[102]

Així mateix, la revisió d’abast també evidencia una escassetat d'estudis dels efectes en salut d'unes temperatures inadequades en els habitatges durant els mesos càlids. Tot i l’emergent evidència dels efectes negatius de les temperatures elevades sobre la salut, encara es desconeix el paper que juga la pobresa energètica en aquesta relació. No obstant això, la tendència a l'increment de temperatures a causa del canvi climàtic, i l'esperable augment en la mortalitat i morbiditat relacionada amb la calor, està començant a posicionar la refrigeració de la llar com un aspecte clau de la pobresa energètica.[114]

1.3.3. Marc conceptual

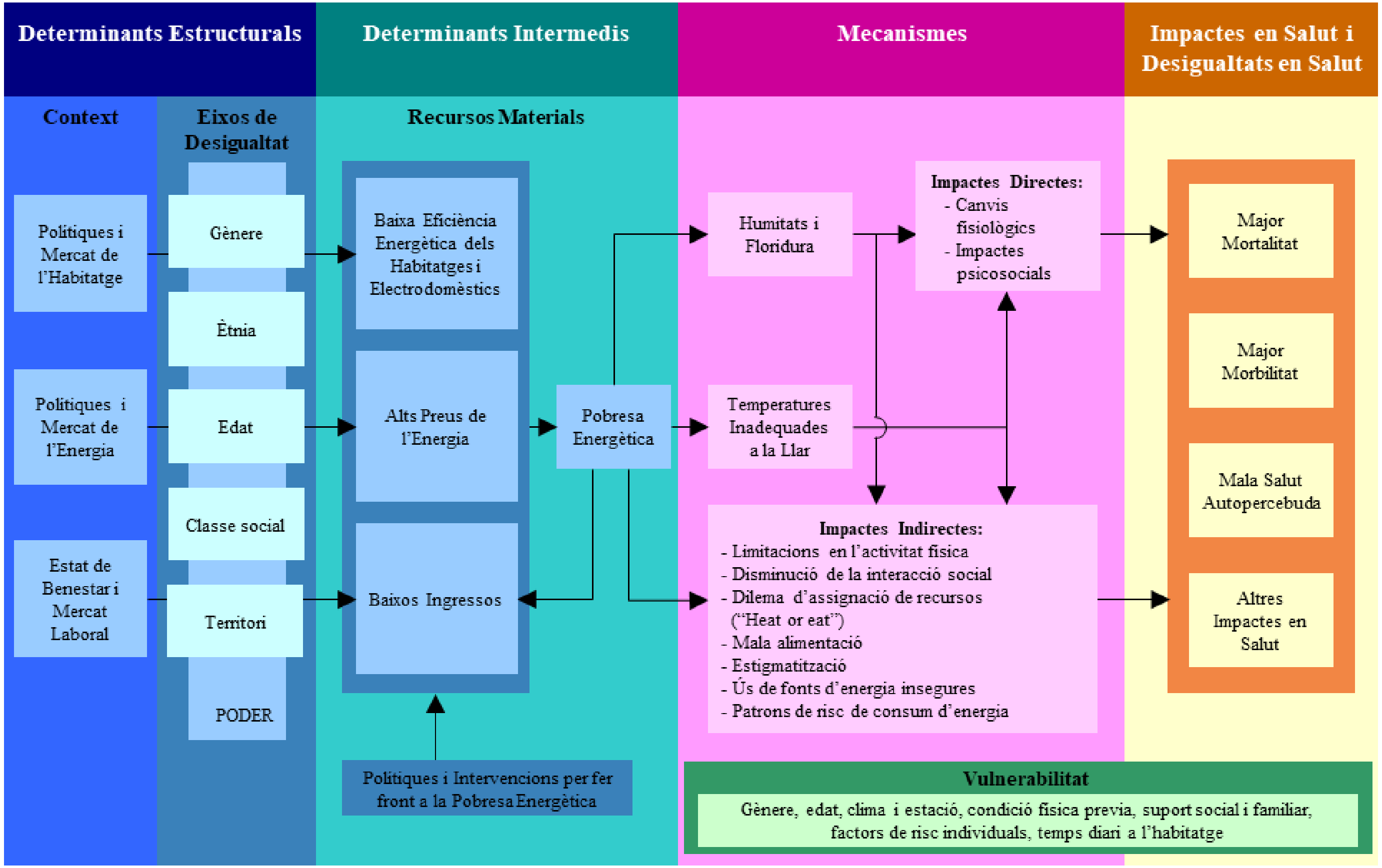
El treball empíric d'aquesta tesi es basa en el marc conceptual de Marí-Dell'Olmo et al. dels determinants de les desigualtats en salut relacionades amb la pobresa energètica.[28] Aquest marc conceptual, al mateix temps, adopta l'enfocament del marc conceptual dels determinants de les desigualtats socials en salut de la Comissió per a Reduir les Desigualtats Socials en Salut a l'Estat espanyol,[115] comentat anteriorment.

Al llarg de la introducció s'han anat revisant les diferents peces que componen aquest marc conceptual. Com mostra la Figura 2, la pobresa energètica, així com les seves causes més proximals (tríada de la pobresa energètica), es consideren els determinants intermedis de les desigualtats en salut relacionades amb la pobresa energètica. D'aquesta manera, aquest marc reconeix també la importància que tenen el context socioeconòmic i polític i l'estratificació social en l'exposició a la pobresa energètica. Els determinants estructurals identifiquen els factors contextuals que es relacionen més directament amb la pobresa energètica, així com els eixos de desigualtat que medien la menor o major exposició a la pobresa energètica i a les seves causes més properes. Aquest marc visualitza també els principals mecanismes a través dels quals la pobresa energètica impacta de manera directa la salut, com les temperatures inadequades o la presència d'humitats i floridura en l'habitatge. Igualment, considera aquells impactes més indirectes de la pobresa energètica, que alhora tenen fortes repercussions sobre la salut, com els dilemes d'assignació de recursos o la disminució de la interacció social i l'estigmatització. D'aquesta manera, s'abasta un ampli espectre d'efectes sobre la salut que inclouen: des de l'augment de la mortalitat i morbiditat fins a una pitjor percepció de l'estat de salut i un menor benestar.

Addicionalment, a part dels eixos de desigualtat que determinen una major o menor exposició a la pobresa energètica, aquest marc també identifica un conjunt de vulnerabilitats que poden generar una major susceptibilitat als efectes de la pobresa energètica sobre la salut. Alguns exemples són: l'edat, l'estat de salut previ, el suport social i familiar o el temps d'estada en l'habitatge.

Figura 2. Marc conceptual dels determinants de les desigualtats en salut relacionades amb la pobresa energètica.

Marí-Dell'Olmo et al., 2017



2. JUSTIFICACIÓ

La pobresa energètica és un fenomen emergent i rellevant a la Unió Europea, on s'estima que afecta més de 50 milions de persones. Arran del fort increment observat en alguns països en el context de la crisi econòmica del 2008, la pobresa energètica ha anat captant cada vegada més atenció tant a l'àmbit social, acadèmic, com polític. A més, en l'actual context de crisi social i climàtica, és esperable que continuïn augmentant les llars que no poden satisfer les seves necessitats energètiques. La seva àmplia afectació a totes les esferes de la vida i, en particular, a la salut i el benestar de les persones, ha despertat també l'interès en l'abordatge d'aquesta problemàtica des de la salut pública.

Tal com s'ha comentat en la introducció, els factors i processos estructurals juguen un paper clau en la configuració de la vulnerabilitat a la pobresa energètica i en les seves conseqüències sobre la salut i el benestar. Aquests varien segons territori, identificant-se dues macro regions a la Unió Europea, una amb major i l'altra amb menor vulnerabilitat estructural a la pobresa energètica.[29] Alguns estudis han evidenciat com la crisi econòmica iniciada l'any 2008 i la conseqüent implementació de polítiques d'austeritat, es van relacionar amb un fort increment de llars en situació de pobresa energètica en països com Grècia[116] o Espanya[61]. Fins al moment, però, no s'han realitzat estudis que examinin aquest fenomen de forma integrada a tota la Unió Europea. Es desconeix també si l'evolució de la pobresa energètica, en el context d'aquesta crisi econòmica, ha estat diferent en funció de la vulnerabilitat estructural dels països i com això s'ha pogut traduir en un major o menor impacte sobre la salut de la ciutadania.

La pobresa energètica afecta al dia a dia de les persones que la pateixen i té importants efectes directes i indirectes sobre la salut i el benestar. Encara que comencen a ser nombrosos els estudis que evidencien i quantifiquen la magnitud d'aquesta problemàtica, fins ara la seva majoria s'han centrat en els efectes de les temperatures inadequades durant els mesos freds i s'han dut a terme en un nombre reduït de països amb climes freds. Les particularitats de cada entorn socioeconòmic i polític, així com altres factors específics com el clima, limiten la validesa externa de l'evidència generada fins al moment. Són necessaris estudis que abordin la problemàtica en altres contextos on la pobresa energètica també pot ser un problema rellevant de salut pública, com és el cas dels contextos urbans del sud d'Europa. És necessari també, ampliar l'estudi a altres problemes de salut poc explorats fins al moment, així com als efectes en salut d'altres dimensions de la pobresa energètica com les temperatures inadequades durant els mesos càlids. La incorporació, per primera vegada, de preguntes de pobresa energètica a l’enquesta de salut de Barcelona ofereix una bona oportunitat per avançar en aquesta direcció.

La pobresa energètica és un determinant social de la salut que pot amplificar les desigualtats en salut. Encara que alguns estudis identifiquen grups poblacionals especialment vulnerables a la pobresa energètica i als seus efectes sobre la salut, són escassos els estudis poblacionals que examinin la desigual distribució de la pobresa energètica segons diferents eixos de desigualtat i la seva intersecció. Aquesta informació és clau per a avançar en la lluita contra les desigualtats socials en salut.

A més, sovint, els eixos de desigualtat interactuen amb factors individuals que augmenten la susceptibilitat als efectes sobre la salut de la pobresa energètica, com és el cas de les persones grans o de les criatures. Així, per exemple, durant la infància, el major efecte biològic d'un menor desenvolupament físic i emocional interactua amb l'efecte social que suposa ser una criatura en la nostra societat adultocèntrica. Encara que les nenes i els nens s'han identificat com un col·lectiu especialment vulnerable a la pobresa energètica, pocs estudis empírics han examinat i quantificat l'efecte que aquesta té sobre la seva salut i el seu benestar, i menys en el context del sud d'Europa. Per a corregir aquesta situació injusta, és essencial també identificar quins factors sociodemogràfics i socioeconòmics així com de l'habitatge caracteritzen les famílies amb criatures en situació de pobresa energètica.

Per últim, la pobresa energètica és un problema global amb afectacions locals i, sovint, són les administracions i entitats locals les que detecten i intenten donar resposta a aquesta problemàtica. Actualment, dos terços de la població mundial viu en zones urbanes i aquestes presenten factors específics relacionats amb la pobresa energètica. Les ciutats, a la vegada, no són àrees homogènies i l'estimació de la pobresa energètica a aquesta escala pot emmascarar patrons geogràfics desiguals en àrees més petites, com són els barris. No obstant això, la dificultat metodològica que suposa realitzar estimacions per a àrees petites fa que siguin molt escassos els estudis que analitzen les desigualtats geogràfiques de la pobresa energètica a aquesta escala. A Barcelona, fins al moment s'ha pogut estimar el percentatge de pobresa energètica segons districte, però existeix un creixent interès per a conèixer la distribució d'aquesta problemàtica per barris. Aquest coneixement és fonamental per a entendre millor el paper d'alguns factors contextuals i per a facilitar la posada en pràctica d'intervencions específiques per a reduir les desigualtats, així com per poder avaluar aquestes intervencions.

Els quatre estudis que formen part d'aquesta tesi constitueixen un primer pas per a avançar en aquests buits de coneixement.

3. OBJECTIUS

3.1. *Objectiu general*

L'objectiu general d'aquesta tesi és ampliar el coneixement sobre la pobresa energètica i la seva relació amb la salut a la Unió Europea i a Barcelona, tenint en compte les desigualtats socials.

3.2. *Objectius específics*

Els objectius formulats per a cadascun dels estudis que conformen aquesta tesi són:

Estudi 1:

- Descriure l'evolució de la pobresa energètica abans i durant la crisi econòmica (anys 2007, 2012 i 2016) a la Unió Europea, segons la vulnerabilitat estructural a la pobresa energètica dels països.
- Analitzar l'associació entre la pobresa energètica i la salut abans i durant la crisi econòmica (anys 2007, 2012 i 2016) a la Unió Europea, segons la vulnerabilitat estructural a la pobresa energètica dels països.
- Estimar l'impacte en salut de la pobresa energètica abans i durant la crisi econòmica (anys 2007, 2012 i 2016) a la Unió Europea, segons la vulnerabilitat estructural a la pobresa energètica dels països.

Estudi 2:

- Descriure el percentatge de pobresa energètica segons sexe, edat, país de naixement i classe social a la ciutat de Barcelona l'any 2016.
- Analitzar l'associació entre la pobresa energètica i l'estat de salut, l'ús de serveis de salut i el consum de fàrmacs a la ciutat de Barcelona l'any 2016.
- Estimar l'impacte de la pobresa energètica sobre l'estat de salut, l'ús de serveis de salut i el consum de fàrmacs a la ciutat de Barcelona l'any 2016.

Estudi 3:

- Conèixer la distribució de la pobresa energètica segons característiques sociodemogràfiques, socioeconòmiques i de l'habitatge en persones menors de 15 anys a la ciutat de Barcelona l'any 2016.
- Analitzar l'associació entre la pobresa energètica i la salut en persones menors de 15 anys a la ciutat de Barcelona l'any 2016.

Estudi 4:

- Examinar les desigualtats geogràfiques de la pobresa energètica a nivell d'àrea petita a la ciutat de Barcelona l'any 2016, a través de sis indicadors de pobresa energètica.
- Estudiar les desigualtats geogràfiques de la pobresa energètica a nivell d'àrea petita a la ciutat de Barcelona l'any 2016, a través d'un indicador compost (índex) de pobresa energètica.

4. HIPÒTESIS

A continuació, es detallen les hipòtesis per a cadascun dels estudis:

Estudi 1:

- Arran de la crisi econòmica del 2008, la pobresa energètica va augmentar a la Unió Europea, sent l'increment major en els països amb major vulnerabilitat estructural a la pobresa energètica.
- La pobresa energètica s'associa amb un pitjor estat de salut a la Unió Europea i aquesta associació varia en funció de la vulnerabilitat estructural a la pobresa energètica dels països. L'associació de la pobresa energètica amb un pitjor estat de salut es va enfortir arran de la crisi econòmica del 2008.
- La pobresa energètica té un fort impacte negatiu en salut a nivell poblacional a la Unió Europea i aquest impacte varia en funció de la vulnerabilitat estructural a la pobresa energètica dels països. L'impacte en salut de la pobresa energètica a la Unió Europea es va accentuar arran de la crisi econòmica del 2008.

Estudi 2:

- La pobresa energètica es distribueix de manera desigual segons diferents eixos de desigualtat a la ciutat de Barcelona.
- La pobresa energètica s'associa a un pitjor estat de salut, un major ús de serveis de salut i un major consum de fàrmacs a la ciutat de Barcelona.
- La pobresa energètica té un fort impacte negatiu a nivell poblacional en l'estat de salut, l'ús de serveis de salut i el consum de fàrmacs a la ciutat de Barcelona.

Estudi 3:

- La pobresa energètica es distribueix de manera desigual segons característiques sociodemogràfiques, socioeconòmiques i de l'habitatge en persones menors de 15 anys a Barcelona.
- La pobresa energètica s'associa a un pitjor estat de salut en persones menors de 15 anys a Barcelona.

Estudi 4:

- A Barcelona, existeixen desigualtats geogràfiques en la distribució de la pobresa energètica a nivell de barri.

5. MÈTODES I RESULTATS

Els quatre estudis realitzats en el marc d'aquesta tesi es detallen en els següents quatre articles científics:

Oliveras, L.; Peralta, A.; Palència, L.; Gotsens, M.; López, M.J.; Artazcoz, L.; Borrell, C.; Marí-Dell'Olmo, M. Energy poverty and health: Trends in the European Union before and during the economic crisis, 2007–2016. *Health Place* 2021, *67*, 102294, doi:10.1016/j.healthplace.2020.102294.

Oliveras, L.; Artazcoz, L.; Borrell, C.; Palència, L.; López, M.J.; Gotsens, M.; Peralta, A.; Marí-Dell'Olmo, M. The association of energy poverty with health, health care utilisation and medication use in southern Europe. *SSM - Popul. Heal.* 2020, *12*, 100665, doi:10.1016/j.ssmph.2020.100665.

Oliveras, L.; Borrell, C.; González-Pijuan, I.; Gotsens, M.; López, M.J.; Palència, L.; Artazcoz, L.; Marí-Dell'Olmo, M. The Association of Energy Poverty with Health and Wellbeing in Children in a Mediterranean City. *Int. J. Environ. Res. Public Health* 2021, *18*, 5961, doi:10.3390/ijerph18115961.

Marí-Dell'Olmo, M.; **Oliveras, L**.; Vergara-Hernández, C.; Artazcoz, L.; Borrell, C.; Gotsens, M.; Palència, L.; López, M.; Martinez-Beneito, M. Geographical inequalities of energy poverty in a Mediterranean city: using small area Bayesian spatial models. *Submitted*.

5.1. Article 1

Oliveras L, Peralta A, Palència L, Gotsens M, López MJ, Artazcoz L, Borrell C, Marí-Dell'Olmo M. Energy poverty and health: Trends in the European Union before and during the economic crisis, 2007-2016. Health & Place. 2021;67:102294.

Health & Place 67 (2021) 102294

Contents lists available at ScienceDirect

Health and Place

journal homepage: http://www.elsevier.com/locate/healthplace

Energy poverty and health: Trends in the European Union before and during the economic crisis, 2007–2016

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A B S T R A C T

The aim of this study is to analyse the time trends in the European Union (EU) before and during the economic crisis in 1) the energy poverty (EP) prevalence; 2) the association between EP and health and 3) the impact of EP on health. We analyse trends among women and men in two EU macro regions, defined by a novel index of structural vulnerability to EP. The study shows how EP and its impact on health worsened during the economic crisis and identifies groups at higher risk such as women and people living in Mediterranean and Eastern European countries, which have been found to be countries with higher structural vulnerability to EP.

1. Introduction

Energy for cooking, lighting, washing or achieving thermal comfort at home is one of the essential elements of adequate housing, which is recognized as a human right by the United Nations (Office of the United Nations, 2009). Energy poverty (EP) can be understood as the inability of a household to secure a socially and materially required level of energy services in the home (Bouzarovski, 2014). The main driver of EP is the interaction of high energy prices, energy-inefficient homes and appliances, low household incomes, and the specific energy needs of the household. These drivers are themselves embedded in more structural determinants such as energy, housing and labour policies and markets, economic policies, and welfare states (Bouzarovski, 2014; Csiba et al., 2016; Marí-Dell'Olmo et al., 2017). A broader and more dynamic conceptualisation of EP is energy vulnerability, which refers to the susceptibility of a household to experience EP if there is a change in the internal conditions of the dwelling unit (such as a loss of employment) or in the external conditions (such as an economic crisis). In this case, EP can be considered as a temporary result of deprivation, meaning that households can enter and exit the condition at specific moments (Tirado Herrero et al., 2016). Another relevant concept is structural vulnerability to EP, which refers to the political and socio-economic conditions of the countries which determine the degree of protection that states provide to its population in the case of changes in the internal or external conditions that may drive households into EP. Structural vulnerability to EP is therefore closely associated with the percentage of people suffering from EP in the countries (Recalde et al., 2019).

EP is a major social problem in Europe and is likely to further increase in the coming years due to rising energy prices, continuing economic hardship, increasing inequalities, and greater climate variability due to climate change (Bouzarovski, 2014; Csiba et al., 2016; EPEE, 2009; Marmot Review Team, 2011). It is estimated that EP affects between 50 and 125 million people in Europe (EPEE, 2009). Specifically, in 2014, 10.2% of households in the European Union (EU) were unable to keep their home adequately warm during the cold months (Tirado Herrero et al., 2016). However, as several studies have shown, EP is not equally distributed socially and geographically. Socially, above-average rates of EP are experienced by the elderly, families with children (especially single parent families), households with people with disabilities or long-term illnesses, the unemployed, and people in poorly paid jobs (Bouzarovski, 2014; Csiba et al., 2016; EPEE, 2009; Hernández, 2016; Gillard et al., 2017; Wright, 2004; Adam and Monaghan, 2016; O'sullivan et al., 2016). Geographically, EP is far more important in Mediterranean and Eastern EU Member States, than in the

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https://doi.org/10.1016/j.healthplace.2020.102294
Received 22 March 2019; Received in revised form 24 December 2019; Accepted 31 January 2020
Available online 4 March 2020
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Central and Northern ones (Bouzarovski, 2014; Bouzarovski and Tirado Herrero, 2017; Bouzarovski, 2018; Bollino and Botti, 2017). By analysing spatial trends in EP at the national level, Bousarovski and Tirado Herrero identified two differentiated macro regions in the EU, which they called the core and the periphery (Bouzarovski and Tirado Herrero, 2017). Going one step further, Recalde et al. studied the structural vulnerability of the EU-27 countries through the creation of an index that considers the structural determinants of EP, including indicators such as the countries expenditure on social protection per inhabitant, the median income, the percentage of social rental stock or the annual electricity switching rate. Through a cluster analysis of the index, that study identified exactly the same two macro regions as Bousarovski and Tirado Herrero, with the countries constituting the core being those with lower structural vulnerability to EP and those identified as belonging to the periphery being those with higher structural vulnerability to EP (Recalde et al., 2019).

Several studies and reports have documented how EP negatively affects people's health and well-being (Csiba et al., 2016; Marí-Dell'Olmo et al., 2017; Marmot Review Team, 2011; Hernández, 2016; Thomson et al., 2017a; Bosch et al., 2019; Healy, 2003; Liddell and Morris, 2010; Liddell and Guiney, 2015; Peralta et al., 2017; Poortinga et al., 2017). So far, most studies have focused on the direct and indirect health effects of cold housing, with little evidence on other consequences of EP such as inadequate household temperature during the hot months. The direct health effects of EP can be divided into increased morbidity rates and a higher risk of mortality. Cold temperatures are strongly related to cardiovascular and respiratory diseases, and double the risk of respiratory problems in children (Marmot Review Team, 2011). Cold also supresses the immune system, increasing the risk of infections and minor illnesses such as colds and flu (Liddell and Morris, 2010). Living in EP also exacerbates existing conditions such as arthritis and rheumatism and negatively affects mental health by increasing the financial stress on households. The most extreme EP-related health outcome is mortality, which has been studied through comparison of excess winter mortality across European countries (Healy, 2003). Among indirect health impacts, the main findings are that EP impairs children's educational attainment, emotional well-being and resilience, reduces dietary opportunities and choices, and increases the risk of accidents and injuries at home (Marmot Review Team, 2011). EP also hampers normal functioning in everyday areas such as work or study and has social consequences such as stigmatisation and reduction in social interaction. In addition, some groups are especially vulnerable to the effects of EP, such as the elderly, children, and dependent or chronically ill people (Thomson et al., 2013). In such cases, individual vulnerability is related to the larger number of hours spent at home. Moreover, the impacts of EP can be aggravated by other situations of vulnerability, such as a lack of social support (Marí-Dell'Olmo et al., 2017).

Structural determinants and drivers of EP have been directly affected by the economic crisis that started in 2008 in Europe and the consequent implementation of austerity packages, which may have led energy vulnerable households to go into EP. As some studies have shown, EP increased considerably during the economic crisis in countries such as Greece (Dagoumas and Kitsios, 2014) and Spain (Tirado Herrero et al., 2016; Tirado Herrero and Jiménez Meneses, 2016). Although recessions pose risks to health, the interaction of fiscal austerity with economic shocks and weak social protection is what ultimately seems to escalate health and social crises in Europe (Karanikolos et al., 2013). However, despite the rising importance of EP in European policy and science agendas, there is a lack of in-depth research on the trend in EP before and during the economic crisis at the European level, as well as on the possible aggravation of its health effects. Although some studies have shown that EP is associated with worse health outcomes, no studies have analysed the magnitude of this public health problem, that is, its impact at the population level.

The aim of this study was to fill this knowledge gap by analysing the time trend in the EU before and during the economic crisis in 1) the EP prevalence; 2) the association between EP and health; and 3) the impact of EP on health. We analysed trends among women and men in the two EU macro regions, defined by the degree of structural vulnerability to EP. We calculated two different epidemiological measures, since association measures allow us to know how EP and health are related and impact measures tell us to what extent EP is an important public health problem (Gefeller, 1990).

2. Methods

2.1. Design, study population, units of analysis, and information sources

This individual-based trends study analysed three cross-sectional waves of the European Quality of Life Surveys, corresponding to the years 2007, 2012, and 2016 (European Foundation for the Improvement of Living and Working Conditions, 2018a). It covers 95 940 individuals (aged 18 years or older) from the 27 European countries constituting the EU in the period 2007–2013 (EU27). The country samples are nationally representative and range from 1000 to 3000 respondents per year, depending on country size (European Foundation for the Improvement of Living and Working Conditions, 2018b).

2.2. Study variables

We included three health outcomes as dependent variables. To assess general health, we used self-reported health status measured by a single item with five response categories that we dichotomised into two: good self-reported health (when very good and good) and poor self-reported health (when fair, bad, and very bad) (Quesnel-Vallée, 2007). To measure subjective psychological well-being, we used the 5-item World Health Organisation Well-being Index, which scores each item on a scale from 0 to 5 and the sum of the five-item score is multiplied by 4, to give a final score ranging from 0 to 100. Higher scores indicate better well-being. We created two dichotomous variables through the application of two commonly used cut-off scores recommended to identify people with reduced well-being (score<50) and clinical depression (score<28) (Topp et al., 2015).

The main independent variables were EP and time. The EP assessment was based on the consensual approach, consisting of subjective self-reported indicators. To capture wider expression of EP, we included two different indicators. The first indicator considers individuals to experience EP if they report that they cannot afford to keep their homes adequately warm and the second one, if they report one or more arrears in utility bills such electricity, water, or gas during the past 12 months. From here on we will designate the first indicator as EP_T (where T stands for Temperature), and the second as EP_A (where A stands for Arrears).

Regarding time, we included the three last waves of the European Quality of Life Surveys, which correspond to the years before (2007) and during the crisis (2012 and 2016).

The stratification variables were sex and country typologies. We used the two macro regions proposed by Recalde et al., which divided the 27 EU member countries into two groups depending on their structural vulnerability to EP: (1) countries with lower structural vulnerability (LSVc) (Denmark, Netherlands, Sweden, Germany, Finland, Austria, Luxembourg, Belgium, France, United Kingdom, and Ireland) and (2) countries with higher structural vulnerability (HSVc) (Czech Republic, Malta, Slovenia, Portugal, Spain, Poland, Cyprus, Estonia, Hungary, Slovakia, Italy, Lithuania, Latvia, Greece, Bulgaria, and Romania). Age was considered as an adjustment variable.

2.3. Data analysis

To describe the study sample, we calculated the prevalence (percentage) of EP and the prevalence of health outcomes among people living with and without EP and performed chi-square tests to assess whether the prevalence changed over time.

We analysed the association between EP and health through age-adjusted prevalence ratios (PR) and their 95% confidence intervals (CI), obtained by fitting Poisson regression models with robust variance (Espelt et al., 2017; Barros and Hirakata, 2003). The dependent variables were health outcomes, and the independent variables were EP, age, and year. To estimate changes in the association over time, we included the interaction between EP and survey year in the models and calculated PRs and CIs for each year.

Finally, as a measure of impact, we calculated the population attributable risk percent (PAR%), that is, the proportion of negative health outcomes (e.g. poor self-reported health) in the population that is attributable to EP and that, theoretically, could be prevented by eliminating EP. Measures of impact are important, because they take into account the proportion of individuals exposed to the risk factor in the population, and not only the strength of the association between the risk factor and the outcome. We obtained age-adjusted PAR% for each year directly from Poisson regression models by subtracting the expected cases if EP were absent from the observed cases and dividing these by the observed cases (Gefeller, 1990; Rückinger et al., 2009). To estimate changes over time, we calculated the PAR% differences between years. For both PAR% and PAR% differences, the bootstrap resampling method was used to calculate their respective 95% CI.

All analyses were performed for the three health outcomes separately for both EP indicators, and were stratified by sex, country typologies, and year. In all analyses we took into consideration the complex sample design by using sampling weights. We used the R software (version 3.4.4, R Foundation for Statistical Computing).

2.4. Supplementary analyses

As a sensitivity analysis, we repeated all the analyses, selecting the individuals in each country that were in the lowest income quartile. Income quartiles were based on equivalised household income in purchasing power parities in euros, which make countries comparable. We also ran the analyses by country. Country-specific results can be found in the supplementary information (S5 to S17).

3. Results

Of the 95 940 included individuals, 51.8% are women and 53.3% are citizens of LSVc. Below, the results are presented separately for the two EP indicators, EP_T and EP_A, respectively.

3.1. Inability to keep home adequately warm (EP_T)

3.1.1. Prevalence of energy poverty

Descriptive statistics for EP and health outcomes stratified by sex, region, and year are provided in Table 1. In the EU, 9.0% of the population could not afford to keep their homes adequately warm in 2007. This percentage rose to 11.8% in 2012 and decreased to 9.0% in 2016. This clear “peak” pattern (Λ) over time, in which EP increased from 2007 to 2012 and decreased between 2012 and 2016 was observed in all groups, independently of sex and region (Fig. 1a). Throughout the study period, EP_T was noticeably higher in HSVc than in LSVc and women experienced also higher EP_T rates than men. The most affected population was therefore women living in HSVc, where EP_T was 16.0%, 18.3%, and 14.8% in 2007, 2012, and 2016, respectively.

3.1.2. Association between energy poverty and health

The association between health outcomes and EP_T is shown in Fig. 2 (subfigures a-c). Detailed data can be found in the supplementary information (S1). We found an overall statistically significant association between the three health outcomes and EP_T, but the strength of the association varied depending on the different health indicators and was also affected by sex, region, and time.

The health outcome most strongly associated with EP_T was depression. Although not statistically significant, PR values were generally higher for LSVc than for HSVc in all three indicators. For example, in LSVc, women with EP_T had 3.24 (CI: 2.24–4.33) times more depression than those without EP_T in 2007 and in the case of men, in 2012 those with EP_T had 4.16 (CI:3.14–5.50) times more depression than those

Table 1
Weighted prevalence (%) of energy poverty and health outcomes by energy poverty over time stratified by sex and region.

	Women									Men								
	EU27			LSV			HSV			EU27			LSV			HSV		
	2007	2012	2016	2007	2012	2016	2007	2012	2016	2007	2012	2016	2007	2012	2016	2007	2012	2016
Cannot afford to keep home adequately warm (n)	**10.0** (2199)	**12.8** (3033)	**9.4** (1850)	**4.8** (325)	**7.9** (574)	**4.8** (327)	**16.0** (1874)	**18.3** (2459)	**14.8** (1523)	**7.9** (1315)	**10.8** (1728)	**8.5** (1132)	**4.5** (191)	**6.7** (340)	**5.2** (239)	**11.9** (1124)	**15.5** (1388)	**12.3** (893)
Poor self-reported health																		
Energy poverty	55.6	57.2	53.6	49.5	56.2	47.0	57.6	57.8	56.1	46.6	49.3	45.8	41.3	49.8	33.9	48.9	49.0	51.8
No energy poverty	**34.1**	**36.5**	**31.7**	**32.3**	**35.4**	**29.5**	**36.4**	**38.0**	**34.6**	**27.6**	**30.3**	**25.5**	**27.8**	**30.8**	**24.4**	**27.3**	**29.6**	**26.9**
Reduced well-being																		
Energy poverty	46.0	46.7	44.3	38.2	47.3	45.8	48.8	46.3	43.7	37.0	41.4	37.8	31.5	41.2	29.3	39.4	41.4	42.0
No energy poverty	25.0	24.8	23.5	**21.8**	**24.6**	**22.9**	**29.2**	**25.2**	**24.3**	**19.6**	**19.5**	**16.0**	**17.0**	**19.5**	**14.7**	**23.0**	**19.6**	**17.7**
Likely depression																		
Energy poverty	22.0	20.0	21.7	21.1	20.9	21.5	22.4	19.6	21.8	16.5	20.4	15.3	15.6	22.4	11.4	17.0	19.4	17.3
No energy poverty	8.3	8.1	8.0	6.6	7.8	7.6	**10.6**	**8.5**	**8.6**	6.0	5.7	5.2	5.0	5.5	4.7	**7.3**	**6.0**	**5.8**
Arrears in utility bills during the past 12 months (n)	**13.1** (2245)	**15.2** (3056)	**9.8** (1799)	**9.1** (623)	**10.2** (785)	**5.8** (407)	**17.7** (1622)	**20.9** (2271)	**14.5** (1392)	**12.1** (1431)	**15.1** (2009)	**9.1** (1188)	**9.9** (458)	**10.3** (564)	**5.9** (307)	**14.6** (973)	**20.6** (1445)	**12.9** (881)
Poor self-reported health																		
Energy poverty	47.9	45.4	44.5	47.6	43.2	37.7	48.1	46.6	47.7	37.2	38.9	40.2	34.5	39.4	29.6	39.4	38.6	46.0
No energy poverty	**34.7**	**38.3**	**32.7**	**31.9**	**36.4**	**29.9**	**38.3**	**40.8**	**36.2**	**28.2**	**31.2**	**26.1**	**27.8**	**31.2**	**24.7**	**28.5**	**31.3**	**27.8**
Reduced well-being																		
Energy poverty	**42.9**	**37.9**	**43.5**	38.9	36.7	43.2	**45.3**	**38.6**	**43.7**	34.0	34.1	35.2	29.8	34.4	26.5	37.4	34.0	39.7
No energy poverty	**25.0**	**25.8**	**23.6**	**21.0**	**25.2**	**22.8**	**29.9**	**26.7**	**24.5**	**19.1**	**19.8**	**16.1**	**16.2**	**19.5**	**14.7**	**22.6**	**20.2**	**17.9**
Likely depression																		
Energy poverty	**20.4**	**15.4**	**20.4**	15.8	14.3	20.6	23.2	16.0	20.3	15.9	13.9	14.8	16.6	14.0	11.7	15.4	13.9	16.4
No energy poverty	8.2	8.7	8.2	**6.5**	**8.3**	**7.6**	10.4	9.2	8.9	5.6	6.1	5.2	**4.2**	**5.8**	**4.6**	7.2	6.4	5.9

LSV: countries with lower structural vulnerability; HSV: countries with higher structural vulnerability. In parentheses, number of cases; in bold if chi-square test assessing change over time of prevalence is statistically significant (p-value < 0.05).

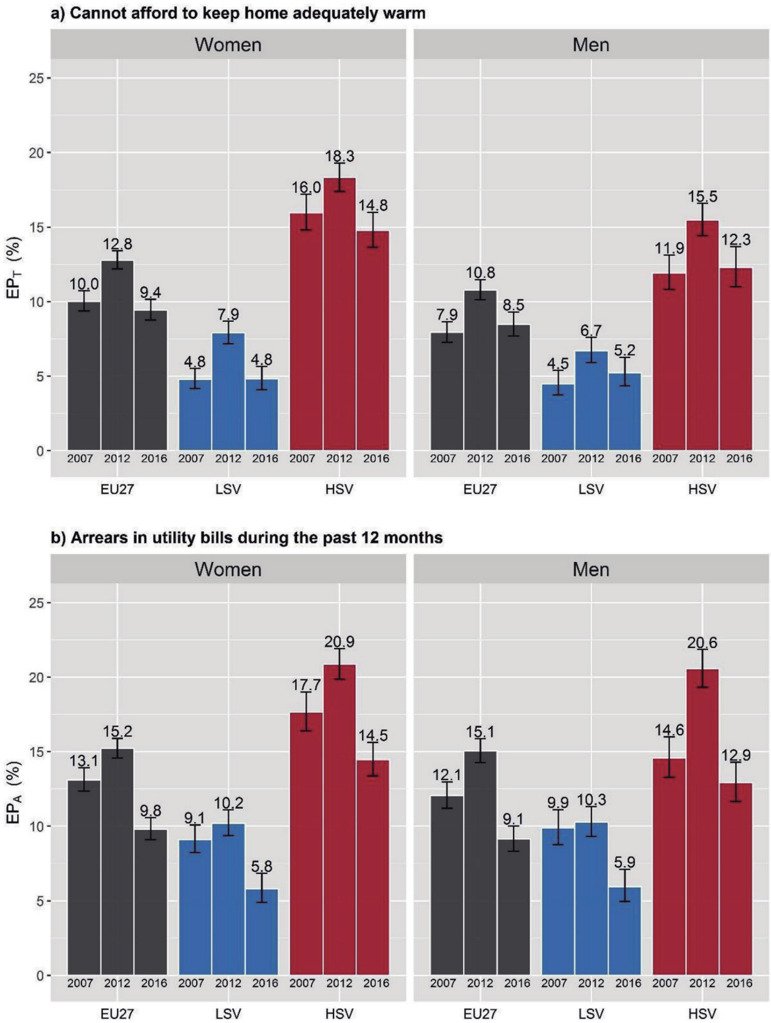

Fig. 1. Energy poverty prevalence over time stratified by sex and region.
EP_T: Energy poverty indicator "Cannot afford to keep home adequately warm; EP_A: Energy poverty indicator "One or more arrears in utility bills during the past 12 months"; LSV: countries with lower structural vulnerability; HSV: countries with higher structural vulnerability. Chi-square tests assessing change over time of EP percentage is statistically significant (p-value$<$0.05) in all cases.

without EP_T (subfigure 2c). Regarding the time trend, from 2007 to 2012, point estimates generally showed an increase in the strength of the association between the selected health indicators and EP_T, which was more marked in reduced well-being and depression in men in HSVc, where the increase was statistically significant (subfigures 2b-c, p-value of the year interaction were 0.011 and 0.02 respectively). Between 2012 and 2016, PRs tended to decrease in men in LSVc, but tended to remain stable or increase in men in HSVc and women in both LSVc and HSVc.

3.1.3. Population impact of energy poverty on health

The PAR% to EP_T of the three health outcomes are also shown in Fig. 2 (subfigures d-f). Detailed data can be found in the supplementary data (S2). EP_T significantly affected the population's health and this impact was clearly stronger in HSVc than in LSVc. For example, in 2012, the proportion of cases of depression due to EP_T was 15.46% (CI: 10.90%–20.35%) in men living in LSVc and 29.87% (CI: 23.84%–36.30%) in those living in HSVc. In women, this proportion in the two macro regions was 11.17% (CI: 7.94%–14.75%) and 21.28% (CI: 16.73%–236.37%), respectively (subfigure 2f).

We observed a clear tendency over time, as the PAR%s increased between 2007 and 2012 and decreased between 2012 and 2016. This "peak" pattern became more evident in reduced well-being (subfigure 2e) and even more so in depression (subfigure 2f), and particularly in HSVc, where differences between years were generally statistically significant (S2).

3.2. Arrears in utility bills during the past 12 months (EP_A)

3.2.1. Prevalence of energy poverty

The prevalence of EP_A stratified by sex, region and year is shown in Fig. 1b. Overall, the proportion of people experiencing EP was higher when we used the EP_A indicator. Again, HSVc and women were more affected by EP_A. Regarding time trends, although we still identified a "peak" pattern (Λ) over time in all cases, the EP_A increase between 2007 and 2012 in LSVc was less marked, but the decrease between 2012 and 2016 was still pronounced.

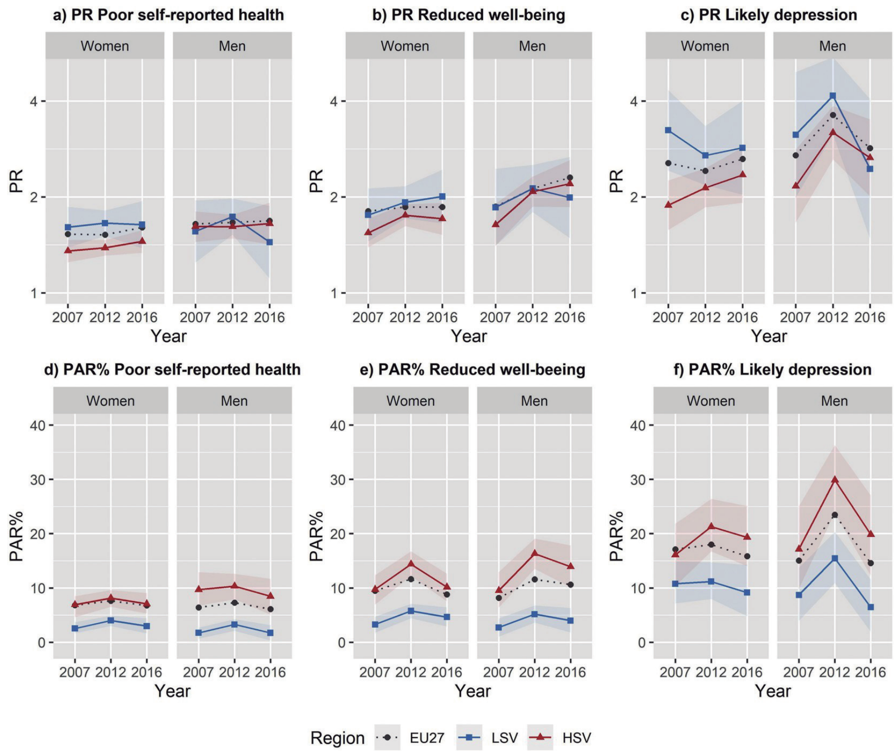

Fig. 2. Age-adjusted prevalence ratio (PR) of poor self-reported health status, reduced well-being and likely depression in people with EP_T versus people without EP_T over time and respective age-adjusted population attributable risk percent (PAR%) of the three health outcomes. Results are stratified by sex and region.
EP_T: energy poverty indicator "Cannot afford to keep home adequately warm; PR: age-adjusted prevalence ratio; PAR%: age-adjusted population attributable risk percent; LSV: countries with lower structural vulnerability; HSV: countries with higher structural vulnerability.

3.2.2. Association between energy poverty and health

The association between health outcomes and EP_A is shown in Fig. 3 (subfigures a-c). Detailed data can be found in the supplementary information (S3). Once more, there was an overall statistically significant association between EP_A and the selected health indicators. Depression was again the most closely associated health outcome with EP_A and that whose PR values experienced the most oscillation over time.

Between 2007 and 2012, time tendencies were less homogeneous between the groups. The strength of the association between EP_A and health outcomes tended to decrease in men in HSVc and especially in LSVc populations, where the decrease was statistically significant in poor self-reported health status and reduced well-being in women and in depression in men. In women in HSVc, point estimates generally showed a constant increase throughout the study period. The increase in the strength of the association between 2012 and 2016 was observed in all groups, but was particularly marked in women in both LSVc and HSVc and in men in HSVc (generally, p-values of the year interaction <0.05).

3.2.3. Population impact of energy poverty on health

The PAR% to EP_A of the three health outcomes is shown in Fig. 3 (subfigures d-f). Detailed data can be found in the supplementary data (S4). Again, EP_A had a significant negative impact on all health indicators, but this impact evolved differently over time according to macro region and sex. Point estimates suggested a general constant increase in the impact of EP_A on health in HSVc. The trends in LSVc were less evident. The impact of EP_A on health in women in LSVc decreased between 2007 and 2012 and tended to increase after 2012. In men, in contrast, the impact of EP_A on health remained stable or decreased throughout the study period.

4. Discussion

4.1. Principal findings

The results of this study show that EP clearly increased in the EU during the economic crisis and decreased in more recent years. It also evidences regional and sex inequities in the distribution of EP across the EU, with higher EP prevalence in women and in HSVc. The main contribution of this study is the evidence generated on the effects of EP on health and well-being. We found a significant association between EP and poor self-reported health status, reduced well-being, and depression. Analysis of changes over time showed that the strength of the association between EP_T and health increased from 2007 to 2012. Between 2012 and 2016, the association between EP_T and health tended to decrease in men in LSVc, but not in women in LSVc or men and women in HSVc, where the association remained stable or became stronger. Time tendencies of the association between EP_A and health were less homogenous between 2007 and 2012. But, between 2012 and 2016 there was a general increase in the strength of the association, which was particularly significant in men in HSVc and in women in both LSVc and HSVc. Although the strength of the association between EP and health tended to be greater in LSVc, the impact of EP on the three health outcomes was clearly greater in HSVc. The impact of EP_T on health followed a "peak" pattern over time, increasing between 2007 and 2012 and decreasing between 2012 and 2016. Analysis of the impact of EP_A on health showed a tendency to constantly increase in women and men in

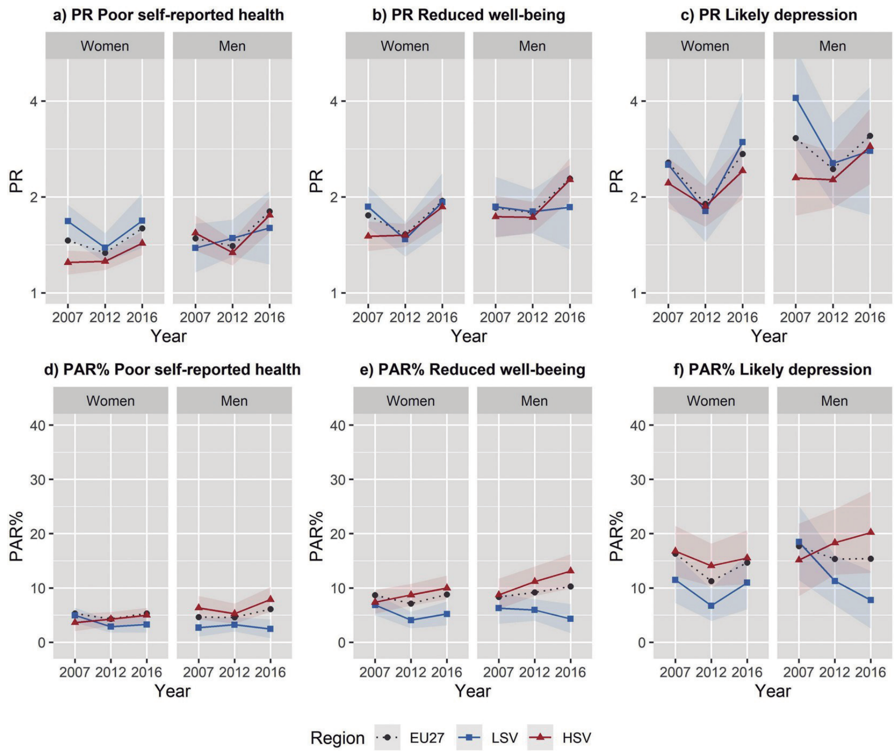

Fig. 3. Age-adjusted prevalence ratio (PR) of poor self-reported health status, reduced well-being and likely depression in people with EP_A versus people without EP_A over time and respective age-adjusted population attributable risk percent (PAR%) of the three health outcomes. Results are stratified by sex and region.
EP_A: energy poverty indicator "One or more arrears in utility bills during the past 12 months"; PR: age-adjusted prevalence ratio; PAR%: age-adjusted population attributable risk percent; LSV: countries with lower structural vulnerability; HSV: countries with higher structural vulnerability.

HSVc. In LSVc, the tendencies were less evident; however, between 2012 and 2016 the impact of EP_A on health tended to decrease in men and to increase in women, particularly regarding depression.

4.2. Interpretation of results

To our knowledge, this is the first study analysing the trend in EP at the European level for the period 2007–2016 and including structural vulnerability to EP. The general "peak" pattern observed is consistent with the hypothesis that the structural determinants and the main drivers of EP were directly affected by the economic crisis and subsequent austerity-driven economic policies implemented in the EU, increasing the number of households that were unable to meet their energy needs. These findings support those of single country studies in Spain (Tirado Herrero et al., 2016; Tirado Herrero and Jiménez Meneses, 2016), Greece (Dagoumas and Kitsios, 2014), and England (Hills, 2012). On the one hand, the number of people at risk of poverty or social exclusion increased after the beginning of the crisis, reaching a peak in 2012, and decreased again slightly between 2012 and 2014. On the other hand, in the EU, average electricity prices increased by 29% between 2005 and 2011, a far larger increment than in other regions such as the United States of America, where average electricity prices increased in the same period by 5% (Csiba et al., 2016). Moreover, as argued by Recalde et al., HSVc are characterised by lower expenditure on social protection, higher long-term unemployment rates (and policies to address them based on unemployment benefits rather than activation measures), increased in-work poverty, poor dwelling efficiency and lack of adequate heating systems in the housing stock, as well as by having less active energy markets, among other factors. This baseline or structural situation in HSVc could explain their higher percentage of EP as well as the greater impact of the consequences of economic crises, which together seem to have pushed a substantial number of energy-vulnerable households into EP.

Consistent with other studies, we found a clear association between EP and negative health outcomes. This association was stronger and more susceptible to the effect of the economic crisis in the mental health dimension, particularly in depression. This may be due to the multiple, and sometimes short-term, mechanisms and pathways in which EP affects mental health, which could have an exponential effect (Liddell and Guiney, 2015). Examples include chronic thermal discomfort, which has a direct impact on mental health (Gilbertson et al., 2012), concern that cold is damaging physical health (Tod et al., 2012), worry about energy bills (Anderson et al., 2012), the experience of falling into debt (or fear of it) (Tod et al., 2012), stigma within the person's community (Anderson et al., 2012), and the absence of any solution or sense of control over the problem (Liddell and Guiney, 2015). EP often goes hand with hand with housing insecurity and household financial debt, which are also associated with worse mental health, as well as with worse physical health. Both situations increased during the economic crisis across the EU, and particularly in some of the HSVc, such as Greece, Portugal, Cyprus, and Spain (Vásquez-Vera et al., 2016; Sweet et al., 2013). The economic crisis also increased unemployment rates in many EU countries. Several studies have shown, how unemployment can have negative consequences on mental health, and these can be harder in the case of long-term unemployment and in countries with weak unemployment protection systems and without active-labour-market programmes, as is the case in HSVc (Karanikolos et al., 2013; Uutela, 2010). Finally, the healthcare sector was also subject to austerity measures which varied from freezes to severe cuts. Some of the HSVc like Greece, followed by Portugal and Italy and Spain to a lesser extent, were the most affected countries (Serapioni, 2017; Simou and Koutsogeorgou, 2014). All this could contribute to the observed association between EP and worse health outcomes and to its trend over time.

Surprisingly, we found that generally the association between EP and negative health outcomes may be stronger in LSVc, particularly when we used the EP_T indicator. These results are in line with the findings of previous research, reporting that Slovenia, Sweden, the Netherlands, Luxembourg, and Denmark experienced the greatest difference in health outcomes among people with and without EP (Thomson et al., 2017a; Healy, 2004). LSVc have higher levels of median income and income equity (Eurostat. Quality of life, 2018) and therefore the absolute deprivation is lower. However, substantial research suggests that this unexpected result could be partly explained by relative deprivation, that is, individual-level socioeconomic comparison (Adjaye-Gbewonyo and Kawachi, 2012). Furthermore, LSVc shape the centre and north of Europe, where cold temperatures during winter are more extreme. This fact could explain why, when people live in EP, the effects on health are likely to be greater and is consistent with our observation that the EP_T indicator was more sensitive to this effect. This should alert us that the traditional focus on cold when studying EP and the lack of studies analysing the effect of hot temperatures in people with EP, could underestimate the already greater impact of EP in Mediterranean EU Member States, which are all included in HSVc. Including the effect of hot temperature when studing EP could increase even further the observed regional inequalities between LSVc and HSVc.

As expected, we observed a general increase in the strength of the association between EP_T and health during the first years of the economic crisis. However, between 2012 and 2016, the trend in the association followed different patterns among groups. On the one hand, men in LSVc tended to recover after 2012, but not women in LSVc or men and women in HSVc, where the association remained stable or became stronger. These findings suggest an increase in health inequalities between regions and genders. Although counterintuitive, the observed decrease in the strength of the association between EP_A and health in women and men in LSVc and men in HSVc during the first years of the crisis has been reported in other studies analysing health trends during the economic crisis (Bartoll et al., 2015; Malmusi et al., 2018). A possible explanation could be that, in times of recession, if more people experience difficulty in paying utility bills, the pool of people living in EP_A tends to include a larger fraction of healthy people, leading to a decrease in aggregated levels of poor health outcomes rather than an increase. This underlying idea is consistent with our finding that the association between EP_A and health became stronger after 2012, when the percentage of people living in EP_A was significantly lower and therefore may represent a more vulnerabilised and affected population. This observed increase was more significant in women in LSVc and women and men in HSVc, supporting the hypotheses that health inequalities may have increased between regions and genders during the economic crisis.

Although the association between EP and negative health outcomes seems to be higher in LSVc, when we analysed the impact of EP, the pattern was reversed, with HSVc clearly being the most affected countries. This is because PAR% is dependent not only on the strength of the association between EP and health, but also on the proportion of individuals exposed to EP, and therefore provides a measure of the public health impact of EP on the entire population. This is essential to assess the potential impact and the cost-effectiveness of preventive interventions at the population level (Rückinger et al., 2009). PAR% are infrequently reported, which may lead to misinterpretation of the real magnitude of the problem and to overlook the existing inequities among different groups. For example, another study analysing the same dataset as ours but just for 2012 concluded that EP produced the largest inequalities in health and well-being in Sweden and Slovenia (Thomson et al., 2017a). Calculating PAR%, we observed that Sweden was one of the EU27 countries with a lesser impact of EP on health and that, among HSVc, Slovenia also showed one of the less significant impacts. In contrast, in 2012, the countries where EP had a greater impact on health were Cyprus and Greece (S14-16), which are both considered as HSVc. It should be noted that impact measures presume causality between risk factors and health outcomes. Cross-sectional studies, as is the case in the present study, do not allow us to prove causal relationship.

The results of this study show how the impact of EP_T on health followed a clear “peak” pattern over time. This “peak” pattern was more pronounced in HSVc, which again suggests an increase in health inequalities among regions during crises. These results are in line with the study by Toffolutti and Suhrcke, who argue that social protection expenditures, which are generally greater in LSVc, appear to help countries to “smooth” the health response to recession (Toffolutti and Suhrcke, 2014). The impact of EP_A on health varied differently over time, depending on region, but also on gender. We observed a constant increase in women and men in HSVc, but different time patterns between the sexes in LSVc, where after 2012 the health impact of EP_A decreased in men and increased in women, as in women and men in HSVc. Intersectionality may be a valuable analytical tool to understand the ways in which both axes of inequality, territory and gender, intersect with each other, resulting in specific realities that may affect health in different ways. Several reports suggest that women are more affected by EP than men due to economic, biological/physiological, and socio-cultural factors (Clancy et al., 2017). Women with low incomes are disproportionately found as heads of households either as single parent families or due to their greater longevity than men, living alone at pensionable age. In addition, EP could have a greater impact on women’s health because they are considered more sensitive to ambient temperature and because women still bear the burden of care and housework, tasks that are energy intensive and imply spending more time at home (Gonzalez Pijuan, 2018; Brodolini, 2011). Women are also responsible for energy management in the household. This puts them in conflict with other family members (a situation that is exacerbated in times of austerity) and makes them responsible for dealing with unpayable debts or requesting subsidies. These situations, which are strongly related to stress, feelings of helplessness, depression and stigma, have been reported in studies in both LSVc (Roehr, 2002; Carlsson-Kanyama and Lindén, 2007) and HSVc (Gonzalez Pijuan, 2018; Petrova, 2017).

4.3. Methodological considerations, strengths and limitations

EP is a complex phenomenon whose measurement provokes broad debate. In this study we used the consensual approach and addressed the affordability dimension of EP. The lack of information on other dimensions of EP such as access, flexibility, energy efficiency, needs, or practices, may hamper understanding of the various causes underlying EP and its effects on health. Because the indicators used in this study are dichotomous, we could not capture intermittent versus persistent thermal discomfort or arrears in utility bills. This approach does not allow measurement of the intensity of EP in households, which could confound the association between EP and health. However, the use of subjective indicators is believed to incorporate a more comprehensive perspective of EP and to be less complex to collect, allowing their use at the European level (Thomson et al., 2017b). Moreover, we analysed the two indicators separately because they do not measure the same issue and, therefore, the mechanisms and pathways mediating their association with health may differ. Further studies should also overcome the dominant focus in EP research on heating and examine other energy needs in greater depth such as cooling, lighting, and the use of modern appliances such as computers or phones.

EP is considered a distinct deprivation condition and not only a symptom of a broader problem of poverty (EPEE, 2009; Bollino and

Botti, 2017; Hills, 2012). Although there is a clear overlap and linkages between income poverty and EP, EP should be considered separately because 1) not everyone who is energy poor is income poor, 2) some of the negative health outcomes of EP are more immediate than those caused by income poverty and 3) EP is more amenable to change than income poverty, since factors other than income can be tackled to reduce EP (Marmot Review Team, 2011). One example is Barcelona's Energy Advice Points (EAP), a service to guarantee the rights to energy and basic supplies, as well as to improve the energy efficiency of homes in the city of Barcelona. The EAPs offer personalized services such as guidance on improving the management and energy efficiency of households or the support and processing of grants, fines or procedures with companies to optimize bills (change of power, rate or company, elimination of unnecessary additional services, etc.) (Ecoserveis, 2011; Memoria d'actuació. Punts, 2018). Another example is the Warm Front scheme in England, a programme to improve energy efficiency of private households in or at risk of EP, which showed positive impacts on alleviating EP and therefore improving mental health, alleviating respiratory problems in children and reducing deaths of older people (Gilbertson and Green, 2008). However, EP disproportionately affects low-income households. To ensure that low income is not the only EP driver that explains the association found between EP and negative health outcomes, we conducted a sensitivity analysis and repeated all analyses for the lowest income quartile. We decided to stratify rather than adjust the analyses by income because income is one of the underlying causes of EP and from a conceptual perspective, we do not consider it appropriate to soften the health effects of EP through income adjustment. This extra analysis for the lowest income quartile confirmed that the low-income population experiences more EP than the general population. Regarding time trends, EP followed the same "peak" pattern in LSVc as in the general population, but this was not the case in HSVc, in which EP affecting a high proportion of women tended to remain stable and increased in men to women's levels. Strikingly, the association between EP and the three health outcomes remained statistically significant in this subpopulation. This extra analysis therefore reaffirms that removing the effect of low income does not remove the clear association between EP and negative health outcomes. We would have liked to conduct a more in-depth examination of how socioeconomic factors modulate the relationship between EP and health but were unable to do so because the income variable showed 25.2% missing values, which would have invalidated the results. For this reason, the results for the lowest income quartile should also be interpreted with caution and are therefore not published in this paper.

In an increasingly globalised and consumer-oriented world, health issues and their determinants increasingly require a transnational perspective (Kickbusch, 2010; Kickbusch et al., 2016). Rethinking boundaries when studying public health issues helps to elucidate the underlying global relations of social determinants of health. A strength of this study is that we analysed the relationship between EP and health across two macro regions, which share key characteristics among the structural determinants of EP. This has enabled us to obtain a broader perspective of the relationship between EP and health and of its susceptibility to external factors such as the economic crisis. At the same time, the economic crisis did not affect all EU countries equally and we are aware that every country has its particularities, which could be overlooked by aggregating data. Single-country data is also essential to advocate actions at the country level. For all these reasons, the whole analyses by country can be found in the supplementary information (S5–S19). Due to the sample size, we could not stratify the analyses by sex. Given the observed sex inequalities, in-depth research using the gender perspective is needed at the country level.

5. Conclusions and recommendations

This study clearly recognises EP as an important public health problem across the EU. We found a strong association between EP and poor health, especially poor mental health, which, combined with a high prevalence of EP, translates into a high impact at the population level. The results show that EP and its impact on health tend to worsen during the economic crisis and identifies vulnerable groups such as women and people living in HSVc. Further research should investigate the increasing regional and gender inequities in the distribution of EP and its impact on health. EP is a complex phenomenon and its solution requires tackling its structural determinants. It is essential to put people and their health and well-being at the centre and rather than conceptualizing energy and housing, among others, as market goods, recognizing them instead as rights. Health must be mainstreamed into all policies at European, national and local level.

Contributors

LO and MM contributed in the conception and design of the study. All the authors contributed to the acquisition and interpretation of data. LO and MM performed the statistical analyses. All the authors contributed in the interpretation and the discussion of the results. LO wrote the first draft of the paper. All the authors critically revised the manuscript and approved the final version. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Funding

The study is part of the PENSA Project ("Pobreza energética y salud desde multiples perspectivas: análisis individual, geográfico y temporal"), which received a research grant from the Carlos III Institute of Health, Ministry of Economy and Competitiveness (Spain), awarded on the 2015 call under the Health Strategy Action 2013–2016, within the National Research Program oriented to Societal Challenges, within the Technical, Scientific and Innovation Research National Plan 2013–2016, with reference PI15/02006, co-funded with European Union ERDF funds (European Regional Development Fund)". The funders were not involved in the research and preparation of the article, including study design; collection, analysis, and interpretation of data; writing of the article; nor in the decision to submit it for publication.

Ethics approval

This study has been approved by the Clinical Research Ethics Committee of Hospital del Mar (2015/6155/I).

Transparency declaration

The lead authors (LO and MM) affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data sharing

Dataset is available free of charge to those who intend to use it for non-commercial purposes at the UK Data Service.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2020.102294.

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5.2. Article 2

Oliveras L, Artazcoz L, Borrell C, Palència L, López MJ, Gotsens M, Peralta A, Marí-Dell'Olmo M. The association of energy poverty with health, health care utilisation and medication use in southern Europe. SSM – Population Health. 2020;12:100665.

SSM - Population Health 12 (2020) 100665

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: http://www.elsevier.com/locate/ssmph

The association of energy poverty with health, health care utilisation and medication use in southern Europe

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ARTICLE INFO

Keywords:
Energy poverty
Fuel poverty
Health
Social determinants of health
Health inequalities
Southern Europe
Urban

ABSTRACT

Energy poverty (EP) is defined as the inability of a household to secure a socially and materially required level of energy services in the home. The main objective of this study was to analyse the association between EP and distinct indicators of health status, health services utilisation and medication use in southern Europe, using the city of Barcelona as a case study.

We conducted a cross-sectional study using the data of the Barcelona Health Survey for 2016 (n = 3519, 53.3% women). We calculated EP percentages according to age, country of birth and social class. We analysed the association between EP and 26 health-related indicators through prevalence ratios (PR), and quantified the impact of EP on health at the population level by calculating the percentage of population attributable risk (PAR %).

In Barcelona, 13.3% of women and 11.3% of men experienced EP. The most frequently affected groups were people born in low- and middle-income countries, those from more disadvantaged social classes, and women aged 65 years and older. We found a strong association between EP and worse health status, as well as higher use of health services and medication. For example, compared with women without EP, those with EP reported poor mental health 1.9 (95% CI: 1.6–2.4) times more frequently. Compared with men without EP, those with EP reported poor mental health 2.1 (95% CI: 1.6–2.8) times more frequently. The combination of high EP prevalence and the strong association between EP and negative health outcomes resulted in high PAR%, indicating the striking impact of EP on health and health services at the population level.

EP is an important public health problem in southern European urban contexts that should be included in policy priorities in order to address its structural causes and minimise its unfair and avoidable health effects.

1. Introduction

Energy is essential for life and for safeguarding a broad range of basic human rights (Walker, 2015). Energy poverty (EP) is defined as the inability of a household to secure a socially and materially required level of energy services in the home (Bouzarovski, 2014). Because of the increasing number of households experiencing EP in Europe, this complex and multidimensional problem has become a topic in policy and science agendas. Although EP has mainly been studied in Anglo-Saxon countries, recent publications have shown that the countries most affected by EP are those in southern and eastern Europe (Bouzarovski & Tirado Herrero, 2017; Recalde et al., 2019). Moreover, these countries experienced a rapid increase in EP rates after the start of the economic crisis in 2008. In 2012, when the impact of the crisis and the policies implemented in response to it became more evident, 20.95% (interquartile range (IQR): 12.95%–25.9%) of the population of southern and eastern European countries experienced EP, whereas in northern and central European countries the median percentage of people living in EP

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https://doi.org/10.1016/j.ssmph.2020.100665
Received 7 July 2020; Received in revised form 5 September 2020; Accepted 7 September 2020
Available online 10 September 2020
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was 2.1% (IQR: 2%–8.2%). Although these percentages dropped slightly in 2016 (12.6% (IRQ: 6.15%–18.15%) and 3.5% (IRQ:2.3%–5.9%) respectively), the economic crisis uncovered the structural vulnerability of the root causes of EP, mainly in southern and eastern European countries (Oliveras et al., 2020).

Insufficient energy for lighting, cooking, and washing and the inability to achieve a comfortable temperature at home (between 18 °C and 20 °C in winter and around 25 °C in summer (Ajuntament de Barcelona, 2018)), as well as the financial stress of being unable to pay energy bills, can obviously affect physical and mental health. Until now, most research on this topic has been carried out in Anglo-Saxon countries, where EP has been related principally to cold housing (Marmot Review Team, 2011). Those studies reported that EP and low indoor temperatures were associated with: i) greater cardiovascular and respiratory morbidity and mortality (Osman et al., 2008; Power et al., 2010; Rudge & Gilchrist, 2005); ii) a higher risk of infections and minor illnesses such as colds and flu (Howden-Chapman et al., 2007); iii) exacerbation of existing health conditions such as arthritis and rheumatism (Shortt & Rugkasa, 2007); iv) mental health problems such as anxiety, depression and stress (Gilbertson et al., 2012); v) a higher risk of accidents and injuries at home (Regional Public Health Group, 2009); and vi) fewer dietary opportunities and choices (Bhattacharya et al., 2003).

To contextualise this evidence, there are substantial differences between southern European and Anglo-Saxon countries. On the one hand, southern European countries have milder winters, but warmer summers. On the other hand, there are major differences in the economic, housing and energy models, which are recognised as the structural determinants of EP (Marí-Dell'Olmo et al., 2017). For example, southern European countries have higher unemployment and in-work poverty rates, less developed social protection systems, an insignificant social rental housing stock, dwellings that are poorly insulated and without adequate heating systems, and less active energy markets (Bouzarovski & Tirado Herrero, 2017; Csiba et al., 2016; Ferrera, 1996; Recalde et al., 2019). In addition, like the post-socialist countries of central and eastern Europe, they have experienced an increase in domestic energy prices above the EU average (Bouzarovski & Tirado Herrero, 2017). Although a few recent studies at the European level have shown that EP also negatively affects health in southern European countries, they have focused on a single or few health outcomes (Bosch et al., 2019; Oliveras et al., 2020; Recalde et al., 2019; Thomson et al., 2017, 2019). There is therefore a need for empirical evidence on the specific health consequences of EP and what it represents for health services in the southern European setting.

Questions on EP were included in the Barcelona Health Survey for the first time in 2016, providing a unique opportunity to explore this field using Barcelona as a case study. The city of Barcelona is a clear example of how EP is becoming increasingly important in the urban contexts of southern Europe. In 2016, 10.6% of the city's population experienced EP (Ajuntament de Barcelona, 2018). EP has also become an explicit priority of the current city council of Barcelona (Tirado Herrero, 2018).

Therefore, the main objective of this study was to analyse the association between EP and distinct indicators of the health status, health services utilisation, and the use of medication in the city of Barcelona in 2016. A secondary objective was to assess the impact of energy poverty on health, that is, the burden of poor health outcomes that can be attributed to energy poverty at the population level.

2. Methods

2.1. Design, study population and information source

We performed a cross-sectional study using data from the Barcelona Health Survey for 2016. The study population consisted of non-institutionalised individuals aged 15 years or older who resided and were included in the Barcelona city register of inhabitants in 2016. The survey was conducted by interview in the households of a representative sample of 3519 individuals (Bartoll et al., 2018).

2.2. Study variables

The **dependent variables** were 26 dichotomous health-related indicators that could be affected by EP. Indicators were selected according to the literature and by subsequent consensus in a meeting with experts. The indicators selected were as follows:

- Health status (13 variables):
  - Self-reported health, dichotomised into 2 categories: good health (excellent, very good or good) and poor health (fair or poor) (Manor et al., 2000). This variable is known to be a good indicator of current overall health and a predictor of morbidity and mortality (Idler & Benyamini, 1997; Quesnel-Vallée, 2007).
  - Mental health, measured using the General Health Questionnaire (GHQ-12) and classified as either good mental health (GHQ-12 $<$ 3) or poor mental health (GHQ-12 $\geq$ 3) (Rocha et al., 2011).
  - Quality of life, assessed through the Euroqol 5D-5L. We used a calculation adapted for the Spanish population by Ramos-Goni et al. that identifies people with and without problems (Ramos-Goñi et al., 2017).
  - Self-reported chronic morbidity: people completing the Barcelona Health Survey are asked if they suffer from any of the chronic disorders included on a list. Of this list we included the following 8: high blood pressure; myocardial infarction and/or stroke; asthma; chronic bronchitis; arthrosis, arthritis and/or rheumatism; allergies; migraine or frequent headaches; diabetes.
  - Overweight: defined as a body mass index (obtained through self-reported weight and height) equal to or greater than 25.
  - Domestic injuries: computed variable which included having experienced burns, cuts, blows and/or falls at home in the past 12 months.
- Health services use (8 variables):
  - Emergency services: 2 or more visits to an emergency service in the last 12 months.
  - Hospitalisations: one or more hospitalisation in the last 12 months.
  - Contact with other health services: people completing the Barcelona Health Survey are asked if they have visited any of the health and social health professionals included on a list in the past 12 months. Of these professionals, we included the following 5: primary care physician, nurse, psychiatrist, psychologist, social worker.
  - Unmet medical need: if respondents reported having had in the last 12 months a health problem that they believed required medical attention but did not ask for it.
- Medication use (5 variables):
  - People completing the Barcelona Health Survey are asked if that have used any of the medications included on a list in the last 2 days. Of this list, we included the following 5 medications or group of medications: painkillers, allergy medication, antibiotics, asthma medication, psychotropic drugs (which include tranquillisers, sedatives, antidepressants, and sleep medication).

The main **independent variable** was living in EP, defined as living in a household that could not afford to maintain the dwelling at an adequate temperature during the cold and/or warm months.

Other covariables used were sex, age (dichotomised into $<$65 and $\geq$ 65 years), country of birth (dichotomised into high income [HI] versus low- and middle-income [LMI] countries according to the 2018 World Bank classification) (The World Bank, 2018) and social class. Social class was based on the current or last occupation of the interviewee, or of the head of the household if the interviewee had never worked, and was dichotomised into non-manual (including management positions in the public administration, large or small companies, professionals and administrative positions, security staff and manual worker supervisors) and manual class (skilled, semi-skilled and unskilled manual workers) (Domingo-Salvany et al., 2013).

2.3. Data analysis

First, we described EP percentages according to age, country of birth and social class and used chi-square tests to detect whether the distribution of EP changed depending on these axes of social inequalities. Then, we calculated the prevalence of the 26 dependent variables among people living with and without EP. To analyse the association between health outcomes and EP, we calculated prevalence ratios (PR) and their 95% confidence intervals (CI) using Poisson regression models with robust variance (Barros & Hirakata, 2003; Espelt et al., 2017). These models provide correct estimates and are a preferred alternative to logistic regression for analysing cross-sectional studies with binary outcomes. We adjusted these models for age and social class, as both can act as confounders because they are related to health and EP. The Poisson models are formulated as follows:

$$\ln(\lambda_i) = \beta_0 + \beta_1 EP_i + \beta_2 AGE_i + \beta_3 SC_i,$$

where λ_i is the Poisson mean for each individual i (this mean approximates the probability of presenting the studied health outcome), β_0 is the model intercept and β_1, β_2 and β_3 are the associated coefficient to the individual variables energy poverty (EP_i), age (AGE_i) and social class (SC_i) respectively.

Finally, to quantify the impact of EP on health at the population level, we calculated the population attributable risk percent (PAR%). PAR% can be interpreted as the proportion of negative health outcomes (e.g. poor self-reported health) in the population that is attributable to EP and that, theoretically, could be prevented by eliminating EP. We obtained PAR% adjusted by age and social class for each of the 26 health outcomes directly from the Poisson regression models with robust variance by subtracting the expected cases if EP were absent from the observed cases and dividing these by the observed cases (Gefeller, 1990; Rückinger et al., 2009). We used the bootstrap resampling method to calculate the respective 95%CI.

All analyses were conducted separately for women and men and we took into consideration the complex sample design by using sampling weights and strata. We used the R software (version 3.4.4, R Foundation for Statistical Computing).

2.4. Supplementary analyses

As a sensitive analysis, we repeated all the analyses selecting the individuals that could not afford to meet an unforeseen expenditure of €750 with their own resources. The results can be found in the supplementary information (S1 to S3).

2.5. Ethical considerations

This study was approved by the Clinical Research Ethics Committee of Hospital del Mar (2015/6155/l).

3. Results

Table 1 shows the sex-stratified distribution of EP by age, country of birth and social class. In Barcelona, 13.3% of the women and 11.3% of the men experienced EP. The most affected groups were those born in LMI countries (24.7% in women and 23.0% in men), people from more disadvantaged social classes (22.2% in women and 17.7% in men) and women aged 65 years and older (15.0%).

3.1. EP and health status

Table 2 shows the prevalence of each of the 13 health status indicators among people with and without EP, as well as the respective crude and adjusted PR and PAR%. EP was consistently associated with worse health outcomes in both women and men. In women, the strongest association was found with respiratory and cardiovascular diseases. Compared with women not experiencing EP, women living in EP reported chronic bronchitis 2.2 (95% CI: 1.3–3.6) times more frequently and myocardial infarction and/or stroke 2 (95% CI: 1.1–3.5) times more frequently. In men, the strongest association was observed in domestic injuries (aPR [95% CI]: 2.7 [1.5–4.7]) and poor mental health (aPR [95% CI]: 2.1 [1.6–2.8]). In both sexes, EP was strongly associated with more often having migraine or frequent headaches, which were 2 (95% CI: 1.6–2.4) times more frequent in women and 1.9 (95% CI: 1.3–2.8) times more frequent in men. Women and men living in EP also self-reported poor health around 2 times more frequently than women and men without EP (aPR [95% CI]: 1.8 [1.5–2.2] and 2.0 [1.6–2.6] respectively). As reflected by PAR% estimates, EP had a major impact on health and well-being at the population level. For example, regarding poor mental health, 12.3% (95% CI: 7.6–17.1) of the cases in women and 12.5% (95% CI: 7.1–18.2) in men could be attributable to EP.

Table 1
Energy poverty distribution by age, country of birth and social class, stratified by sex. Barcelona, 2016.

	Women (n = 1847)			Men (n = 1629)			p-value[a]
	cases	%	95%CI	cases	%	95%CI	
Total	244	13.3	(11.8–14.9)	186	11.3	(9.8–12.9)	0.076
Age (years)							
Less than 65	162	12.7	(10.9–14.5)	158	12.2	(10.4–14.0)	0.691
65 or more	82	15.0	(11.9–18.0)	28	8.1	(5.2–11.0)	0.003*
p-value[b]		0.201			0.035*		
Country of birth							
HI	159	10.7	(9.1–12.3)	116	8.7	(7.2–10.3)	0.086
LMI	85	24.7	(20.1–29.4)	70	23.0	(18.2–27.7)	0.598
p-value[b]		<0.001*			<0.001*		
Social class							
Non-manual	64	6.1	(4.7–7.6)	57	6.3	(4.7–7.9)	0.901
Manual	162	22.2	(19.2–25.3)	124	17.7	(14.9–20.6)	0.037*
p-value[b]		<0.001*			<0.001*		

n: sample size; cases: number of energy poverty cases; CI: Confidence interval; HI: High income: LMI: Low and middle-income; *: statistically significant p-value (<0.05).

[a] Chi-square test assessing sex differences within each category.

[b] Chi-square test assessing differences between categories within each sex; there were 43 missing values in the EP indicator; the final sample consisted of 3476 individuals.

Table 2
Prevalence of health status indicators among people with and without energy poverty, crude prevalence ratios (cPR), adjusted prevalence ratios (aPR) and adjusted population attributable risk percent (PAR%), stratified by sex. Barcelona, 2016.

Women

	Energy poverty (n = 244)			No energy poverty (n = 1603)								
	c	%	95%CI	c	%	95%CI	cPR	95%CI	aPR	95%CI	PAR%	95%CI
Poor self-reported health	113	45.3	38.9–51.6	346	21.2	19.2–23.2	2.1	1.8–2.5	1.8	1.5–2.2	10.8	7.0–14.7
Poor mental health	86	38.0	31.5–44.4	267	17.5	15.6–19.5	2.2	1.8–2.7	1.9	1.6–2.4	12.3	7.6–17.1
Poor quality of life	178	72.5	66.8–78.2	827	51.2	48.7–53.7	1.4	1.3–1.6	1.3	1.2–1.4	4.0	2.4–5.7
High blood pressure	80	31.8	26.0–37.7	321	20.1	18.0–22.1	1.6	1.3–2.0	1.4	1.2–1.8	5.9	2.3–9.6
Myocardial infarction and/or stroke	17	6.6	3.5–9.7	42	2.6	1.8–3.4	2.6	1.5–4.5	2.0	1.1–3.5	13.1	0.4–27.1
Asthma	25	10.2	6.3–14.0	81	5.0	3.9–6.1	2.0	1.3–3.1	1.6	1.0–2.5	8.1	-1.4–18.2
Chronic bronchitis	24	9.6	5.8–13.3	60	3.6	2.7–4.5	2.7	1.7–4.2	2.2	1.3–3.6	15.5	4.2–27.4
Arthrosis, arthritis, rheumatism	83	32.7	26.8–38.6	389	24.0	21.9–26.2	1.4	1.1–1.7	1.3	1.0–1.5	3.4	0.3–6.6
Allergies	59	24.0	18.6–29.5	240	15.0	13.3–16.8	1.6	1.2–2.1	1.6	1.2–2.1	7.4	2.6–12.4
Migraine or frequent headaches	91	37.7	31.5–43.9	296	18.2	16.3–20.1	2.1	1.7–2.5	2.0	1.6–2.4	11.4	7.0–15.9
Overweight	124	50.1	43.7–56.5	605	37.8	35.4–40.2	1.3	1.2–1.5	1.2	1.0–1.3	2.1	-0.2–4.5
Diabetes	32	13.2	8.9–17.5	87	5.5	4.3–6.6	2.4	1.6–3.5	1.9	1.3–2.9	12.3	3.6–21.5
Domestic injuries	23	8.6	5.2–12.0	98	5.9	4.7–7.1	1.5	0.9–2.3	1.4	0.9–2.3	4.9	-2.7–13.1

Men

	Energy poverty (n = 186)			No energy poverty (n = 1443)								
	c	%	95%CI	c	%	95%CI	cPR	95%CI	aPR	95%CI	PAR%	95%CI
Poor self-reported health	57	30.1	23.5–36.8	226	15.2	13.3–17.1	2.0	1.5–2.6	2.0	1.6–2.6	10.1	5.5–15.0
Poor mental health	57	33.9	26.7–41.1	195	14.0	12.2–15.8	2.4	1.9–3.1	2.1	1.6–2.8	12.5	7.1–18.2
Poor quality of life	115	61.8	54.8–68.9	581	39.5	36.9–42.0	1.6	1.4–1.8	1.6	1.4–1.8	5.9	3.8–8.2
High blood pressure	39	21.3	15.3–27.3	274	18.8	16.7–20.8	1.1	0.8–1.5	1.4	1.0–1.9	3.4	-0.2–7.2
Myocardial infarction and/or stroke	13	6.6	3.1–10.1	71	4.6	3.6–5.7	1.4	0.8–2.5	1.6	0.9–2.9	5.3	-2.5–13.9
Asthma	20	10.7	6.2–15.1	86	6.1	4.9–7.4	1.7	1.1–2.8	1.6	1.0–2.7	6.6	-0.9–14.7
Chronic bronchitis	12	6.3	2.8–9.8	57	3.9	2.9–4.9	1.6	0.9–3.0	1.7	0.9–3.2	7.6	-2.0–18.4
Arthrosis, arthritis, rheumatism	31	16.9	11.4–22.4	165	11.0	9.4–12.6	1.5	1.1–2.2	1.9	1.3–2.7	7.8	2.7–13.4
Allergies	43	24.0	17.7–30.3	200	14.2	12.4–16.1	1.7	1.3–2.3	1.7	1.2–2.2	6.9	2.0–12.0
Migraine or frequent headaches	36	19.3	13.6–25.0	126	9.0	7.5–10.5	2.2	1.5–3.0	1.9	1.3–2.8	10.5	3.6–17.6
Overweight	109	58.4	51.2–65.5	760	52.2	49.6–54.8	1.1	1.0–1.3	1.1	0.9–1.3	1.0	-0.7–2.7
Diabetes	13	6.5	3.1–10.0	102	6.9	5.6–8.2	1.0	0.5–1.7	0.9	0.5–1.7	-1.1	-7.3–5.7
Domestic injuries	15	8.3	4.2–12.3	45	3.0	2.1–3.9	2.7	1.5–4.8	2.7	1.5–4.7	16.8	4.6–30.0

N = sample size; c = number of cases with the health outcome; CI: Confidence interval.

3.2. *EP and the use of health services and medication*

Table 3 shows the prevalence of each of the 13 health services and medication use indicators among people with and without EP, as well as the respective crude and adjusted PR and PAR%. We observed a generalised increase in the use of general health services, such as visits to emergency services, primary care physicians, nurses and hospitalisation in both sexes. Specialised mental health services were those most strongly associated with EP, especially in women with EP, who, compared with women without EP, reported having seen a psychiatrist 2.5 (95% CI: 1.6–3.9) times more frequently and a psychologist 3 (95% CI: 2.0–4.6) times more frequently in the last 12 months. In men, the aPR (95% CI) were 2.3 (1.4–3.9) and 1.7 (0.9–3.3) respectively. Women and men living in EP also used social work services significantly more than women and men not experiencing EP: 2.7 (95% CI: 1.7–4.1) and 3.6 (95% CI: 2.2–6.0) times more, respectively. These results translated into a significant burden on health services. We observed high PAR% estimates for numerous indicators, such as social work visits, with 20.4% (95% CI: 9.7–31.6) of the visits in women and 24.4% (95% CI: 11.9–37.3) of those in men being attributable to EP. Of note, even with this higher use of health services, women with EP reported unmet needs 1.5 (95% CI: 1.2–1.9) times more frequently and men 1.2 (95% CI: 0.9–1.6) times more frequently than people without EP.

Medication use in the last 2 days was higher in women with EP than in those without. The strongest associations were found for allergy medication (aPR [95%CI]: 2.5 [1.5–4.3]) and antibiotics (aPR [95%CI]: 2.8 [1.5–5.0]). In men, EP was strongly associated with asthma medication (aPR [95%CI]: 2.2 [1.1–4.3]) and psychotropic drugs (aPR [95% CI]: 2.0 [1.4–2.8]).

4. Discussion

4.1. *Main findings*

This study shows that EP is a major public health problem in the urban contexts of southern Europe, such as the city of Barcelona. We found that Barcelona has above EU average rates of EP and with an unequal distribution, affecting above all people with a more disadvantaged social class, people born in LMI countries, and women aged 65 years and older. The results show a strong association in women and men between EP and worse health status, as well as with a higher use of health services and medication. Because of the combination of the high prevalence of EP and its strong association with poor health outcomes, EP has a substantial impact on health and health services at the population level.

4.2. *Interpretation of results*

We found a strong association between EP and poor self-reported health. This is consistent with 3 previous European studies that have also reported this association in southern European countries (Bosch et al., 2019; Oliveras et al., 2020; Thomson et al., 2017). So far, almost all the evidence of the negative effects of EP on health in southern European countries is based on European studies at the country level that have mainly used this indicator. The present study also shows a strong association between EP and poor mental health. In a previous European study, we found that the effects of EP were stronger on mental health than on self-reported health (Oliveras et al., 2020). Some Anglo-Saxon studies have discussed the multiple, and sometimes short-term, mechanisms and pathways through which EP affects mental health, which

Table 3
Prevalence of health services and medication use indicators among people with and without energy poverty, crude prevalence ratios (cPR), adjusted prevalence ratios (aPR) and adjusted population attributable risk percent (PAR%), stratified by sex. Barcelona, 2016.

Women

	Energy poverty (n=244)			No energy poverty (n=1603)								
	c	%	95%CI	c	%	95%CI	cPR	95%CI	aPR	95%CI	PAR%	95%CI
Use of health services in the last 12 months												
Emergency services*	68	27.4	21.7 - 33.0	234	14.7	13.0 - 16.5	1.9	1.5 - 2.4	1.6	1.3 - 2.1	8.1	3.2 - 13.2
Hospitalisations	36	14.7	10.2 - 19.2	204	12.6	10.9 - 14.2	1.2	0.8 - 1.6	1.1	0.8 - 1.5	1.0	-4.0 - 6.1
Primary health care	216	88.0	83.7 - 92.2	1252	77.9	75.8 - 79.9	1.1	1.1 - 1.2	1.1	1.0 - 1.2	1.2	0.4 - 2.0
Nursing	92	36.8	30.7 - 42.9	407	25.4	23.2 - 27.6	1.4	1.2 - 1.7	1.4	1.1 - 1.7	4.7	1.4 - 8.1
Psychiatry	30	12.3	8.1 - 16.4	76	4.9	3.8 - 5.9	2.5	1.7 - 3.8	2.5	1.6 - 3.9	15.9	6.4 - 25.9
Psychology	30	12.3	8.1 - 16.5	83	5.2	4.1 - 6.3	2.4	1.6 - 3.5	3.0	2.0 - 4.6	17.9	8.9 - 27.5
Social Work	32	13.5	9.1 - 17.9	71	4.4	3.4 - 5.4	3.1	2.0 - 4.6	2.7	1.7 - 4.1	20.4	9.7 - 31.6
Unmet medical need	62	26.9	21.2 - 32.7	253	15.8	14.0 - 17.5	1.7	1.3 - 2.2	1.5	1.2 - 1.9	6.9	2.2 - 11.7
Medication use in the last 2 days												
Painkillers	129	51.5	45.1 - 57.9	594	36.6	34.2 - 39.0	1.4	1.2 - 1.6	1.3	1.1 - 1.5	4.2	1.7 - 6.7
Allergy medication	21	8.1	4.7 - 11.4	54	3.2	2.4 - 4.1	2.5	1.5 - 4.1	2.5	1.5 - 4.3	16.6	4.9 - 29.0
Antibiotics	17	7.2	3.8 - 10.6	43	2.7	1.9 - 3.5	2.7	1.5 - 4.6	2.8	1.5 - 5.0	18.6	5.4 - 32.6
Asthma medication	15	5.9	3.0 - 8.9	42	2.6	1.8 - 3.4	2.3	1.3 - 4.1	1.9	1.0 - 3.5	12.4	-1.0 - 26.9
Psychotropic drugs	80	31.6	25.7 - 37.4	295	18.0	16.1 - 19.8	1.8	1.4 - 2.2	1.6	1.3 - 2.0	7.8	3.5 - 12.2

Men

	Energy poverty (n=186)			No energy poverty (n=1443)								
	c	%	95%CI	c	%	95%CI	cPR	95%CI	aPR	95%CI	PAR%	95%CI
Use of health services in the last 12 months												
Emergency services*	36	19.3	13.6 - 25.0	135	9.4	7.9 - 10.9	2.1	1.5 - 2.9	1.9	1.3 - 2.7	9.7	3.4 - 16.4
Hospitalisations	31	16.5	11.1 - 21.8	147	10.0	8.4 - 11.5	1.6	1.2 - 2.4	1.7	1.2 - 2.4	7.0	1.3 - 13.0
Primary health care	150	81.0	75.4 - 86.7	1032	71.3	68.9 - 73.6	1.1	1.1 - 1.2	1.1	1.0 - 1.2	1.4	0.4 - 2.4
Nursing	48	25.6	19.3 - 31.9	281	19.3	17.3 - 21.4	1.3	1.0 - 1.7	1.4	1.0 - 1.8	3.7	0.0 - 7.5
Psychiatry	21	10.7	6.3 - 15.1	67	4.7	3.6 - 5.8	2.3	1.4 - 3.6	2.3	1.4 - 3.9	13.1	3.2 - 23.5
Psychology	11	5.6	2.4 - 8.8	54	3.8	2.8 - 4.8	1.5	0.8 - 2.8	1.7	0.9 - 3.3	6.8	-3.1 - 17.9
Social work	25	13.7	8.7 - 18.8	49	3.3	2.4 - 4.2	4.1	2.6 - 6.6	3.6	2.2 - 6.0	24.4	11.9 - 37.3
Unmet medical need	43	23.4	17.3 - 29.6	240	16.8	14.9 - 18.8	1.4	1.0 - 1.9	1.2	0.9 - 1.6	2.6	-1.7 - 7.1
Medication use in the last 2 days												
Painkillers	85	45.7	38.4 - 52.9	388	26.9	24.5 - 29.2	1.7	1.4 - 2.0	1.6	1.3 - 1.9	6.9	3.8 - 10.1
Allergy medication	11	5.7	2.4 - 9.0	49	3.5	2.5 - 4.4	1.6	0.9 - 3.1	1.4	0.7 - 2.8	4.7	-5.2 - 15.8
Antibiotics	7	3.5	0.9 - 6.0	55	3.8	2.8 - 4.8	0.9	0.4 - 2.0	0.9	0.4 - 2.1	-0.9	-9.5 - 8.8
Asthma medication	10	5.3	2.1 - 8.6	40	2.6	1.8 - 3.4	2.0	1.0 - 4.0	2.2	1.1 - 4.3	11.4	-0.8 - 24.9
Psychotropic drugs	37	19.7	13.9 - 25.5	162	10.8	9.2 - 12.4	1.8	1.3 - 2.5	2.0	1.4 - 2.8	9.5	3.8 - 15.4

n= sample size; c=number of cases with the health outcome; CI: Confidence intervals; *Two or more visits to emergency services.

may also apply to the southern European context. Some examples are chronic thermal discomfort, worries about energy bills, the experience of falling into debt (or fear of it) and the absence of any solution or sense of control over the problem (Anderson et al., 2012; Gilbertson et al., 2012; Liddell & Guiney, 2015; Tod et al., 2012). In southern European countries, the increase in housing insecurity and household financial debt in the wake of the economic crisis, which are strongly related to EP and are also associated with poorer physical and mental health, could contribute to the association observed between EP and poor self-reported and mental health.

Due to their strong association with cold temperatures, cardiovascular and respiratory diseases have been the most studied EP health effects to date (Marmot Review Team, 2011). We also found a relevant association between EP and high blood pressure, myocardial infarction, stroke, asthma and chronic bronchitis. Although winters are milder in southern Europe, respiratory function appears to be impaired at temperatures below 16 °C, while the cardiovascular system becomes impaired at temperatures below 12 °C (Marmot Review Team, 2011). Furthermore, the housing stock in southern European countries is characterised by low energy efficiency and the lack of adequate heating systems (Bouzarovski & Tirado Herrero, 2017), which can result in cold housing in mild winters. In Barcelona, for example, the average monthly temperature during the winter of 2016 fluctuated between 9.7 and 13.1 °C (Meteorològic de Catalunya, 2016) and, according to the census, 48.2% of inhabitants had no central or individual heating systems (Ajuntament de Barcelona, 2001). Moreover, the risk of harm is greater at lower temperatures, but also during longer periods of exposure to cold indoor temperatures. This could explain the stronger association between EP and cardiovascular and respiratory diseases that we found in women. Due to the sexual division of work, women still bear the brunt of the burden of care and housework, tasks that are energy intensive and involve spending more time at home, whereas men spend much more time in activities outside the home. This could play a particularly important role in southern European countries, which are characterised by traditional family models and low levels of support for female participation in the labour force (Artazcoz et al., 2016).

Furthermore, cardiovascular and respiratory problems have also been linked to warm temperatures (Oudin Åström et al., 2011). According to the data in this study, 12.1% of the women and 10.1% of the men living in Barcelona could not afford to maintain their dwelling at an adequate temperature during the warm months. In addition, 52.4% of the women and 50.4% of the men did not have air conditioning or did not use it when needed (data not shown). This finding is consistent with a European study showing that, although countries in southern Europe have the highest rates of air conditioning, they had higher percentages of the population living in a dwelling that was not comfortably cool during summertime (Thomson et al., 2019). We believe that the association between EP and cardiovascular and respiratory diseases in Barcelona is also influenced by the high vulnerability of households to heat. This can be especially critical in the context of extreme heat events, which are expected to become more common, more severe and longer-lasting due to climate change (Jessel et al., 2019).

Previous studies have shown that EP can exacerbate existing conditions (Marmot Review Team, 2011). In this study, we found a higher prevalence of arthrosis, arthritis or rheumatism, allergies, and migraine or frequent headaches in women and men living in EP. Although this is a cross-sectional study and we cannot assess changes over time, those are all conditions that can remain stable, but can be triggered by cold, heat, damp, mould or stress, common situations in energy poor households. In people living in EP, these conditions may become more common and therefore more frequently self-reported as chronic morbidity.

EP has also been linked to food insecurity, due to the constant dilemma of resource allocation and difficulties in conserving and cooking food (Hernández, 2016; Nord & Kantor, 2006). In the case of Barcelona, data from the 2016 health survey reveal that 35.9% of people with EP experienced food insecurity compared with 4.9% of people without EP (data not shown). Dietary impoverishment and higher consumption of cheap calorific food could explain the greater overweight found in women and men with EP, as well as the higher prevalence of diabetes in energy poor people. The cases of diabetes identified in the survey concerned mainly people with type 2 diabetes, which is usually acquired in adulthood and due to overweight and sedentariness.

As in previous studies, we found an association between EP and domestic injuries, although this finding was statistically significant only in men. It is known that strength and dexterity decrease as temperatures drop, increasing the risk of unintentional injuries (Marmot Review Team, 2011). As well as cold temperatures, both heat and lack of light increase the risk of falls in the elderly (Marmot Review Team, 2011). In addition, people with EP sometimes have to use less safe energy sources or to adapt some consumption behaviours that may also be less safe and increase the risk of domestic injuries. Some examples are cooking with a portable gas stove, heating water for the bath in the kitchen, restricting the use of lights or using candles to light the home, or even irregularly connect to the electricity grid. In Barcelona, firemen have been involved in detecting households experiencing energy poverty since 2017 and have introduced indicators in their regular reports to identify risk situations. In the last 2.5 years, there have been reports of 1100 cases (ara.cat, 2020).

There is little evidence of the effects of EP on the use of health services. Some studies have reported increased emergency respiratory hospital episodes among people with EP aged 65 years and older (Rudge & Gilchrist, 2007) and an increased likelihood of physician visits in people experiencing difficulties in paying fuel bills (Gilbertson et al., 2012). Our study adds new and relevant evidence. The results demonstrate that people with EP more frequently use general health services, such as emergency services, primary health care, nursing and hospitalisations, as well as specialised mental health services. This is consistent with the strong association found between EP and poor mental health. Our study also reveals a higher contact with social workers in people with EP. In the Catalan health system, social workers liaise between health and social services. One of the many tasks of social services is to issue residential exclusion risk reports. These reports prevent suppliers from cutting off water, electricity or gas due to non-payment due to lack of financial resources, as prescribed by the 24/2015 Catalan law of urgent measures to tackle housing and energy poverty emergencies, published on July 29, 2015.

This study also found significantly higher medication use in people living in EP. The importance of this result is that questions about medication use in the 2 days prior to the survey can sometimes be a proxy of acute medical processes. The observed increase in the use of antibiotics and other drugs such as painkillers and asthma medication supports the results of other studies demonstrating that people living in EP are more at risk of infections and minor illnesses such as colds, as well as of experiencing decompensations of their chronic diseases (Marmot Review Team, 2011). A notable finding of the present study was the high medication use in people living in EP. In the 2 days prior to the survey, 31.6% of the women and 19.7% of the men with EP had used psychotropic drugs, while for painkillers these percentages increased to 51.5% in women and 45.7% in men.

A final point is that EP can increase existing health inequalities. This study demonstrates that, as with other material resources, access to domestic energy services and adequate energy levels differ by several axes of inequality such as sex, social class, age and region of birth, reducing the opportunities for good health. According to the data in this study, women without EP generally have worse health outcomes than men without EP. This gender gap is further exacerbated among women and men experiencing EP. Furthermore, some social groups may be particularly vulnerable to EP, such as people with no alternative but to become squatters (an increasing problem in Barcelona) or children. This groups are not represented in this study and further research should try to include data from these invisibilized groups.

4.3. Methodological considerations, strengths and limitations

EP is a complex multidimensional phenomenon caused by multiple factors that interact with each other and configure different realities. EP can be considered as part of a set of widely heterogeneous emerging situations of inequality and precariousness that go beyond the traditional framework of poverty (Subirats et al., 2005). There is growing concern that income-based poverty indicators are ineffective at identifying population groups that are most at risk of being unable to meet their basic needs. A good alternative may be material hardship indicators, such as those of EP (Beverly, 2001). However, even though EP cannot be explained by income poverty alone, income remains one of its main causes and is also strongly related to health status; consequently, it can act as a confounder in the association between EP and health. In this study, we used social class as a proxy of socioeconomic position and adjusted the models by this single variable of socioeconomic position. We saw how EP is still associated with worse health and higher use of healthcare and medication, independently of social class. Even so, a single measure of socioeconomic position cannot capture the entirety of its effect on health (Galobardes et al., 2006) and there probably remains an unexplained aspect of the association found between EP and health and healthcare and medication use. To ensure that income is not the only EP driver that explains the association found between EP and negative health outcomes, we conducted a sensitivity analysis and repeated all analyses in a subgroup of people with greater financial difficulties, identified through their self-reported inability to meet an unforeseen expenditure of €750 with their own resources. The analysis showed how EP disproportionately affects low-income households, increasing the percentage of people living in EP in this subgroup to almost 40% (S1). We observed that, in general the association between EP and the studied health indicators decreased slightly, in some cases losing its statistical significance, but the PAR% increased (S2–S3). By contrast, we did not adjust the final models by country of birth because, although people born in LMI experienced much more EP, this result did not modify the association with health status and the use of healthcare and medication.

Studying EP as a distinct condition of deprivation has clear advantages. On the one hand, it helps to identify the more structural and systemic factors that go beyond low-income, such as an inefficient and substandard housing stock and the unfair and abusive energy models (Middlemiss & Simcock, 2019). On the other hand, it can be used to allow better understanding of the circumstances and mechanisms through which it affects health. In this study, we aimed to study health effects separately in households that could not afford to maintain their dwellings at an adequate temperature during the cold months and in those that could not do so during the warm months. We finally analysed these groups together because we found an overlap in 68% of the cases. This indicates that, although It is true that cold and hot homes are 2 different manifestations of EP that can affect health through distinct mechanisms, they share many of the root causes such as low energy efficiency of dwellings or high energy prices. Therefore, the interventions needed to address the difficulty of keeping the home at an adequate temperature are the same.

This study analysed the effects of EP on health and healthcare and medication use in Barcelona, a southern European urban setting. Although Southern European countries share many similarities in the structural determinants of EP (Recalde et al., 2019), other factors may affect the extrapolation of EP health implications to similar settings. The results may also not apply to rural contexts, as there are substantial differences between urban and rural contexts. For example, in cities, the heat island effect and a physical context with less green space can aggravate the effects of EP in the warmer months, while in some rural areas, winters are colder, while larger and isolated houses can be more difficult to keep at an adequate temperature. There is a need to gain deeper insight into how EP and its effects on health are embedded in the rural contexts of southern Europe. However, urban spaces and global cities like Barcelona are privileged settings for studying complex realities and implementing and evaluating innovative and comprehensive interventions.

Finally, is should be notice that this is a cross-sectional study and therefore does not allow us to prove causality or rule out reverse causality. Nevertheless, one of the main strengths of this study is that the inclusion of questions about EP in a population-based health survey allowed us to study the association of EP with multiple indicators of health status and use of health services and medication. Although some of the indicators could be related to each other and this has not been studied in depth, the inclusion of all these indicators allows us to state more robustly that EP is associated with poorer health and to quantify the strength of this association. Moreover, the results obtained in this study are representative at the city level. Thus, we were able to estimate the burden of poor health and health services use made on the city by EP.

5. Conclusions

EP is also a major public health problem in Barcelona, a southern European urban context. This study observed a high prevalence of EP and a strong association between EP and worse health status and higher use of health services and medication. Underprivileged social groups, such as people from disadvantaged social classes, people born in LMI countries and older women, suffered disproportionately from EP, which can be one of the mechanisms explaining health inequalities. Southern European countries should therefore include EP in their political priorities to address the structural causes of this public health problem and minimise its unfair and avoidable health effects.

Declarations of interest

None.

Funding

The study is part of the PENSA Project ("Pobreza energética y salud desde multiples perspectivas: análisis individual, geográfico y temporal"), which received a research grant from the Carlos III Institute of Health, Ministry of Economy and Competitiveness (Spain), awarded on the 2015 call under the Health Strategy Action 2013–2016, within the National Research Program oriented to Societal Challenges, within the Technical, Scientific and Innovation Research National Plan 2013–2016, with reference PI15/02006, co-funded with European Union ERDF funds (European Regional Development Fund)". LO was supported by a Rio Hortega grant (CM19/00184 – Contratos Rio Hortega/ Fondo Social Europeo) from the Carlos III Institute of Health. The funders were not involved in the research and preparation of the article, including study design; collection, analysis, and interpretation of data; writing of the article; nor in the decision to submit it for publication.

Ethical statement

The authors declare no conflict of interest.

This paper has not previously been published and no similar paper is in press or under review elsewhere.

All authors meet authorship criteria and have contributed as specified below.

CRediT authorship contribution statement

Laura Oliveras: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Lucia Artazcoz:** Conceptualization, Methodology, Writing - review & editing. **Carme Borrell:** Conceptualization, Methodology, Writing - review & editing. **Laia Palència:** Conceptualization, Methodology, Writing - review & editing. **María José López:** Conceptualization, Methodology, Writing - review & editing. **Mercè Gotsens:** Conceptualization, Methodology, Writing - review & editing. **Andrés Peralta:** Conceptualization, Methodology, Writing - review & editing. **Marc Marí-Dell'Olmo:** Conceptualization, Methodology, Writing - review & editing, Supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2020.100665.

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5.3. Article 3

Oliveras L, Borrell C, González-Pijuan I, Gotsens M, López MJ, Palència L, Marí-Dell'Olmo M. [The association of energy poverty with health and wellbeing in children in a Mediterranean city](). Internationa Journal of Environmental Research and Public Health. 2021;18(11):5961.

International Journal of
Environmental Research and Public Health

MDPI

Article

The Association of Energy Poverty with Health and Wellbeing in Children in a Mediterranean City

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Abstract: Children have been identified as being particularly vulnerable to energy poverty (EP), but little empirical research has addressed the effect of EP on children's health and wellbeing, especially in southern Europe. In this work we aimed to provide an in-depth description of the distribution of EP by sociodemographic, socioeconomic and housing characteristics, as well as to analyse the association between EP and health and wellbeing in children in Barcelona. We performed a cross-sectional study using data from the Barcelona Health Survey for 2016 (n = 481 children under 15 years). We analysed the association between EP and health outcomes through prevalence differences and prevalence ratios (PR) and their 95% confidence interval (CI), using Poisson regression models with robust variance. In Barcelona, 10.6% of children were living in EP and large inequalities were found by sociodemographic, socioeconomic and housing characteristics. EP was strongly associated with poor health in children (PR (95% CI): 7.70 (2.86, 20.72)). Living in EP was also associated with poor mental health (PR (95% CI): 2.46 (1.21, 4.99)) and with more cases of asthma (PR (95% CI): 4.19 (1.47, 11.90)) and overweight (PR (95% CI): 1.50 (1.05, 2.15)) in children. It is urgent to develop specific measures to avoid such serious and unfair health effects on children.

Keywords: energy poverty; fuel poverty; health; health inequalities; social determinants of health; children; southern Europe; urban

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Citation: Oliveras, L.; Borrell, C.; González-Pijuan, I.; Gotsens, M.; López, M.J.; Palència, L.; Artazcoz, L.; Marí-Dell'Olmo, M. The Association of Energy Poverty with Health and Wellbeing in Children in a Mediterranean City. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5961. https://doi.org/10.3390/ijerph18115961

Academic Editor: Paul B. Tchounwou

Received: 20 April 2021
Accepted: 30 May 2021
Published: 2 June 2021

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1. Introduction

Housing is a key social determinant of health [1]. Children are especially vulnerable to the effects of inadequate housing, because they spend more time at home and because a safe and adequate home is essential for their favourable development and physical and emotional wellbeing [2]. Adequate housing is not just four walls. It involves, among many other factors, basic supplies to carry out reproductive and caregiving activities, such as cooking or cleaning, and to achieve thermal comfort and the use of appliances and other electronic devices enabling effective participation in society [3]. If a household cannot secure a materially and socially required level of energy services, there is a situation of energy poverty (EP) [4].

EP is a major public health problem in the European Union (EU), affecting 9% of the population in 2016 [5]. EP is gaining increasing academic and policy attention in southern European countries because its rates are above the EU average (32.6% in Greece, 24.8% in Portugal or 13.4% in Spain in 2016) [5] and because of the emerging need for space cooling to adapt to climate change and increasingly high temperatures [6]. In Barcelona, for example, 12.4% of the population cannot afford to maintain their dwellings at an adequate temperature during the cold and/or warm months. This average value, however, hides much higher percentages in specific social groups, such as women born in low- and middle-income countries, where the percentage of EP is as high as 24% [7]. Like other social determinants of health, EP follows the classic lines of social stratification and is rarely an isolated problem. It tends to coexist with financial difficulties, unemployment and other material hardship [8,9]. Therefore, specific sociodemographic, socioeconomic and housing characteristics may be related to a disproportionate burden of EP [10]. For example, higher EP rates have been found in single-parent families, families living in market-price rented accommodation and those with food or housing insecurity [8,10–12].

Several studies have shown that EP negatively affects people's health and wellbeing [5,13–17]. Although children have been identified as a particularly vulnerable population group, little empirical research has addressed how, specifically, they are affected by EP, especially in southern Europe. According to the scarce existing literature, the main negative effects of EP on infants and young children concern physical health. In this age range, some studies suggest that EP is associated with a higher risk of health problems, mainly respiratory problems, greater health services use and worse disease course, with more recurrences [18–20]. Children living in EP are also at higher risk of under-nutrition or being overweight due to poor nutrition resulting from austerity in expenditure control, purchase of obesogenic products that are usually cheaper or, in more extreme cases, the inability to cook or preserve food [21,22]. Moreover, irregular connection of supplies or the use of alternative heating sources may increase the risk of domestic accidents such as burns or carbon monoxide inhalation [23,24]. EP and its effects on physical health can in turn affect children's wellbeing and school performance [2,25]. In contrast, among adolescents, EP appears to primarily affect mental health. Difficulties in finding the needed privacy and personal space at home, feeling unhappy with their families and poorly cared for, being afraid of bullying and spending more time in public spaces such as parks or shopping precincts are some of the described effects of EP that can affect the mental health of adolescents and can also increase risk behaviours (e.g., early alcohol and tobacco abuse) [13,15,26]. Recently, a study in China showed that EP had a negative impact on subjective well-being in adolescents aged 10–15 years and suggested that academic performance might be one of the most important mediating mechanisms [27]. Finally, families' difficulties in paying their utility bills and the accumulation of debt can also affect the mental health of children and adolescents through the influence of economic stress on parental mental health [28], couple interaction and parenting [29].

This study was motivated by the lack of empirical data on how EP affects families differently and its effects on the health and wellbeing of children in southern Europe. Therefore, the aim of this study was to provide an in-depth description of the distribution of EP by sociodemographic, socioeconomic and housing characteristics, as well as to analyse the association between EP and health and wellbeing in children in Barcelona in 2016.

2. Materials and Methods

2.1. Design, Information Source and Study Population

We performed a cross-sectional study using data from the Barcelona Health Survey for 2016. This survey covers a representative sample of the non-institutionalised population in the city and includes a specific questionnaire for people under the age of 15 years. This under-15 s population includes infants through adolescents, and will henceforth be referred to as children. This study includes all the children who participated in the survey, which represents a sample size of 481 children, sufficient to obtain representative population estimates of percentages with a precision of +/− 4.5% [30]. The questionnaire was completed by the child's usual caregiver.

2.2. Study Variables

2.2.1. Health and Wellbeing

To assess general health, we used caregiver-reported child health and we dichotomised it into two categories: good health (excellent, very good or good) and poor health (fair or poor) [31]. Mental health was measured using the Strengths and Difficulties Questionnaire (SDQ) for ages 4–17 years. We analysed the total difficulties score, as well as the individual scales of conduct problems, hyperactivity, emotional problems and peer problems. We dichotomised the five scales using the borderline cut-points [32]. We also studied health-related quality of life (HRQoL) for ages 6–14 years through the Kidscreen-10. This is a 10-item questionnaire that provides a Rashed-scaled single score where higher scores indicate better HRQoL [33,34]. Finally, we also analysed two health outcomes that, according to the literature, can be significantly affected by EP, namely asthma and overweight [19,35]. Asthma was assessed through a chronic morbidity checklist, where the caregivers were asked, among others things, if the children suffered from asthma. Overweight was calculated from the height and weight provided by the cargiver. Overweight was defined as a BMI-for-age greater than 1 standard deviation above the WHO Growth Reference median [36,37].

2.2.2. Energy Poverty

The main EP variable used in this study was constructed from the following two questions: Can the household afford to keep the home at an adequate temperature during the cold months? Can the household afford to keep the home at an adequate temperature during the warm months? EP was considered when the caregiver reported that the household could not afford to keep the home at an adequate temperature during the cold and/or warm months. However, to assess the overlap between different dimensions of EP, the socioeconomic and household conditions variables (described below) also included other primary and secondary EP indicators [38].

2.2.3. Sociodemographics

We included sex, age, the parents' country of birth and household composition and we categorize the variables as defined hereafter. The parents' country of birth was classified into high-income (HI) and low- and middle-income (LMI) countries according to the 2018 World Bank classification [39]. We then classified children into three groups: both parents from HI countries; one from HI and the other from LMI countries; and both from LMI countries. Households were categorised into four groups, single-parent, extended single-parent when the parent and children lived with more people, two-parent and extended two-parent households.

2.2.4. Socioeconomics

We included social class, the ability of the household to afford an unforeseen expenditure of €750 with their own resources (based on one of the primary indicators to measure material deprivation used by the European Commission (European Statistics on Income and Living Conditions [40,41]), arrears on utility bills in the last 12 months (primary EP indicator), food insecurity and housing tenure. We categorize the variables as defined hereafter. Children were assigned the most privileged social class among the parents, based on their current or last occupation. Social class was dichotomised into non-manual and manual class [42]. To measure food insecurity, we used an adaptation of the 6-item US Household Food Security Survey Module, which has been validated for the Hispanic population [43]. Housing tenure was categorised into five categories: paid property, property paying mortgage, rent at market price, social renting and other (re-renting of part of the dwelling, squatting and cession by family members, social services or non-governmental organisations).

2.2.5. Housing Conditions Related to EP

We included three dichotomous variables, which are also secondary EP indicators: dwelling with a leaking roof, damp walls, floors or foundations, or rot in window frames or floors; dwelling without means of heating or with central heating or room-heating appliances, but not used when necessary; and dwelling without an air conditioner or with an air conditioner, but not used when necessary.

For more information on the variables used, as well as to check the specific questions, please consult the Barcelona Health Survey manual, which also includes the complete questionnaire [30].

2.3. Data Analysis

First, we categorized the different sociodemographic, socioeconomic and housing conditions variables as detailed in the previous section and we described the sample according to theses variables. Then, we calculated the percentage of EP and its 95% confidence interval (CI) for the total population, as well as by sociodemographic, socioeconomic and housing condition variables and we used the Pearson chi-square test with the second-order Rao-Scott correction to assess differences in EP percentage within categories of each variable [44]. Subsequently, we obtained the prevalence of health indicators among children with and without EP. Finally, we used Poisson regression models with robust variance to assess absolute and relative differences of the prevalence of health indicators among children with and without EP [45]. To do this, we calculated prevalence differences (PD) and prevalence ratios (PR) and their 95%CI, respectively. In the case of the Kidscreen, the only continuous health outcome, we calculated means and their 95%CI for both groups and their association with EP was studied using linear models. EP often occurs in a wider context of material hardship and disadvantaged economic situation, which can also affect health and wellbeing during childhood. For this reason, we calculated raw PD and PR and also adjusted by social class, as a proxy of the family's socioeconomic position. Adjusted PD were calculated with the adjusted prevalence obtained from the same Poisson regression model through the marginal standardisation method [46]. In all the analyses we took into consideration the complex sample design. We used the R software (version 3.6.3, R Foundation for Statistical Computing, Viena, Austria).

3. Results

3.1. EP by Sociodemographic and Socioeconomic Characteristics and Housing Conditions

Table 1 describes the sociodemographic and socioeconomic characteristics and housing conditions of the sample, as well as the percentage of EP according to these characteristics and conditions. In Barcelona, 10.6% of children lived in EP. The most affected age group was 4–11 year-olds, in which the percentage of children living in EP was 13%. There was a clear gradient in the percentage of children living in EP according to the parents' country of birth, being 6.6% in children with both parents born in HI countries, 18.2% in those with one parent born in an HI country and another in an LMI country and 20.7% in those with both parents born in a LMI country. Point estimates also suggested a gradient in the percentage of EP in relation to household composition. Single-parent families were worst affected, and especially if they were extended single-parent families.

Table 1. Description of the sample and percentages of energy poverty by sociodemographic and socioeconomic characteristics and housing conditions. Barcelona 2016.

	Total		Energy Poverty *			
	n	%	Cases	%	95%CI	*p*-Value †
Total	481	100	48	10.6	(7.7, 13.4)	
Sociodemographic characteristics						
Sex						
Girl	240	48.7	21	9.2	(5.4, 12.9)	0.367
Boy	241	51.3	27	11.9	(7.5, 16.2)	
Age (years)						
0–3	89	17.9	5	6.3	(1.1, 11.4)	0.091
4–11	284	61.7	35	13.0	(8.8, 17.1)	
12–14	108	20.3	8	7.0	(2.3, 11.8)	
Parents country of birth						
Both HI	339	70.6	21	6.6	(3.7, 9.6)	**<0.001**
One HI, one LMI	38	7.6	6	18.2	(5.0, 31.4)	
Both LMI	103	21.7	21	20.7	(12.7, 28.7)	
Household composition						
Single-parent	43	8.6	5	11.4	(1.8, 20.9)	0.553
Extended single-parent	39	7.9	6	16.4	(4.3, 28.5)	
Two-parents	350	72.8	31	9.4	(6.2, 12.7)	
Extended two-parents	49	10.7	6	13.2	(3.1, 23.3)	
Socioeconomic characteristics						
Social class						
Non-manual laborer	341	71.2	13	4.5	(1.9, 7.1)	**<0.001**
Manual laborer	134	28.8	34	25.2	(17.7, 32.7)	
Can afford unforeseen expenditure of 750€						
Yes	336	70.7	6	2.3	(0.3, 4.4)	**<0.001**
No	137	29.3	42	30.8	(22.9, 38.6)	
Arrears on utility bills in the last 12 months **						
No	337	82.7	23	7.3	(4.2, 10.3)	**<0.001**
Yes	70	17.3	22	32.7	(21.5, 43.9)	
Food insecurity						
No	432	89.9	22	5.7	(3.3, 8.2)	**<0.001**
Yes	49	10.1	26	53.4	(39.1, 67.6)	
Tenure status						
Paid property	100	20.7	1	1.0	(−1.0, 3.0)	**<0.001**
Property paying mortgage	169	36.2	12	6.9	(3.0, 10.7)	
Rent at market price	184	39.1	30	17.6	(11.7, 23.5)	
Social renting	5	1.1	0	0.0	(0.0, 0.0)	
Other	13	2.9	5	40.7	(14.0, 67.5)	
Housing conditions						
Leaks, dampness in walls, floors, ceilings or foundations, or rot in floors, window frames or doors						
No	432	89.7	37	9.1	(6.2, 11.9)	**0.003**
Yes	49	10.3	11	23.5	(11.3, 35.7)	
No means of heating or central heating or room-heating appliances, but not used when necessary						
No	444	92.5	35	8.3	(5.6, 11.0)	**<0.001**
Yes	35	7.5	13	38.5	(22.1, 54.9)	
No air conditioner or air conditioner, but not used when necessary						
No	251	52.2	2	0.9	(−0.4, 2.1)	**<0.001**
Yes	228	47.8	46	21.2	(15.6, 26.7)	

* Three missing values; ** 74 missing values; *n* = sample size; cases: number of children with EP; 95%CI: 95% confidence interval; HI: high-income; LMI: low- and middle-income; †: Pearson chi-square test with the second-order Rao-Scott correction, differences are considered statistically significant if *p*-value is less than 0.05 (marked in bold).

The most significant differences in the percentage of EP were related to the socioeconomic situation. For example, the percentage of EP in households unable to afford an unforeseen expenditure of €750 with their own resources was 30.8%, compared with 2.3% in those that could. The percentage of EP in families with food insecurity was 53.4%. We also found differences according to tenure, where the EP percentage was 1% in paid-ownership households and 17.6% in market-rate renting households. Finally, there was a strong overlap between different dimensions of EP: 32.7% of households with arrears on utility bills in the last 12 months also lived in dwellings with inadequate temperatures.

3.2. EP and Children's Health and Wellbeing

Table 2 shows the prevalence of health and wellbeing outcomes among children with and without EP, as well as the respective absolute (PD) and relative (PR) differences. Children living in EP had 7.70 (95%CI: 2.86, 20.72) times more poor health than those without EP and the respective PD was 12.2%. EP was also associated with poor mental health (PD: 11.6% and PR [95%CI]: 2.46 [1.21, 4.99]) and the most affected dimensions were peer (PD: 8.9% and PR [95%CI]: 2.48 [1.09, 5.63]) and emotional (PD: 8% and PR [95%CI]: 1.70 [0.86, 3.34]) problems. Children living in EP also had lower HRQoL, with an average of 2.57 points less in the Kidscreen. The prevalence of asthma (10.3% vs. 2.5%) and overweight (44.4% vs. 29.6%) was also higher in children living in EP, specifically, it was 4.19 (95%CI: 1.47, 11.90) and 1.50 (95%CI: 1.05, 2.15) times more frequent than in children without EP, respectively. After adjustment of the models by social class, the association between EP and poor health was consistent and, for the rest of the outcomes examined, children living in EP were still more likely to have poorer results, although the differences were not statistically significant (at the 5% level).

Table 2. Health measures prevalence among children with and without energy poverty and crude and adjusted absolute (prevalence difference—PD) and relative (prevalence ratio—PR) differences. Barcelona 2016.

	Energy Poverty (n = 48)		No Energy Poverty (n = 430)		PD	PR (95%CI)	aPD	aPR (95%CI)
	Cases	% (95%CI)	Cases	% (95%CI)				
Poor health	7	14.0 (4.1, 23.9)	8	1.8 (0.6, 3.1)	12.2	**7.70 (2.86, 20.72)**	10.3	**6.51 (2.45, 17.29)**
Mental health: SDQ for age 4 to 14								
Poor mental health (Total difficulties score)	9	19.6 (7.7, 31.4)	28	8.0 (5.1, 10.8)	11.6	**2.46 (1.21, 4.99)**	6.5	1.78 (0.91, 3.51)
Conduct problems	9	19.7 (7.8, 31.6)	49	14.2 (10.5, 17.9)	5.5	1.39 (0.72, 2.69)	1.1	1.08 (0.56, 2.08)
Hyperactivity	7	16.6 (5.1, 28.0)	42	12.2 (8.7, 15.7)	4.4	1.36 (0.64, 2.88)	1.2	1.09 (0.53, 2.26)
Emotional problems	9	19.6 (7.8, 31.4)	40	11.5 (8.1, 15.0)	8.0	1.70 (0.86, 3.34)	3.6	1.30 (0.68, 2.51)
Peer problems	7	14.9 (4.4, 25.3)	21	6.0 (3.5, 8.5)	8.9	**2.48 (1.09, 5.63)**	5.6	1.89 (0.81, 4.40)
Health-related quality of life: Kidscreen for age 6 to 14 *		59.7 (54.5, 64.9)		62.3 (60.8, 63.7)		−2.57 (−8.03, 2.89)		−2.61 (−8.94, 3.72)
Asthma	5	10.3 (1.5, 19.2)	11	2.5 (1.0, 3.9)	7.9	**4.19 (1.47, 11.90)**	4.8	2.84 (0.91, 8.80)
Overweight	22	44.4 (29.9, 59.0)	127	29.6 (25.3, 34.0)	14.8	**1.50 (1.05, 2.15)**	6.4	1.21 (0.84, 1.74)

SDQ: Strengths and Difficulties Questionnaire; n = sample size; cases: number of children with the health outcome; 95%CI: 95% confidence interval; PD: crude Prevalence Difference; PR: crude Prevalence Ratio; aPD: social class-adjusted Prevalence Difference; aPR: social class-adjuste Prevalence Ratio; * Kidscreen is the only continuous variable and therefore the values shown are means and their 95%CI among children with and without EP and mean differences and their 95%CI calculated through linear models; in bold statistically significant PR.

4. Discussion

4.1. Main Findings

This study shows a high percentage of EP in families with children in the city of Barcelona, as well as inequalities by sociodemographic and socioeconomic characteristics and housing conditions. We found a strong association between EP and poor health in children. The findings also suggest that EP is associated with poorer mental health, lower HRQoL and with more cases of asthma and overweight in children.

4.2. Interpretation of Results

In this study, 10.6% of children in Barcelona were living in EP. A value well above the EU average according to the most up-to-date data from the EU Energy Poverty Observatory, which indicate that in 2018, 7.3% of the EU population was not able to keep their home adequately warm. This result is consistent with the percentages found in a previous study in adults, reporting that 13.3% of women and 11.3% of men in the city of Barcelona lived in EP [7]. Robustly, both studies show how the axes of inequality that place our society in a hierarchy lead to greater exposure to EP in more vulnerable groups such as people born in LMI countries, those from more disadvantaged social classes and women. In this study, we found no differences between sexes. This may be because women are more affected by EP in adulthood due to gender roles that make them more responsible for reproductive and caregiving activities [47] and to the lesser economic, political and social power that women have in patriarchal societies, which hinders their access to commoditized goods such as energy. These aspects do not yet manifest at such early ages. However, gender differences can be observed related to household composition. As in other studies [18,24], in our study the prevalence of EP was higher in single-parent households, which are generally headed by women (in 85.4% of those in the study population).

We found slightly lower percentages of EP in households with children aged 0–3 years. This may be because infants and toddlers are more vulnerable to extreme variations in ambient temperatures due to their immature physiologic capacity for thermoregulation [21] and parents may choose strategies to cope with EP other than self-rationing of energy consumption. Not being able to keep the house at an adequate temperature is only one of the many expressions of EP. Families who decide to go into debt or reduce other basic needs to pay for energy services and those who are forced to connect irregularly to the distribution network also suffer from EP [11]. These situations often coexist in the same household, as found in this study where families with arrears on utility bills also had greater difficulty in keeping their homes at an adequate temperature. This can place a double burden on health, due to the specific direct effects of each dimension of EP.

Because the current energy model turns basic supplies into a commodity accessible only to those able to pay for them, EP usually occurs in disadvantaged socioeconomic contexts. For this reason and as also shown in this study, EP generally coexists with other economic and material hardship, such as job, food or housing insecurity [8,10,21,22,48]. This interaction of difficulties increasingly results in deteriorating health and makes it more difficult to break out of the circle of precariousness.

The most striking result in this study was the strong association between EP and poor child health. After adjustment for social class, children living in EP had 6.51 times more poor health than children without EP. Very few studies have quantified the magnitude of the association between EP and children's health. A United States study that also examined the association between EP and poor health in children younger than 36 months found that children in households with moderate or severe EP had an adjusted odds of poor health 30% higher than those in households without EP. The authors suggest that there is a low "threshold effect" of EP on children's health, affecting both moderate and severe cases of EP [21].

EP has been found to predominantly affect physical health in children and mental health in adolescents, but there have been few systematic assessments of the mental health effects on children [13]. In this study, we assessed the effects of EP on mental health in 435 young people, 319 children aged between 4 and 11 years and 116 young adolescents aged between 12 and 14 years. The results suggest worse mental health in young people living in EP. The most affected scales were emotional and peer problems, which are those composing the SDQ internalising score. Internalising behaviours include anxiety, withdrawal and dysphoria [49]. Although measured with another scale, a recent study found that 9-year-old children experiencing dual food and energy hardship had a greater odds of coexisting internalising and externalising behaviours [48]. Mental health in children living in EP may be affected by different mechanisms; for example, by the effects of EP on physical health, since children's mental health is more adversely affected by illness than adults health [13]. Stress and other mental health problems experienced by parents living in EP can be transferred to children, and can also negatively affect parental relationships and parenting behaviour [50]. In addition, children with EP may find their play space and opportunities for leisure and socialisation reduced [24].

So far, asthma has been the most widely studied health effect of EP in children. Previous studies have shown that asthma is associated with cold homes and damp and mouldy conditions, and that interventions to reduce EP improve asthma symptoms in children and reduce school absence [19,51–53]. The present study found a much higher percentage of children with asthma in households with EP. Although this result was not statistically significant after adjustment for social class, point estimation revealed that, in more temperate climates, there is also a strong association between EP and asthma, with children with EP having almost 3 times more asthma than those without EP.

Finally, the relationship between EP and poor nutrition in children is also a major concern. Families with EP have greater difficulty in buying healthy, quality food and in preserving and cooking it properly. Poor nutrition in children can lead to underweight and overweight, with significant long-term consequences for their health and wellbeing. One study showed that infants up to the age of 3 living in EP were 29% more likely to be underweight, but the effects of EP on child overweight have not yet been studied. In this study we found a much greater prevalence of overweight in children with EP, suggesting that children living in EP were 50% more likely to be overweight.

4.3. Limitations and Strengths

The main limitation of this study is the sample size. The low statistical power did not allow us to show many statistically significant associations after adjustment of the models for social class, and the low number of observations limited us to stratifying the analyses by possible effect modifiers. Another limitation is that the survey was completed by caregivers. Children and adolescents have valid opinions that should be collected. The lived experience of children living in EP is essential to better understand and scale how EP affects their health and wellbeing and build meaningful policy and practice to address EP [53]. Moreover, there are successful experiences of studies of EP with the participation of adolescents [26]. It should also be noted that this study was conducted in the city of Barcelona and may not be generalizable to other contexts. Finally, data are from 2016. Although these are the latest data available, they may be outdated, especially due to the exceptional circumstances caused by the Covid-19 this past year. This study, however, is the first to analyse and quantify the magnitude of the effects of EP on various child health and wellbeing outcomes in southern Europe and its relevant findings should draw the attention of practitioners, researchers and policy-makers to further advance this much-needed field.

5. Conclusions and Recommendations

EP is an important public health problem in the city of Barcelona, with a highly uneven distribution among families and that negatively affects children's health and wellbeing. The poorer physical and mental health experienced by children living in EP has an immediate effect on their quality of life, but may also have important long-term health implications and may hamper children's learning and socialising. Long-term health problems and a lower educational achievement can, in turn, affect employment opportunities and economic wellbeing in adulthood, increasing health inequalities and perpetuating cycles of precariousness, which may even affect future generations.

These serious consequences in the short- and long-term should prompt policy-makers to develop specific measures that prioritise children and adolescents and guarantee basic supplies for their favourable development and wellbeing. This is especially important in the context of the COVID-19 pandemic, when we are on the verge of a possible new economic crisis, which could drag many families into EP and aggravate its effects on health.

Author Contributions: Conceptualization, L.O., C.B., I.G.-P., M.G., M.J.L., L.P., L.A. and M.M.-D.; methodology, L.O., C.B., I.G.-P., M.G., M.J.L., L.P., L.A. and M.M.-D.; formal analysis, L.O.; writing—original draft preparation, L.O.; writing—review and editing, C.B., I.G.-P., M.G., M.J.L., L.P., L.A. and M.M.-D.; supervision, M.M.-D. All authors have read and agreed to the published version of the manuscript.

Funding: The study is part of the PENSA Project ("Pobreza energética y salud desde multiples perspectivas: análisis individual, geográfico y temporal"), which received a research grant from the Carlos III Institute of Health, Ministry of Economy and Competitiveness (Spain), awarded on the 2015 call under the Health Strategy Action 2013–2016, within the National Research Program oriented to Societal Challenges, within the Technical, Scientific and Innovation Research National Plan 2013–2016, with reference PI15/02006, co-funded with European Union ERDF funds (European Regional Development Fund)". LO was supported by a Rio Hortega grant (CM19/00184—Contratos Rio Hortega/Fondo Social Europeo) from the Carlos III Institute of Health.

Institutional Review Board Statement: This study was approved by the Clinical Research Ethics Committee of Hospital del Mar (2015/6155/l).

Informed Consent Statement: Not applicable.

Data Availability Statement: Data available upon request.

Conflicts of Interest: The authors declare no conflict of interest.

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5.4. Article 4

Marí-Dell'Olmo M, Oliveras L, Vergara-Hernández C, Artazcoz L, Borrell C, Gotsens M, Palència L, López MJ, Martínez-Beneito, MA. Geographical inequalities in energy poverty in a Mediterranean city: using small-area Bayesian spatial models. Submitted.

Geographical inequalities in energy poverty in a Mediterranean city: using small-area Bayesian spatial models

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Highlights

- We obtained 6 indicators and an index of energy poverty at the small-area level
- The index revealed geographical inequalities in energy poverty
- We compared the spatial distribution of 6 small-area indicators of energy poverty
- A novel method was used by employing small-area Bayesian spatial models

Abstract

Energy poverty (EP) is becoming an increasingly important problem in the urban contexts of southern Europe. In Barcelona, EP indicators are higher than those of the European Union and are strongly associated with poor health status and high use of health services and medication, becoming a major public health problem. EP is unevenly distributed in the population of Barcelona, according to axes of social stratification. However, its geographic distribution at the small-area level remains unknown because it cannot be directly estimated with the available information sources and commonly used methods. Therefore, the aim of this study was to analyze geographical inequalities in EP in Barcelona by estimating reliable small-area EP indicators and a composite indicator (index). We used a novel method that allowed us to obtain 6 EP indicators for the 73 Barcelona neighborhoods and an EP index from a principal component analysis of these indicators. We found major geographical inequalities in the distribution of EP in Barcelona. Many neighborhoods had significantly higher EP than the city average, and these areas made up 3 well-defined spatial clusters. Therefore, the estimated small-area indicators and index allowed identification of the most affected neighborhoods. These results indicate the need to prioritize these areas for local interventions to alleviate EP, and could also be used for policy making.

Key words: Energy poverty; Fuel Poverty; Index; Geographical inequalities; Multivariate analysis, Bayesian model, Spatial analysis; Social Determinants of Health

1. Introduction

Energy poverty (EP) is defined as the inability of a household to secure a socially and materially required level of energy services in the home (Bouzarovski, 2013). EP is currently a social problem in Europe and recent publications have shown that the most affected countries are those in southern and eastern European Union (EU) (Bouzarovski and Tirado Herrero, 2017; Recalde et al., 2019). For example, in 2016, 9.0% of the EU population was unable to keep their home adequately warm during the cold months, while in Spain this percentage increased to 13.4% (Oliveras et al., 2021b). Several studies have shown that EP is strongly associated with worse health and wellbeing, making it a major public health problem (Bosch et al., 2019; Marí-Dell'Olmo et al., 2017; Marmot Review Team, 2011; Oliveras et al., 2020; Thomson et al., 2017).

The distribution of EP in the population is uneven, following the classical lines of social stratification. The phenomenon particularly affects people with a more disadvantaged social class, those born in low- and middle-income countries and women aged 65 years and older (Carrere et al., 2020; Oliveras et al., 2020). Geographical inequalities in EP at the small-area level have also been found in various contexts. Some of the best studied regions are England (Baker et al., 2003; DECC, 2009; Fahmy et al., 2011a; Fahmy and Gordon, 2007; HM Government, 2013; Robinson et al., 2018; Sun and Sundell, 2011), Scotland (Morrison and Shortt, 2008) and Portugal (Gouveia et al., 2019), with all showing marked geographical inequalities. Some studies have found such inequalities within cities such as Oberhausen (Germany) (März, 2018), London (United Kingdom) and Madrid (Spain) (Martín-Consuegra et al., 2019; Sanchez-Guevara et al., 2019). Other studies have found marked geographical inequalities in EP at the medium- to large-area level, such as districts, in cities such as Valencia and Barcelona(Ajuntament de Barcelona, 2018a; Gómez-Navarro et al., 2021; Tirado Herrero, 2018). However, the geographical inequalities found within cities may be oversimplified by the size of these areas, leading to the danger of falling into the modifiable areal unit problem (MAUP) which could lead, for example, to misinterpretations by policymakers and local authorities(Openshaw, 2016). Unfortunately, in these cities, EP distribution at the smaller area level such as neighborhoods or census tracts is still unexplored.

Most EP analyses are undertaken at the country level or even on a larger scale such as the EU level. However, estimates of EP at the small-area level are a versatile and powerful tool that could be used for the following (Baker et al., 2003; Morrison and Shortt, 2008; Wilson et al., 2012): (1) identifying the most affected areas and prioritizing them in the fight against EP (developing evidence-based local public policies prioritizing the most affected areas, including effective targeting of EP programs or developing local affordable warmth and cold strategies); (2) identifying more contextual causes of EP, such as deficiencies in the housing stock or in the distribution network; (3) raising social and political awareness of EP as an issue of concern and providing civil society with tools for advocacy (maps are a very powerful tool for this purpose) and (4) advancing research, e.g. exploring the relationship between EP and health inequalities and other health and deprivation indicators.

EP is also becoming an increasingly important problem in the urban contexts of southern Europe. A clear example is the city of Barcelona (Spain), where several EP indicators show values above those of the EU and EP has become an explicit priority for the city council (Tirado Herrero, 2018). For instance, in 2016, 9.4% of the population in Barcelona could not afford to keep their homes adequately warm and 13.9% were in arrears in utility bills in the last 12 months. In this city, EP is also a major public health problem. There is a proven strong association between EP and worse health status, as well as with a higher use of health services and medication, which substantially impacts health and health services at the population level(Carrere et al., 2020; Oliveras et al., 2021a, 2020). However, the maximum level of spatial disaggregation at which the EP situation is known in detail are the 10 districts of the city, mainly because surveys are usually representative at this level at most. In contrast, there are important city-level strategies focusing on a smaller level than the district, specifically on the neighborhood level. This is the case, for example, of the Barcelona Neighborhoods Plan, which aims to reduce social inequalities in different neighborhoods of the city with actions on education, employment, public space and urban ecology, among other areas (Ajuntament de Barcelona, 2016a). In addition, it isknown that people living in EP are more vulnerable to climate change due to their reduced ability to adapt (Jessel et al., 2019). For example, living in poorly insulated houses with no means of cooling does not protect people from high daytime and nighttime temperatures and heat waves. Consequently, among the objectives of the Barcelona City Council Climate Plan for 2030 is the elimination of EP with actions designed to improve knowledge of the phenomenon and its impact on health and to reinforce interventions that are already under way (Ajuntament de Barcelona, 2018a). Moreover, the Public Health Agency of Barcelona is working on the design of a system to monitor over time and space the effects of climate change on health including, among many other indicators, EP and its effects on health (Marí-Dell'Olmo et al., 2019a; Mercuriali et al., 2021). Therefore, there is a clear need for a tool able to detect the small areas with the highest levels of EP.

The aim of this study was to analyze geographical inequalities in EP in Barcelona by estimating reliable EP indicators and a composite indicator (index) at the neighborhood level, a small-area division of the city that allows these inequalities to be addressed in practice.

2. Methods

2.1. Design, information source, units of analysis and study population

We performed a cross-sectional study using EP indicators and sociodemographic variables at the individual level and sociodemographic variables at the neighborhood level. Individual-level variables were obtained from the 2016 Barcelona Health Survey (BHS). This survey was conducted by interviewing 3519 individuals. The sample was representative of the city and the 10 districts of Barcelona (median population 164,881 people)(Bartoll et al., 2018). The aggregated values of sociodemographic variables for each of the 73 neighborhoods of Barcelona (median population 20,369 people) was drawn from the 2016 municipal register (Barcelona city council) and from the 2011 Housing and Population Census (National Statistics Institute). The study population consisted of non-institutionalized individuals aged 15 years or older who resided and were included in the Barcelona municipal register of inhabitants in 2016. To aid understanding of this article, a map is provided with the geographical location of the neighborhoods, their identification number and their full name (Figure A.1).

2.2. Study variables and data analysis

The EP index and small-area estimates of the EP indicators comprising the index were obtained by using a novel method. To promote the reproducibility of the research conducted, the statistical methods and the R scripts used for data analysis are documented in detail in an RMarkdown document (Supplementary file 1). In summary, the method was based on the following 5 steps:

Step 1: Variables of the BHS that allowed detection of a situation of EP in households were identified, henceforth termed *EP indicators*. These indicators were: 1) households that could not afford to keep the home at an adequate temperature during the cold months (Temp_cold); 2) households that could not afford to keep the home at an adequate temperature during the hot months (Temp_hot); 3) households in arrears in utility bills in the last 12 months (Arrears); 4) dwellings with leaks, dampness in walls, floors, ceilings or foundations, and/or rot in floors, window frames or doors (Conditions); 5) dwellings without means of heating or with central heating or room-heating appliances, but not used when necessary (Heating); and 6) dwellings without an air conditioner or with an air conditioner, but not used when necessary (Air_cond). Other EP indicators related to energy expenditure and household income were excluded due to the large number of missing data, 33.7% and 48.9%, respectively. Thus, a total of 6 indicators were included (Table 1). Of note, all indicators are recommended and monitored by the EU Energy Poverty Observatory, 2 of which are primary indicators and the remaining 4 are secondary indicators (EU Energy Poverty Observatory, 2021).

Step 2: Using the conceptual framework of the determinants of health inequalities related to EP previously developed by our group(Marí-Dell'Olmo et al., 2017), we identified those sociodemographic variables included in the BHS that could be related to EP (indicators selected in step 1) and which, in turn, were available at the neighborhood level from population-based records (not based on a sample). A total of 7 variables were obtained (Table 1).

Step 3: To make estimates at the small-area level (neighborhood) of each of the EP indicators, we used the M-model, a multivariate model for estimation in small areas (Botella-Rocamora et al., 2015; Corpas-Burgos et al., 2019). This allowed, on the one hand, analysis of all EP indicators in the same model, taking into account their possible dependence and, on the other hand, to take into account the possible spatial dependence of data between adjacent neighborhoods by means of the Leroux distribution (Leroux et al., 2000).

In summary, a Bayesian hierarchical model was estimated where the dependent variables were the 6 EP indicators (obtained in step 1). As covariates of the model, all variables obtained in step 2 were explored. Not all of the covariates mentioned were included in the final model, as we did not find a relationship with EP indicators for all of them. To select the covariates for the final multivariate model, we used the following criteria: (1) each of the covariates had to be significantly associated with at least 2 dependent variables and, (2) a lower value of the deviance information criterion (DIC) of multivariate models. The covariates of the final model were age group, educational level, country of birth, housing tenure and employment status (Table 1). A random effects matrix combining the spatial and multivariate dependence of the EP indicators was included in the model. Cases with missing values in any of the covariates were excluded in the estimation of the final model and therefore this model included a sample of 3378 individuals instead of 3519 (4% loss).

All models were fitted using a full Bayesian approach. Posterior distributions were obtained using Markov Chain-based Monte Carlo methods via WinBUGS and R (Lunn et al., 2012; R Core Team, 2021).

Step 4: The above-mentioned model allowed us to estimate the relationship between the demographic covariates and the EP indicators, as well as the spatial effects that could not be explained by the covariates. Once these components had been estimated, the exhaustive demographic information for each neighborhood was used, together with the estimated spatial effects, to calculate the indicators in each neighborhood, taking into account all the available demographic and spatial information.

Step 5: Once the estimates of the EP indicators were obtained at the small-area level (smaller than originally planned in the BHS), to obtain the EP composite indicator or index (at the neighborhood level), a principal component analysis (PCA) was performed on the posterior mean of the proportions (of the 6 EP indicators) obtained in step 4. In particular, the logit of the posterior mean of these indicators was used to normalize their values. Finally, the index was constructed from the first component of the PCA that explained 91% of the variance. The indicator with the highest weight was inadequate temperature in cold months, while the indicator with the lowest weight was that related to the presence of leaks and dampness (Table 1).

As a result of the entire process described above, using posterior means, point estimates of the proportions of each of the 6 EP indicators and the EP index were obtained for the 73 neighborhoods. Henceforth, we will refer to these 6 indicators as "small-area indicators" (SAI). Moreover, to quantify the statistical evidence of these parameters in each neighborhood, we estimated the probability of each EP SAI and the index to be higher than the overall value for the city. This means that for all EP estimates (the 6 SAIs and the index) and for each neighborhood, we calculated a probability of excess in comparison to the city average. These excess probabilities were categorized with the following cut points: [0, 0.025), [0.025, 0.05), [0.05, 0.95), [0.95, 0.975), and [0.975, 1].

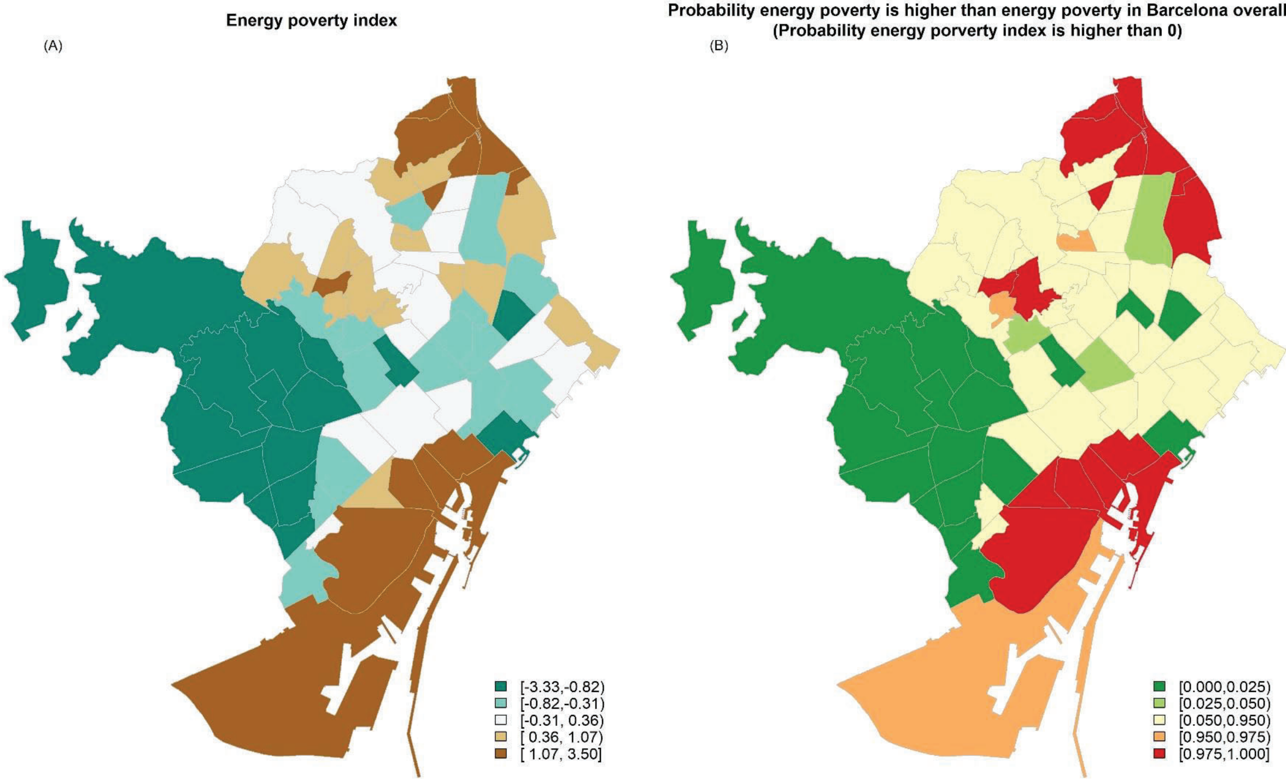
3. Results

Table 2 shows the distribution of each SAI and of the EP index in the Barcelona neighborhoods, as well as their correlation matrix. There was wide variability in the EP SAIs by neighborhood. For example, the SAI of inadequate temperature in cold months had a median of 8.39%, the 25th and 75th percentile values were 6.62% and 13.28%, respectively, and their values ranged from 2.10% to 35.38%. Therefore, all the dwellings in neighborhoods above the 3rd quartile showed this problem, at least twice as often as those below the 1st quartile. The EP SAIs were highly correlated with each other, with the SAIs referring to inadequate temperatures in the cold and hot months and the availability of air conditioning being the most closely correlated, with correlations greater than 0.95. In contrast, the presence of conditions such as leaks or dampness showed the lowest correlations with the remaining SAIs. This is possibly the reason why this SAI showed the lowest weight, and therefore the lowest contribution, to the EP index (Table 1).

The rows in Table 3 show the 73 Barcelona neighborhoods, ordered from highest to lowest value of the EP index, while the columns show the 6 SAIs and the EP index. Each cell shows the SAI percentages and the index values with their 95% credible intervals (95%CI). The cells are colored according to the categories of the probability of EP excess with respect to the overall city specified above. Thus, red cells indicate a high probability of the EP SAIs and of the index being higher than that for the rest of the city and green cells a low probability. Fifteen neighborhoods were notable for their high values of the EP index and a significant excess of EP in 3 or more EP SAIs. Thus, for example, the neighborhood with the highest EP according to the index obtained (3.50) was Ciutat Meridiana. Examination of the different SAIs of this neighborhood showed that 31.41% of households could not afford to keep their homes at an adequate temperature during the cold months and that 35.95% could not do so during the warm months, 41.25% of households had at least one delay in utility bills in the last 12 months, 21.88% reported leaks, dampness in walls, floors, ceilings or foundations, and/or rot in floors, window frames or doors, 32.29% had no means of heating the home or did not use heating when necessary, and 83.19% had no air conditioning or did not use it when necessary. These values are higher than the respective average percentages for the city (9.36%; 11.41%; 13.90%; 9.66%; 9.96% and 51.43%) with a probability greater than 0.95. Finally, 20 of the 73 neighborhoods had a significantly higher EP index (probability greater than 0.95) than the average value for the city.

Figure 1 shows the spatial distribution of the EP index and its probability of being higher, for each neighborhood, than for the city overall. The geographical pattern of the EP index was uneven, with the northernmost neighborhoods, some in the north-west, those in the historic city center (around the port area) and those in the south-east showing the highest values of the EP index (Figure 1A). In addition, there were 3 spatial clusters of neighborhoods with significantly higher EP indexes (probability greater than 0.95) than the average value for the city (Figure 1B).

Figure 1. Geographical distribution of the energy poverty index at the neighborhoods level (A) and probability of the index being higher than the overall value for the city (B). Barcelona, 2016.



However, examination of the different geographical patterns of the EP SAIs (see Supplementary file 2) revealed some differences with respect to the index. The 2 EP SAIs related to inadequate household temperatures in the cold and warm months followed a similar geographical pattern to each other and to the EP index (Figures S1.A, S1.B, S2.A and S2.B). However, the EP SAI referring to the warm months showed fewer significant percentages (than the EP SAI considering the cold months) in 2 neighborhoods close to the coast (El Gòtic and Barceloneta). The SAI referring to late payment of energy bills showed a significant cluster of high percentages in the historic center and followed a more spatially heterogeneous pattern, with numerous neighborhoods with high percentages in the north and northwest (figures S3.A and S3.B). The SAI of dwellings with physical deficiencies (figures S4.A and S4.B) showed significantly higher values than the city in the historic city center, with 2 neighborhoods in the north of the city (Ciutat Meridiana and Baró de Viver) standing out. In these areas, there was also a high percentage of dwellings without heating or which, even if heating was available, did not use it when necessary (figures S5.A and S5.B), e.g.,32.29% in Ciutat Meridiana, 25.68% in La Barceloneta and 23.66% in El Raval (Table 3). Finally, in the city, 51.43% of dwellings reported not having air conditioning or having it but not using it when necessary and, according to our study, this percentage increased in the city center and southeast, and in various northern neighborhoods, especially those located in the north and northeast (Figures S6.A and S6.B). In some of these neighborhoods, this SAI could even reach values above 75%, as is the case of Ciutat Meridiana (83.19%), Baró de Viver (81.83%), Vallbona (76.19%) and El Raval (76.00%).

4. Discussion

4.1. Main findings

This study identified substantial geographical inequalities in the distribution of EP in the city of Barcelona. The highest EP levels were found in the northernmost neighborhoods, some in the north-west, those in the historic city center and those in the south-east. Within these areas, there were 3 well-defined spatial clusters of neighborhoods with a significant excess of EP compared with the city as a whole.

4.2. Interpretation of results

EP is a complex, multidimensional and dynamic construct that affects different people depending on the combination of multiple social and economic determinants(Bouzarovski and Petrova, 2015; Marí-Dell'Olmo et al., 2017). Important intermediate determinants are low household income, low energy efficiency of housing and high energy prices (Hills, 2011). These intermediate determinants are in turn the result of structural determinants related to the labor, housing and energy markets and their policies (Recalde et al., 2019). All these complexities make measuring EP a difficult task that requires methods that take into account the multiple characteristics of EP and allow its optimal quantification. In recent years, various proposals have been made to try to measure EP more comprehensively through composite indicators (or indices). These range from simple combinations of EP indicators to more complex methods, vary in the geographical level of analysis, and have been proposed for different contexts (e.g. high- and low-income countries) (Siksnelyte-butkiene et al., 2021). The index presented in this study is based on 6 underlying indicators, which are also estimated at the neighborhood level, a more detailed disaggregation level than that used at the sampling stage.

In Barcelona, most of the key intermediate determinants of EP show a geographical pattern in the city. Additionally, these geographical patterns may differ across these determinants. For example, the household disposable income per capita index calculated for each neighborhood shows large contrasts between the north and west of the city (Ajuntament de Barcelona, 2017). Regarding proxy indicators of the energy efficiency of dwellings, such as the age of buildings, there are notable geographical differences that reflect the historical process of urbanization of the city. Thus, the city center has a high percentage of old buildings (pre-1940), while in other areas most of the housing stock was built in the decades of greatest growth of the city, because the city had to absorb a large wave of migration (between 1961 and 1980), and finally, in the eastern part of the city, there have been large urban development operations in the last 30 years(Ajuntament de Barcelona, 2021, 2016b; Donat et al., 2015). The state of preservation of buildings is also unevenly distributed across the city. The highest percentages of buildings considered to be in a dilapidated or poor state of repair are found in the city center and in neighborhoods with greater socioeconomic deprivation, where the percentage can exceed 10%(Ajuntament de Barcelona, 2021, 2016b). Therefore, the uneven spatial distribution observed in this study in the EP SAIs and index was similar to that expected and is consistent with the different patterns of some of its determinants in the city (Robinson et al., 2018).

EP SAIs related to inadequate home temperatures in the cold and warm months follow a very similar geographical pattern, probably due to poor building isolation. In addition, neighborhoods with higher values for these SAIs tend to be those where there are older, hastily constructed buildings with low construction standards(Ajuntament de Barcelona, 2016b; Donat et al., 2015). On the other hand, the less significant percentages of the SAI of inadequate temperatures in the warm months in 2 neighborhoods close to the coast could be due to the effect of sea breezes on daytime temperatures in these neighborhoods (Yamamoto and Ishikawa, 2020).

In turn, the SAI referring to arrears in utility bills showed a similar geographical pattern to that of the income of its inhabitants. Except for some neighborhoods on the north-eastern border of the city, such as La Verneda i la Pau and El Besos i el Maresme, which have very low incomes(Ajuntament de Barcelona, 2017), their values for this EP SAI were not significantly higher than the Barcelona average. In contrast, the income level of Barri Gòtic (located in the city center) is medium-high, but the percentage of households with late payment of bills is 24.24% (1.73 times higher than that of the city as a whole). This could be because the disposable household income per capita indicator calculated by the City Council may be affected by an ecological fallacy. According to the National Institute of Statistics(Instituto Nacional de Estadística, 2020), many areas of this neighborhood have a much lower average income level (per person) than that of the rest of the city, while in other areas there has been a major gentrification where many residents of the neighborhood have been replaced by inhabitants from northern Europe, with higher purchasing power(Ajuntament de Barcelona, 2017; Sánchez-Ledesma et al., 2020). This artifact could modify the average income level of the neighborhood but have little influence on the percentage of people with difficulties in paying bills.

With regard to the spatial distribution of the SAI that identified dwellings with physical deficiencies, such as the presence of leaks or damp, the highest values were concentrated in neighborhoods with older buildings and poor construction quality, such as those in the historic city center. In addition, the Ciutat Meridiana neighborhood stands out, where 94.85% of dwellings were built hastily between 1961 and 1980 and many of them show construction deficiencies, and Baró de Viver, with 14.95% of dwellings in a poor state of repair(Ajuntament de Barcelona, 2021).

An important finding was the continued existence of neighborhoods in the city with a high percentage of the population that did not have heating or did not use heating when necessary. This factor is relevant because, although Barcelona enjoys a temperate climate, cold temperatures currently have a greater impact on mortality in the city than warm temperatures, and it is estimated that in the period 1992-2015 they were responsible for more than 5% of mortality in Barcelona (Marí-Dell'Olmo et al., 2019b).

Barcelona also has periods of the year with high or extremely high temperatures. In the last 34 years, there have been 8 heat waves and, due to climate change, it is estimated that this frequency will increase significantly, with between 1 and 4 a year by the end of the century (Ajuntament de Barcelona, 2018a). Moreover, these high temperatures and heat waves in Barcelona pose a demonstrated risk and have a major impact on people's health (Borrell et al., 2006; Ingole et al., 2020; Marí-Dell'Olmo et al., 2019b). However, a high percentage of the households in the city report not having air conditioning or not using it when necessary. In this study, this percentage rose to more than 75% in some of the low and very low-income neighborhoods.

4.3. Limitations and strengths

Obtaining reliable EP estimates at the small-area level is by no means a trivial task, since most information sources (usually surveys) used to obtain EP indicators are not usually representative at this geographical disaggregation. Several approaches to estimating EP at the small-area level have been used(Baker et al., 2003; Castaño-Rosa et al., 2019; Centre for Sustainable Energy, 2001; DECC, 2009; Fahmy et al., 2011b; Gouveia et al., 2019; HM Government, 2013; März, 2018;

Morrison and Shortt, 2008; Robinson et al., 2018; Sanchez-Guevara et al., 2019; Simoes et al., 2016; Wilson et al., 2012), ranging from simple procedures such as looking for reliable proxy indicators of EP available at the small-area level, to employing procedures with several steps (including several information sources with different scales and statistical methods).

The main strength of this study is that, for the first time in Barcelona, it obtained reliable estimates of EP at the neighborhood level, identifying significant geographical differences that could be highly useful for local EP policies. To obtain these estimates, we designed a sophisticated new method, employing statistical models that draw on the information provided by all the EP indicators used, taking into account the information available in adjacent neighborhoods, which is a key aspect in small-area estimation models. Moreover, our multivariate approach considers the EP indicators as potentially dependent. This assumption preserves the potential relationship, in contrast to models assuming independence, which is the cornerstone for the subsequent PCA used to construct the EP index. However, as a drawback, less accurate estimates of EP SAIs may occur in some neighborhoods at the outskirts of the city, due to the lack of information from adjacent neighborhoods outside the city (frontier effect) (Martinez-Beneito and Botella-Rocamora, 2021).

Another strength of the study is the use of the last BHS as an information source, in which questions on EP were included for the first time, providing a unique opportunity to explore this phenomenon with information from more than 3500 individuals. Nonetheless, we were unable to include EP indicators based on expenditure and income because the variables needed to construct them had a high percentage of missing values in the BHS. However, as previously stated, the indicators used are part of the main indicators recommended by the EU Energy Poverty Observatory and cover different expressions of EP(EU Energy Poverty Observatory, 2021). Finally, it should be noted that official statistics sometimes make the most affected groups invisible, such as, in the case of the study in question, people who do not have a rental or property contract (squatters) and who therefore cannot access even regular energy supplies.

5. Conclusion and Policy Implications

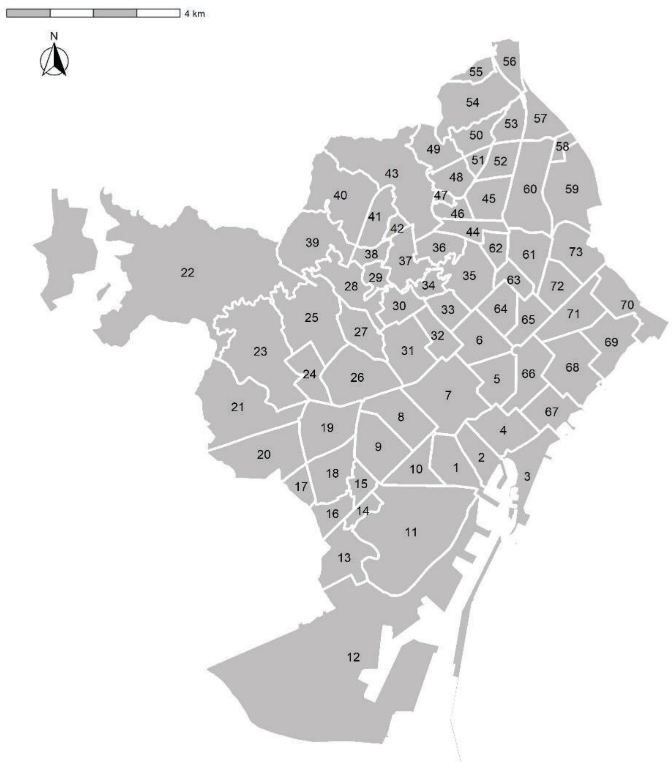
This study has different EP policy implications in Barcelona. First, local governments could implement policies to reduce geographical inequalities by focusing their EP interventions on the neighborhoods with the highest levels and specifically on the populations most vulnerable to EP within these neighborhoods. For example, the Barcelona City Council has Energy Advice Points (EAP), which offer personalized attention on energy rights(Ajuntament de Barcelona, 2018b). Currently, there is an EAP in each of the 10 districts of Barcelona, so they are evenly distributed throughout the city. Our index could be useful to improve this service with proportional universality, taking into account the areas where there is a greater need to reinforce the EAPs and place new resources in those neighborhoods with higher levels of EP. In the same vein, interventions to improve the energy efficiency of buildings could be prioritized in neighborhoods with the worst EP SAIs related to inadequate temperatures, physical deficiencies and lack of heating or air conditioning.

Finally, in the context of a climate emergency, reliable estimates at the neighborhood level, such as the percentage of people with inadequate summer temperatures in their homes or the percentage of people who do not have air conditioning or who do not use it when necessary, could be useful from a climate justice point of view. Such estimates allow prioritizing the location of interventions that are being carried out to reduce the impact of heat on the health of the most vulnerable people, such as the creation of climate shelters(Ajuntament de Barcelona, 2019). However, in all these cases, once the areas have been prioritized, interventions should focus on people who are particularly vulnerable to EP and its effects on health, such as children, the elderly, women from disadvantaged social classes, dependent people and people with illnesses(Oliveras et al., 2020; Thomson and Snell, 2013). Monitoring EP over time is also a key issue. The methods applied to future surveys will allow monitoring over time of recognized EP indicators, allowing, for example, their comparison with other areas or cities in Europe. Furthermore, to facilitate the monitoring of EP in small areas in other contexts, a detailed document (Supplementary file 1) is provided to replicate the method used in this study. In Barcelona, for example, EP monitoring will allow assessment of neighborhood compliance with the climate plan target of eliminating EP by 2030(Ajuntament de Barcelona, 2018a). Furthermore, calculation of these indicators before and after the implementation of a local policy or intervention could also allow evaluation of its effectiveness(Gouveia et al., 2019). Finally, the EP index could be used in future research to study hypotheses in groups of neighborhoods according to their EP or to study their association or interaction with other indicators, such as, for example, indicators of health, residential insecurity or food insecurity.

In conclusion, this study has obtained several indicators and a composite indicator (index) of EP at the small-area level in the city of Barcelona using a novel method. These SAIs have allowed analysis of the multidimensionality of EP in the city and its diverse geographical patterns, and identification of the most affected neighborhoods and, therefore, those most susceptible to interventions to alleviate EP. Moreover, the calculation of these SAIs in future surveys will allow improved surveillance of EP and monitoring and evaluating its trends over time at the small-area level. In short, these indicators are a very useful tool for policy makers and local authorities.

6. Appendix

Figure A.1. Geographical distribution, identification (ID) number and name of the neighborhoods of Barcelona city.



ID number	Neighborhood name	ID number	Neighborhood name
1	el Raval	38	la Teixonera
2	el Barri Gòtic	39	Sant Genís dels Agudells
3	la Barceloneta	40	Montbau
4	Sant Pere, Santa Caterina i la Ribera	41	la Vall d'Hebron
5	el Fort Pienc	42	la Clota
6	la Sagrada Família	43	Horta
7	la Dreta de l'Eixample	44	Vilapicina i la Torre Llobeta
8	l'Antiga Esquerra de l'Eixample	45	Porta
9	la Nova Esquerra de l'Eixample	46	el Turó de la Peira
10	Sant Antoni	47	Can Peguera
11	el Poble Sec	48	la Guineueta
12	la Marina del Prat Vermell	49	Canyelles
13	la Marina de Port	50	les Roquetes
14	la Font de la Guatlla	51	Verdun
15	Hostafrancs	52	la Prosperitat
16	la Bordeta	53	la Trinitat Nova
17	Sants - Badal	54	Torre Baró
18	Sants	55	Ciutat Meridiana
19	les Corts	56	Vallbona
20	la Maternitat i Sant Ramon	57	la Trinitat Vella
21	Pedralbes	58	Baró de Viver
22	Vallvidrera, el Tibidabo i les Planes	59	el Bon Pastor
23	Sarrià	60	Sant Andreu
24	les Tres Torres	61	la Sagrera
25	Sant Gervasi - la Bonanova	62	el Congrés i els Indians
26	Sant Gervasi - Galvany	63	Navas
27	el Putxet i el Farró	64	el Camp de l'Arpa del Clot
28	Vallcarca i els Penitents	65	el Clot
29	el Coll	66	el Parc i la Llacuna del Poblenou
30	la Salut	67	la Vila Olímpica del Poblenou
31	la Vila de Gràcia	68	el Poblenou
32	el Camp d'en Grassot i Gràcia Nova	69	Diagonal Mar i el Front Marítim del Poblenou
33	el Baix Guinardó	70	el Besòs i el Maresme
34	Can Baró	71	Provençals del Poblenou
35	el Guinardó	72	Sant Martí de Provençals
36	la Font d'en Fargues	73	la Verneda i la Pau
37	el Carmel		

7. Tables

Table 1. Characteristics of each of the 6 energy poverty indicators (step 1 of the method) and the 7 sociodemographic variables related to energy poverty available in the Barcelona Health Survey and at the neighborhood level in population-based registries (step 2 of the method). Barcelona, 2016.

Name	Description	Data source	Year	Overall value for the city (%)	Number of missing values	Weight in the 1st principal component analysis dimension
Energy poverty indicators						
Temp_cold	Identifies households that cannot afford to maintain the dwelling at an adequate temperature during the cold months.	Barcelona Health Survey	2016	9.36	39	0.47
Temp_hot	Identifies households that cannot afford to maintain the dwelling at an adequate temperature during the hot months.	Barcelona Health Survey	2016	11.41	43	0.45
Arrears	**Identifies households that have one or more arrears in utility bills in the last 12 months**	Barcelona Health Survey	2016	13.90	738	0.45
Conditions	Identifies dwellings with leaks, dampness in walls, floors, ceilings or foundations, and/or rot in floors, window frames or doors	Barcelona Health Survey	2016	9.66	0	0.25
Heating	Identifies dwellings without means of heating or with central heating or room-heating appliances, but not used when necessary	Barcelona Health Survey	2016	9.96	20	0.40
Air_cond	Identifies dwellings without an air conditioner or with an air conditioner, but not used when necessary	Barcelona Health Survey	2016	51.43	23	0.39

Sociodemographic variables related to energy poverty available in the Barcelona Health Survey and at the neighborhood level in population-based registries

Sex	Describes sex classified into female and male	Barcelona Health Survey	2016	0
		Municipal Register	2016	-
Age group[1]	Describes age according to the groups: 0-19, 20-39, 40-59, 60-79, >79 years	Barcelona Health Survey	2016	0
		Municipal Register	2016	-
Education level[1]	Describes education level grouped into 4 categories: no education, primary education, secondary education and higher education	Barcelona Health Survey	2016	44
		Municipal Register	2016	-
Country of birth[1]	Describes country of birth classified into high-income and low-and middle-income countries according to the 2018 World Bank classification[2]	Barcelona Health Survey	2016	9
		Municipal Register	2016	-
Housing tenure[1]	Describes the tenancy regime distinguishing between paid property and others (including property paying mortgage, rent at market price, social and other situations)	Barcelona Health Survey	2016	66
		Census	2011	-
Employment status[1]	Describes employment status classified into unemployment and other	Barcelona Health Survey	2016	43
		Municipal Register	2016	-
Households composition	Describes household composition classified into single-parent households and other	Barcelona Health Survey	2016	0
		Municipal Register	2016	-

[1] Covariates included in the final statistical model; [2] The World Bank World Bank Country and Lending Groups – World Bank Data Help Desk Available online: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519 (accessed on Jul 25, 2021).

Table2. Summaries and Spearman correlations between the 6 energy poverty small-area indicators and index. Barcelona, 2016.

Energy poverty indicadors and index	**Minimum**	**P25**	**P50**	**P75**	**Maximum**	**Correlation matrix**						
						Temp_cold	Temp_hot	Arrears	Conditions	Heating	Air_cond	Index
Temp_cold	2.10	6.62	8.39	13.28	35.38	1.00	0.99	0.87	0.77	0.89	0.96	0.98
Temp_hot	3.12	8.50	10.75	16.49	42.72	0.99	1.00	0.84	0.78	0.84	0.95	0.97
Arrears	3.24	11.00	14.50	19.94	41.25	0.87	0.84	1.00	0.56	0.87	0.82	0.91
Conditions	4.85	7.57	9.13	11.31	22.29	0.77	0.78	0.56	1.00	0.75	0.88	0.79
Heating	2.58	7.19	9.10	11.54	32.29	0.89	0.84	0.87	0.75	1.00	0.93	0.94
Air_cond	25.60	45.21	52.29	60.88	83.19	0.96	0.95	0.82	0.88	0.93	1.00	0.98
Index	-3.33	-0.68	-0.12	0.81	3.50	0.98	0.97	0.91	0.79	0.94	0.98	1.00

P: Percentile

Table 3. Energy poverty index and small-area indicators with their 95% credible intervals (95%CI) and their probability of being higher than the overall value for the city, for each of the 73 neighborhoods. Barcelona, 2016.

Neighborhood		Energy poverty indicators						Energy poverty index
ID number	Name	Temp_cold	Temp_hot	Arrears	Conditions	Heating	Air_cond	
55	Ciutat Meridiana	31.41 (20.13, 46.02)	35.95 (23.54, 51.48)	41.25 (23.79, 59.40)	21.88 (10.67, 35.90)	32.29 (18.79, 48.23)	83.19 (74.19, 90.39)	3.50 (2.60, 4.44)
58	Baró de Viver	35.38 (19.39, 56.83)	42.72 (23.38, 64.90)	32.00 (12.93, 57.99)	22.29 (9.74, 41.50)	25.19 (12.01, 44.74)	81.83 (69.86, 91.54)	3.33 (1.92, 4.85)
56	Vallbona	26.66 (14.33, 43.89)	32.48 (17.96, 53.32)	33.90 (15.55, 57.56)	17.73 (7.70, 33.77)	18.96 (8.81, 33.28)	76.19 (63.05, 87.28)	2.62 (1.23, 4.07)
1	el Raval	19.44 (15.64, 24.06)	21.61 (17.41, 26.80)	22.72 (16.97, 28.69)	16.75 (12.17, 21.35)	23.66 (18.14, 29.13)	76.00 (71.40, 80.96)	2.08 (1.73, 2.43)
54	Torre Baró	19.62 (10.36, 34.27)	23.36 (12.79, 39.03)	28.78 (13.05, 50.95)	14.05 (6.62, 25.92)	17.64 (8.30, 31.07)	69.99 (56.51, 81.99)	1.88 (0.60, 3.30)
57	la Trinitat Vella	20.06 (12.95, 29.03)	24.49 (16.15, 36.12)	23.61 (12.36, 36.80)	13.61 (8.00, 21.46)	14.41 (7.78, 22.29)	68.73 (58.84, 77.67)	1.71 (0.84, 2.51)
3	la Barceloneta	13.54 (8.84, 18.94)	14.90 (9.19, 21.53)	24.62 (16.49, 34.07)	16.82 (10.88, 23.80)	25.68 (18.10, 34.26)	72.46 (65.43, 79.18)	1.67 (1.09, 2.22)
2	el Barri Gòtic	14.28 (9.50, 20.13)	16.55 (10.84, 23.28)	24.24 (15.05, 35.65)	16.62 (10.46, 24.66)	22.08 (14.81, 31.39)	71.90 (63.93, 79.42)	1.65 (0.96, 2.30)
4	Sant Pere, Santa Caterina i la Ribera	13.41 (9.32, 17.87)	15.52 (10.74, 20.82)	21.21 (14.10, 29.92)	17.55 (12.16, 24.60)	20.95 (15.10, 27.34)	72.19 (65.61, 78.75)	1.51 (0.97, 2.01)
12	la Marina del Prat Vermell	18.90 (8.83, 32.71)	22.79 (10.85, 39.53)	19.13 (6.96, 36.41)	14.61 (6.84, 27.11)	14.26 (6.11, 26.96)	68.31 (51.64, 81.89)	1.45 (0.00, 2.78)
53	la Trinitat Nova	17.14 (11.67, 24.38)	20.59 (14.02, 29.24)	23.50 (13.47, 35.12)	12.64 (7.76, 19.38)	13.79 (7.55, 20.77)	66.38 (56.91, 75.47)	1.43 (0.62, 2.18)
38	la Teixonera	16.39 (10.75, 23.23)	20.72 (14.14, 28.94)	23.31 (13.92, 34.23)	10.61 (5.66, 15.95)	12.88 (7.69, 19.79)	63.98 (54.40, 72.42)	1.29 (0.60, 1.95)
51	Verdun	14.14 (9.32, 20.45)	16.49 (10.90, 23.18)	23.18 (14.46, 33.67)	10.93 (6.57, 16.68)	14.68 (9.00, 21.59)	63.50 (54.58, 72.41)	1.14 (0.38, 1.87)
11	el Poble Sec	14.85 (11.01, 19.85)	17.39 (12.84, 23.17)	15.80 (9.33, 23.21)	13.65 (9.26, 18.73)	13.80 (9.15, 19.55)	65.68 (59.52, 72.23)	1.07 (0.51, 1.60)
37	el Carmel	15.43 (11.03, 20.69)	19.57 (14.38, 26.18)	19.82 (13.09, 27.87)	10.72 (6.83, 15.51)	11.20 (7.00, 16.36)	62.61 (55.32, 69.80)	1.06 (0.51, 1.61)
47	Can Peguera	14.12 (5.70, 26.06)	18.75 (7.76, 33.59)	19.94 (6.89, 39.63)	15.01 (6.78, 29.04)	11.41 (4.30, 21.47)	64.08 (46.47, 78.94)	1.01 (-0.68, 2.49)
59	el Bon Pastor	13.28 (8.14, 20.32)	16.87 (10.52, 25.95)	18.24 (8.59, 31.04)	12.17 (6.79, 19.73)	13.34 (7.14, 22.07)	62.39 (52.54, 72.92)	0.92 (0.04, 1.82)
29	el Coll	11.91 (6.95, 18.08)	16.51 (9.77, 25.39)	19.09 (10.10, 31.18)	14.84 (8.02, 24.22)	11.51 (5.60, 19.43)	64.38 (53.96, 74.99)	0.90 (-0.05, 1.76)
10	Sant Antoni	13.28 (9.23, 18.58)	16.85 (11.63, 23.69)	18.08 (11.00, 27.21)	10.63 (6.23, 15.66)	11.54 (6.79, 17.39)	60.79 (53.00, 68.49)	0.81 (0.18, 1.46)
42	la Clota	13.16 (5.71, 25.64)	17.19 (8.04, 33.14)	21.42 (8.09, 43.22)	11.32 (4.45, 21.65)	10.64 (4.20, 21.39)	59.99 (42.39, 75.78)	0.79 (-0.75, 2.47)
46	el Turó de la Peira	11.96 (7.36, 16.71)	15.14 (9.41, 21.85)	22.04 (13.26, 33.29)	9.82 (5.63, 15.59)	10.93 (5.97, 16.96)	59.77 (50.98, 68.56)	0.73 (-0.01, 1.38)
49	Canyelles	11.89 (7.32, 17.84)	14.48 (8.98, 21.82)	20.29 (11.00, 31.65)	9.29 (5.25, 15.81)	11.64 (6.47, 18.49)	58.97 (48.97, 69.28)	0.66 (-0.18, 1.51)
39	Sant Genís dels Agudells	13.47 (8.15, 20.94)	17.57 (10.53, 27.57)	14.26 (6.78, 23.67)	11.13 (6.21, 17.50)	9.82 (4.86, 16.85)	60.88 (50.66, 71.26)	0.62 (-0.32, 1.51)
61	la Sagrera	10.96 (7.66, 14.92)	13.52 (9.54, 18.59)	17.06 (10.10, 25.14)	8.65 (5.21, 12.86)	12.72 (8.42, 18.40)	56.72 (49.00, 64.05)	0.49 (-0.12, 1.10)

70	el Besòs i el Maresme	10.43 (6.27, 15.64)	11.39 (6.57, 16.58)	15.50 (8.80, 25.89)	10.23 (5.73, 15.37)	14.50 (8.42, 22.45)	59.81 (50.88, 69.08)	0.46 (-0.27, 1.12)
41	la Vall d'Hebron	10.82 (5.86, 17.86)	14.18 (8.06, 23.07)	22.52 (11.56, 37.94)	7.58 (3.52, 12.90)	9.10 (4.40, 15.68)	54.35 (41.00, 66.49)	0.38 (-0.60, 1.42)
34	Can Baró	11.20 (6.48, 17.53)	15.01 (8.87, 23.77)	16.12 (8.01, 28.61)	10.24 (5.78, 17.58)	8.61 (3.95, 14.57)	56.83 (45.51, 68.42)	0.36 (-0.60, 1.32)
62	el Congrés i els Indians	11.08 (6.82, 17.06)	13.90 (8.52, 21.55)	13.69 (5.48, 24.38)	10.11 (5.65, 16.35)	11.34 (6.63, 18.19)	57.60 (46.61, 67.78)	0.36 (-0.54, 1.21)
50	les Roquetes	10.66 (6.39, 15.85)	13.03 (8.07, 19.09)	18.66 (10.95, 29.09)	9.20 (5.10, 14.96)	9.92 (5.29, 15.84)	55.12 (45.11, 64.44)	0.36 (-0.48, 1.12)
40	Montbau	10.92 (5.36, 18.84)	13.93 (6.42, 24.30)	16.49 (6.23, 31.29)	9.39 (4.17, 17.08)	9.79 (4.06, 18.66)	57.28 (41.66, 71.39)	0.31 (-1.05, 1.58)
43	Horta	9.70 (6.51, 13.53)	12.52 (8.79, 17.32)	21.71 (14.69, 30.62)	7.31 (4.50, 10.65)	9.04 (5.70, 13.39)	52.28 (44.12, 59.90)	0.25 (-0.34, 0.82)
52	la Prosperitat	9.21 (5.89, 13.04)	11.11 (7.24, 15.98)	14.88 (8.57, 22.19)	9.36 (6.10, 13.91)	9.64 (5.95, 14.41)	54.24 (45.81, 62.27)	0.07 (-0.61, 0.72)
5	el Fort Pienc	8.32 (5.16, 12.75)	10.08 (6.04, 15.21)	16.12 (9.02, 25.00)	8.09 (4.12, 12.44)	11.46 (7.09, 17.64)	54.04 (44.60, 62.84)	0.03 (-0.68, 0.76)
14	la Font de la Guatlla	9.41 (5.05, 15.44)	12.19 (6.71, 19.89)	14.02 (6.36, 26.72)	8.90 (4.61, 15.25)	8.42 (3.84, 14.90)	52.05 (39.31, 64.28)	-0.06 (-1.16, 1.00)
69	Diagonal Mar i el Front Marítim del Poblenou	7.64 (3.70, 13.22)	9.77 (4.96, 17.11)	16.91 (7.50, 30.90)	9.13 (3.90, 16.11)	11.06 (5.31, 19.83)	52.29 (39.03, 64.42)	-0.06 (-1.21, 1.05)
8	l'Antiga Esquerra de l'Eixample	8.69 (5.66, 12.42)	11.90 (7.36, 17.74)	11.00 (5.55, 17.93)	10.93 (6.59, 16.46)	8.86 (5.11, 13.89)	55.47 (46.60, 64.56)	-0.07 (-0.84, 0.65)
36	la Font d'en Fargues	8.57 (4.69, 14.19)	11.49 (6.35, 18.40)	14.21 (6.77, 23.78)	9.15 (4.66, 15.39)	8.58 (4.28, 14.95)	51.36 (39.68, 64.09)	-0.12 (-1.13, 0.89)
33	el Baix Guinardó	8.07 (5.30, 11.40)	10.44 (6.68, 15.44)	14.38 (8.74, 21.75)	8.52 (5.00, 12.60)	8.87 (5.39, 13.62)	53.18 (45.63, 61.61)	-0.13 (-0.82, 0.53)
44	Vilapicina i la Torre Llobeta	8.39 (5.64, 11.71)	10.64 (7.16, 14.58)	16.29 (10.37, 23.81)	7.23 (4.54, 10.43)	7.95 (5.30, 11.57)	49.24 (41.94, 56.77)	-0.18 (-0.76, 0.39)
7	la Dreta de l'Eixample	6.90 (4.29, 9.77)	9.27 (6.15, 13.01)	11.89 (7.05, 18.36)	11.40 (7.89, 16.14)	9.61 (6.29, 13.60)	55.09 (47.42, 62.80)	-0.21 (-0.95, 0.41)
45	Porta	8.62 (5.53, 12.51)	10.90 (7.00, 15.78)	14.30 (8.26, 22.41)	7.57 (4.15, 11.81)	7.73 (4.23, 12.00)	50.12 (41.36, 58.31)	-0.23 (-0.90, 0.48)
71	Provençals del Poblenou	7.30 (4.27, 11.34)	8.94 (5.11, 13.69)	14.56 (8.20, 22.34)	7.60 (4.20, 11.50)	10.27 (5.98, 15.82)	49.72 (40.45, 59.04)	-0.28 (-1.11, 0.49)
35	el Guinardó	7.57 (5.46, 10.18)	9.80 (6.73, 13.08)	13.19 (8.37, 18.84)	8.20 (5.31, 11.11)	8.21 (5.31, 11.60)	50.55 (43.95, 57.29)	-0.31 (-0.83, 0.23)
73	la Verneda i la Pau	7.45 (4.06, 11.42)	8.76 (5.08, 13.69)	13.19 (7.27, 21.18)	7.58 (4.25, 12.11)	10.23 (5.92, 15.46)	51.26 (42.17, 61.09)	-0.32 (-1.15, 0.43)
31	la Vila de Gràcia	7.37 (5.03, 10.19)	10.34 (7.25, 14.17)	9.13 (5.43, 13.52)	13.02 (9.46, 17.96)	7.19 (4.49, 10.17)	53.73 (47.60, 60.00)	-0.36 (-0.89, 0.14)
64	el Camp de l'Arpa del Clot	6.86 (4.05, 10.69)	8.47 (4.52, 13.10)	23.62 (14.14, 34.34)	4.85 (2.30, 8.54)	7.92 (4.07, 12.77)	43.21 (34.39, 51.64)	-0.42 (-1.14, 0.22)
60	Sant Andreu	7.60 (5.46, 10.26)	10.14 (7.34, 13.77)	14.50 (9.62, 20.68)	6.79 (4.42, 9.47)	6.87 (4.35, 9.78)	46.45 (40.23, 52.43)	-0.43 (-0.91, 0.02)
28	Vallcarca i els Penitents	7.76 (4.63, 11.41)	10.75 (6.64, 15.69)	9.93 (5.08, 16.54)	9.88 (6.22, 15.05)	6.71 (3.75, 10.57)	51.95 (43.50, 60.58)	-0.43 (-1.17, 0.30)
6	la Sagrada Família	6.89 (4.71, 9.59)	8.81 (5.92, 12.23)	14.50 (9.30, 21.05)	6.79 (4.03, 9.73)	7.78 (4.82, 11.27)	47.61 (40.56, 54.58)	-0.48 (-1.04, 0.07)
15	Hostafrancs	7.57 (4.36, 11.67)	9.50 (5.57, 14.91)	12.53 (5.84, 21.52)	7.61 (3.99, 12.38)	7.56 (3.98, 12.70)	47.56 (37.12, 57.24)	-0.50 (-1.45, 0.35)
68	el Poblenou	6.34 (3.64, 9.96)	8.05 (4.45, 12.86)	12.55 (6.71, 20.84)	8.88 (5.17, 14.09)	9.17 (5.20, 14.58)	48.71 (39.03, 57.53)	-0.52 (-1.30, 0.30)
48	la Guineueta	6.85 (3.87, 10.12)	8.66 (4.86, 12.81)	13.78 (7.07, 22.12)	7.26 (4.21, 11.31)	7.82 (4.21, 11.90)	47.08 (36.84, 55.90)	-0.54 (-1.43, 0.21)
65	el Clot	6.49 (3.74, 9.61)	8.11 (4.81, 12.01)	16.87 (10.05, 25.90)	5.70 (2.95, 9.15)	8.40 (4.86, 13.09)	44.75 (35.41, 53.84)	-0.55 (-1.29, 0.16)

66	el Parc i la Llacuna del Poblenou	5.79 (3.35, 8.86)	7.07 (3.96, 10.39)	11.40 (5.62, 18.88)	8.51 (4.81, 13.07)	9.54 (5.60, 14.78)	48.56 (39.44, 58.33)	-0.67 (-1.52, 0.13)
9	la Nova Esquerra de l'Eixample	7.36 (4.85, 10.67)	9.86 (6.38, 14.16)	12.03 (6.89, 18.96)	6.74 (4.02, 10.01)	5.86 (3.25, 8.99)	44.54 (36.45, 51.79)	-0.68 (-1.36, -0.01)
30	la Salut	6.58 (3.97, 9.98)	9.54 (5.90, 14.06)	10.26 (5.05, 16.63)	8.16 (4.60, 12.61)	5.85 (3.21, 9.14)	47.28 (38.31, 56.09)	-0.75 (-1.53, 0.03)
13	la Marina de Port	6.85 (4.03, 10.39)	8.51 (5.12, 12.76)	10.95 (5.30, 17.72)	5.89 (3.12, 9.29)	7.12 (4.14, 11.44)	43.63 (35.37, 51.42)	-0.82 (-1.52, -0.15)
63	Navas	6.62 (4.08, 10.05)	8.50 (5.04, 12.85)	10.95 (5.47, 18.24)	6.10 (3.46, 9.45)	7.27 (4.13, 12.02)	43.04 (35.02, 51.80)	-0.82 (-1.62, -0.07)
18	Sants	6.98 (4.64, 9.97)	9.33 (5.95, 13.28)	9.19 (4.90, 14.86)	7.83 (4.94, 11.30)	5.61 (3.16, 8.67)	45.21 (37.46, 53.03)	-0.84 (-1.48, -0.15)
32	el Camp d'en Grassot i Gràcia Nova	5.70 (3.54, 7.85)	7.86 (5.11, 11.23)	8.43 (4.75, 13.08)	8.91 (5.89, 12.64)	6.77 (4.08, 10.02)	48.22 (41.63, 55.20)	-0.90 (-1.52, -0.29)
16	la Bordeta	6.32 (3.46, 10.06)	8.05 (4.29, 13.03)	8.79 (3.85, 16.53)	7.72 (4.28, 12.93)	6.47 (3.26, 11.30)	44.18 (34.14, 55.33)	-0.98 (-1.96, -0.04)
17	Sants - Badal	6.45 (3.74, 10.04)	8.07 (4.57, 12.54)	9.27 (4.32, 16.20)	6.34 (3.22, 10.26)	6.32 (3.39, 10.33)	42.99 (33.80, 53.03)	-1.02 (-1.88, -0.17)
72	Sant Martí de Provençals	4.79 (2.48, 7.77)	5.71 (2.84, 9.36)	12.59 (6.22, 20.98)	5.08 (2.37, 8.18)	7.67 (3.96, 12.94)	39.95 (29.81, 49.20)	-1.21 (-2.15, -0.37)
67	la Vila Olímpica del Poblenou	3.89 (1.60, 6.91)	5.09 (2.10, 9.59)	11.81 (4.77, 22.75)	7.48 (3.25, 13.43)	7.82 (3.50, 14.46)	41.06 (27.51, 53.15)	-1.31 (-2.59, -0.17)
22	Vallvidrera, el Tibidabo i les Planes	5.11 (2.06, 9.70)	7.39 (2.93, 13.90)	5.77 (1.79, 12.78)	11.31 (5.60, 21.72)	5.58 (2.15, 11.26)	44.58 (30.82, 60.59)	-1.36 (-2.78, -0.06)
27	el Putxet i el Farró	4.51 (2.30, 7.60)	6.41 (3.36, 10.65)	4.60 (1.77, 8.68)	11.08 (6.71, 17.33)	5.63 (2.89, 9.69)	44.76 (35.21, 53.57)	-1.53 (-2.42, -0.67)
25	Sant Gervasi - la Bonanova	3.69 (1.97, 6.00)	5.40 (3.18, 8.58)	4.43 (1.93, 7.82)	8.05 (4.85, 12.08)	4.19 (2.11, 6.91)	37.36 (30.00, 46.22)	-2.04 (-2.90, -1.26)
19	les Corts	3.63 (2.26, 5.39)	5.02 (3.23, 7.27)	4.47 (2.31, 7.22)	5.33 (3.45, 7.32)	3.89 (2.40, 5.89)	32.78 (27.89, 37.89)	-2.27 (-2.87, -1.76)
26	Sant Gervasi - Galvany	2.96 (1.68, 4.52)	4.23 (2.41, 6.38)	3.96 (1.99, 6.69)	8.04 (5.21, 11.71)	4.48 (2.50, 6.95)	36.44 (30.04, 42.96)	-2.29 (-2.98, -1.65)
23	Sarrià	3.13 (1.46, 5.45)	4.62 (2.29, 8.00)	3.86 (1.31, 7.78)	6.43 (3.35, 10.60)	3.56 (1.60, 6.54)	32.39 (23.13, 42.21)	-2.51 (-3.54, -1.58)
20	la Maternitat i Sant Ramon	3.21 (1.66, 5.16)	4.16 (2.07, 6.81)	4.21 (1.75, 7.92)	4.91 (2.47, 8.07)	3.92 (1.93, 6.54)	31.34 (24.29, 39.16)	-2.54 (-3.41, -1.80)
24	les Tres Torres	2.58 (1.14, 4.72)	3.81 (1.67, 6.71)	3.73 (1.17, 7.47)	5.73 (2.85, 9.72)	3.40 (1.54, 6.49)	29.93 (19.82, 40.44)	-2.84 (-4.03, -1.76)
21	Pedralbes	2.10 (0.84, 3.69)	3.12 (1.31, 5.70)	3.24 (1.06, 6.90)	4.99 (2.61, 8.61)	2.58 (1.13, 4.86)	25.60 (17.37, 34.52)	-3.33 (-4.46, -2.32)
*	Overall Barcelona city	9.36	11.41	13.90	9.66	9.96	51.43	0

Probability of being higher than the overall value for Barcelona city (*)

- [0, 0.025)
- [0.025, 0.05)
- [0.05, 0.95)
- [0.95, 0.975)
- [0.975, 1]

Author Contributions

Conceptualization, M.M.D., L.O., C.V., L.A. , C.B., M.G., L.P, M.J.L. and M.A.M.B.; methodology, M.M.D., L.O.,C.V. and M.A.M.B; formal analysis, C.V., M.A.M.B, L.O. and M.M.D.; writing—original draft preparation, M.M.D.; writing—review and editing, M.M.D., L.O., C.V., L.A. , C.B., M.G., L.P, M.J.L. and M.A.M.B.; supervision, M.M.D and M.A.M.B. All authors have read and agreed to the published version of the manuscript.

Funding

The study is part of the PENSA Project ("Pobreza energética y salud desde multiples perspectivas: análisis individual, geográfico y temporal"), which received a research grant from the Carlos III Institute of Health, Ministry of Economy and Competitiveness (Spain), awarded on the 2015 call under the Health Strategy Action 2013–2016, within the National Research Program aimed at Societal Challenges, within the Technical, Scientific and Innovation Research National Plan 2013–2016, with reference PI15/02006, co-funded with European Union ERDF funds (European Regional Development Fund)". This study was also partially funded by "CIBER Epidemiología y Salud Pública" (CIBERESP) sub-program "Energy Poverty and Health". L.O. was supported by a Rio Hortega grant (CM19/00184—Contratos Rio Hortega/Fondo Social Europeo) from the Carlos III Institute of Health.

Institutional Review Board Statement

This study was approved by the Clinical Research Ethics Committee of Hospital del Mar (2015/6155/I).

Informed Consent Statement

Not applicable.

Data Availability Statement

Data available upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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6. DISCUSSIÓ

Aquesta secció s'estructura en tres apartats. En el primer apartat es resumeixen breument els resultats principals dels quatre estudis que conformen la tesi. En el segon apartat es realitza una discussió conjunta de les principals aportacions. Per últim, en el tercer apartat es revisen les limitacions i fortaleses més rellevants del treball.

6.1. Resultats principals

Els resultats obtinguts en aquesta tesi constitueixen un avenç en el coneixement de la pobresa energètica i de la seva relació amb la salut, tenint en compte l'evolució en el temps i diferents eixos de desigualtat. Les principals troballes dels quatre estudis realitzats són:

1) La pobresa energètica va augmentar de forma generalitzada a la Unió Europea arran de la crisi econòmica del 2008 seguint un patró de pic (∧). Per exemple: l'any 2007, un 9% de la població no podia permetre's mantenir la llar a una temperatura adequada durant els mesos freds. Aquest percentatge es va incrementar fins l'11,8% l'any 2012 i va tornar a descendir fins al 9% l'any 2016. Conseqüentment, l'any 2012 s'agreuja també l'impacte de la pobresa energètica en: la salut percebuda, la reducció del benestar i el risc de depressió. Durant el període d'estudi, l'evolució temporal de la pobresa energètica i de la seva relació amb

la salut va ser més desfavorable en els països amb major vulnerabilitat estructural a la pobresa energètica (sud i est de la Unió Europea) i en les dones. Així, l'any 2012, el percentatge de dones de països amb major vulnerabilitat estructural a la pobresa energètica que no podia permetre's mantenir la llar a una temperatura adequada durant els mesos freds va arribar al 18,3%, al que se li podria atribuir al voltant d'un 9% dels casos de mala salut percebuda d'aquesta població.

2) A la ciutat de Barcelona, un 12,4% de la població viu en situació de pobresa energètica. Aquest percentatge global amaga fortes desigualtats en la distribució de la pobresa energètica per raó de: gènere, edat, classe social o país de naixement. Així, per exemple, les dones migrades nascudes en països de renda baixa i mitjana pateixen el doble de pobresa energètica que la mitjana de la ciutat (24,7%).
   La pobresa energètica s'associa a un pitjor estat de salut física i mental. Per exemple, tant les dones com els homes en situació de pobresa energètica tenen al voltant de dues vegades més mala salut percebuda i mala salut mental que aquelles i aquells sense pobresa energètica. Així mateix, viure en situació de pobresa energètica s'associa a un major ús de serveis de salut i a un major consum de fàrmacs.

3) A la ciutat de Barcelona, un 10,6% de les persones menors de 15 anys viuen en situació de pobresa energètica. Aquesta es distribueix de manera desigual segons diferents característiques sociodemogràfiques, socioeconòmiques i

de l'habitatge. Per exemple, el percentatge és major en famílies amb menys recursos econòmics (30,8%) i, encara més alt, en famílies que pateixen altres situacions de dificultat com la inseguretat alimentària (53,4%). Els nens i nenes en situació de pobresa energètica tenen vora set vegades més mala salut que els seus iguals sense pobresa energètica. Els resultats també suggereixen una associació entre la pobresa energètica i una pitjor salut mental i una major prevalença d'asma i sobrepès, a la infància.

4) A la ciutat de Barcelona, existeixen fortes desigualtats geogràfiques en la distribució de la pobresa energètica. S'identifiquen tres agrupacions espacials de barris amb un excés significatiu de pobresa energètica, en relació amb la mitjana de la ciutat. Aquestes agrupacions se situen al nord, nord-oest i centre històric de la ciutat. Els barris amb pitjors puntuacions a l'índex de pobresa energètica són Ciutat Meridiana, Baró de Viver, Vallbona, el Raval, Torre Baró, la Trinitat Vella, la Barceloneta, el Barri Gòtic i Sant Pere, Santa Caterina i la Ribera.

6.2. Discussió conjunta de les principals aportacions

Amb l'objectiu d'integrar l'evidència generada a partir dels quatre estudis que conformen aquesta tesi, aquest apartat s'organitza segons els dos marcs conceptuals que han guiat el treball empíric: a) el marc conceptual de les desigualtats en salut de la Comissió per Reduir les Desigualtats en Salut a l'Estat espanyol (Figura 1) i b) la seva adaptació a la pobresa energètica, a través del marc conceptual de les desigualtats en salut relacionades amb la pobresa energètica (Figura 2). Es distingeixen, per tant, tres grans subapartats que fan referència a: els determinants estructurals, els determinants intermedis i les condicions de salut i les desigualtats en salut relacionades amb la pobresa energètica.

6.2.1. Determinants estructurals de les desigualtats en salut relacionades amb la pobresa energètica

Els resultats d'aquesta tesi fan palès el paper cabdal del context socioeconòmic i polític, i de l'estratificació social i les relacions de poder que se'n deriven, en les desigualtats en salut relacionades amb la pobresa energètica. Aquest reconeixement pot contribuir a treure la pobresa energètica de l'àmbit de la llar i a no seguir naturalitzant-la, com una conseqüència pròpia de les persones amb menys recursos econòmics.[56] S'afavoreix així, superar la predominant culpabilització individual i apuntar cap a la responsabilitat estructural.

El context socioeconòmic i polític

Alguns estudis previs han demostrat com les particularitats del context socioeconòmic i polític determinen una major o menor vulnerabilitat a la pobresa energètica.[29,58] En aquesta línia, Recalde et al. defineixen la vulnerabilitat estructural a la pobresa energètica com la capacitat d'un país de protegir, en major o menor mesura, la seva població de patir una situació de pobresa energètica quan es produeix un canvi en les condicions internes o externes de la llar. El primer estudi d'aquesta tesi examina l'efecte de la crisi econòmica i financera del 2008 (una condició externa a les llars) en l'increment de la pobresa energètica a la Unió Europea, segons el grau de vulnerabilitat estructural a la pobresa energètica dels països. Els resultats reforcen la hipòtesi que els països amb més vulnerabilitat estructural a la pobresa energètica tenen majors taxes de pobresa energètica. Així mateix, s'observa com l'increment de persones en situació de pobresa energètica, arran de la crisi econòmica, és major als països amb més vulnerabilitat estructural a la pobresa energètica. Per exemple: entre l'any 2007 i el 2012, el percentatge de llars que reportava algun endarreriment en el pagament de factures de subministraments en els últims 12 mesos va incrementar del 16,2% al 20,7%, en els països amb major vulnerabilitat estructural a la pobresa energètica. En canvi, en els països amb menor vulnerabilitat estructural a la pobresa energètica l'increment va ser tan sols del 9,5% al 10,2%. El major increment observat, en els països amb més vulnerabilitat estructural a la pobresa energètica, també es va traduir en un major agreujament de l'impacte en salut de la pobresa energètica en aquests països augmentant, així, les desigualtats en salut entre territoris.[117]

Aquests resultats s'afegeixen a la, cada cop més abundant, evidència científica sobre el paper clau del sistema polític-econòmic així com de la robustesa dels estats del benestar i de l'abast de la protecció social en les desigualtats en salut.[118,119] En consonància, diversos estudis han abordat la relació entre les desigualtats en salut i polítiques d'àmbits tan diversos com: la fiscalitat[120], el mercat laboral[121], el treball domèstic i de cures[122], l'habitatge (tant en l'àmbit de l'accessibilitat com de l'eficiència energètica)[113,123], la regeneració urbana[124], l'estat del benestar[125] o les polítiques d'igualtat de gènere[126]. Es posa així de manifest, l'impacte que tenen les polítiques d'àmbits molt diferents del de la salut sobre les desigualtats en salut i la necessitat d'incorporar la salut en totes les polítiques.

En l'àmbit de la pobresa energètica, un sector rellevant és el de polítiques de rehabilitació energètica. Diversos estudis suggereixen que les intervencions per millorar l'eficiència energètica de les llars poden comportar millores en: la salut, el benestar i certs determinants psicosocials, de la salut de les persones què se'n beneficien.[127–130] Aquest tipus d'intervencions, però, també poden augmentar les desigualtats en salut si no persegueixen millorar l'equitat en salut de forma explícita. Així s'evidencia en una revisió realista sobre el procés d'implementació d'intervencions de millora de l'eficiència energètica dels edificis i els seus efectes en els determinants de les desigualtats en salut. En aquest estudi, Camprubí et al. van observar com les polítiques de rehabilitació sovint persegueixen objectius diferents a la reducció de la pobresa energètica, com per exemple: la mitigació del canvi climàtic. Per tant, generalment no contemplen que certs grups socials més exposats a la pobresa energètica (persones amb baixos ingressos, persones grans o persones llogateres) són els que experimenten més dificultats per emprendre la rehabilitació d'un edifici, el que es tradueix en un augment de les desigualtats en salut. Algunes de les principals barreres identificades i que s'haurien de tenir en compte en futures intervencions són: les despeses inicials, la falta d'incentius per a les persones propietàries per millorar l'eficiència energètica o, fins i tot en el cas d'intervencions públiques, la insuficient atenció sobre les necessitats i preferències de les persones residents.[131]

Així doncs, l'acció intersectorial en salut no és suficient per avançar cap a l'equitat en salut per si sola. Per tal que les polítiques públiques no (re)produeixin desigualtats socials en salut, és necessari que també abordin les estructures i dinàmiques socials que perpetuen les relacions de poder desiguals. Això passa entre d'altres, per replantejar quines són les prioritats de l'actual sistema polític-econòmic. Així, les polítiques públiques vinculades als principals determinants estructurals de la pobresa energètica obtindran resultats diferents, depenent de si prioritzen maximitzar el benefici en termes econòmics o de benestar.

El nostre sistema polític-econòmic actual es regeix per l'imperatiu de l'acumulació de capital, que s'acaba expressant en una creixent concentració de riquesa i exclusió social, així com en una constant explotació de la naturalesa i la seva degradació.[132] En les últimes dècades, la lògica neoliberal ha intensificat pràctiques per a maximitzar el benefici econòmic com la mercantilització del què, fins ara, s'havien considerat sectors de domini públic com: l'educació, la sanitat o l'energia.[85] En l'àmbit de l'energia, la seva conceptualització com un bé de consum a la Unió Europea ha centrat els esforços per combatre la pobresa energètica en la protecció de les persones consumidores vulnerables a través de mecanismes econòmics compensatoris, com ara subsidis per pagar les factures energètiques.[69] Aquest tipus de polítiques han demostrat no ser suficients. En no qüestionar críticament l'actual model energètic permeten, entre d'altres, que els grups de pressió i les grans companyies energètiques segueixin exercint el seu poder per defensar els seus interessos. S'assumeix així, per exemple, que el preu de l'energia estigui sobredimensionat i que les grans corporacions obtinguin beneficis desorbitats, a costa del benestar de la ciutadania i dels diners públics.

La contradicció entre el capitalisme i la salut exigeix avançar cap a sistemes polític-econòmics alternatius, que permetin aconseguir una veritable equitat en salut.[85] L'ecofeminisme, per exemple, ofereix reflexions i propostes interessants. Lligant els corrents de pensament i lluites socials de l'ecologisme i els feminismes, l'ecofeminisme entén que l'actual model econòmic i cultural occidental és fruit de la dominació, explotació i degradació de la terra i la naturalesa no humana, i l'opressió de les dones i altres grups socials com els pobles originaris, les persones racialitzades o les persones LGTBI, entre d'altres. Es connecta, així, la subordinació de les dones i altres grups socials i l'explotació de la natura, com a part d'una lògica comuna: la idea de poder viure al marge de la naturalesa, exercint el poder heteropatriarcal i sotmetent la vida a l'exigència de l'acumulació.[133,134] Aquesta lògica és incompatible amb la d'un món sostenible i just i cal, per tant, un nou paradigma que posi la vida al centre. L'ecofeminisme busca desmuntar els binarismes: humanitat i naturalesa, home i dona i producció i reproducció, entenent aquests últims com a elements indissociables del procés econòmic. Així, la producció hauria d'estar estretament lligada al sosteniment de la vida i al benestar de les persones. És a dir, el que produïm ha de permetre satisfer les necessitats humanes amb criteris d'equitat. L'organització de la vida quotidiana entorn a la subsistència afavoreix: la sobirania alimentària i l'energètica, la democràcia participativa i la reciprocitat amb els ecosistemes naturals, entre d'altres.[133]

Això, aplicat a l'àmbit de la pobresa energètica i en consonància amb el discurs dels moviments per la justícia energètica, vol dir conceptualitzar l'energia com un bé comú essencial, necessari per al sosteniment d'unes vides dignes. També, vol dir avançar cap a un model energètic més sostenible, descentralitzat, democràtic i participatiu. És a dir: apostar per fonts d'energia renovables i respectar els límits del planeta; descentralitzar i (re)localitzar les activitats energètiques per aproximar la generació i el consum; i reconèixer el dret de la ciutadania a decidir i governar el seu abastiment d'energia, incorporant noves estructures de governança que comportin major participació ciutadana, en les polítiques energètiques, i noves formes de propietat i gestió públic-comunitàries.[135–137] En definitiva, també vol dir garantir el dret a l'energia.

Eixos de desigualtat

Consistentment amb estudis previs, els resultats dels quatre estudis d'aquesta tesi mostren com la pobresa energètica es distribueix de manera desigual en la població, seguint els patrons clàssics d'estratificació social. Els resultats mostren desigualtats quant a: gènere, edat, classe social, país de naixement i territori.

De forma recurrent, els diferents estudis realitzats mostren com la pobresa energètica es concentra, sobretot, en les classes socials més desafavorides. A Barcelona, per exemple, el 25,2% de les criatures de famílies de classes socials més desafavorides viuen en situació de pobresa energètica. En les classes socials més afavorides, aquest percentatge és tan sols del 4,5%.[138] Aquestes fortes desigualtats s'observen també en la població adulta, tant en dones com en homes.[139] Tot i que la pobresa energètica és un fenòmen complex i multidimensional, i no pot considerar-se una simple expressió més de la pobresa, la posició socioeconòmica hi està estretament relacionada. Els subministraments, al ser considerats un bé de consum, acaben sent només accessibles per a aquelles persones que poden pagar-los. Això es fa especialment palès en l'anàlisi de sensibilitat realitzada en l'estudi 2 (Annex IV), on s'observa com la pobresa energètica afecta a aquelles persones que tenen menys recursos econòmics, de forma desmesurada. Així a Barcelona, entre les persones amb menys poder adquisitiu els percentatges de pobresa energètica se situen al voltant del 40%.[139]

No obstant això, en parlar d'eixos de desigualtat és essencial tenir en compte que totes les persones estem ubicades amb relació a tots ells, podent ocupar diferents posicions de privilegi i opressió, simultàniament. És la intersecció dels diferents eixos de desigualtat la què crea les diferents realitats socials. A més, analitzar els eixos de desigualtat de forma exclusivament monofocal pot portar a una homogeneïtzació dels grups socials i a negar la seva pròpia diversitat.[140–142]

Un bon exemple de la necessitat d'incorporar l'enfocament de la interseccionalitat, en relació amb els resultats d'aquesta tesi, és l'anàlisi de les desigualtats de gènere. A nivell poblacional, en els estudis realitzats s'ha observat com les taxes de pobresa energètica són, consistentment, lleugerament més elevades en les dones, tant als països amb menor com amb major vulnerabilitat estructural a la pobresa energètica i, també, a la ciutat de Barcelona. Tanmateix, l'anàlisi només desagregada per sexe no permet visualitzar als col·lectius especialment vulnerabilitzats. Així, les diferències de percentatge de pobresa energètica entre dones i homes s'exacerben quan també tenim en compte: l'edat, el país de naixement o la classe social.

Aquestes altres categories socials estan fortament vinculades al menor poder econòmic, social i polític que tenen les dones en les societats heteropatriarcals. La menor participació de les dones en el mercat laboral i les seves pitjors condicions, explicades, principalment, per la divisió sexual del treball, la segregació vertical i horitzontal i la bretxa salarial entre dones i homes, juntament amb les conseqüents menors prestacions d'atur i jubilació entre d'altres, condemna moltes dones a una situació econòmica molt desafavorida i comporten una creixent feminització de la pobresa. Aquesta es fa palesa, sobretot, en les llars encapçalades per una dona i, en particular, en el cas de les mares soles o de les dones majors de 65 anys que viuen soles.[143]

Estudis recents també mostren una creixent feminització de la pobresa energètica i identifiquen com a principals grups vulnerabilitzats: les mares soles, les dones majors de 65 anys, les dones migrades i les treballadores de la llar i del sector de serveis domèstics.[55,144–146] Els resultats obtinguts en aquesta tesi aporten evidència al respecte. A Barcelona, un 15% de les dones majors de 65 anys viu en situació de pobresa energètica, mentre que en els homes majors de 65 anys aquest percentatge és tan sols del 8,1%. Aquestes diferències podrien ser encara més grans si limitéssim l'anàlisi, tan sols, a les dones majors de 65 anys que viuen soles. En les classes socials més desafavorides, trobem que un 22,2% de les dones pateixen pobresa energètica, gairebé el doble de la mitjana de la ciutat. Les dones nascudes en països de renda baixa i mitjana són el col·lectiu que presenta més pobresa energètica, un 24,7%.[139] Pel que fa a les llars amb infants, a Barcelona, les llars monoparentals i sobretot les llars monoparentals on hi viu una altra persona adulta, són les què mostren majors taxes de pobresa energètica (11,4% i 16,4% respectivament). D'aquestes, un 85,4% són llars encapçalades per dones.[138]

Respecte al gènere també cal mencionar, que els indicadors de pobresa energètica fan referència a les llars, assumint que aquestes són espais homogenis. Però l'esfera privada, el lloc on s'expressa i es viu la pobresa energètica, segueix sent un dels àmbits més condicionats pel gènere. L'encara desigual distribució del treball domèstic i de cures comporta que moltes dones passin més temps a casa i siguin les principals responsables de la gestió de la pobresa energètica, per exemple: controlant el consum energètic i adoptant estratègies per reduir-lo o tramitant les sol·licituds d'ajudes, com el bo social.[146] A Barcelona, per exemple, un 67,1% de les persones que acudeixen als Punts d'Assessorament Energètic són dones.[74] Tot plegat, fa que l'experiència viscuda per les dones, amb relació a la pobresa energètica, pugui ser més severa[146] i pugui tenir una major repercussió sobre la seva salut.

Els resultats obtinguts també revelen fortes desigualtats en l'exposició a la pobresa energètica, segons el país de naixement. Un cop més, cal tenir en compte la diversitat dels grups socials deguda a la intersecció dels diferents eixos. La població migrant a Barcelona és molt heterogènia. En aquesta tesi s'ha diferenciat entre les persones nascudes en països de renda alta (que inclou l'Estat espanyol) i les persones nascudes en països de renda baixa i mitjana. En aquest últim col·lectiu, l'experiència migratòria sovint se solapa amb una classe social desafavorida (72,4%). Així per exemple, en l'estudi en població infantil, s'ha constatat un gradient de pobresa energètica segons si els pares i/o les mares havien nascut: ambdós en països de renda alta (6,6%); un en un país de renda alta i l'altre en un país de renda baixa i mitjana (18,2%) o ambdós en països de renda baixa i mitjana (20,7%).[138] Aquests resultats se sumen a l'evidència generada per altres estudis, on s'identifica a la població migrant com especialment vulnerabilitzada. Les dificultats econòmiques i, en l'accés al mercat laboral i de l'habitatge, la situació administrativa irregular, el menor reconeixement de drets i necessitats, la discriminació, la barrera idiomàtica o el manteniment econòmic de criatures o d'altres familiars en els països d'origen, són algunes de les causes de la vulnerabilitat energètica que s'identifiquen en aquest col·lectiu.[33,69,114,147,148]

Finalment, els resultats d'aquesta tesi mostren fortes desigualtats territorials en l'exposició a la pobresa energètica, a diferents escales. Es confirmen les desigualtats entre les dues macro regions de la Unió Europea[117] i es mostren, per primera vegada, les fortes desigualtats entre els barris de Barcelona.[149] La pobresa energètica es considera un fenomen intrínsecament espacial[150] i la seva desigual distribució territorial un component clau per a la justícia energètica.[151] Els patrons de desigualtat espacial depenen de l'escala i del territori analitzat. Així doncs, l'agregació i les estimacions dels valors mitjans, en diferents unitats d'anàlisi revelen i oculten diferències, al mateix temps.[33,152] En el cas de Barcelona, per exemple, un 9,4% de la població no pot permetre's mantenir la llar a una temperatura adequada durant els mesos freds. Aquest percentatge, tot i ser molt major a la mitjana de la macro regió europea amb menor vulnerabilitat estructural a la pobresa energètica (4,9%), és també menor a la mitjana dels països amb major vulnerabilitat estructural (14,2%), la macro regió europea on se situa la ciutat.[117] La dada global de la ciutat oculta, però, fortes desigualtats que poden observar-se en l'anàlisi desagregada per districte, on el percentatge de persones que no poden permetre's mantenir la llar a una temperatura adequada durant els mesos freds oscil·la entre el 2,7%, al districte de Sarrià-Sant Gervasi i el 18,2% a Ciutat Vella.[153] Aquestes desigualtats encara s'accentuen més a nivell de barri, on el percentatge de persones que no poden permetre's mantenir la llar a una temperatura adequada durant els mesos freds és només del 2,1% al barri de Pedralbes i supera el terç de la població de barris com Baró de Viver (35,4%) o Ciutat Meridiana (31,4%).[149] L'espai no és un contenidor neutre en el qual "succeeix" el món social. L'espai es construeix socialment a través de diferents relacions i pràctiques socials que, alhora, el mateix espai contribueix a (re)produir.[154] Per tant, la desigual exposició a la pobresa energètica als barris de Barcelona pot explicar-se per la desigual distribució espacial de factors que augmenten la vulnerabilitat a la mateixa,[55,155,156] així com pel context històric i les trajectòries de cada barri,[150] tenint en compte que aquestes particularitats es (re)produeixen per factors i processos més estructurals.[151]

Per últim, com s'ha esmentat a la introducció, la distribució del poder, segons els diferents eixos de desigualtat i la seva intersecció, es considera una de les causes més fonamentals de les desigualtats en salut. Però el poder no té una única expressió. En els estudis que conformen aquesta tesi, i seguint els marcs conceptuals sobre els quals s'ha fonamentat, es reconeix el paper de la que, segurament, és l'expressió més reconeguda del poder. Aquella que es relaciona amb aspectes com: el control, la coerció, la dominació o l'opressió, i que dona lloc a relacions jeràrquiques de poder amb persones guanyadores i perdedores, que es reprodueixen, sistemàticament, en les principals institucions econòmiques, polítiques i culturals.[88] Abordar aquest poder estructural hegemònic, que a l'hora limita l'agència individual i col·lectiva dels grups més desafavorits, és essencial per reduir les desigualtats en salut. Al mateix temps, però, és interessant ressaltar el paper d'altres expressions més positives del poder. El poder també es relaciona amb la capacitat d'empoderar-se i transformar.[157] En l'empoderament col·lectiu, el poder es crea quan les persones actuen de forma solidària per lluitar contra la subordinació.[158] En aquest cas, el poder no té una connotació negativa, sinó que es refereix a la construcció d'aliances i de força col·lectiva, claus per transformar les relacions de poder[157] i, per tant, per reduir les desigualtats en salut.[88]

En l'àmbit de la pobresa energètica, un bon exemple és l'Aliança contra la Pobresa Energètica. Aquest moviment social, format per persones afectades per la pobresa energètica i altres col·lectius i entitats, està transformant el paradigma de la pobresa energètica a Catalunya, el que també està tenint ressò internacionalment.[81] A través dels assessoraments col·lectius, que organitzen cada 15 dies, es construeixen espais comunitaris de confiança, on les persones afectades poden empoderar-se i capacitar-se, tècnicament i emocionalment, per buscar solucions reals a la seva situació. Així, compartir les diferents experiències permet socialitzar eines i coneixement i que les persones afectades es transformin en subjectes actius, coneixedores dels seus drets, i de com defensar-los, i transmissores d'aquest coneixement, podent assessorar altres persones a la vegada.[76] Els assessoraments col·lectius, a part d'un espai de suport mutu i des d'on s'intenta anivellar la relació de forces desigual entre la persona afectada i l'administració i les empreses subministradores, són també un espai de col·lectivització i politització de la problemàtica.[159] Des de l'Aliança contra la Pobresa Energètica, s'està propiciant un canvi de discurs sobre la pobresa energètica,[160] visibilitzant i donant veu a les persones afectades i reclamant que els subministraments són un bé essencial pel sosteniment d'unes vides dignes.[161] Es lluita, per tant, per garantir el dret universal als subministraments bàsics assenyalant tant la responsabilitat de les administracions a l'hora de garantir aquest dret, com la culpa de la gestió de l'actual model energètic, que es tradueix en una forta mercantilització dels subministraments i en un abús, cada cop més gran, per part de les companyies subministradores. La incidència política de l'Aliança contra la Pobresa Energètica també està aconseguint transformacions a nivell estructural, mitjançant: campanyes i accions, denúncia pública a través de mitjans de comunicació o creació de coneixement, entre d'altres. Algunes de les principals victòries d'aquesta lluita col·lectiva són: l'adopció i implementació de la llei 24/2015 (prèviament comentada a la introducció), la condonació del deute acumulat de milers de famílies per part d'una de les empreses de l'oligopoli energètic o la provisió de comptadors socials d'aigua i electricitat a persones que viuen en situació d'ocupació en precari.[76] Així doncs, el poder col·lectiu també és imprescindible per acabar amb les desigualtats socials en salut relacionades amb la pobresa energètica, gràcies a la seva acció transformadora, tant a nivell micro com macro.

6.2.2. La pobresa energètica com a determinant intermedi de les desigualtats en salut

D'acord amb els marcs conceptuals utilitzats en aquesta tesi, la pobresa energètica, així com les seves causes materials més directes (els alts preus de l'energia, els baixos ingressos i la baixa eficiència energètica dels habitatges i dels equipaments i electrodomèstics) es consideren part dels determinants intermedis de les desigualtats socials en salut, que afecten les condicions de vida de les persones. Com ja s'ha esmentat a la introducció, la multidimensionalitat d'aquest fenomen fa que les seves expressions també siguin plurals i, per tant, difícils de capturar amb un únic indicador. Tal com recomana l'Observatori de la Pobresa Energètica de la Unió Europea, una estratègia per entendre millor aquesta complexitat és fer servir diferents indicadors que informin sobre diferents causes, símptomes i conseqüències de la pobresa energètica. Aquest també és l'enfocament que s'ha intentat adoptar en els estudis que conformen aquesta tesi, intentant combinar sempre diferents indicadors de pobresa energètica, així com explorant indicadors poc utilitzats fins al moment.

En el primer estudi, l'evolució de la pobresa energètica i de les seves conseqüències per a la salut, a la Unió Europea en el context de la crisi econòmica, es va estudiar a partir de dos indicadors autoreportats. Les diferències trobades en els percentatges de pobresa energètica segons els dos indicadors però, sobretot, les diferents evolucions de les respectives conseqüències en salut[117] donen suport a la premissa que cal abordar la problemàtica de la manera més completa possible. En aquest cas, els dos indicadors es van poder analitzar per separat, perquè no existia un solapament important entre ells. Aquesta troballa coincideix amb els resultats d'estudis poblacionals previs a l'Estat espanyol i a Barcelona, que suggereixen que només una minoria de llars reporten no poder mantenir l'habitatge a una temperatura adequada durant els mesos freds i, al mateix temps, haver-se endarrerit en el pagament de rebuts.[40,69]

No obstant això, no sempre és fàcil aprofundir en les diferents expressions de la pobresa energètica perquè, sovint, aquestes estan estretament entrellaçades i se solapen. Per exemple en els estudis dos i tres, on s’analitza la relació de la pobresa energètica i la salut a la ciutat de Barcelona, el fort solapament (68%) entre les llars que no poden permetre’s mantenir la casa a una temperatura adequada durant els mesos freds i les que no ho poden fer durant els mesos càlids, no va permetre estudiar per separat els efectes sobre la salut d’aquests dos símptomes de la pobresa energètica. D’altra banda, l’estudi realitzat en infants també revela com el percentatge de llars que no poden permetre’s mantenir la casa a una temperatura adequada durant els mesos freds i/o càlids a Barcelona es duplica i, fins i tot, es triplica si les llars refereixen un altre indicador de pobresa energètica, com ara: haver-se endarrerit en el pagament de rebuts, tenir humitats, floridura o goteres a l’habitatge o no tenir calefacció o aire condicionat, o tenir-ne, però no fer-ne ús quan és necessari.[138]

El solapament de diferents indicadors de pobresa energètica és més notable en poblacions especialment vulnerabilitzades. Així ho mostra un estudi realitzat a la ciutat de Barcelona que avalua una intervenció per reduir la pobresa energètica, en població atesa a serveis socials. L’estudi apunta que el major solapament de diferents indicadors de pobresa energètica en aquest col·lectiu es tradueix en una major intensitat de la pobresa energètica que s’associa, també, amb un pitjor estat de salut.[53] Així mateix, en aquesta línia, es descriu un major solapament d’expressions de la pobresa energètica en un estudi realitzat amb les persones afectades que participen de l’Aliança contra la Pobresa Energètica i la Plataforma d’Afectades per la Hipoteca.[162]

La complexitat de la casuística de les diferents expressions de la pobresa energètica també es reflecteix quan la unitat d'anàlisi és el barri. A Barcelona, tenint en compte els 6 indicadors de pobresa energètica utilitzats en el quart estudi d'aquesta tesi, s'identifiquen: des de barris amb percentatges significativament superiors a la mitjana de la ciutat en tots 6 indicadors, fins a barris amb percentatges significativament inferiors a la mitjana de la ciutat en tots 6 indicadors trobant, entremig, tota mena de combinacions. Així, l'obtenció d'un índex que resumeixi les diferents expressions de la pobresa energètica té un important valor afegit, ja que pot ajudar a la correcta detecció dels barris més afectats.[149]

Estudiar la pobresa energètica, com a condició pròpia de privació material, ens permet identificar els factors i processos més estructurals i sistèmics que la provoquen i anar més enllà de les causes exclusivament monetàries. Ens ajuda, també, a entendre millor els mecanismes a través dels quals la pobresa energètica afecta la salut. Però el lligam de la desigual distribució de recursos, a la nostra societat, amb el context socioeconòmic i polític i els eixos de desigualtat fa que, sovint, la pobresa energètica formi part d'un context d'exclusió social més ampli.[163] Tenir en compte la interacció de diferents dificultats és rellevant perquè aquest context, més advers, pot amplificar els efectes negatius sobre la salut i fer que sigui més difícil trencar amb el cercle de la precarietat.

Els resultats obtinguts en aquest treball recolzen la tesi de la coexistència de la pobresa energètica amb altres situacions de precarietat i dificultat. A Barcelona, com mostra l'anàlisi de sensibilitat realitzada en l'estudi 2 (Annex IV), en aquelles llars amb més dificultats econòmiques, el percentatge de pobresa energètica és gairebé quatre vegades superior que en la població general.[139] En l'estudi realitzat en infants s'observa, també, com el percentatge de pobresa energètica és superior en persones que viuen de lloguer a preu de mercat (17,6%) i, sobretot, en persones que viuen en situacions residencials precàries com rellogant una part d'un habitatge, ocupant en precari o vivint en habitatges cedits per familiars, serveis socials o organitzacions no governamentals (40,7%). A més, destaca l'altíssim percentatge de famílies amb inseguretat alimentària que també pateixen pobresa energètica (53,4%).[138]

Aquests resultats són consistents amb diferents estudis que mostren com, sovint, es produeix una acumulació de condicions específiques de desigualtat, precarietat o desavantatge en la població més vulnerabilitzada.[163] Per exemple, en l'estudi prèviament mencionat en població atesa a serveis socials a la ciutat de Barcelona, es va evidenciar com aquest col·lectiu, en comparació amb la població general de la ciutat sense pobresa energètica, presentava: taxes més altes d'atur, més dificultats econòmiques, menor nivell d'estudis i vivien, majoritàriament, en règim de lloguer a preu de mercat.[53] Per a les llars en situació de vulnerabilitat haver de pagar un lloguer a preu de mercat a la ciutat de Barcelona, en molts casos pot suposar que els ingressos restants no siguin suficients per fer front als preus de les factures dels subministraments.[162] En la mateixa línia, l'estudi realitzat amb persones afectades que participen de l'Aliança contra la Pobresa

Energètica i la Plataforma d'Afectades per la Hipoteca, revela la forta relació entre la pobresa energètica i la inseguretat residencial. L'informe posa també de manifest l'estret vincle d'algunes situacions de màxima precarietat, mostrant com un 72% de les persones que declaren tenir el subministrament elèctric irregular viuen en situació d'ocupació en precari. La manca de títol habilitant (escriptura de propietat o contracte de lloguer) de les persones que s'han vist obligades a ocupar un habitatge per necessitat, també les condemna a no poder regular els subministraments perquè les empreses subministradores els neguen la possibilitat de formalitzar un contracte regular. L'informe també examina la coexistència de la pobresa energètica i la inseguretat residencial amb la inseguretat alimentària, fent palès com un 39% de les dones enquestades i un 34% dels homes, pateixen les tres inseguretats.[162] Aquesta múltiple dificultat, que obliga les llars amb baixos recursos a fer tries difícils sobre quines despeses prioritzar, també s'ha constatat en estudis realitzats en altres contextos. Aquests posen de manifest, un cop més, l'estreta relació entre la pobresa energètica i la inseguretat alimentària[108,164] i residencial.[54] La literatura suggereix que, a diferència del lloguer o la hipoteca que són despeses fixes i que s'acostumen a pagar primer, la flexibilitat i la possible variació diària de les despeses en aliments i energia fan que siguin aquestes el centre de les retallades per equilibrar pressupostos.[96,165]

Per últim, i com també s'ha observat en el quart estudi d'aquesta tesi, les llars en situació de pobresa energètica moltes vegades es concentren en determinades àrees com ara, alguns barris concrets.[149] En aquests casos, sovint la vulnerabilitat individual de la llar se suma a condicions específiques de l'àrea com, per exemple: una major inseguretat residencial, deguda a una major gentrificació o turistificació de l'àrea, o una oferta més precària de serveis essencials (transport, escoles, centres de salut o comerços, entre d'altres).[55,156,166]

6.2.3. Les condicions de salut i les desigualtats en salut relacionades amb la pobresa energètica

Les principals aportacions d'aquesta tesi són envers la relació de la pobresa energètica amb la salut i el benestar de les persones i sobre les desigualtats en salut relacionades amb la mateixa. Aquestes s'han discutit, en profunditat, a cada un dels articles pel que, a continuació, només es farà esment a algunes idees clau de forma conjunta.

Condicions de salut relacionades amb la pobresa energètica

En aquesta tesi, s'ha constatat que la pobresa energètica és un problema de salut pública a la Unió Europea i, de forma més acusada, als països amb major vulnerabilitat estructural a la pobresa energètica. Al material suplementari del primer article (Annex III), s'inclou l'anàlisi per a cada un dels 27 països que formaven part de la Unió Europea, durant el període 2007-2013. En aquest, es pot comprovar com la pobresa energètica s'associa, consistentment, a una pitjor salut durant tot el període d'estudi en gairebé tots els països. No obstant això, l'impacte en salut a nivell poblacional de la pobresa energètica és molt més significatiu als països del sud i est de la Unió Europea.[117] Contradictòriament, en aquests països fins al moment, i a diferència d'altres com Irlanda, Regne Unit o Nova Zelanda, la pobresa energètica ha estat poc o gens abordada des de la salut pública. En aquest sentit per exemple, suposa un avenç la incorporació per primera vegada d'indicadors de pobresa energètica a l'enquesta de salut de la ciutat de Barcelona l'any 2016. Aquesta ha demostrat ser una bona pràctica d'una institució local de salut pública, que ha permès aprofundir en el coneixement dels efectes de la pobresa energètica sobre la salut en un context urbà de clima mediterrani i validar, per aquest entorn, els resultats d'estudis previs realitzats en altres contextos.[139]

L'estudi dels efectes en salut de la pobresa energètica, segons diferents indicadors, fa palès com les seves diferents expressions poden afectar la salut per diferents mecanismes[28] i tenir, per tant, repercussions distintes. Això també es fa evident en la diferent evolució de l'associació entre la pobresa energètica i la salut, observada a la Unió Europea abans i durant la crisi econòmica. Trobem com la força de l'associació, entre no poder permetre's mantenir la llar a una temperatura adequada durant els mesos freds i una pitjor salut, augmenta durant els primers anys de la crisi econòmica i, posteriorment, disminueix. En canvi, en l'associació entre haver-se endarrerit una o més vegades en el pagament de rebuts de subministraments en els últims 12 mesos i la salut, la tendència és inversa: disminueix durant els primers anys de la crisi i, en general, s'observa un efecte rebot augmentant després entre els anys 2012 i 2016. Una possible explicació és la limitació d'aquest tipus d'indicadors dicotòmics que, en estudis transversals, no permeten identificar si es tracta de situacions intermitents versus persistents ni quina és la seva intensitat. L'indicador de temperatura, fa referència a una capacitat de la llar pel que, segurament, identifica situacions més persistents tot i que la intensitat experimentada, en cada llar, també pot variar. L'indicador d'endarreriments en el pagament de factures, en canvi, pot identificar situacions molt diverses. No és el mateix haver-se endarrerit un cop, de forma puntual en un moment difícil al llarg d'un any, que presentar endarreriments constants i acumulació de deute. Aquest indicador, per tant, no permet diferenciar entre situacions de vulnerabilitat energètica i de pobresa energètica. Així, l'any 2012, quan es van fer més evidents els efectes de la crisi econòmica, l'increment observat en el nombre de llars que es van endarrerir en el pagament de rebuts de subministraments, podria fer referència a persones que van experimentar pobresa energètica de forma més transitòria i, per tant, haver tingut un menor efecte sobre la salut. En canvi, l'any 2016, la davallada observada en el percentatge de persones amb endarreriments en els pagaments fa pensar que les persones identificades patien la problemàtica de forma més crònica i intensa, la qual cosa explicaria la major força d'associació observada aquest any. Dos estudis, en poblacions especialment vulnerabilitzades, han posat de manifest la importància de la intensitat amb la qual s'experimenta la pobresa energètica. Aquests mostren un clar gradient en la prevalença de mala salut percebuda en funció del nombre d'indicadors de pobresa energètica que les persones reporten, tant als diferents països de la Unió Europea[92] com a la ciutat de Barcelona. L'estudi realitzat a Barcelona també posa de manifest un gradient en la prevalença d'asma, bronquitis crònica i depressió i/o ansietat, d'acord amb el nombre d'indicadors de pobresa energètica reportats.[53]

A la revisió d'abast sobre pobresa energètica, salut i desigualtats en salut (Annex II), també s'indaga en els efectes en salut segons diferents expressions de la pobresa energètica. Els resultats mostren com la dimensió més estudiada, en relació amb els efectes sobre la salut, és la temperatura inadequada a la llar i com aquesta també és la què mostra els resultats més concloents. Cal remarcar que, dels dotze estudis observacionals inclosos a la revisió d'abast que analitzen l'efecte en salut de les temperatures inadequades a la llar, onze examinen l'efecte de les temperatures fredes i només un té en compte tant les temperatures fredes com les càlides. Els estudis d'aquesta tesi, realitzats a la ciutat de Barcelona, també adopten aquest últim enfocament aportant informació sobre els efectes en salut de les temperatures inadequades tant als mesos freds com als càlids. Tot i que els efectes en salut no s'han pogut estudiar de forma diferenciada, segons els dos indicadors, a Barcelona hi ha més persones que declaren no poder permetre's mantenir l'habitatge a una temperatura adequada durant els mesos càlids (12,1% de les dones i 10,7% dels homes) que durant els mesos freds (10,2% de les dones i 8,4% dels homes), fet que suggereix un major impacte de la pobresa energètica relacionada amb les temperatures càlides en aquest context. Així i tot, per esclarir l'impacte relatiu de la pobresa energètica en relació amb les temperatures fredes i càlides, calen estudis que aprofundeixin sobre quin paper juguen les temperatures inadequades dins la llar, en l'associació entre la calor i la morbiditat i mortalitat.

L'emergent literatura científica, sobre la relació entre les temperatures ambient subòptimes i la mortalitat, aporta informació interessant al respecte. S'estima que al voltant del 7% de la mortalitat pot atribuir-se a les temperatures subòptimes i que el fred n'és el principal responsable, en tots els països estudiats.[167,168] No obstant això, els estudis de projeccions de la mortalitat atribuïble a la temperatura, en els diferents escenaris de canvi climàtic, preveuen un important augment de l'excés de mortalitat relacionat amb la calor. Aquest s'espera que sigui més rellevant a les regions més càlides, com per exemple la conca del Mediterrani on en els escenaris més pessimistes (RCP 8.5) s'invertiria el patró, passant a ser la calor la principal responsable de la mortalitat atribuïble a les temperatures subòptimes.[167,169] Com s'ha comentat a la introducció, és difícil estimar quin paper juguen els habitatges que no protegeixen de les temperatures inadequades, en l'excés de mortalitat, en els mesos freds i càlids. En el cas del fred, l'Organització Mundial de la Salut estima que, a Europa, un 30% de l'excés de mortalitat hivernal està directament relacionada amb les cases fredes.[100] En el cas de la calor, encara no hi ha estimacions al respecte. Estudis recents, però, suggereixen que no tenir aire condicionat, o no poder-lo fer servir quan és necessari, juga un paper determinant en la mortalitat relacionada amb les onades de calor.[170] Tot plegat posa de manifest la urgència d'incloure a l'equació de la pobresa energètica: les necessitats energètiques per refredar la llar, la importància d'adaptar la construcció dels habitatges per protegir de la calor i les conseqüències que el sobreescalfament de la llar pot tenir per a la salut i el benestar de les persones.[171]

Els resultats d'aquesta tesi són consistents amb l'evidència recollida a la revisió d'abast sobre pobresa energètica, salut i desigualtats en salut i, per tant, aporten robustesa a aquesta. Al mateix temps, també s'ha generat nova informació rellevant. Una aportació important és en relació als efectes en salut mental. Tot i el reconeixement oficial de la importància de la salut mental en la salut i el benestar de les persones,[172] aquesta segueix estant fortament invisibilitzada, estigmatitzada, discriminada i infrapressupostada.[173] Els resultats obtinguts fan palès l'importantíssim efecte de la pobresa energètica sobre la salut mental. D'una banda, els resultats mostren com la pobresa energètica, de forma consistent en tots els territoris de la Unió Europea i tant en dones com en homes, s'associa més fortament amb la reducció del benestar i, sobretot, amb la depressió. Els valors absoluts mostren la magnitud del problema, revelant que un 44,3% de les dones i un 37,8% dels homes en situació de pobresa energètica pateixen una reducció del benestar i, altrament, que un 21,7% de les dones i un 15,3% dels homes podrien patir depressió clínica, percentatges molt superiors als de la població general sense pobresa energètica.[117] Aquests resultats són consistents amb les troballes a la ciutat de Barcelona, on les persones en situació de pobresa energètica pateixen al voltant de dues vegades més mala salut mental que les persones sense pobresa energètica. De forma congruent, l'ús de serveis de psicologia i psiquiatria, així com el consum de fàrmacs psicotròpics, també és entre dues i tres vegades superior en aquest col·lectiu. Un cop més, els valors absoluts són importants, ja que destapen l'abast de l'afectació així com la bretxa entre l'afectació i l'assistència i acompanyament d'aquesta, suggerint una desatenció de la problemàtica per part dels serveis de salut mental. Per exemple, en el cas de les dones en situació de pobresa energètica, que són les que més es veuen afectades, trobem que un 38% presenta mala salut mental i un 31,6% reporta haver pres alguna medicació psicotròpica en els últims 2 dies. En canvi, tan sols el 12,3% ha tingut contacte amb un servei especialitzat de salut mental en els últims 12 mesos.[139] Aquests resultats són coherents amb estudis que mostren que les intervencions per reduir la pobresa energètica mostren beneficis, sobretot, per a la salut mental.[103,174,175] Per últim, els resultats també suggereixen una afectació de la salut mental en les criatures repercutint, sobretot, en l'àmbit emocional i relacional.[138] Aquesta informació s'afegeix a la, fins ara molt escassa, evidència dels efectes de la pobresa energètica sobre la salut mental en les persones més petites que, bàsicament, assenyala: a) un major risc de problemes de salut mental i comportaments de risc en adolescents[176] i b) un major risc de depressió en pares i mares, que podria repercutir de forma negativa en els infants.[177]

Una altra aportació destacable és l'estudi de resultats en salut fins ara poc o gens explorats, com per exemple: l'ús de diferents serveis de salut i el consum de fàrmacs. Fins ara, alguns estudis havien relacionat la pobresa energètica amb un major nombre de visites ambulatòries en pacients amb diabetis mellitus[101] i més visites als centres d'atenció primària i a altres serveis ambulatoris en població general.[97] També, algunes intervencions per reduir la pobresa energètica han mostrat una reducció tant en el nombre de visites als centres d'atenció primària i d'ingressos per problemes respiratoris en llars intervingudes amb una persona amb problemes respiratoris[103], com en el de visites als centres d'atenció primària en població especialment vulnerabilitzada, atesa per serveis socials.[178] El segon estudi d'aquesta tesi mostra com, a Barcelona, la pobresa energètica s'associa a un major ús generalitzat de serveis de salut, concretament, de serveis d'urgències, hospitalitzacions, atenció primària, infermeria, psicologia, psiquiatria i treball social. Aquesta forta associació trobada, juntament amb l'alta prevalença de pobresa energètica a la ciutat, es tradueix en una càrrega important pels serveis sanitaris, tal i com mostren els alts percentatges poblacionals d'ús de serveis de salut atribuïbles a la pobresa energètica (PAR%). La pobresa energètica impacta, especialment, sobre els serveis de treball social sanitari i els de salut mental, aquests últims, sobretot, en el cas de les dones. Cal destacar que, tot i el major ús de serveis de salut, les persones en situació de pobresa energètica també refereixen, amb més freqüència, haver tingut algun problema de salut que creien que requeria atenció mèdica i no haver-la demanat. És a dir, les persones en situació de pobresa energètica també pateixen una major desatenció mèdica. Altrament, segons el nostre coneixement, no existeixen estudis previs que hagin avaluat el consum de fàrmacs en relació amb la pobresa energètica. Els resultats obtinguts a Barcelona són importants, ja que mostren un augment generalitzat en les persones en situació de pobresa energètica del consum de: analgèsics, medicació per l'al·lèrgia i l'asma, antibiòtics i fàrmacs psicotròpics. Per exemple, un 51,5% de les dones i un 45,7% dels homes en situació de pobresa energètica refereixen haver pres analgèsics en els dos dies previs a l'enquesta. En el cas de fàrmacs psicotròpics, els percentatges corresponents són 31,6% en les dones i 19,7% en els homes. [139]

Un altre buit de coneixement rellevant que s'ha abordat en aquesta tesi és l'efecte de la pobresa energètica sobre la salut i el benestar dels infants. Com s'ha comentat prèviament, les criatures acumulen diverses vulnerabilitats que les fa especialment susceptibles a la pobresa energètica. En primer lloc, la vulnerabilització social que suposa ser una criatura en un món adultocèntric. Segon, la seva major vulnerabilitat física i emocional relacionada amb la seva edat biològica. Per últim, un major temps d'exposició a les condicions adverses que hi pugui haver a la llar, pel fet de passar-hi més temps. Els resultats obtinguts a Barcelona fan palès aquest fet mostrant com l'efecte de la pobresa energètica sobre l'estat de salut general és molt superior en les criatures. A diferència de la població adulta, on trobem que les persones en situació de pobresa energètica tenen al voltant de dues vegades més mala salut que les persones sense pobresa energètica,[139] en el cas de les persones menors de 15 anys aquesta diferència relativa és de vora set cops més. Els resultats també suggereixen: una pitjor salut mental, una menor qualitat de vida relacionada amb la salut i una major prevalença d'asma i sobrepès, en les criatures que creixen en llars que no poden satisfer les seves necessitats energètiques.[138] Aquestes desigualtats en salut observades en les criatures en situació de pobresa energètica són crítiques, ja que a part dels problemes de salut immediats, aquests també suposen un major risc de morbiditat a l'edat adulta. Créixer en pobresa energètica i les seves conseqüències sobre la salut també s'han relacionat amb un major absentisme escolar[179] i un menor rendiment escolar[180]. Així, els problemes de salut a llarg termini, juntament amb les majors dificultats en l'aprenentatge i la socialització, poden afectar les oportunitats de treball i benestar en l'edat adulta, perpetuant unes condicions de vida més precàries i reproduint i amplificant, així, les desigualtats en salut.

Desigualtats en salut relacionades amb la pobresa energètica

Les desigualtats socials en salut són un dels problemes de salut pública més importants dels nostres temps.[181] Com s'ha exposat a la introducció, aquestes operen a través dels determinants socials de la salut i, per tant, per avançar en l'equitat en salut, la investigació i l'abordatge dels mateixos és clau.[88,89] Els resultats obtinguts en aquest treball mostren com la pobresa energètica actua com un amplificador de les desigualtats en salut. Així, la desigual distribució de la pobresa energètica, segons diferents eixos d'estratificació social i la seva intersecció, juntament amb els evidenciats efectes de la pobresa energètica sobre la salut poden explicar part de les diferències injustes en l'estat de salut entre diferents grups poblacionals. En un informe recent de l'Organització Mundial de la Salut, la pobresa energètica també ha estat identificada com un dels majors reptes de les desigualtats ambientals en salut.[182]

Per monitorar i estudiar les desigualtats en salut, és important analitzar tant les desigualtats relatives com les absolutes i indagar en les diferències entre grups i dintre d'aquests.[183] Aquest també és l'enfocament que s'ha intentat adoptar en els estudis que conformen aquesta tesi, en els quals s'ha procurat combinar sempre diferents mesures epidemiològiques per tal d'entendre millor els resultats obtinguts. Així per exemple, a l'estudi realitzat a la Unió Europea, el càlcul de raons de prevalença i de percentatges poblacionals atribuïbles ha estat cabdal per entendre millor la complexitat de la relació entre la pobresa energètica i les seves conseqüències per a la salut, així com la seva evolució en el temps. En aquest cas, el càlcul exclusiu de mesures d'associació no permet evidenciar les desigualtats en la magnitud del problema i pot portar a conclusions esbiaixades, com s'ha donat en algun estudi previ.[184] En canvi en aquest estudi, la combinació de mesures epidemiològiques ens ha permès identificar una tendència a l'alça en les desigualtats en salut relacionades amb la pobresa energètica. Arran de la crisi econòmica del 2008 s'haurien exacerbat les desigualtats entre els països de la Unió Europea amb major i menor vulnerabilitat estructural a la pobresa energètica, així com entre les dones i els homes a la regió amb menor vulnerabilitat estructural a la pobresa energètica.[117]

Les desigualtats en salut habitualment es presenten utilitzant només mesures relatives de l'efecte fet que, a vegades, pot portar a interpretacions errònies sobre diferents aspectes com: la magnitud, la direcció, la importància i les implicacions de les desigualtats en salut observades.[185] En el cas de la pobresa energètica, les mesures relatives (raons de prevalença) han permès identificar desigualtats en salut entre les persones afectades i les no afectades i observar com la força de l'associació amb la mala salut és major en infants que en població adulta. Cal, però, fixar-se també en els valors absoluts perquè també aporten informació interessant. Per exemple, en el cas de la població adulta de Barcelona, trobem que la raó de prevalença de mala salut percebuda, entre les persones que viuen en situació de pobresa energètica i les que no, és d'1,8 en les dones i 2,0 en els homes, raons que no presenten diferències estadísticament significatives entre elles. No obstant això, si fem atenció als percentatges de mala salut percebuda veiem que, en el cas de les dones, aquesta augmenta del 21,2% en les dones sense pobresa energètica al 45,3% en aquelles què es troben en situació de pobresa energètica. En el cas dels homes, aquest augment és del 15,2% al 30,1%. Així, si compararem la mala salut percebuda entre dones i homes veiem com, en la població sense pobresa energètica, aquesta és 6 punts percentuals major en dones que en homes. En canvi, en la població en situació de pobresa energètica aquesta diferència entre dones i homes és de 15 punts percentuals. Per tant, els valors absoluts ens mostren que la pobresa energètica actua com un amplificador de desigualtats en salut entre dones i homes.[139]

Per últim, com s'ha comentat a l'apartat anterior, la pobresa energètica sovint es dona en un context més ampli de dificultat i precarietat, el que pot traduir-se en pitjors resultats de salut. L'estudi realitzat en persones afectades, participants de l'Aliança contra la Pobresa Energètica i de la Plataforma d'Afectades per la Hipoteca, suggereix que existeix un gradient de mala salut mental i mala salut percebuda en relació amb el nombre d'inseguretats reportades (energètica, habitacional i alimentària).[162] A Barcelona aquest gradient també es posa de manifest si comparem els percentatges de salut de: a) la població general sense pobresa energètica, b) la població general amb pobresa energètica i c) la població especialment vulnerabilitzada, atesa a serveis socials que va participar en el programa *Energia, la justa* que, com s'ha explicat prèviament, presenta una major coexistència de dificultats. Així per exemple, trobem que un 21,2% de les dones sense pobresa energètica refereix mala salut. Aquest percentatge augmenta fins al 45,3% en les dones amb pobresa energètica i arriba fins al 58,6% en les dones amb pobresa energètica, ateses a serveis socials, que van participar en el programa *Energia, la justa*. En els homes, aquests percentatges són: el 15,2%, el 30,1% i el 56,7% respectivament. Aquest gradient s'observa, també, en altres problemes de salut, com per exemple: l'asma, la bronquitis crònica o la mala salut mental.[53,139]

6.3. Limitacions i fortaleses

6.3.1. Limitacions

Aquesta tesi no està exempta de limitacions que poden haver influenciat els resultats i, per tant, és important tenir-les en compte a l'hora d'interpretar-los.

Probablement, la principal limitació d'aquest treball és amb relació a la mateixa conceptualització i mesura de la pobresa energètica. La pobresa energètica és una problemàtica complexa i emergent. Tot i que les primeres mencions es remunten als anys 70, no ha estat fins a la primera dècada dels anys 2000 que l'interès per la recerca sobre pobresa energètica s'ha estès per tota la Unió Europea. La novetat de la temàtica fa que la seva definició i mesura estiguin en constant desenvolupament i que fins ara, no s'hagi arribat a un consens ampli al respecte. Això repercuteix, principalment, en la identificació de les diferents situacions de pobresa energètica en les quals es troben les persones per poder avaluar, després, les conseqüències en salut que suposen. En aquest sentit, hi ha certs aspectes importants a remarcar que poden haver limitat els resultats obtinguts.

En els quatre estudis d'aquesta tesi s'ha treballat amb indicadors basats en les percepcions i declaracions de la llar. Aquests indicadors, com s'ha anat comentant al llarg de la tesi, tenen algunes limitacions. D'una banda, en ser dicotòmics (sí/no) no permeten valorar la intensitat de les diferents dimensions que avaluen. D'altra banda, en referir-se a la totalitat de la llar, poden no ser sensibles a les desigualtats de gènere. A més, igual que els indicadors no són neutres en qüestió de gènere, tampoc ho són en relació amb altres eixos de desigualtat. Per tant, els indicadors utilitzats poden invisibilitzar aspectes rellevants com, per exemple, les diferències culturals. Així mateix, no existeix un indicador consensuat amb relació a les temperatures inadequades a la llar en els mesos càlids. L'indicador emprat en aquesta tesi va ser formulat per primera vegada a l'Enquesta de salut de Barcelona i podria no ser comparable amb futurs estudis que analitzin aquesta problemàtica amb un indicador diferent. Per últim, cal remarcar que no existeixen indicadors de pobresa energètica validats per a població infantil i que la informació de pobresa energètica de l'estudi quatre, igual que la de salut, va ser reportada per la persona cuidadora principal de les criatures.

Així mateix, cal esmentar que cap dels estudis de la tesi inclou indicadors basats en els ingressos i les despeses de la llar. En el primer estudi, aquesta informació no estava disponible a les dades utilitzades. En el cas dels tres altres estudis, basats en l'Enquesta de Salut de Barcelona, l’elevat nombre de valors perduts en les preguntes d’ingressos i, sobretot, en les de despeses energètiques que s’havien inclòs per primera vegada a l’enquesta, van invalidar l’ús d’aquest altre tipus d’indicadors.

També comporta una sèrie de limitacions el fet que tots els estudis que conformen aquesta tesi són de naturalesa transversal. D’una banda, en analitzar la realitat d’un moment determinant, no s’ha pogut diferenciar entre situacions intermitents i persistents. Queda limitada, per tant, la valoració de la naturalesa dinàmica de la vulnerabilitat energètica. D’altra banda, els estudis transversals poden introduir el que es coneix com a biaix de causalitat inversa. Si bé és cert que la direcció més plausible és l’estudiada en aquesta tesi, una pitjor salut també podria explicar una major pobresa energètica. Les persones amb problemes de salut sovint tenen necessitats energètiques diferents i, al mateix temps, l’estat de salut i la diversitat funcional són un important eix de desigualtat que modula l’accés al poder i als recursos. La trama relacional entre la pobresa energètica i la salut evoca la importància de no caure en el reduccionisme de l’epidemiologia positivista, i de superar el pensament lineal i unidireccional, per intentar entendre la complexitat de la determinació social de la salut.[186]

Una altra limitació que tenen en comú tots els estudis és que s’alimenten només d’estadístiques oficials. Les estadístiques oficials, en formar part de les estructures de poder que (re)produeixen les desigualtats en salut, poden invisibilitzar certs col·lectius i naturalitzar la seva falta d’inclusió social. Així, els estudis d’aquesta tesi no han pogut tenir en compte, per exemple, les identitats de gènere dissidents i només inclouen les persones que viuen i estan empadronades en habitatges privats o les persones que parlen algun dels idiomes oficials del país on es va realitzar l'enquesta.[187,188] Per tant, a l'hora d'interpretar els resultats cal tenir en compte que poden invisibilitzar alguns dels col·lectius més fortament afectats per la pobresa energètica, com ara: les persones en situació administrativa irregular, les persones en situació d'ocupació en precari o les persones migrades amb barrera idiomàtica.

La grandària de la mostra també és una limitació comuna a tots els estudis. En el primer estudi, no va permetre ni desagregar per sexe l'anàlisi feta per a cada un dels països de la Unió Europea. En el segon estudi, la grandària de la mostra i, sobretot, la baixa freqüència d'alguns dels resultats de salut estudiats, no van permetre desagregar l'anàlisi analítica per altres eixos de desigualtat ni aprofundir en la intersecció d'aquests. La grandària de la mostra és especialment limitant en el tercer estudi, on l'anàlisi analítica no es va poder estratificar per possibles variables modificadores de l'efecte i, en alguns casos, la baixa potencia estadística va dificultar la significació estadística. En el cas del quart estudi, la grandària de la mostra i la no representativitat d'aquesta a nivell de barri, més que una limitació és la principal motivació de l'estudi. En aquest estudi, però, cal remarcar la pitjor estimació dels barris limítrofs de la ciutat a causa de l'efecte frontera. Per tal de superar les limitacions de la grandària de la mostra, una de les estratègies del mètode utilitzat és la suavització de les estimacions a partir dels valors de les àrees adjacents. En restringir l'anàlisi a les dades de la ciutat de Barcelona, en els barris limítrofs, com per exemple Sants Badal o La Verneda i La Pau, les estimacions no es poden suavitzar amb les dades d'alguns dels seus barris adjacents perquè formen part dels municipis de l'Hospitalet de Llobregat i Sant Adrià del Besos, respectivament.

Per últim, cal esmentar que aquests resultats i la seva interpretació s'han generat des de l'acadèmia/administració pública, el què limita la seva capacitat transformadora. L'epidemiologia, com qualsevol altra disciplina científica, forma part del poder simbòlic. És a dir, té el poder de constituir, enunciar, fer veure i fer creure, confirmar o transformar la visió del món i, d'aquesta manera, l'acció sobre el món.[189,190] Una epidemiologia que sigui realment transformadora requereix la participació de la ciutadania i, especialment, de les persones afectades en la creació de coneixement i la incidència política.

6.3.2. Fortaleses

Al mateix temps, aquest treball també presenta una sèrie de fortaleses, algunes d'elles relacionades amb les seves principals limitacions.

La principal fortalesa recau en el fet d'haver abordat una temàtica rellevant i poc explorada fins al moment. Tot i les limitacions que això hagi pogut suposar, les aportacions d'aquesta tesi constitueixen un avenç en el coneixement del tema. D'una banda, el marc conceptual adoptat ha permès polititzar la problemàtica i emfatitzar el paper dels factors i processos més estructurals, en la desigual distribució de pobresa energètica així com dels seus efectes en salut. D'altra banda, s'ha fet palès que la pobresa energètica és un important problema de salut pública a tota la Unió Europea. Especialment, als països del sud i est de la mateixa i, en particular, a la ciutat de Barcelona.

En aquesta tesi s'ha tingut l'oportunitat d'analitzar les preguntes sobre pobresa energètica incloses, per primera vegada, a l'Enquesta de Salut de Barcelona. Aquest fet, poc habitual, ha possibilitat l'avenç en punts clau com, per exemple: a) estudiar la pobresa energètica i la seva relació amb la salut en un context poc investigat fins al moment; b) explorar múltiples resultats en salut només disponibles en enquestes de salut i que, per tant, els estudis basats en altres fonts de dades no havien pogut tenir en compte fins ara; c) aprofundir en el coneixement de la relació entre la pobresa energètica i la salut en la infància; d) obtenir estimacions representatives per a la ciutat de Barcelona; i, e) estimar indicadors de pobresa energètica a nivell de barri.

Per últim, una altra fortalesa d'aquesta tesi és la combinació de diferents aspectes metodològics que donen robustesa als resultats obtinguts. En aquest sentit, s'han utilitzat diferents tipus d'indicadors de pobresa energètica, tan simples com compostos; s'han calculat diferents mesures epidemiològiques, tant relatives com absolutes (freqüències, raons de prevalença, diferències de prevalença i percentatges poblacionals atribuïbles); s'ha treballat amb població adulta i amb població infantil i, per últim, s'ha treballat a diferents escales, obtenint resultats per a: la totalitat de la Unió Europea, les dues macro regions de la Unió Europea, els diferents Estats membres de la Unió Europea i la ciutat de Barcelona i els seus barris.

7. RECOMANACIONS I IMPLICACIONS

A partir dels resultats obtinguts en aquesta tesi, poden sorgir una sèrie de noves línies de recerca així com de propostes per a l'acció.

7.1. *Futures línies de recerca*

L'estudi dels efectes de la pobresa energètica sobre la salut i les desigualtats en salut és un àmbit relativament poc explorat, des del punt de vista de la salut pública. Per tant, encara queden molts aspectes per indagar, analitzar i en els quals aprofundir. A continuació, es detallen una sèrie de propostes que emergeixen a partir dels resultats obtinguts en aquesta tesi.

Identificació i mesura de la pobresa energètica. En els últims anys, s'ha fet un important treball per consensuar indicadors simples de pobresa energètica i per desenvolupar indicadors compostos.[44] La precisió en la identificació i quantificació de la pobresa energètica és clau per entendre, amb profunditat, els seus efectes sobre la salut i les desigualtats en salut. Calen, encara, indicadors que permetin: a) valorar la intensitat de les diferents dimensions de la pobresa energètica; b) diferenciar entre situacions puntuals, intermitents i persistents; c) ser sensibles a les desigualtats de gènere, classe social i a la diversitat cultural, entre d'altres; d) tenir en compte les diferents necessitats de cada llar; e) abordar altres dimensions de la pobresa energètica poc estudiades fins al moment, com per exemple: les temperatures inadequades durant els mesos càlids, l'acumulació de deute o l'ús de noves tecnologies;

i f) monitorar els determinants més estructurals de la pobresa energètica com, per exemple, en relació amb el model energètic. Així mateix, seria molt interessant realitzar més estudis que utilitzin mesures directes de la pobresa energètica com ara el monitoratge de la temperatura a la llar durant els mesos freds i càlids.

Mètode i disseny d'estudis. Tant els estudis d'aquesta tesi, com la gran majoria dels estudis identificats a la revisió d'abast de pobresa energètica, salut i desigualtats en salut, són de metodologia quantitativa i de disseny transversal. També és important abordar la relació entre la pobresa energètica i la salut amb estudis qualitatius i/o de metodologia mixta, per poder aprofundir en les percepcions i les barreres identificades per les persones afectades i avançar en la comprensió dels mecanismes, a través dels quals, la pobresa energètica afecta la salut. D'altra banda, la naturalesa dinàmica de la vulnerabilitat energètica i els possibles efectes sobre la salut a llarg termini de la pobresa energètica, sobretot en el cas de les criatures, fan palesa la necessitat de realitzar estudis longitudinals, com el seguiment de cohorts o la realització d'històries de vida. Per últim, per tal de no estudiar tan sols el problema, sinó d'aprofitar la recerca per emprendre solucions i generar transformació social, cal fomentar la investigació acció participativa.

Població d'estudi. Calen estudis dirigits a grups poblacionals concrets. Per exemple, és cabdal arribar a col·lectius en situacions especialment complexes que poden quedar fora de les estadístiques oficials, com: les persones en situació d'ocupació en precari, les persones en situació administrativa irregular, les persones amb barrera idiomàtica o les persones institucionalitzades (com per exemple, les persones que viuen en centres penitenciaris o en residències de persones grans). També, és important aprofundir en el coneixement de com la pobresa energètica afecta la salut de persones amb necessitats energètiques particulars o més susceptibles als seus efectes, com ara les persones grans o les persones amb condicions de salut cròniques. És convenient, també, indagar en les conseqüències de la pobresa energètica sobre la salut i el benestar en col·lectius recentment identificats com especialment afectats, com ara: els adults joves i els estudiants que viuen de lloguer.[56]

Contextos immediats i futurs. Són diverses les condicions externes que actualment amenacen, de forma significativa, la capacitat d'una llar per fer front a les seves necessitats energètiques, tant a curt com a llarg termini. En un context immediat, és cabdal estudiar, per exemple, quins efectes està tenint la pandèmia de la COVID-19 o el constant increment del preu de l'electricitat que s'està donant a l'Estat espanyol sobre la vulnerabilitat energètica i les conseqüències en salut associades. Així mateix, davant dels diferents escenaris previstos pel canvi climàtic, calen estudis que avancin en el coneixement del paper que juga la pobresa energètica en la relació entre l'augment de les temperatures i les onades de calor amb la morbiditat i mortalitat. En aquesta línia, cal també ampliar l'estudi a condicions de salut relacionades amb la calor, com: les malalties renals, els cops de calor, les malalties neurodegeneratives o certes condicions de salut mental.[191–196]

Avaluació de polítiques i altres accions transformadores. Per tal d'eliminar la pobresa energètica i els seus efectes sobre les desigualtats en salut, és essencial saber quines polítiques i accions són més efectives. En els últims anys, s'han avaluat diversos programes i intervencions per a reduir la pobresa energètica des de l'àmbit de la salut pública. Principalment, aquests es basen en la millora de l'eficiència energètica de les llars i dels equipaments per escalfar-la.[102,103,113,179,197–201] Més recentment, també s'han avaluat intervencions basades en la protecció de les persones consumidores vulnerables, a través de la provisió d'informació i assessorament.[147,178] De cara a properes recerques, seria interessant avaluar l'efecte de polítiques més estructurals com, per exemple, la implementació a Catalunya de la llei 24/2015 o les intervencions que limiten la influència dels grups de pressió de les grans companyies energètiques tradicionals en el sector de l'energia. Així mateix, és cabdal evidenciar els efectes d'altres accions transformadores, com ara el fet de participar de l'Aliança contra la Pobresa Energètica.

Perspectiva d'equitat. Per últim, i com a recomanació general, la inherent connexió de la pobresa energètica i les desigualtats socials evidencia la necessitat d'abordar l'estudi de les conseqüències de la pobresa energètica des d'una perspectiva de desigualtats en salut. És important que els futurs estudis tinguin en compte els diferents eixos de desigualtat així com la seva interacció. Entendre com interactuen les múltiples identitats socials (com el gènere, l'estat migratori o la classe social) a nivell micro de l'experiència individual, ens permet assenyalar les veritables causes a nivell macroestructural de les desigualtats en salut.[140]

7.2. *Implicacions per a la salut pública i altres recomanacions per a l'acció*

Els resultats obtinguts en aquesta tesi corroboren que la pobresa energètica és un important problema de salut pública i que cal intervenir per reduir els greus efectes que té sobre la salut i les desigualtats en salut. Al mateix temps, també s'evidencia la complexitat i multidimensionalitat del problema, que cal tenir en compte a l'hora d'actuar. A continuació, es comparteixen una sèrie de reflexions que es considera que poden ser d'utilitat per guiar futures accions.

Inclusió de la pobresa energètica en l'agenda de la salut pública. Les importants conseqüències de la pobresa energètica sobre la salut, el seu potencial per amplificar les desigualtats socials en salut i la càrrega que suposa per als serveis de salut, posen de manifest la necessitat que la salut pública s'involucri en l'abordatge d'aquesta problemàtica. Gran part de l'evidència científica generada en aquesta tesi és gràcies a la inclusió, per primera vegada, d'indicadors de pobresa energètica a l'enquesta de salut de Barcelona l'any 2016. Aquesta ha demostrat ser una bona pràctica que caldria mantenir en el temps. El monitoratge en el temps de la pobresa energètica i dels seus efectes sobre la salut és clau per a promoure, dissenyar i avaluar programes, intervencions i polítiques públiques. És recomanable extrapolar aquesta pràctica a altres escales, com a l’enquesta de salut de l’Estat espanyol o a altres contextos on s’ha demostrat que la pobresa energètica té un fort impacte sobre la salut de la població (països amb major vulnerabilitat estructural a la pobresa energètica). Així mateix, és pertinent millorar i ampliar la bateria de preguntes, la mida de la mostra enquestada i la representació de tots els grups poblacionals per tal de poder superar les limitacions esmentades en apartats anteriors. Aquest monitoratge és especialment rellevant en l’actual context de crisi social i climàtica.

Revertir les desigualtats en salut relacionades amb la pobresa energètica. Les polítiques de salut han de tenir el doble objectiu de promoure la millora de la salut en el conjunt de la població però, també, de reduir les desigualtats en salut. Per aconseguir aquest objectiu, existeixen diferents estratègies que van: des de les intervencions que busquen exclusivament reduir la bretxa de salut i, per tant, es dirigeixen només als col·lectius més afectats, fins a les polítiques universals amb beneficis progressius a través del gradient social. Aquest tipus d’estratègies no tenen per què ser excloents, sinó al contrari, poden ser complementàries en molts casos.[202,203] Els resultats obtinguts en aquesta tesi poden facilitar el desenvolupament dels dos tipus d’estratègies a la ciutat de Barcelona. D’una banda, la identificació de col·lectius especialment vulnerabilitzats, fa palesa la necessitat de fer polítiques que millorin les condicions de vida d’aquestes persones, des d’una mirada interseccional que permeti entendre la complexitat de les desigualtats socials. D’altra banda, la identificació dels barris amb més pobresa energètica permet la implementació, o la millora de serveis, amb universalitat proporcional. Així per exemple, seria recomanable incrementar els serveis prestats pels Punts d'Assessorament Energètic en els barris que tenen més població que no pot satisfer les seves necessitats energètiques, mantenint la universalitat del servei. En l'actual context d'emergència climàtica, també serà important aplicar el mateix criteri en futures intervencions per adaptar-se al canvi climàtic com, per exemple, en la distribució del nombre de refugis climàtics als barris de la ciutat.

Mesures excepcionals en moments de crisi. Els resultats d'aquesta tesi posen en evidència com, en moments de crisi, la forta vulnerabilitat estructural a la pobresa energètica es tradueix en un augment molt significatiu del nombre de llars que no poden satisfer les seves necessitats energètiques així com de les conseqüències que això comporta per a la salut. Preveient i observant, ja actualment, com es comencen a evidenciar les conseqüències socials i econòmiques de la crisi generada per la COVID-19, és necessari desenvolupar mesures d'urgència per evitar un nou increment de la pobresa energètica. Les mesures pal·liatives adoptades per l'Estat espanyol, en el marc de l'escut social per reforçar l'estructura del benestar social durant la pandèmia, tot i protegir les persones beneficiàries del bo social de la suspensió dels subministraments d'electricitat, gas i aigua,[204] estan mostrant ser insuficients. Els resultats de l'Enquesta de Condicions de Vida de 2020 ja evidencien com, en relació al 2019, la pobresa energètica ha augmentat: del 7,7% al 10,9% a l'Estat espanyol[205] i del 8,3% al 9,4% a Catalunya.[206] Cal, per tant, ampliar les mesures extraordinàries per evitar que les persones que fins ara no patien pobresa energètica entrin en aquesta situació de precarietat. De la mateixa manera, és necessari preveure què passarà a la resta de l'Estat espanyol quan se suspenguin les mesures de protecció social extraordinàries i les llars que hagin acumulat deute es quedin desprotegides davant dels talls de subministraments.

Detecció i formació. Els múltiples rostres de la pobresa energètica, el sovint poc coneixement sobre aquesta problemàtica emergent o, fins i tot, la pròpia acceptació de la carència o la por a l'estigma associat, poden interferir en la detecció de persones que es troben en situació de pobresa energètica i dificultar-ne l'acompanyament. Són molts els sectors, des d'on es poden identificar les diferents conseqüències de la pobresa energètica, que podrien col·laborar en la seva detecció i en la posada en marxa de protocols pel seu abordatge. Actualment, els Bombers de l'Ajuntament de Barcelona ja compten amb un protocol de detecció de pobresa energètica que ha facilitat la identificació de centenars de casos des de l'any 2017. Seria convenient reforçar aquest servei i estendre'l a tot el territori. El major ús dels serveis socials i de salut per part de les persones en situació de pobresa energètica, observada en els estudis d'aquesta tesi, indica que aquests també poden contribuir en la seva detecció. A Catalunya, els Centres d'Atenció Primària ja disposen d'un protocol per a la detecció de pobresa energètica i derivació a serveis socials, així com per a l'abordatge de la dependència energètica relacionada amb la salut. Tot i que, fins ara, no s'ha avaluat aquest servei, sembla que la seva aplicació està sent molt limitada. Seria recomanable incentivar l'ús d'aquesta eina de detecció, així com avaluar quina és la utilització i abast d'aquest servei i detectar les barreres que s'estan trobant les persones professionals per aplicar-lo. Per últim, altres serveis o equipaments com: els mateixos serveis socials, els centres educatius, els centres de dia per a la gent gran, les oficines d'habitatge o les oficines d'ocupació, poden ser peces claus en la detecció de la pobresa energètica. Per tal de promoure la detecció de la pobresa energètica des dels diferents sectors, és essencial desenvolupar un treball previ de formació i establir protocols de col·laboració i derivació. En aquesta línia, és també essencial que la formació sobre els importants efectes que tenen diferents factors socials sobre la salut de les persones, estigui degudament representada en els graus i postgraus relacionats amb la salut.

Actuació simultània sobre els determinants estructurals i intermedis. La gran majoria de polítiques i intervencions per pal·liar la pobresa energètica es dirigeixen a les seves causes més directes, millorant l'eficiència energètica de les llars i els equipaments de calefacció o protegint les persones consumidores vulnerables.[91] Aquestes estratègies són essencials per alleujar, a curt i mitjà termini, el patiment de les persones que viuen en situació de pobresa energètica. El fort impacte de la pobresa energètica sobre totes les esferes de la vida i, en particular, sobre la salut i el benestar de les persones, requereix ampliar l'abast d'aquest tipus d'estratègies per donar suport immediat a totes aquelles persones en aquesta situació. Per exemple, seria recomanable ampliar i estendre la xarxa de Punts d'Assessorament Energètic a la resta de Catalunya i oferir ajudes per a la rehabilitació energètica dels edificis que promoguin la justícia social. Al mateix temps, però, és cabdal prevenir d'arrel la pobresa energètica i això només és possible atacant el seu veritable origen: els determinants més estructurals. Per tant, també calen polítiques contundents que transformin els sectors de l'energia, l'habitatge i el treball i que reforcin l'estat del benestar i la protecció social per tal de capgirar les actuals relacions de poder. Això requereix, per exemple, acabar amb la influència de les grans empreses privades en els sectors de l'habitatge i l'energia que, només, busquen maximitzar els seus beneficis econòmics i polítics i que, alhora, tenen una forta participació de grans fons d'inversió internacionals que van imposant les seves pròpies estratègies i guanyant capacitat d'influència, tant sectorial com estructural. En canvi, és necessari apostar per la consolidació de marcs públic-comunitaris que vetllin per l'accés universal als béns essencials. Per exemple: promovent més habitatge social i altres models alternatius, com l'habitatge cooperatiu, o remunicipalitzant els subministraments i impulsant comunitats energètiques locals. En definitiva, és necessari avançar cap a models econòmics, energètics i d'habitatge que posin la vida al centre i promoguin l'equitat en salut. El marc internacional dels drets humans és una estructura conceptual i jurídica apropiada per avançar en aquesta direcció,[88] promovent el dret a l'energia, el dret a l'habitatge i el dret a la salut, entre d'altres. És pertinent remarcar que, en l'actual context d'emergència climàtica, la urgent necessitat d'impulsar una transició energètica no és només un dels majors reptes que afrontem com a societat. Alhora, estem davant d'una gran oportunitat per replantejar el nostre model energètic i fer-lo no només ecològicament sostenible sinó, també, socialment just.

Abordatge integral, salut en totes les polítiques, intersectorialitat i aliances. La multidimensionalitat de la pobresa energètica així com la freqüent coexistència d'altres situacions de dificultat i precarietat, fan palesa la necessitat d'abordar la problemàtica des d'una perspectiva àmplia. La literatura suggereix que les intervencions dirigides a diferents necessitats materials insatisfetes són més efectives que aquelles dirigides a una sola inseguretat.[101] Per tant, pot ser beneficiós promoure intervencions que busquin reduir la pobresa energètica però que, alhora, promoguin la seguretat residencial, laboral i/o alimentària. Aquestes intervencions queden fora de l'abast de la salut pública i, per tant, per tal que millorin la salut de la població i l'equitat en salut és indispensable adoptar l'estratègia de salut a totes les polítiques. És a dir, que tota política o intervenció, independentment del sector que la lideri, consideri de forma sistemàtica les implicacions que té per a la salut i el benestar de les persones. Aquest enfocament també requereix estimular el treball intersectorial i fomentar aliances entre els diferents nivells de l'administració pública, l'acadèmia i els moviments socials, per tal d'aconseguir dissenyar polítiques que responguin a les necessitats reals i que estiguin basades en l'evidència.

Ciutadania mobilitzada i activa. Per últim, per tal de canviar el paradigma de la pobresa energètica, cal fomentar el debat social i visibilitzar i polititzar la problemàtica. Experiències exitoses, com la de l'Aliança contra la Pobresa Energètica, mostren com és cabdal que la ciutadania estigui informada i empoderada per poder reclamar els seus drets i potenciar respostes col·lectives i alternatives, que afavoreixin models més sobirans i una democràcia més participativa. Els canvis en les relacions de poder també exigeixen donar veu i escoltar a les persones afectades, que sovint també són col·lectius que veuen les seves opcions de participació social més limitades.

8. CONCLUSIONS

Les principals conclusions d'aquesta tesi són:

- La pobresa energètica és un important problema de salut pública a la Unió Europea: afecta un percentatge important de la població, especialment en els països amb major vulnerabilitat estructural a la pobresa energètica (sud i est de la Unió Europea), i s'associa a una pitjor salut percebuda, una reducció del benestar i un major risc de depressió.

- A la Unió Europea, la crisi econòmica del 2008 va comportar un increment generalitzat del percentatge de persones en situació de pobresa energètica, així com del seu impacte en salut. L'evolució temporal va ser més desfavorable en els països amb major vulnerabilitat estructural a la pobresa energètica i en les dones, ampliant-se les desigualtats territorials i de gènere.

- A la ciutat de Barcelona, el percentatge de persones que viuen en situació de pobresa energètica és superior a la mitjana de la Unió Europea, existint fortes desigualtats socials i geogràfiques. Els col·lectius més afectats són: les persones de classes socials més desafavorides, les persones migrades nascudes en països de renda baixa i mitjana i les dones grans. En l'àmbit geogràfic, s'identifiquen tres agrupacions de barris amb nivells de pobresa energètica significativament superiors a la mitjana de la ciutat.

- A la ciutat de Barcelona, la pobresa energètica s'associa amb una pitjor salut percebuda, una pitjor salut mental i una pitjor qualitat de vida, així com amb una major prevalença de malalties respiratòries, malalties cardiovasculars i altres condicions cròniques de salut. Viure en situació de pobresa energètica també s'associa amb un major ús de serveis de salut, especialment de serveis especialitzats de salut mental i de treball social sanitari. La pobresa energètica també es relaciona amb un major consum de fàrmacs.

- La població infantil de Barcelona també es veu fortament afectada per la pobresa energètica, especialment les criatures que viuen en llars amb situacions socioeconòmiques més desafavorides. Durant la infància, la pobresa energètica s'associa a: un pitjor estat de salut general, una pitjor salut mental i una major prevalença d'asma i sobrepès.

- La important relació entre la pobresa energètica i la salut i les desigualtats en salut requereix la implicació de la salut pública en l'abordatge de la problemàtica. Així mateix, és necessari combinar mesures immediates que ataquin els determinants més directes de la pobresa energètica i alleugin el patiment de les persones afectades, amb mesures estructurals, que transformin els sistemes i les estructures injustes que configuren les veritables causes de la pobresa energètica.

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10. ANNEXOS

10.1. Annex I: article addicional 1

Energy Policy 133 (2019) 110869

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Structural energy poverty vulnerability and excess winter mortality in the European Union: Exploring the association between structural determinants and health

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ARTICLE INFO

Keywords:
Energy poverty
European union
Public health
Social determinants of health
Excess winter mortality

ABSTRACT

Energy poverty (EP) is a growing problem in the European Union (EU) that affects the population's health. EP is structurally determined by broader political and socio-economic conditions. Our aims were to analyze the configuration of these determinants in each EU-27 country through the creation of a structural energy poverty vulnerability (SEPV) index, to group countries according to their SEPV index scores, and to explore the association between SEPV and EP prevalence, and also with excess winter mortality (EWM). We created a SEPV index through seriated principal component analyses and then validated the index. We performed a hierarchical cluster analysis (HCA) to group countries according to their SEPV. A Poisson regression model was fitted to analyze the association between SEPV and EWM. The final index comprised 13 indicators and showed an unequal distribution of SEPV across the EU. The HCA identified countries with high structural vulnerability (southeastern Europe) and countries with low structural vulnerability (northwestern Europe). The most vulnerable countries showed a statistically significant higher EP prevalence and risk of EWM. The SEPV index summarizes the structural determinants of EP across the EU, allows to identify geographical patterns and to study how the structural determinants of EP affect health.

1. Background

1.1. Introduction

Energy poverty (EP) can be understood as the inability of a household to secure a socially and materially required level of energy services in the home (Bouzarovski, 2013). EP is a growing problem in the European Union (EU) that is gaining increasing academic and policy attention, particularly after the economic crisis that hit the continent from 2007 onward (García Paris and Mundó, 2013).

Although EP currently affects one in every seven households in Europe (EPEE project, 2014), significant differences have been reported across Member States as EP shows highly unequal distribution across the EU. Bouzarovski (2013) has suggested a number of reasons for the high proportion of EP in the south and east of the EU. Firstly, he argues that Post-Socialist States of central and eastern Europe are subject to cold climates, inefficient residential dwellings and insufficiently developed or decaying infrastructure; they also suffer from higher rates of income inequality and systemic issues in the governance of the energy and housing sectors and social welfare net. Secondly, the higher prevalence in Mediterranean countries of southern Europe can be attributed to the lack of adequate heating systems and the poor quality of

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https://doi.org/10.1016/j.enpol.2019.07.005
Received 7 January 2019; Received in revised form 30 May 2019; Accepted 7 July 2019
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Abbreviations

EP	Energy Poverty
EU	European Union
UK	United Kingdom
SEPV	Structural Energy Poverty Vulnerability
EWM	Excess Winter Mortality
WHO	World Health Organization
IRR	Incidence Rate Ratio
PCA	Principal Component Analysis
HCA	Hierarchical Cluster Analysis

residential dwellings (Bouzarovski, 2013).

1.2. Driving factors vs. structural determinants of energy poverty

Across the literature there are three main drivers that are widely recognized as being key determinants of EP: low household incomes, low energy efficiency of the dwelling and home appliances and high energy prices (Ambrose, 2015; Boardman, 2010; Hills, 2011). Nevertheless, EP is a multi-dimensional phenomenon with multiple causes and, as such, any attempts to understand it as being the result of only three factors might seem simplistic. Marí-Dell'Olmo (2016) has proposed a novel conceptual framework of EP-related health and social inequalities in which income, energy efficiency and energy prices are considered as intermediate determinants of EP, which themselves result from more profound structural determinants (Marí-Dell'Olmo et al., 2016). Such structural determinants can be understood as governmental, political and social aspects, among other, that have the potential to affect EP-related health and equity without being the main target of policies in these sectors (CSDH, 2008). In this framework, household incomes are affected by the labor market and welfare state configuration, housing energy efficiency is influenced by the housing market and policies, and energy bills are determined by the energy market and policies.

In this framework, firstly, the labor market is seen as a key component of any economy with powerful effects on health and equity. This can be observed in Europe as the financial crisis and its consequences have had a significant negative effect on working conditions, thus becoming one of the main drivers of the increased risk of precariousness in the EU (Broughton et al., 2016; Van Gyes and Szekér, 2013). One of the major factors when attempting to mitigate the precariousness and the inequalities of the labor market over time has been the welfare state. Rather than just being a transferring mechanism of goods and services, the welfare state is supposed to intervene and correct inequalities (Bambra and Eikemo, 2009). Theoretically, it deliberately modifies market forces by guaranteeing citizens and families a minimum income and by reducing the welfare responsibilities of the family (Bambra and Eikemo, 2009). According to Esping-Andersen, the level of welfare state capitalism in a country could affect the level of disposable income among householders (Esping-Andersen, 1991).

Secondly, the European building stock is highly diverse in terms of size, age, energy performance, tenure size, heating and cooling needs and the availability of energy carriers that affect a dwelling's energy efficiency (Andrews et al., 2011; Csiba et al., 2016). However, in this study, we consider the dwelling function in the EP phenomenon beyond its energy efficiency; the housing market depends on market fluctuations and policy implementations. Therefore, the role of housing in the economy should be considered as affecting the dynamics of EP. In countries where, before the 2007 financial crisis, housing was viewed an engine to grow the national economy, the use of housing as a speculative good replaced its conception as a first-necessity good (Observatorio DESC and PAH, 2013; Rodríguez A, 2010). This situation affected household economies as the number of persons struggling to meet their housing costs or being evicted subsequently increased in Europe (Cáritas, 2013). To reduce these negative consequences of the crisis, short-term fixes were implemented, such as debt refinancing or deed of assignment in payment. In the long-term, however, it has been argued that the most effective policies are mechanisms to avoid speculative trends in the housing market, the development of a sufficient creation of a social rental housing stock and the provision of rental assistance to households in need (Novoa et al., 2014; Pittini and Laino, 2011).

Lastly, over the last two decades, the price of domestic energy in the EU has consistently increased at faster-than-inflation rates. This has been related to changes in the EU's energy sector occurring in the form of privatization of utility companies, vertical disintegration of generation, distribution and retailing activities, and the liberalization and opening of markets for competition (Florio, 2013). These measures were aimed at increasing levels of competition and achieving a reduction in end-user prices. This has not always been the case, as in some countries consumer welfare and satisfaction levels with domestic energy tariffs, as well as households' ability to pay bills on time, has decreased (Fiorio and Florio, 2008; Poggi and Florio, 2010; Pollitt, 2012). Because households are often unprotected against these changes in energy markets, in countries where this process has largely occurred without a fair implementation of compensating social welfare mechanisms, the number of inadequately heated homes has expanded considerably (Bouzarovski and Tirado Herrero, 2017).

In short, the configuration of the structural determinants of EP in each EU Member State determines the capacity of a country to protect its population from external and internal factors that may drive households into EP. In this study, this phenomenon is designated structural energy poverty vulnerability (SEPV). This concept is therefore used to address the likelihood of a country having a high prevalence of EP, considering EP as a dynamic situation. Thus, EP is not a permanent condition but a temporal one in which households can leave and enter EP at a specific moment in their lives (Tirado Herrero et al., 2012). The likelihood of experiencing EP at the household level and its continuity therefore depends on the SEPV of a country. We argue that analyzing SEPV at the macro-scale is important because there are substantial knowledge gaps about how structural determinants of EP interact to create an adverse environment for vulnerable households in each individual country.

1.3. Health effects

EP is a problem that has been associated with direct and indirect health effects. Its indirect outcomes include poor mental health, anxiety, stress and depression (Gilbertson et al., 2012; Harrington et al., 2005; Hernandez et al., 2016; Rademaekers et al., 2016; Thomson et al., 2017; Wood, 2011), and its direct effects include increased morbidity rates and greater mortality risk. More precisely, cold housing has been directly linked to respiratory illness (Barnes et al., 2010; Gilbertson et al., 2006; Gilchrist et al., 2009; Hajat et al., 2004; Liddell and Morris, 2010; Regional Public Health Group, 2009; Rudge and Gilchrist, 2007, 2005; Somerville et al., 2000; Strachan, 1988), and circulatory diseases (Barnett et al., 2005; DEFRA, 2003; Donaldson, 2010; Lloyd et al., 2008; Regional Public Health Group, 2009; Stone et al., 2010). Furthermore, conditions such as flu, colds, arthritis and rheumatism could be worsened due to cold housing (Marmot Review Team, 2011). Nevertheless, the most extreme health outcome related to EP is excess winter mortality (EWM), defined as the surplus number of deaths occurring during the four winter months compared with the average for the non-winter seasons (Healy, 2003; Wilkinson et al., 2001). Fowler et al. (2015) has estimated an absolute EWM rate of over two million in Europe for the winters from 2002/2003 to 2010/2011, with the highest proportion being found in countries with milder winters (Mediterranean) and with worse thermal insulation (UK). According to the World Health Organization regional office for Europe, 30% of the EWM in Europe could be attributed to cold housing (Braubach et al., 2011). Although there is considerable evidence of the effects of EP on health, there is no knowledge of whether the structural determinants of EP can affect health directly across the EU.

Therefore, studying SEPV at the macro-scale is important because there are substantial gaps in knowledge of how the structural determinants of EP interact to create a hostile environment for households in each country. New evidence to explain the EP phenomenon geographically by grouping countries according to their similarities in structural determinants is needed, as well as knowledge of the relationship between these structural determinants and health.

The main aim of this study was to analyze the SEPV of the EU-27 countries through the creation of an index that considers the structural determinants of EP and related factors. A secondary aim was to propose country typologies according to their SEPV level. To validate the typologies, we examined the patterns of EP prevalence in each of them. To test the possible applications of this study for public health, we also estimated the association between country typologies and EWM.

2. Methods

We conducted an ecological cross-sectional study in which the analysis units were the 27 countries constituting the EU as of January 2013 (Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom).

We obtained most of the indicators to create the index from Eurostat, the European Commission and the Housing Europe Observatory ("Building stock observatory - European Commission," n.d., "Database - Eurostat," n.d.; CECODHAS, 2011). More precisely, we gathered the Eurostat indicators from the databases of Economy and Finance, Population and Social Conditions, and Environment and Energy. Additionally, other included indicators were drawn from the EU Building Stock Observatory, The Energy Union Indicators and Energy Country Datasheets of the European Commission. Only one indicator was obtained from the Housing Europe Review 2012 (Pittini and Laino, 2011). Furthermore, the collected data pertained to a temporal horizon from 2010 to 2017, although we prioritized the most recent indicators (the data source of each indicator can be seen in Appendix A).

The prevalence of EP (calculated as a percentage of negative responses to the item "Can you afford to keep your home adequately warm?") for each country was obtained from the 2016 European Quality of Life Surveys dataset, which covers 29,798 individuals (aged 18 years or older) from the 27 EU countries (Eurofund, 2016).

To estimate the EWM for each country, monthly mortality databases from 2010 to 2016 (last available year) were obtained through Eurostat (Health database) (European Comission, 2018).

2.1. Structural energy poverty vulnerability index

To describe SEPV, we constructed a composite index, a widely used methodology to simplify complex concepts that is considered useful for policy analysis and public communication. An index provides simple comparisons of countries that can illustrate complex and ambiguous issues in wide-ranging fields (OECD, 2008), such as SEPV. In this study, the index was created based on the Carr-Hill and Chalmers-Dixon three-step method (Carr-hill and Chalmers-dixon, 2005).

Firstly, we identified a wide range of country level indicators that were available for the EU-27 countries in the above-mentioned data sources, which we assigned to one of the three structural dimensions of EP ("Labor Market and Welfare State", "Housing Market and Policies" and "Energy Market and Policies"). We then held a meeting with a group of experts, one for each of the three different fields studied. The experts were selected for convenience and because each of them had a long trajectory and highly relevant expertise in each dimension field. In the meeting we discussed and decided which indicators were the most relevant, resulting in a pre-selection of 47 indicators (the indicators that compose each dimension can be seen in Appendix A). Next, we performed a Spearman correlation analysis among the indicators. Pairs of indicators with a correlation higher than 0.8 were identified and one was selected by consensus with the group of experts (indicators eliminated because they were redundant are marked in gray in Appendix A).

Secondly, a principal component analysis (PCA) with varimax orthogonal rotation was used to create the index. This is one of the most widely used techniques to reduce the dimensionality of large datasets, while preserving as much variability as possible (Jolliffe et al., 2016). Datasets are transformed into a smaller number of uncorrelated

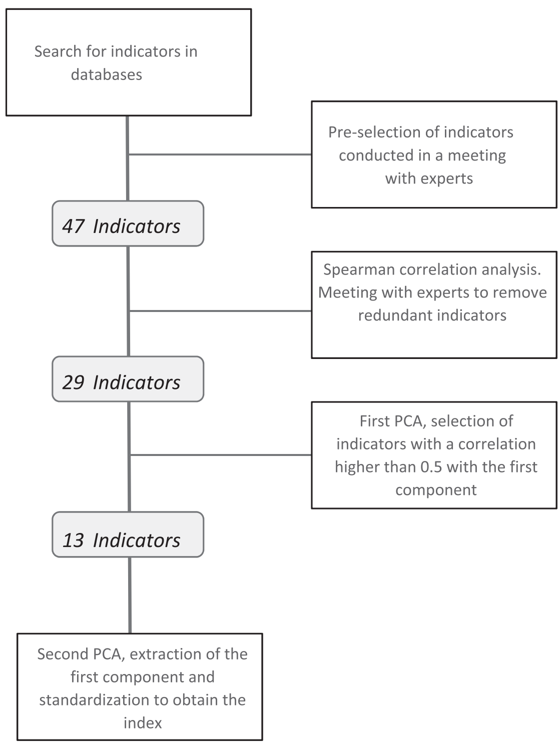

Fig. 1. Flowchart representing the steps taken to obtain the index.

Table 1
Detailed description of the included indicators that constitute the SEPV Index by dimension.

	Indicator	Definition[1]	Year	Database
Labor				
L2	Long-term unemployment rate (%)	This indicator measures the share of the economically active population aged 15–74 years who have been unemployed for 12 months or more. Unemployed persons are defined as all persons who were without work during the reference week, were currently available for work and were either actively seeking work in the last 4 weeks or had already found a job to start within the next 3 months. The unemployment period is defined as the duration of a job search, or as the length of time since the last job was held (if shorter than the time spent on a job search). The economically active population comprises employed and unemployed persons.	2016	Eurostat
L4	Median income in purchasing power standard (PPS)	The weighted median of the distribution of the equivalized net income. The equivalized disposable income is the total income of a household, after tax and other deductions, that is available for spending or saving, divided by the number of household members converted into equalized adults. Household members are equalized or made equivalent by weighting each according to their age, using the modified OECD equivalence scale. This indicator is measured in PPS.[2]	2016	Eurostat
L5	Disposable income ratio - S80/S20 (%)	The ratio of total income received by the 20% of the population with the highest income (top quintile) to that received by the 20% of the population with the lowest income (lowest quintile). Income must be understood as equivalized disposable income.	2016	Eurostat
L9	Young people neither in employment nor in education or training (%)	This indicator corresponds to the percentage of the population of a given age group and sex who are not employed and not involved in further education or training. The numerator of the indicator refers to persons who are not employed (i.e. unemployed or inactive according to the International Labor Organization -ILO- definition) and who have not received any education or training in the 4 weeks preceding the survey. The denominator is the total population of the same age group and sex, excluding the respondents who have not answered the question 'participation in regular education and training'.	2016	Eurostat
L1	Employment rate of recent graduates (%)	This indicator presents the employment rates of persons aged 20–34 years fulfilling the following conditions: being employed according to the ILO definition, having attained at least upper secondary education (ISCED 3) as the highest level of education, not having received any education or training in the 4 weeks preceding the survey and having successfully completed their highest educational attainment 1, 2 or 3 years before the survey.	2016	Eurostat
L12	Expenditure on social protection in PPS per inhabitant	Total expenditure comprises all transactions recorded under positive uses in the European System of National and Regional Accounts (ESA) framework, and subsidies payable, in the current accounts as well as transactions (gross capital formation, acquisition less disposals of non-financial non-produced assets plus capital transfers payable) in the capital account of the government. Sickness and disability; old age; survivors; family and children; unemployment; housing; research and development; social protection and social exclusion not elsewhere classified (n.e.c.). This indicator is measured in PPS[2] per inhabitant.	2014	Eurostat
L16	Labor Market Policies (LMP) – category 1 as a % of gross domestic product (GDP)	LMP services (category 1) cover the costs of the public employment service together with any other publicly funded services for jobseekers. This indicator is measured as a percentage of the country's GDP.[3]	2010	Eurostat
L17	Labor Market Policies – categories 2 to 7 as a % of GDP	LMP measures (categories 2–7) cover activation measures for the unemployed and other target groups including the categories of training, job rotation and job sharing, employment incentives, supported employment and rehabilitation, direct job creation, and start-up incentives. This indicator is measured as a percentage of the country's GDP.[3]	2010	Eurostat
Housing				
H10	Tenants, rent at market price (%)	This indicator covers tenants or subtenants that pay rent at prevailing or market rent. It also includes households where the rent is wholly recovered from housing benefits or other sources, including public, charitable, or private sources. Moreover, no distinction is made when the accommodation is directly rented from a 'landlord', or from a tenant who is subrenting.	2016	Eurostat
H12	Overcrowding rate (total population) (%)	This indicator is defined as the percentage of the population living in an overcrowded household. A person is considered as living in an overcrowded household if the household does not have at its disposal a minimum of rooms equal to: one room for the household, per couple in the household, for each single person aged 18 and older, per pair of single people of the same sex between 12 and 17 years, for each single person between 12 and 17 years of age and not included in the previous category and per pair of children under 12 years of age.	2016	Eurostat
H16	Social rental stock as a % of total housing stock	Social rental stock divided by total housing stock multiplied by 100. Social rental refers to housing for households whose needs are not met by the open market and where there are rules for allocating housing to benefiting households (CECODHAS, November 2006) available for rental.	2012	Housing Europe's Observatory
Energy				
E1	Annual electricity switching rates 2009-2015 (%)	Average of the annual electricity switching rates of the available years from 2009 to 2015. This indicator measures the percentage of final electricity consumers changing suppliers in a given year.	2015	EU Energy Atico Country-sheet

(*continued on next page*)

Table 1 (*continued*)

	Indicator	Definition[1]	Year	Database
E10	Final electricity consumption per capita (KWh per capita)	Total electricity consumption measured in kilowatts per hour in a country divided by the total population. Final electricity consumption covers electricity supplied to the final consumer's door for all energy uses; it does not include own use by electricity producers or transmission and distribution losses. It is calculated as the sum of final electricity consumption from all sectors. These are disaggregated to cover industry, transport, households, services (including agriculture and other sectors).	2016	Energy Data-sheet

1) Definitions were obtained from their correspondent data source.
2) The purchasing power standard (PPS), is an artificial currency unit. Theoretically, one PPS can buy the same amount of goods and services in each country. However, price differences across borders mean that different amounts of national currency units are needed for the same goods and services depending on the country. PPS are derived by dividing any economic aggregate of a country in national currency by its respective purchasing power parities. PPS is the technical term used by Eurostat for the common currency in which national accounts aggregates are expressed when adjusted for price level differences using PPPs. Thus, PPPs can be interpreted as the exchange rate of the PPS against the euro.
3) Gross domestic product (GDP), is a basic measure of the overall size of a country's economy. As an aggregate measure of production, GDP is equal to the sum of the gross value added of all resident institutional units engaged in production, plus any taxes on products and minus any subsidies on products. Gross added value is the difference between output and intermediate consumption. GDP is also equal to: the sum of the final uses of goods and services (all uses except intermediate consumption) measured in purchasers' prices, minus the value of imports of goods and services; the sum of primary incomes distributed by resident producer units.

variables known as principal components. In this step, the first component was extracted.

Finally, to construct a more operational and replicable index and to maximize the variance of the first component, we followed a procedure commonly used in index creation studies (Domínguez-Berjón et al., 2008; Havard et al., 2008). We correlated the indicators to the first component and dropped all those that had a correlation lower than 0.5. After that, we conducted a second PCA with these indicators. The first component was extracted again and its scores were predicted and standardized to obtain the index (the full selection process is described in Fig. 1).

2.2. Grouping countries across the European Union

To explore the geographical pattern of the index values, a hierarchical cluster analysis (HCA) was conducted on the index variable. HCA is a descriptive method used to analyze how datasets can be grouped (Peña, 2002). Ward's method (a type of HCA) was performed to categorize the 27 countries by taking into account their SEPV index similarities. The results were presented through a dendrogram, a type of tree diagram that was used to visually create the country groups. Then, we used a choropleth map to show the geographic distribution of the index clusters.

2.3. Structural energy poverty vulnerability validation

To test whether the SEPV index properly identified the countries that are more or less structurally vulnerable to EP, we studied the association between the country typologies obtained through the HCA and the EP prevalence of each country. We first graphically explored the relationship between the country groups and the EP prevalence among countries through boxplots with jitter. Then, we obtained prevalence ratios and their 95% confidence intervals (CI) of EP in the different country groups compared with the less structurally vulnerable EP country group. We fitted Poisson regression models with robust variance (Barros and Hirakata, 2003; Marí-Dell'Olmo et al., 2007), where the dependent variable was EP prevalence and the independent variable was the country typologies. The analyses were weighted to take into account the complex sample design.

2.4. Association between excess winter mortality and structural energy poverty vulnerability

To test the application of the SEPV Index to public health, we explored the association between EWM and the country typologies. The dependent variable of this analysis, EWM, was calculated by obtaining the interannual number of deaths in the winter season as well as that of the non-winter seasons for each country for the 7 years with available data (from August 2010 to July 2016). The winter season is defined as December to March inclusive, and the non-winter season as the 4 months previous to the winter season (from August to November) as well as the 4 months following the winter season (from April to July). For each country, EWM was estimated with the following formula:

$$EWM_i = \frac{\text{Winter Deaths Dec to Mar} - 0.5 \cdot \text{Non} - \text{Winter Deaths (Aug to Nov,} \quad \text{Apr to Jul)}}{0.5 \cdot \text{Non} - \text{Winter Deaths (Aug to Nov,} \quad \text{Apr to Jul)}} = \frac{n1_i}{n2_i}$$

The independent variable of this analysis was the country groups obtained through the HCA.

We fitted a Poisson regression model to determine whether there was an association between EWM and the country groups. These models allowed the estimation of the EWM incidence rate ratio (IRR), with its respective 95% CI, taking as a reference category the group of countries that are the least structurally vulnerable to EP (first cluster).

All the statistical analyses were carried out using STATA Standard Edition 13.1 and R-3.3.1 for Windows.

3. Results

3.1. Structural energy poverty vulnerability index

After reviewing the databases, 47 indicators were included: 18 for the Labor Market and Welfare State dimension, 19 for the Housing Market and its Policies and 10 for the Energy Market and its Policies. According to the Spearman correlation analysis and the consensus of the expert group, redundant indicators were excluded and 29 indicators were retained (11 for the first dimension, 10 for the second and 8 for the third) (Appendix A describes the initial 47 variables and indicates those that were later eliminated). Table 1 shows the final 13 indicators that composed the index, which were extracted from the PCA analysis.

The first component of the final PCA (50.8% of variance explained) was correlated (0.98) with the first component of the first PCA, which contained the 29 indicators. Table 2, shows the univariate description of the 13 indicators, as well as their respective correlation and percentage of contribution to the index.

For the "Labor Market and Welfare State" dimension, the variable with the highest correlation to the index was "Median Income in PPS" (r = −0.91) and it was also that with the highest percentage of contribution to the index (11.73%). The median income in PPS in the EU-27 was 15,985; however, there was wide disparity across countries, with Luxemburg having the highest median income in PPS, which was almost six times higher than the lowest one, found in Romania (28,087 vs 4794). For the "Housing Market and Policies" dimension, the most closely correlated variables to the index were "Tenants, Rent at Market Price" and "Social Rental Stock as a % of Total Housing Stock" (r = −0.73) (contributing 8.94% and 8.44% to the index, respectively). The latter indicator captures the wide range of available social housing in different EU countries: while the median value of social housing over the total available housing stock was 5.3%, the Netherlands had the highest proportion of social housing (32%) while Greece and Cyprus had none. Finally, for the third dimension, "Energy Market and its Policies", the variable most closely correlated to the index was "Final Electricity Consumption Per Capita" (r = −0.79), which had the highest percentage of contribution to the index (6.33%). The median electricity consumption was 5185.5 KW h but, as for the other indicators, there was wide asymmetry between the lowest and the highest

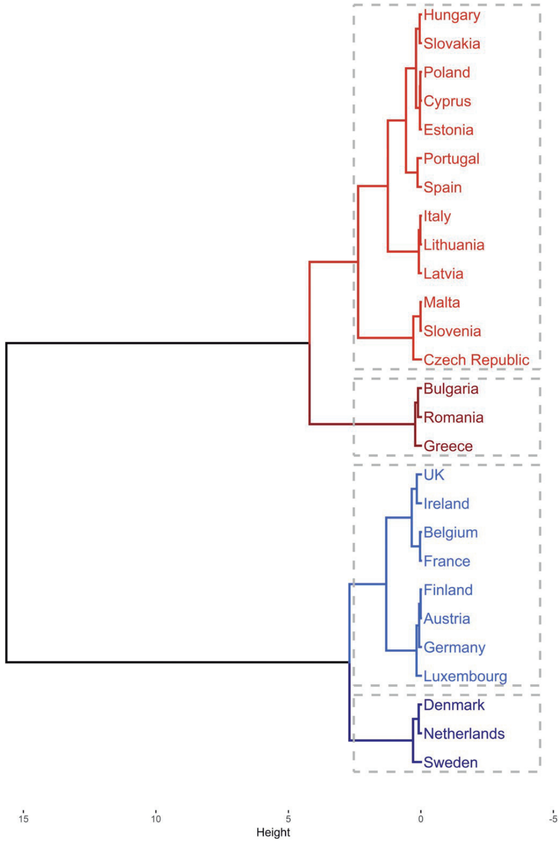

Fig. 2. Dendrogram representing the hierarchical cluster analysis performed on the SEPV index.

Table 2
Univariate description of the final indicators constituting the SEPV Index and their respective correlations and percentage of contribution to the index.

	Variable	Mean	SD	Median	IQR	Range	Correla-tion with Index	% of contribution to the Index
Labor								
L2	Long-term unemployment rate	3.9	3.3	3	1.9–4.6	1.3–17	0.57	3.71
L4	Median income in PPS	15,379.3	5795.1	15,985	10,507 – 20,756	4794 – 28,087	−0.91	11.73
L5	Disposable income ratio S80–S20	5	1.3	4.6	4.1–6.2	3.5–7.9	0.64	7.73
L9	Young people neither in employment nor education	10.8	4.1	10.5	7.7–13	4.6–19.9	0.75	8.83
L10	Employment rate of recent graduates	78.7	10.5	80.2	73.4–85.4	49.2 – 96.6	−0.60	5.25
L12	Expenditure on social protection in PPS per inhabitant	6973.9	5118.1	4479.4	2273.5–11110.7	1095.1 – 20,127.8	−0.88	10.85
L16	Labor market policies – cat. 1 as a % of GDP	0.2	0.1	0.1	0.1–0.2	0–0.5	−0.87	9.59
L17	Labor market policies – cat. 2 to 7 as a % of GDP	0.5	0.3	0.5	0.2–0.7	0–1.4	−0.65	7.15
Housing								
H10	Tenants, rent at market price	15.4	11.2	13.4	4.5–20.8	1.3 – 39.8	−0.73	8.94
H12	Overcrowding rate (total population)	18.0	15.1	12.6	6.6 – 28.7	2.4 – 48.4	0.63	7.59
H16	Social rental stock as a % of total housing stock	8.6	84	5.3	2.3–17	0–32	−0.73	8.44
Energy								
E1	Annual electricity switching rate	4.9	5.3	3.4	0.01–9.7	0–15.3	−0.59	3.87
E10	Final electricity consumption per capita	5884.7	2840.9	5185.6	4482.3–6309.9	2189.1–14730.4	−0.79	6.33

GDP: Gross domestic product, PPS: purchasing power standard, SD: standard deviation, IQR: interquartile range.

values. The average electricity consumption was 2189 KW h in Romania but was approximately seven times higher in Finland (14,730 KW h).

The index is interpreted as follows: higher scores indicate more SEPV and lower scores indicate lower SEPV. The maximum value was 1.72 (attributed to Romania, the country with the highest level of SEPV) and the minimum score was −1.74 (attributed to Denmark, the country with the lowest SEPV level).

3.2. Grouping countries across the European Union

The graphic representation of the HCA can be seen in Fig. 2, where we selected countries grouped in two and in four clusters (inside the dashed boxes). In the 4-cluster option, the first and least vulnerable group to structural EP consisted of Denmark (−1.74), the Netherlands (−1.66) and Sweden (−1.45). The second least vulnerable group was constituted by Germany (−1.08), Finland (−1.04), Austria (−1.02), Luxembourg (−0.93), Belgium (−0.72), France (−0.69), the UK (−0.56), and Ireland (−0.41). The third group was composed of the Czech Republic (−0.17), Malta (0.04), Slovenia (0.05), Portugal (0.29), Spain (0.42), Poland (0.55), Cyprus (0.57), Estonia (0.60), Hungary (0.65), Slovakia (0.69), Italy (0.89), Lithuania (0.91) and Latvia (0.97). Finally, the fourth and most vulnerable group of countries consisted of Greece (1.48), Bulgaria (1.61) and Romania (1.72).

Fig. 3 shows the geographical distribution of the index values across countries by four clusters. The 2-cluster selection reveals a geographical pattern: northern and western countries in shades of blue are less vulnerable (first and second clusters), while southern and eastern countries (in shades of red) are more vulnerable (third and fourth clusters).

3.3. Structural energy poverty vulnerability validation

The SEPV index categorized by country groups was associated with EP prevalence. The prevalence ratios (PR) for the most vulnerable country-clusters were significant considering either the 2- and 4-group clusters. In the first scenario (2 clusters), the countries with high structural vulnerability had a PR that was significantly higher than the countries with low structural vulnerability (PR = 2.86; 95% CI: 2.45–3.33). In the second scenario (4 groups), when comparing the clusters to the first and least vulnerable cluster, the PR was 0.77 times higher in the second cluster (PR = 1.770; 95% CI: 1.339–2.340), 3.14 times higher in the third cluster (PR = 4.138; 95% CI: 3.227–5.305), and 6.66 times higher in the fourth cluster (PR = 7.66; 95% CI: 5.948–9.865). The results of the various scenarios are shown on the left-hand side of Fig. 4.

3.4. Association between excess winter mortality and structural energy poverty vulnerability

There was an association between EWM and the index categorized by country groups, as shown on the right-hand side of Fig. 4. For example, using the 4-cluster selection and taking the cluster of the least vulnerable countries as reference, the EWM index was 11.4% higher in the second cluster (IRR = 1.114; 95% CI: 1.105–1.123), 27.8% higher in the third cluster (IRR = 1.278; 95%CI: 1.268–1.288), and 13.1% higher in the fourth cluster (IRR = 1.131; 95% CI: 1.121–1.141).

4. Conclusions and policy implications

This study contributes to the literature by providing an index that

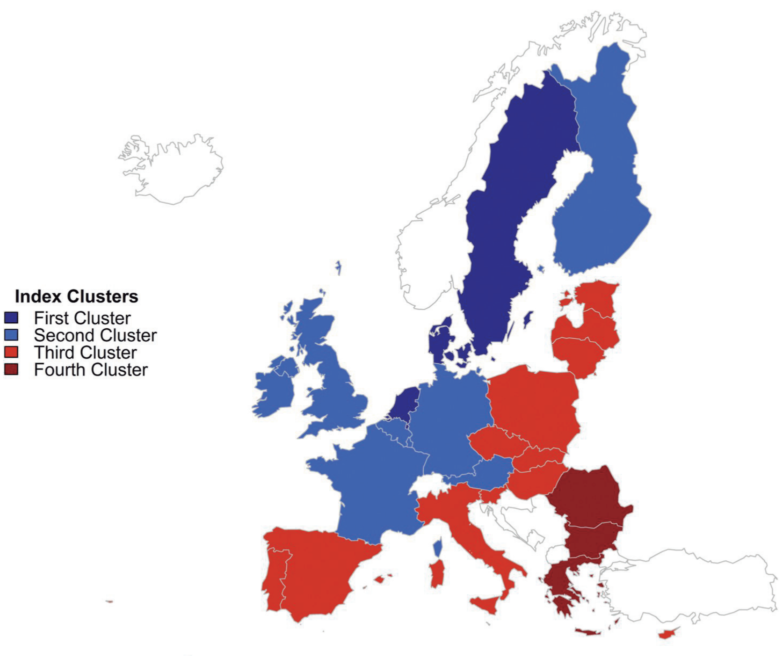

Fig. 3. SEPV Index 4-cluster distribution across the EU.

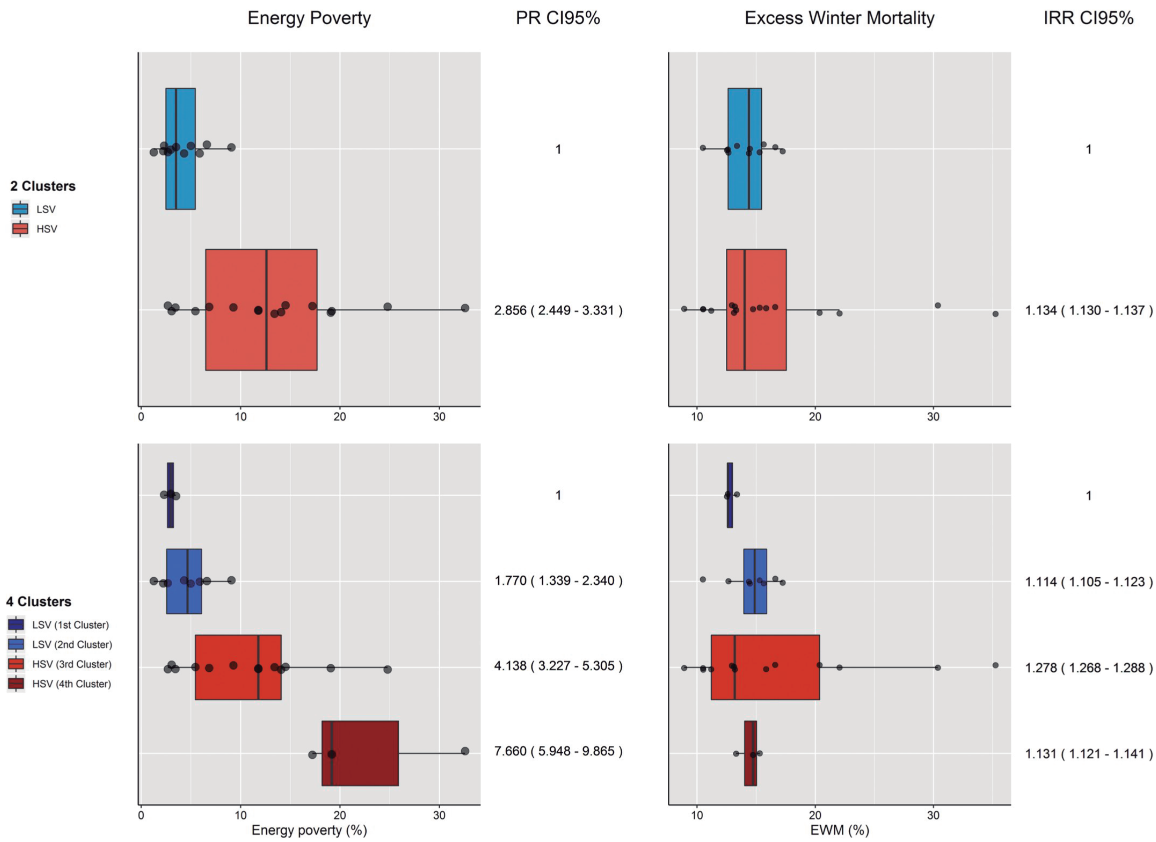

Fig. 4. Structural energy poverty vulnerability index validation with energy poverty prevalence and association with excess winter mortality by clusters.
On the left-hand side of the figure, the index is validated with the energy poverty prevalence by two groups (upper figure) and four groups (lower figure) by using prevalence ratios (PR). On the right-hand side, the index is associated to excess winter mortality (EWM) by two groups (upper figure) and four groups (lower figure) by using incidence rate ratios (IRR).

summarizes SEPV in the EU-27 and allows more nuanced and empirically rich comparisons across countries and analyses its geographical distribution. Moreover, this index was validated and can have different applications; one of them is the study of the impact of SEPV on public health. The index highlights the important role of the Labor Market and Welfare State as well as the wide distribution of its scores. Furthermore, the cluster analysis proposes different groupings and we believe that those that create 2- or 4-group clusters are appropriate to study SEPV in the EU. The 4-cluster country classification was associated with EWM, showing a greater risk of mortality in winter in country groups that are more structurally vulnerable to EP.

The first step of the study was to create an index that could capture the SEPV of EU countries by exploring how structural determinants operate in Member States. Until now, pan-European comparisons in the field of EP have been made following expert criteria or by assigning arbitrary weights to consensus-based EP indicators (EPEE project, 2014; Thomson and Snell, 2013). Nevertheless, some authors have attempted to create indices to consider several aspects of the EP phenomenon (Fabbri, 2015; Okushima, 2017; Pérez-Fargallo et al., 2017). We believe that the construction of our index goes a step further, by providing an EU analysis based on a more objective methodology and comprehensive perspective, taking into consideration structural determinants of the three most common drivers of EP. This could help to fill the gaps in knowledge of EP mentioned by other authors (Bouzarovski and Tirado Herrero, 2017). The development of the index highlighted the importance of the Labor Market and the Welfare State in modifying the emergence of EP at the country level. This means that the main determinants of higher SEPV in a given country are employment, income and its unequal distribution, as well as government expenditure on social protection and public interventions. These findings could prompt readers to consider a welfare state typology instead of the SEPV index. Nevertheless, the range of countries used in these typologies does not include the latest members entering the EU (for instance, Post-Socialist States) and newer typologies have not achieved consensus in establishing the type of welfare regime of those countries (Van de Velde et al., 2014). Further, by definition, they do not include housing or energy items (Bambra, 2007). Although these dimensions are not predominant, there are certain factors that prevail in the index. These factors are tenure type, the number of people living in the same dwelling, the proportion of social housing, the possibility of switching electricity supplier, and electricity consumption.

In this study, the four country groups obtained through the HCA can be interpreted as being on a gradient from lower to greater vulnerability to EP. The most vulnerable group of countries (fourth cluster) was composed of Bulgaria, Romania and Greece, which had a respective EP prevalence of 19.2%, 17.2% and 32.6% (2016), being ranked as third, fifth and first country, respectively, in terms of EP prevalences in the EU. The two Post-Socialist States (Bulgaria and Romania) were the last two countries to enter the EU (in 2007), which could explain their delay in some market and policy transitions compared with other countries. Both countries were in the most vulnerable quartile for almost every indicator included in the index, had a very low percentage of the population renting dwellings at market price, a high proportion of overcrowding (affecting half of the population), very low switching rates of electricity suppliers and low electricity consumption. Bulgaria has the highest income inequality (the income of the richest 20% is eight times higher than that of the poorest 20%) and the lowest expenditure on social protection (1095 PPS per inhabitant). Romania has the lowest median income in the EU-27 (4794 PPS) and the lowest expenditure on labor market measures as a percentage of GDP (0.01%). It also has the highest overcrowding rate (48.8%) and the lowest electricity consumption in the EU-27 (2189 KW h). The extreme results in these indicators could be due to the way in which these countries are transitioning from a centrally planned economy to a neo-liberal one, often without developing adequate social welfare and energy efficiency mechanisms, and therefore, putting vulnerable households at higher risk of falling into EP (Bouzarovski and Tirado Herrero, 2017; Kovacevic, 2004). Vulnerable groups have lost the universal support or subsidy mechanisms that characterized centrally planned economies, while not being able to fully profit from the potential benefits of a liberalized market (Bouzarovski and Tirado Herrero, 2017). The comparative literature in terms of welfare state typologies has not come with a conclusive categorization for these countries due to their heterogeneous economic upheavals and comprehensive social reforms (Kovács, 2002; Van de Velde et al., 2014). The third member of this highly vulnerable group is Greece, a southern country. Southern countries are characterized by an increased risk of having high proportions of EP. The effect of the financial crisis on Greece is evidenced by its increased EP prevalence, which increased from 18% before the crisis (2007) to 32.6% in 2016. This vulnerability is also highlighted by values of the index indicators. Greece was situated in the worst quartiles for almost all indicators and had the highest rate of long-term unemployment (23.6%) and the lowest values in terms of employment among recent graduates (49.2%), expenditure on services in labor market policies as a percentage of GDP (0.01%) and social rental stock (none) compared with the rest of the EU-27.

The second most vulnerable group (third cluster) was composed of southern and eastern countries (the Czech Republic, Malta, Slovenia, Portugal, Spain, Poland, Cyprus, Estonia, Hungary, Slovakia, Italy, Lithuania and Latvia), indicating that the two most vulnerable clusters share the vulnerabilities described above for Post-Socialist States, as well as those of southern Member States. The vulnerability of southern countries might be due to their poor dwelling efficiency and lack of adequate heating systems in the housing stock (Wilkinson et al., 2001). In welfare state typologies, southern countries are described as "rudimentary" since they have a fragmented system of welfare provision (income maintenance schemes range from generous to meager and the healthcare system is limited) (Leibfreid, 1992). Nevertheless, while these countries have a high prevalence of EP in common, there are substantial regional disparities in the exposure of countries to the drivers of EP, reflected by the division of these vulnerable countries into two separate groups (third and fourth clusters). For instance, welfare provision varies extensively between countries of the same regime type (Bouzarovski and Tirado Herrero, 2017).

The third most vulnerable group (second cluster) was mostly composed of countries from the western region (Germany, Finland, Austria, Luxembourg, Belgium, France, the UK and Ireland), where there is much less EP. In these countries, EP is more restricted to specific demographic groups or those residing in certain types of housing. This restriction could be due to their better position in terms of domestic energy deprivation (they have a higher macroeconomic performance and income levels) as well as profit from improved conditions in the housing stock and more effective targeting of vulnerable groups than in eastern and southern EU countries (Liddell and Morris, 2010; Marí-Dell'Olmo et al., 2016; Wilkinson et al., 2001). Regarding welfare state typologies, these countries have been partially grouped as Corporatist (Korpi and Palme, 1998) Bismarckian (Ferrera, 1996), as well as Conservative Bismarckian and Liberal (Esping-Andersen, 1991; Pitruzello, 1999).

The least vulnerable group (first cluster) comprised Denmark, the Netherlands and Sweden, with EP prevalences of 3.5%, 3%, and 2.3%, respectively (2016). Denmark is the least vulnerable country and also that with the lowest EP levels. This country has by far the highest level of expenditure as a percentage of GDP in Labor Market Policies, making it a high employment promoter country. The Netherlands has the lowest percentage of young people who are neither in employment nor studying (4.6%) and has the highest proportion of social housing in the total dwelling stock (32%). Finally, Sweden has the lowest rate of long-term unemployment in the EU-27 (1.3%). Further, the three countries are also in the least vulnerable situation for almost every index indicator (lowest/highest quartile depending on the interpretation of the indicator). In terms of welfare state typologies, these countries have been categorized as Social Democratic or as Scandinavian (Kangas et al., 1994; Leibfreid, 1992; Navarro and Shi, 2001; Pitruzello, 1999; Ragin et al., 1994).

Bouzarovski and Tirado-Herrero (2017) have proposed that EP can be summarized into two spatial clusters: a core and a periphery, the first with lower EP prevalences and the second with higher prevalences (Wilkinson et al., 2001). These authors concluded that the core-periphery binary is a better way to group countries according to their EP rates across the EU compared with the traditional 3-region model (core, semi-periphery, periphery) (Bouzarovski and Tirado Herrero, 2017; Featherstone and Kazamias, 2000). Our study emphasizes that the 4-group categorization is a good fit for inter-group discrimination; however, these authors measured EP directly whereas our analysis measures SEPV. We believe that the 4-group categorization is relevant to understand structural vulnerability processes and that keeping two large regions (fourth and third clusters as countries with higher structural vulnerability (HSVs), and second and first clusters as countries with lower structural vulnerability (LSV)) is also a good fit. Although we used different methods and procedures, our results are consistent with the findings of Bouzarovski and Tirado-Herrero.

Since the index measures the vulnerability of a country to display high EP rates, it was validated by comparing the country groups (established by the SEPV index values) to the observed EP prevalence in these clusters. The more structurally vulnerable a country was to EP, the higher the EP prevalence within that country group. Therefore, the index correctly identifies countries' vulnerability.

Finally, we found a clear association between the cluster classification and EWM. However, compared with the first group, the third group has a higher risk of EWM than the fourth group, which seems counterintuitive as the fourth cluster is the most vulnerable. An explanation is that the third cluster is composed of southern countries, which have higher EWM levels than the rest of Europe (Liddell and Morris, 2010; McKee, 1990). The highest levels of EWM can be found in Portugal, Spain, Italy, Cyprus and Malta (pertaining to the third cluster), as well as in Greece (which belongs to the fourth cluster) (Hernandez et al., 2016). Furthermore, the effects of EP are more marked in aged populations. Therefore, the stronger health effects in the third cluster could be because it includes countries with the highest life expectancies and, at the same time, because Bulgaria and Romania (fourth cluster) are those with the lowest life expectancies (Mortality and life expectancy statistics, 2013).

Our study has certain limitations. First, some indicators that we wanted to include in the set of variables used to create the index were not available for the 27 countries. This absence may limit the scope of the structural determinants analyzed and was especially important in the Energy market and policies indicators, where the level of data availability varied widely from one country to another. However, at least two indicators were included per dimension. Second, although significant steps have been taken to homogenize the data collection process in the EU, the indicators are measured in a heterogeneous way across countries. Third, although we explored territorial inequalities, we were not able to examine other sources of inequality such as age, gender or degree of urbanization due to a lack of data. Studying such inequalities could further clarify the impact of structural determinants on EP. Fourth, the EWM calculation following the conventional equation in Section 2.4 has been criticized by some authors because it measures winter mortality excess or shortage as much as it does summer mortality excess or shortage (Hajat and Gasparrini, 2016; Liddell et al., 2015). However, better methods to measure this phenomenon and its association with EP have not been validated yet. Finally, the expert selection criteria (for convenience) could have leaded us to subjective results, as choosing other experts would have possibly resulted in a different selection of indicators. Though this subjective component cannot be avoided, we believe the extensive long and relevant trajectory of each expert is an asset rather than a source of bias.

The strengths of the analysis are that, to our knowledge, this is the first study that explores vulnerability to EP through its structural determinants at the national level, thus contributing to a more comprehensive perception of EP at this scale. As we were able to compare the State Members of the EU-27, we produced a pan-European comparison that could be useful to better understand the inequalities prevailing within the EU and to compare different typologies. Further, the SEPV index developed could be useful to establish country groups and analyze the health impacts of EP. Another asset of this index is that it can be applied to other regions outside the EU if all the indicators are available; the context is similar to the EU and well known to the authors. However, authors should be aware that the index score values are standardized and cannot be used to compare these regions to the EU-27. Finally, the SEPV index could be used to analyze regional variations within one country as long as there is sufficient heterogeneity in the structural determinants of EP within the analysis units.

The SEPV index summarizes the structural determinants of EP across the EU and allows observation of geographical patterns as well as study of how the structural determinants of EP affect health at the country level. We observed that the three policies and markets studied have an impact on SEPV as they do on health. These findings suggest response plans to mitigate EP should overcome individual actions as acting upon the structural determinants could be more beneficial for the population.

This study can have different policy implications aimed at reducing a country's structural vulnerability to EP for country governments at the EU-27 level. First, governments could implement policies to reduce inequality such as increasing minimum wages or making taxes more progressive, to increase their expenditure on social protection and to actively create and promote programs to reduce unemployment. Second, governments should ensure affordable housing by encouraging social housing policies at the national level. Finally, governments should guarantee the possibility to easily switch from one energy supplier to another at the household level.

Future research could use the SEPV index to stratify analyses related directly or indirectly to EP, to investigate EP structural vulnerability within countries and in other non-EU regions and to study the association between SEPV and other health outcomes.

Funding sources

The study is part of the PENSA Project ("Pobreza energética y salud desde multiples perspectivas: análisis individual, geográfico y temporal"), which received a research grant from the Carlos III Institute of Health, Ministry of Economy and Competitiveness, awarded on the 2015 call under the Health Strategy Action 2013–2016, within the National Research Program oriented to Societal Challenges, within the Technical, Scientific and Innovation Research National Plan 2013–2016, with reference PI15/02006, co-funded with European Union ERDF funds (European Regional Development Fund)". Martina Recalde was supported by the Agència de Salut Pública de Barcelona Scholarship of the Public Health Master (UPF-UAB) Program. Sergio Tirado was supported through funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement TRANSFAIR No. 752870. The funders were not involved in the research and preparation of the article, including study design; collection, analysis, and interpretation of data; writing of the article; nor in the decision to submit it for publication.

Declarations of interest

None.

Acknowledgments

We are grateful for the help provided by Carmen Trilla, expert of the Housing Market and policies dimension.

Appendix A. The 47 initial indicators according to their respective dimension

	Indicator	Definition*	Year	Database
	LABOR			
L1	**Unemployment rate (%)**	An unemployed person is defined by Eurostat, according to the guidelines of the International Labor Organization, as: someone aged 15 to 74 (in Italy, Spain and the United Kingdom, 16 to 74 years) without work during the reference week but available to start work within the next 2 weeks (or has already found a job to start within the next 3 months) and that has actively having sought employment at some time during the last 4 weeks. The unemployment rate is the number of people unemployed as a percentage of the labor force.	2016	Eurostat
L2	**Long-term unemployment rate (%)**	This indicator measures the share of the economically active population aged 15 to 74 years who has been unemployed for 12 months or more. Unemployed persons are defined as all persons who were without work during the reference week, were currently available for work and were either actively seeking work in the last 4 weeks or had already found a job to start within the next 3 months. The unemployment period is defined as the duration of a job search, or as the length of time since the last job was held (if shorter than the time spent on a job search). The economically active population comprises employed and unemployed persons.	2016	Eurostat
L3	**Temporary employment rate (%)**	A job may be considered temporary if employer and employee agree that its end is determined by objective conditions such as a specific date, the completion of a task or the return of another employee who has been temporarily replaced (usually stated in a work contract of limited duration).	2016	Eurostat
L4	**Median income in purchasing power standard (PPS)**	The weighted median of the distribution of the equivalized net income. The equivalized disposable income is the total income of a household, after tax and other deductions, that is available for spending or saving, divided by the number of household members converted into equalized adults. Household members are equalized or made equivalent by weighting each according to their age, using the modified OECD equivalence scale. This indicator is measured in PPS.[2]	2016	Eurostat
L5	**Disposable income ratio - S80/S20 (%)**	The ratio of total income received by the 20% of the population with the highest income (top quintile) to that received by the 20% of the population with the lowest income (lowest quintile). Income must be understood as equivalized disposable income.	2016	Eurostat
L6	**People at risk of poverty before social transfers (%)**	The share of persons with an equivalized disposable income, before social transfers, below the risk-of-poverty threshold, which is set at 60% of the national median equivalized disposable income (after social transfers). Retirement and survivor's pensions are counted as income before transfers and not as social transfers.	2016	Eurostat
L7	**People at risk of poverty after social transfers (%)**	The persons with an equivalized disposable income below the risk-of-poverty threshold, which is set at 60% of the national median equivalized disposable income (after social transfers).	2016	Eurostat
L8	**Gini coefficient of equivalized disposable income**	The indicator measures the extent to which the distribution of income among individuals or households within a society deviates from a perfectly equal distribution. It ranges from 0 to 100, where 0 represents perfect equality (everyone has the same income) and 100 represents maximum inequality (all income is accrued by a single household).	2016	Eurostat

L9	**Young people neither in employment nor in education and training (%)**	This indicator corresponds to the percentage of the population of a given age group and sex that is not employed and not involved in further education or training. The numerator of the indicator refers to persons that are not employed (i.e. unemployed or inactive according to the International Labor Organization definition) and that have not received any education or training in the 4 weeks preceding the survey. The denominator is the total population of the same age group and sex, excluding the respondents who have not answered the question 'participation to regular education and training'.	2016	Eurostat
L10	**Employment rate of recent graduates (%)**	This indicator presents the employment rates of persons aged 20 to 34 years fulfilling the following conditions: being employed according to the International Labor Organization definition, having attained at least upper secondary education (ISCED 3) as the highest level of education, not having received any education or training in the 4 weeks preceding the survey and having successfully completed their highest educational attainment 1, 2 or 3 years before the survey.	2016	Eurostat
L11	**Expenditure on social protection in PPS**	Total expenditure comprises all transactions recorded under positive uses in the European System of National and Regional Accounts (ESA) framework, and subsidies payable, in the current accounts as well as transactions (gross capital formation, acquisition less disposals of non-financial non-produced assets plus capital transfers payable) in the capital account of the government. Sickness and disability; old age; survivors; family and children; unemployment; housing; research and development; social protection and social exclusion not elsewhere classified. This indicator is measured in PPS.[2]	2014	Eurostat
L12	**Expenditure on social protection in PPS per inhabitant**	Same as the last category but this indicator is measured in PPS[2] per inhabitant.	2014	Eurostat
L13	**Expenditure on social protection as a % of gross domestic product (GDP)**	Same as penultimate category but this indicator is measured as a percentage of the country's GDP.[3]	2014	Eurostat
L14	**Expenditure on pensions as a % of GDP**	Expenditure on pensions comprises the following social benefits: disability pension, early retirement due to reduced capacity to work, old-age pension, anticipated old-age pension, partial pension, survivors' pension and early retirement due for labor market reasons. This indicator is measured as a percentage of the country's GDP.[3]	2014	Eurostat
L15	**Labor market policies (LMP) as a % of GDP**	Expenditure on LMP is limited to public interventions that are explicitly targeted at groups of persons with difficulties in the labor market: the unemployed, the employed at risk of involuntary job loss and inactive persons who would like to enter the labor market. Total expenditure of LMP is broken down into LMP services, measures and supports. This indicator is measured as a percentage of the country's GDP.[3]	2010	Eurostat
L16	**Labor market policies – category 1 as a % of GDP**	LMP services (category 1) cover the costs of the public employment service together with any other publicly funded services for jobseekers. This indicator is measured as a percentage of the country's GDP.[3]	2010	Eurostat
L17	**Labor market policies – categories 2 to 7 as a % of GDP**	LMP measures (categories 2-7) cover activation measures for the unemployed and other target groups including the categories of training, job rotation and job sharing, employment incentives, supported employment and rehabilitation, direct job creation, and start-up incentives. This indicator is measured as a percentage of the country's GDP.[3]	2010	Eurostat

L18	**Labor market policies – categories 8 & 9 as a % of GDP**	LMP supports (categories 8-9) cover out-of-work income maintenance and support (mostly unemployment benefits) and early retirement benefits. This indicator is measured as a percentage of the country's GDP.[3]	2010	Eurostat
	HOUSING			
H1	**% of Building stock built before 1970**	Sum of dwellings built before 1945 and from 1945 to 1969.	2014	EU Buildings Database
H2	**Housing cost as a % of disposable income (total population)**	Housing costs include gross housing benefits, regular maintenance and repairs and the cost of utilities, as well as mortgage interest payments, structural insurance, mandatory services and charges and taxes for owners; rent payments, structural insurance, services and charges, taxes on dwellings for tenants (at market price or at reduce price); and gross housing benefits, structural insurance, services and charges, and taxes on free-rent dwellings when applicable. The total disposable income of a household is calculated by adding together the personal income received by all of household members plus income received at household level.		Eurostat
H3	**Housing cost as a % of disposable income (population at risk of poverty)**	Same as last category but for the population at risk of poverty.[1]	2016	Eurostat
H4	**Housing overburden rate (total population) (%)**	This indicator is defined as the percentage of the population living in a household where the total housing costs (net housing allowances) represent more than 40% of the total disposable household income (net of housing allowances).	2015	Eurostat
H5	**Housing overburden rate (population at risk of poverty) (%)**	Same as last category but for population at risk of poverty.[1]	2015	Eurostat
H6	**Housing overburden rate (tenants, rent at reduced price) (%)**	Same as penultimate category but for tenants renting at a reduced price (see indicator "Tenants, rent at a reduced price or free".)	2012	Eurostat

H7	**Household final consumption expenditure PPS**	Household final consumption expenditure includes: services of owner-occupied dwellings; income in kind; items not treated as intermediate consumption; items not treated as capital formation; financial services directly charged and the part of financial intermediation services indirectly measured (FISIM) used for final consumption purposes by households; insurance services by the amount of the implicit service charge; pension funding services by the amount of the implicit service charge; payments by households for licenses, permits, etc. which are regarded as purchases of services; the purchase of output at not economically significant prices. This indicator is measured in PPS.[2]	2016	Eurostat
H8	**Arrears on mortgage or rent payments (total population) (%)**	Indicator obtained from the European Union Statistics on Income and Living Conditions (EU-SILC) survey. It is defined as the percentage of householders that have, in the last 12 months, been unable to pay the rent or mortgage repayment for the main dwelling on time due to financial difficulties, divided by the total population.	2016	Eurostat
H9	**Arrears on mortgage or rent payments (tenants, rent at reduced price) (%)**	Same as last category but for tenants at reduced price (see indicator “Tenants, rent at reduced price or free”).	2016	Eurostat
H10	**Tenants, rent at market price (%)**	This indicator covers tenants or subtenants that pay rent at prevailing or market rent. It also includes households where the rent is wholly recovered from housing benefits or other sources, including public, charitable, or private sources. Moreover, no distinction is made when the accommodation is directly rented from a ‘landlord’, or from a tenant who is subrenting.	2016	Eurostat
H11	**Tenants, rent at reduced price or free (%)**	This indicator is composed of two tenure categories: tenants at reduced price and for free. Accommodation is rented at a reduced rate when a lower price than the market price is paid. This category includes those renting social housing, renting at a reduced rate from an employer and those in accommodation where the actual rent is fixed by law. Accommodation provided rent-free applies only when there is no rent to be paid, such as when the accommodation comes with the job or is provided rent-free from a private source. The situation when rent is recovered from housing benefit or other sources is covered by tenants at reduced price.	2016	Eurostat
H12	**Overcrowding rate (total population) (%)**	This indicator is defined as the percentage of the population living in an overcrowded household. A person is considered as living in an overcrowded household if the household does not have at its disposal a minimum number of rooms equal to: one room for the household, one room per couple in the household, one room for each single person aged 18 and older, one room per pair of single people of the same sex between 12 and 17 years, one room for each single person between 12 and 17 years and not included in the previous category and one room per pair of children under 12 years.	2016	Eurostat
H13	**Overcrowding rate (population at risk of poverty) (%)**	Same as last category but for the population at risk of poverty.[1]	2016	Eurostat

H14	**Government expenditure on 'housing and communities amenities' confirm as a % total expenditure**	Housing and communities amenities divided by the government's total expenditure. Housing and communities amenities are a category of the OECD "Classification of the functions of government". It is composed of expenditure on housing development; community development; water supply; street lighting; research and development &D related to housing and community amenities as well as housing and community amenities n.e.c. Total expenditure comprises all transactions recorded under positive uses in the ESA framework, and subsidies payable, in the current accounts as well as transactions (gross capital formation, acquisition less disposals of non-financial non-produced assets plus capital transfers payable) in the capital account of the government.	2016	Eurostat
H15	**Government expenditure on 'housing and communities amenities' confirm as a % of GDP**	Same as last category but this indicator is measured as a percentage of the country's GDP.	2016	Eurostat
H16	**Social rental stock as a % of total housing stock**	Social rental stock divided by total housing stock multiplied by 100. Social rental refers to housing for households whose needs are not met by the open market and where there are rules for allocating housing to benefiting households (CECODHAS, November 2006) available for rental.	2012	Housing Europe's Observatory
H17	**U-value of building shell in residential (W/m² °C)**	Thermal transmittance (U-value) is the rate of heat transfer through a structure (which can be a single material or a composite), divided by the difference in temperature across that structure. It is measured by the equation $\Phi = A \times U \times (T_1 - T_2)$, where Φ is the heat transfer in watts, U is the thermal transmittance, T_1 is the temperature on one side of the structure, T_2 is the temperature on the other side of the structure and A is the area in square meters. Here measured for the building shell in dwellings.	2014	EU Buildings Database
H18	**U-value of residential building external walls (W/m² °C)**	Same as last category but this indicator is measured for external walls in dwellings.	2014	EU Buildings Database
H19	**U-value of windows in residential buildings (W/m² °C)**	Same as penultimate category but this indicator is measured for windows in dwellings.	2014	EU Buildings Database
	ENERGY			
E1	**Annual electricity switching rates 2009-2015 (%)**	Average of the annual electricity switching rates of the available years over the period 2009-2015. This indicator measures the percentage of final electricity consumers changing suppliers in a given year.	2015	EU Energy Atico Country-sheet

E2	**Annual gas switching rates 2009-2015 (%)**	Average of the annual gas switching rates of the available years over the period 2009-2015. This indicator measures the percentage of final gas consumers changing suppliers in a given year.	2015	EU Energy Atico Country-sheet
E3	**Cumulative market share generation, main entities (%)**	Percentage of market share of main electricity generation companies. Market share is calculated by taking a company's sales over a period and dividing the result by the total sales of the industry over the same period. Electricity generation companies (GENCO) are regulated or non-regulated companies that engage solely in producing electricity, a company that generates energy. While a GENCO may engage in activities other than energy generation (e.g. it could be a cogenerator), GENCOs do not (and in many regions cannot) engage in any other activity in the energy supply chain.	2015	Energy Data-sheet
E4	**Cumulative market share capacity, main entities (%)**	Percentage of capacity market share of main electricity entities. In a capacity market electricity suppliers or utilities are required to have enough resources to meet their customers' demand as well as to have reserves in case these are needed. Therefore, capacity can be defined as the possibility to generate resources to ensure that the demand for electricity can be constantly met.	2015	Energy Data-sheet
E5	**Number of companies representing at least 95% of net power generation**	Total number of companies that represent at least 95% of net electricity generation. Net electricity generation is equal to gross electricity generation minus the consumption of power stations' auxiliary services. Gross electricity generation can be defined as the total amount of electrical energy produced by transforming other forms of energy. Auxiliary power is electric power that is provided by an alternate source and that serves as a backup for the primary power source at the station main bus or prescribed sub-bus.	2012	EU Energy Atico Country-sheet
E6	**Electricity prices for household consumers (PPS)**	Electricity prices for household consumers are defined as follows: Average national price in euros per kWh including taxes and levies applicable for the first semester of each year for medium-sized household consumers. This indicator is measured in PPS.[2] The kilowatt hour (kWh) is a unit of energy equal to 3.6 megajoules. If the energy is being transmitted or used at a constant rate (power) over a period of time, the total energy in kilowatt hours is equal to the power in kilowatts multiplied by the time in hours.	2017	Eurostat
E7	**Energy consumption of all end-uses in residential dwellings per m² (kWh/m2)**	Ratio between the energy consumption of residential (normal climate) and the floor area of permanently occupied dwellings. Making climatic corrections allows measurement of the energy consumption trend without climate effects, i.e. regardless of yearly variations in the winter severity.	2014	EU Buildings Database
E8	**Energy consumption of space heating in residential dwellings per m² (kWh/m2)**	Same as last category but only for energy used for space heating purposes.	2014	EU Buildings Database

E9	**Energy per capita (kgoe/cap)**	Total energy measured in kilogram(s) of oil equivalent in a country divided by the total population. Kilogram(s) of oil equivalent (kgoe), is a normalized unit of energy. By convention it is equivalent to the approximate amount of energy that can be extracted from one kilogram of crude oil.	2016	Energy Datasheet
E10	**Final electricity consumption per capita (KWh per capita)**	Total electricity consumption measured in kilowatt per hour in a country divided by the total population. Final electricity consumption covers electricity supplied to the final consumer's door for all energy uses. It does not include own use by electricity producers or transmission and distribution losses. It is calculated as the sum of final electricity consumption from all sectors. These are disaggregated to cover industry, transport, households, services (including agriculture and other sectors).	2016	Energy Datasheet

* Definitions were obtained from their correspondent data source.

[1]Population at risk of poverty are persons with an equivalized disposable income below the risk-of-poverty threshold, which is set at 60% of the national median equivalized disposable income (after social transfers).

[2]The purchasing power standard (PPS), is an artificial currency unit. Theoretically, one PPS can buy the same amount of goods and services in each country. However, price differences across borders mean that different amounts of national currency units are needed for the same goods and services depending on the country. PPS are derived by dividing any economic aggregate of a country in national currency by its respective purchasing power parities. PPS is the technical term used by Eurostat for the common currency in which national accounts aggregates are expressed when adjusted for price level differences using PPPs. Thus, PPPs can be interpreted as the exchange rate of the PPS against the euro.

[3]Gross domestic product (GDP), is a basic measure of the overall size of a country's economy. As an aggregate measure of production, GDP is equal to the sum of the gross value added of all resident institutional units engaged in production, plus any taxes on products and minus any subsidies on products. Gross added value is the difference between output and intermediate consumption. GDP is also equal to: the sum of the final uses of goods and services (all uses except intermediate consumption) measured in purchasers' prices, minus the value of imports of goods and services; the sum of primary incomes distributed by resident producer units.

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10.2. Annex II: article addicional 2

What are the effects of energy poverty on people's health and well-being?: a scoping review with an equity lens

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Abstract

Energy poverty [EP] is a growing problem worldwide. One of the major impacts of EP is its negative effects on people's health and well-being. Several studies have shown how EP increases morbidity and mortality though different mechanisms, such as exposure to inadequate indoor temperatures and deteriorating housing conditions. We conducted a scoping review to synthesize the evidence relating EP to health effects and health risk exposures and analysed the results as a function of inequality axis. We conducted a scoping review of available literature (up to July 2020) using PubMed [Medline and In Process], Embase, Cochrane Database of Systematic Reviews, Campbell Library, Scopus, and Web of Science; searchs of the European Observatory of Energy Poverty, Teseo database, and World Health Organization website; additional a group of experts was consulted. MeSH terms and free-text terms were used. A data extraction form was designed and used and data organized in tables and figures. Selection criteria included: 1] studies, programs, or interventions related to exposure to EP or its different expressions, such as inadequate indoor temperatures [cold or hot]; the existence of dampness, mould, or related allergens; the absence, misuse, or disuse of hot/cold equipment; the absence of or inadequate thermal insulation; the inability to use light and/or hot water; expenditure-based studies; arrears in utility bills; etc.; 2] studies that presented relevant outcome measures in relation to physical or mental health, such as a surge in illnesses or health conditions, worsening previous health conditions, and a decreased quality of life or self-reported health status, and/or presented relevant measures for exposure to health-based risk factors, such as exposure to pollutants, dampness, etc.; 3] studies conducted in OECD countries; 4] studies that were written in English or Spanish; and 5] studies that were published before July 2020. Reports, editorials, opinions, and conference abstracts were excluded. Finally, 38 documents were included, 23 observational and 15 interventions. The interactions between bad housing, low income, and EP are complex, and many factors are involved. Thus, further research is warranted. In general, the results show that EP has a negative effect on health and that this effect varies across social class, gender, territory, age, and racial/ethnic groups.

Keywords

Energy poverty; Health; Risk exposures; Inequities; Quality of life; Scoping review.

Abreviations

EP: Energy poverty. MeSH: Medical Subject Headings. OECD: Organisation for Economic Co-operation and Development. PRISMA: Preferred reporting items for systematic reviews and meta-analyses. NS, [-]: not specified; UK: United Kingdom; USA: United States of America

1. Introduction

EP is a growing problem worldwide that is gaining social, academic, and political recognition. Different terms have been used to refer to energy deprivation in the home. The term “fuel poverty” began to be used in the United Kingdom as a result of the 1973 oil crisis, when the increase in fuel prices resulted in many households, especially those with low income, being unable to afford adequate warmth at home [1]. Other terms include “energy precariousness” and “energy insecurity”, which are mainly used in France and the United States, respectively. However, in recent years, the term “energy poverty” [EP] has become widespread.

Just as there is no single term for EP, so too is there no agreed upon definition for this complex and multidimensional phenomenon in which the causes and consequences can vary according to the context under analysis. A global definition that tries to overcome geographical barriers and to appeal to multiple realities and contexts was proposed by Bouzarovski and Petrova [2]. This definition considers EP as “the inability of a household to secure a socially and materially required level of energy services in the home”. Focusing on the deficit of domestic energy services allows one to consider the different dimensions of EP under the same conceptual framework, such as energy affordability, access to adequate energy carriers, flexibility to change energy service providers, energy efficiency, each household’s needs and practices, and specific climatic conditions.

There is also significant heterogeneity in how EP is measured [3,4]. On the one hand, some indicators based on household energy expenditures. This approach has been widely used in the United Kingdom, where, for many years, the official definition of fuel poverty was to allocate more than 10% of a household’s income to achieve an adequate level of energy services. One of the most common approaches, recommended by the European Union EP Observatory [EPOVE], is the use of the following expenditure-based indicators: 1] a high share of energy expenditures in one’s income [when the share of energy expenditures in one’s income is more than twice the national median share] and 2] low absolute energy expenditures [when absolute energy expenditures are below half the national median] [5]. Another widely used approach examines households’ self-reported assessments of their material and living conditions. Some of the most commonly used indicators include an inability to keep one’s home adequately warm or comfortably cool, having been in arrears in one’s utility bills during the last twelve months, and the presence of physical deficiencies in the home, such as damp walls and/or floors and rotten window frames. EP can also be measured directly by verifying whether a sufficient level of energy services is achieved in the home. For example, indoor temperatures can be measured to determine whether the adequate minimal indoor temperatures recommended by the World Health Organization [21 ºC in the living room and 18 ºC elsewhere in winter] are met. Moreover, the presence and safety of power services should be observed. Recently, increasingly more composite indices are being used to capture different aspects of EP in a single indicator. For example, the Structural EP Vulnerability Index includes 13 indicators of structural determinants for EP at the country level, such us the median income, the percentage of social rental stock, and the annual electricity switching rate [5].

One of the major impacts of EP is its negative effects on people’s health and well-being. Several studies have shown how EP increases morbidity and mortality through different mechanisms, such as exposure to inadequate indoor temperatures, deteriorating housing conditions [6], and the financial stress of needing to pay bills or deciding which basic needs to prioritize [7,8]. EP also makes everyday tasks such as housework, paid work, and studying difficult and has various social consequences, such as stigmatisation and reduced social interactions [9]. This, in turn, can also affect health more indirectly. In addition, EP is unevenly distributed among the population, following—as with other social determinants of health—different axis of inequality. According to the conceptual framework of the World Health Organisation's Commission on Reducing Health Inequalities, the axis of inequality are the set of structural determinants of health inequalities, which determine unequal power relations and shape social stratification. Some of the most relevant are gender, age, social class, ethnicity, and territory [10]. The elderly, children, and people with chronic conditions or special needs are also more vulnerable to the effects of EP on health. All of these factors contribute to increasing health inequalities [11].

In the last decade, the number of households suffering from EP has increased significantly. In Europe, for example, the economic crisis that impacted the continent in 2008 and the resulting austerity measures left millions of households experiencing inadequate levels of energy services in the home. This was particularly severe in countries of Southern and Eastern Europe, where, when the social consequences of the economic crisis became more evident in 2012, the percentage of people suffering from EP reached 17% [12]. This context has made EP the focus of many academics and policy makers. Thus, numerous studies have been conducted on the causes and consequences of EP, and much new evidence has been generated on EP's effects on people's health and well-being. The difficulty in defining the margins of EP has led to a great heterogeneity in the studies that assess EP's effects on health. Thus far, some reviews have synthesized existing evidence related to specific aspects of EP, such as cold housing [6,13] and improvements in the energy efficiency of houses [14].

In the context of climate change and increasing socioeconomic inequalities [15], EP is expected to increase. Thus, there is a need to integrate all of the evidence generated so far to guide future research, to support policy-making processes, and to facilitate the design of evidence-based public policies both to mitigate EP and its effects on health and well-being and to act as an advocacy tool for civil society. The objective of this study is to collect and synthesise all existing evidence related to the effects of EP on people's physical and mental health and exposure to health risk factors as well as the health effects of interventions aimed at ameliorating EP. We performed this review from a broad perspective to include as many expressions of EP as possible and analyse how the distribution of EP and/or its effects on health and well-being vary along the different axis of inequality, using the methodology of a scoping review.

2. Methodology

We performed a scoping review, a methodological framework for evidence synthesis developed by Arksey and O'Malley [16] and the Joanna Briggs Institute [17]. A scoping review is a particularly suitable approach for the study of emerging, complex and diverse topics [16] such as the effects of EP on health. Its purpose is to provide an overview of the available research evidence rather than to provide an answer to a discrete research question [17]. Thus, scoping reviews allow the collection of information from a broad scope, including findings from a range of different study designs and methods [18]. Appendix A shows "Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews" (PRISMA-ScR) Checklist [19].

2.1. Search strategy

We developed a review protocol and reviewed the available literature in July 2020 using the following electronic databases: PubMed [Medline and In Process], Embase, Cochrane Database of Systematic Reviews, Campbell Library, Scopus, and Web of Science. This review was complemented by searching the European Observatory of Energy Poverty, Teseo database, and World Health Organization website. A group of experts was requested by email to recommend key studies, publications, or resources in this field [see Appendix B].

Key words included temperature and EP, economic difficulty, and health. Both Medical Subject Headings [MeSH] terms and free-text terms were used. The search strategies adopted for the different databases were validated and carried out by a librarian specialized in public health [Appendix C].

2.2. Selection criteria

The included studies were selected upon the fact of studying a possible association between exposure to EP and health outcomes. The studies had to meet the following criteria: 1] studies, programs, or interventions related to exposure to EP or its different expressions, such as inadequate indoor temperatures [cold or hot]; the existence of dampness, mould, or related allergens; the absence, misuse, or disuse of hot/cold equipment; the absence of or inadequate thermal insulation; the inability to use light and/or hot water; expenditure-based studies; arrears in utility bills; etc.; 2] studies that presented relevant outcome measures in relation to physical or mental health, such as a surge in illnesses or health conditions, worsening previous health conditions, and a decreased quality of life or self-reported health status, and/or presented relevant measures for exposure to health-based risk factors, such as exposure to pollutants, dampness, etc.; 3] studies conducted in OECD countries; 4] studies that were written in English or Spanish; and 5] studies that were published before July 2020. Reports, editorials, opinions, and conference abstracts were excluded.

2.3.Selection of studies, data extraction, and analysis

Once the studies were identified and duplicate articles were excluded, the title and abstract of each study were checked against the inclusion and exclusion criteria before requesting the full text. The Rayyan QCRI app [https://rayyan.qcri.org/] was used for all data management [20]. Three pairs of reviewers [V.B. and L.O., A.O. and E.M., and J.C. and A.P.] determined whether the papers met the inclusion criteria by assessing the titles and abstracts independently; papers satisfying the criteria were saved as potential documents [first screening]. Additional studies were obtained after screening by crosschecking the references of previously identified papers. Differences between reviewers were resolved through consensus by including a third reviewer [M.M., A.C., or I.M.]. Two pairs of reviewers [second screening] then independently assessed the selected documents with full-text screening [V.B. and L.O.; A.O. and E.M.].

A data extraction form was developed to record the bibliographic information, general characteristics of each study, EP measures, health-related outcomes or risk exposures, and the inclusion [or absence] of any axis of inequality. Two major groups of study types were then created: observational studies and studies related to an intervention to ameliorate EP. Measures of exposure to EP were grouped in the following five categories for observational studies—[1] inadequate temperature, 2] financial strain, 3] inadequate housing conditions, 4] EP index, and 5] qualitative assessment—and into two categories for the intervention studies—[1] energy efficiency improvements and 2] indoor temperature improvements.

The analysed health-related outcomes were grouped into six categories: 1] general health status, 2] mental health, 3] respiratory health, 4] chronic conditions, 5] mortality, and 6] use of health services. Finally, exposure to health risks were grouped as follows: 1] inadequate temperature, 2] Indoor air quality, 3] presence of dampness and/or mould, and 4] food insecurity. Based on the conceptual framework of Marí-Dell'Olmo et al. on the determinants of health inequalities related to EP [11]. We reviewed whether the studies considered any of the following axis of inequality: gender, age, race/ethnicity/place of origin, social class/income, and territory. We differentiated between studies that provided disaggregated data by social group on the distribution of EP and/or its effects on health [disaggregated analysis], studies that targeted social groups particularly vulnerable to suffering from EP [target group], and studies that did not take into account any axis of inequality.

The data were then extracted, synthesized, and organised according to the different health-related outcomes, exposure to health risk categories, and the type of study, distinguishing between observational studies and studies related to interventions to ameliorate EP. Finally, social inequalities in the distribution of EP and its effects on health and well-being were analysed according to the different axis of inequality. Due to the heterogeneity of studies included in this scoping review, individual risk of bias was not evaluated as it is common in systematic reviews.

3. Results

A total of 2768 documents were retrieved, of which 314 were found to be potentially eligible and 38 were ultimately included in this review. Figure 1 presents a flow diagram of the selection process, adapted from the Preferred reporting items for systematic reviews and meta-analyses [PRISMA] statement flowchart [21].

3.1. Description of studies included

Table 1 shows the main characteristics of the documents selected, and Table 2 provides detailed information about the studies. More than three quarters of the studies [29/38] were conducted in Europe, and 6 of these included data from several European countries. Most studies were carried out in the United Kingdom [18/38, 47.4%], followed by the USA [5/38, 13.2%] and New Zealand [3/38, 7.9%]. More than half were observational studies [24/38, 63.2%], and the rest were intervention studies [14/38, 36.8%]. Only a few studies used qualitative methods [3/38, 7.7%] or mixed methods [1/38, 2.6%], while the rest used quantitative methods, including cross-sectional [20/38, 52.6%], longitudinal [14/38, 36.8%], multiple time series [3/38, 7.9%], and trend-based studies [1/38, 2.6%]. The most commonly studied type of EP exposure in observational studies was inadequate temperature [10/23, 43.5%], the most common intervention was energy efficiency improvement [10/15, 66.7%], and the most common outcome was general health status [14/38, 36.8%].

Most studies [28/38, 73.7%] considered one or more of the five axis of inequality [18]: social class [15/38, 42.1%], gender [4/38, 10.5%], age [12/38, 31.6%], ethnicity/race [1/38, 2.6%], and territory [7/38, 18.4%]. Moreover, 11/38 [28.9%] studies disaggregated the analyses by at least one axis of inequality and 21/38 [55.3%] studies specifically targeted a vulnerable group.

3.2. Health effects in observational studies

Table 3 synthesizes the health effects in the observational studies. The most commonly studied outcome was *general health status*, measured mainly as self-reported health by surveys [12,22–30]. All ten studies found a positive association between EP [different measures such as inadequate temperatures, financial strain, inadequate housing conditions, and composite indexes] and poor self-reported health in the different groups studied: general adult population [12,24,28–30], low income population [22,27,31], and the elderly [25,26].

For *mental health,* worse levels were found in relation to EP [12,29,31]. Perceived stress was associated with difficulties in paying energy bills as well as the use of secondary heating equipment and badly insulated homes [32,33]. Moreover, in a study on 32 European countries, emotional well-being in all countries except Finland was found to be lower for individuals living under EP [29]. In a study among mothers, dampness and cold were associated with probable postnatal depression [34].

The presence or worsening of *respiratory conditions* was reported in association with dampness, mould problems, and cold temperatures at home. Such respiratory conditions included asthma in mothers [34], excess winter morbidity for respiratory diseases among older people [35], and well-being among children with asthma and their families [36]. Other studies found positive associations between EP and respiratory conditions, including respiratory infections treated by Greek hospitals [37] and worse respiratory health among elderly people [25,38].

In relation to other *chronic conditions*, in a study on diabetic patients in Massachusetts, USA, energy insecurity and housing instability were associated with increased outpatient visits and emergency department/inpatient visits [39]. An estimated 2.7–7.4% of cardiovascular diseases treated by Greek hospitals were attributed to EP [40].

Mortality was studied in three articles. Thermal efficiency and EP were found to be significantly related to variations across European countries in relative excess winter mortality, which was the highest in Portugal, Spain, and Ireland [41]. One of the studies calculated a Structural EP Vulnerability Index among EU countries and found a positive association with excess winter mortality, with the highest being found in southern and eastern EU countries [42]. Conversely, another study in the UK found little evidence for vulnerability to winter mortality associated with factors previously thought to predict such vulnerability [EP] and found no socioeconomic gradient [43].

3.3. Health effects in intervention studies

Table 3 synthesizes the health effects in intervention studies. Several impacts on health were found within intervention studies, commonly including significant improvements in health conditions after an intervention designed to ameliorate EP conditions at home [33,44–49].

Better *self-reported health* and reduced odds of fair or poor self-rated health were significantly associated with interventions aimed at improving insulation [33,50] and ventilation [51]. The renovation of boilers, lofts, and wall insulation and overall programs were positively associated with good general health in another study [52].

Regarding *well-being and mental health*, the results of a previous intervention demonstrated an improvement in stress levels and mental health [48]. In another study, those in households with improved heating and insulation measures were significantly less likely to score high on the GHQ-12 measure of anxiety and depression [32]. Significant positive associations with mental health were observed with the renovation of doors, windows, boilers, kitchens, bathrooms, and electric installations; improvements in insulation; and a higher number of interventions and total spending [52]. Other studies observed increased emotional security [resulting from the relief of tension and anxiety about the home environment], including an increased sense of control and self-esteem, a more positive sense of home among householders [45], and qualitative general mental health improvements; less stressful situations due to financial worries were also reported [44]. In some cases, there was no association with gains in self-reported health, but there was with satisfaction with household warmth and better social functioning [53].

In general, an improvement in *respiratory outcomes* was observed after interventions aimed at diminishing EP conditions and at improving insulation and energy efficiency in households. Significant reductions were observed in adults with asthma and children with non-asthma respiratory problems, such as high fever, sinusitis, chronic bronchitis, ear infections, and respiratory allergies [51]. Other studies reported positive associations between different interventions at home [renovation of doors, windows, boilers, lofts, and wall insulation and overall programs] with respiratory symptoms [47,52]. An improvement in insulation was associated with reduced odds of self-reported wheezing in the past three months and hospital admissions for respiratory conditions [50]. More effective home heating reduced school absences among children with asthma [47,49].

After interventions to improve energy efficiency and install central heating, in some cases, there was a significant reduction observed in the number of inhabitants that self-reported *chronic conditions* [48] as well as improvements in such conditions [44].

Finally, there were no conclusive trends for interventions related to excess winter *mortality* [54]. A study in Barcelona city [Spain] found a positive impact of energy efficiency façade retrofitting interventions on extreme cold-related mortality among women, especially from circulatory system causes but found a negative impact among men [55].

3.4. Exposure to health risks in observational studies

Table 4 synthesizes the exposures to health risks reported in the included observational studies. Exposure to *dampness and/or mould* was found for participants living with inadequate heating or no heating due to the cost of energy, regardless of adult risk perception and heating or ventilation practices [56]. A study in Chile did not find a relationship between EP, measured as income spent on energy, and *exposure to indoor air pollution* but did find a positive relationship with exposure to *inadequate temperatures in winter* [57]. Self-reported and objectives measures of thermal comfort showed that energy-poor households persistently endured poorer levels of thermal comfort than other households and inhabitants, especially among elderly people [58], who were exposed at home to temperatures below those set by the WHO as the minimum satisfactory levels of warmth for comfort and health purposes. Lastly, in relation to *food security* [defined as access by all people at all times to enough food to live an active, healthy life], an association was found between household food insecurity and seasonally high heating and cooling costs in the USA, where individuals from poor and elderly-only households in high-cooling states had greater odds of very low food security in the summer. In high-heating states, this pattern was reversed for such households, and the odds of very low food security were lower in the summer [59].

3.5. Exposure to health risks in intervention studies

Table 4 synthesizes exposures to health risks in intervention studies. In relation to the exposure to health risks analysed in intervention studies, the installation of a more effective heater in houses with an asthmatic child resulted in lower levels of air humidity and reduced *exposure to mould and dust mite allergens* and, in turn, fewer school absences among asthmatic children due to their condition [49]. The installation of central heating systems and other efficiency measures resulted in a significant reduction in the number of households reporting the presence of condensation, mould, and dampness [48]. Another study that evaluated the effects of installing new heating systems suggested that the elimination of dampness/mould prevented further deterioration in health rather than bringing about an improvement in health indicators for children ≤16 years old [46]. A study that evaluated levels of *indoor pollutants* before and after a weatherization intervention found higher post-levels of formaldehyde during the cooling season in homes without pets, higher relative humidity, >1.0 mm particles, and higher PM_{10} during the heating season in homes with pets and 10 mm particles in homes during the cooling season [60]. Furthermore, after interventions to improve energy efficiency, most participants in a previous study stated that their homes were then much *warmer* during the winter and cheaper to heat [44]; however, another study reported no considerable improvements in internal temperature. After the intervention, the satisfaction levels among the intervention group surpassed the levels of those who did not receive any form of intervention [48].

3.6. EP and health inequities

Eight studies presented disaggregated data on EP based on one or more axis of inequality. Higher EP prevalence was found among women [particularly those living in Mediterranean and Eastern EU countries] [12], elderly people [34,59], more disadvantaged social classes and low income people [12,34,40], and those in certain territories of Europe, mainly Mediterranean and Eastern countries [12,22,24,29,42] as well as certain areas of Greece [40]. Ethnic differences were also found in a study conducted in New Zealand, where Niuean, Tongan, and non-Pacific ethnic groups had higher EP [34].

Health inequalities related to EP according to one or more axis of inequality were analysed in eight studies. Regarding gender, one study noted that the economic crisis of 2008 exacerbated the health impacts of EP in the EU generally but that women across the EU and men in Mediterranean and Eastern countries were the most strongly affected [12]. Higher mortality related to EP was also observed among women [43], as was the positive impact of an energy efficiency façade retrofitting intervention on extreme cold-related mortality among women [55]. In relation to age, elderly people suffered from greater negative effects of EP on food insecurity [59] and a greater reduction in problems with dampness and mould after an intervention [48]. A study in Britain did not find evidence that socioeconomic deprivation or self-reported financial worries were predictive of mortality associated with cold [43]. Finally, Mediterranean and Eastern European countries and transitional countries suffered from the greatest impacts of EP on health [12,22,42], and countries with the poorest housing stock [Portugal, Greece, Ireland, and the UK] presented the highest excess winter mortality [41].

Several studies targeted specifically vulnerable population groups. The most commonly used inequality axis as a sample selection factor were social class/income [22,27,31–33,44,46,51,59,60] and age, considering both young [36,46,47,49] and advanced age [25,26,35,38,54]. Gender was considered by one study that targeted women who had a child in the last 6 months [34]. Territory was targeted by one study that analysed the health effects of an intervention to ameliorate EP in rural communities [48].

Finally, some studies did not consider any axis of inequity [24,28,30,40,50,52,53,56–58].

3.7. Limitations of studies

The various studies reported several limitations. More than half [51.28%] were cross-sectional studies [22,24,36,38,39,41–43,52,56,57,59,25–31,35], a type of design that is not suitable for studying causality and does not allow to rule out reverse causality. Although it is true that the relationship between EP and poorer health is neither linear nor unidirectional, the most plausible and relevant path is the one explored in the articles included in this review and this is also evidenced by the mechanisms they suggest to explain this relationship. Other limitations included small sample sizes [28,35,36,39,50,60] and small subsample sizes [12,39,46]; sample attrition in longitudinal studies [in one study, due to the long follow-up period] [46]; a lack of ethnic diversity in the sample [mentioned in two studies as a limitation] [36,50]; the use of surveys with possible recall bias [26,34,52], unique respondents for all members at home [47,51], or designed for other purposes [24]; and low response rates [39,56]. Large studies with data from several countries presented limitations such as the use of aggregated data, small subsamples in some countries, and a lack of homogenous data [12,41,42]. Only one study presented a direct estimation of EP's effects on country morbidity rates [mortality, cardiovascular diseases, and respiratory infections] [40]. Some intervention studies lacked a control group [31,33,46–48,51,52], while some studies presented only a descriptive analysis [33,46,57,58] or did not adjust for all variables [22,38,42]. The reasons underlying behaviour changes are not analysed in any of the intervention studies that acknowledged such changes. This analysis could improve knowledge on how improve effectiveness of interventions [61] .

However, there are axis of inequality not identified in this scoping review that may be relevant and should be considered in future research. An example is disability or long-term illness, which on top, illustrates the complex and not always unidirectional relationship between EP and health. People in poorer health face greater social exclusion, making it more difficult to access adequate energy services. At the same time, increased energy needs and greater exposure to adverse conditions by spending more time at home worsen the situation.

4. Discussion

4.1. Main findings

This review synthesized the existing evidence on the relationship between EP and health from a broad perspective, including as many expressions of EP as possible, viewed through an equity lens. The results from the observational studies showed that living under EP conditions is associated with worse physical and mental health and higher odds of being exposed to health risks such as indoor inadequate temperatures, allergens, increased risk of mouldy and damp conditions, or food insecurity. Countries with greater levels of EP and lower energy efficiency suffered from higher morbidity–mortality rates. Interventions aimed at handling EP are generally associated with improvements in health and a reduction in exposure to health risk factors [or at least no worsening of health conditions]. These results corroborate previous findings [13,62,63]. Nonetheless, some interventions can have also negative effects on health, as it is possible that in order to prevent energy loss, sealing can result in higher concentrations of indoor pollutants as a result of lower ventilation [60].

Few studies analysed EP and its effects on health according to the axis of inequality, but the existing evidence suggests that EP increases health inequalities and impacts more women, elderly people, people belonging to disadvantaged social classes with lower income, and territories with more disadvantaged socioeconomic and physical contexts. Many studies, especially those related to EP interventions, targeted specific social groups, mainly involving those with low income and young or elderly people.

4.2. Issues arising from this review

Interactions between the impacts of poor housing conditions and low income on health are complex and involve many factors, so the results can be difficult to interpret. There are also other factors related to EP that are known to influence physical and mental health status, such as financial or social difficulties, economic worries, one's surrounding area when disadvantaged, other housing problems, individual behaviours, social relations [9] and contextual factors such as economic crises [57–59]. These factors may hinder the benefits of interventions and are often difficult to disentangle from exposure to EP or health risk factors derived from living under EP conditions. EP and the strategies that households develop to cope with it have a wide-ranging impact on many spheres of life, which in turn can affect health and well-being. This is reflected in some of the health risks identified in this review, such as the resource allocation dilemma and the consequent coexistence of food insecurity, or school absenteeism. Other situations related to EP and relevant to health, such as social isolation or stigmatisation, are not reflected. Moreover, there is a lack of qualitative studies that outline the lived experiences and perceptions of the relationship between EP and health of those affected by EP. This could help us better understand the mechanisms through which EP affects people's physical and mental health.

There is also a lack of studies on other kinds of interventions to tackle EP, such as workshops on energy tariffs, energy efficiency, the health effects of inadequate temperatures, information points, etc. These types of interventions could help decrease energy expenditures [64,65] and may be associated with health outcomes, as such interventions could have a relationship with EP behaviours, as noted by some studies [43,66–68].

In a society where essential goods are increasingly commodified, social groups with less economic and political power may suffer from limited access to such basic needs as energy supplies. Many of the studies included in this review addressed significantly affected social groups that often combine social vulnerability with physical fragility, such as the elderly and children. However, there are other axes of inequality not identified in this scoping review that may be relevant and should be considered in future research. An example is disability or long-term illness, which on top, illustrates the complex and not always unidirectional relationship between EP and health. People in poorer health face greater social exclusion, making it more difficult to access adequate energy services. At the same time, increased energy needs and greater exposure to adverse conditions by spending more time at home worsen the situation. In addition, there is a lack of population-based studies that provide disaggregated data based on the different axes of inequality or the intersections of these axes. For instance, only one of the 38 studies included in this review presented data disaggregated by the intersection between two axis of inequality: gender and territory. The analysis revealed that, in 2012, at the peak of the economic crisis, the average rate of EP in the EU [12.8%] hid important inequalities. The EP ranged from 6.7% among men in countries with low structural vulnerability to EP to 18.3% among women in countries with high structural vulnerability to EP [12]. Future research should consider the intersections between the different dimensions of oppression and seek to understand what processes of inequity lie behind those structures to reduce the health inequalities amplified by EP. The study of energy cannot be isolated from its socio-ecological contexts and feedbacks [69].

Most studies are from northern European countries, where climatic and socioeconomic characteristics, housing and energy models, etc. differ greatly from those of Mediterranean and southern European countries. Countries with milder climates suffer from more severe EP conditions in winter, contrary to expectations [41,70]. In colder countries, buildings are designed for harsh winter conditions, but in warmer countries, winters can be quite cold and most buildings are not adequately protected. Conversely, due to climate change, warmer summers are expected, even in northern countries that lack infrastructures against hot weather [71]. For example, in the Netherlands and Finland, heatwaves were observed to have a greater impact on mortality than cold spells [72,73]. Knowledge on the relationship between EP and hot weather conditions remains lacking, especially information on how the interactions between changing climates across different territories and EP can affect health.

4.3. Strengths and limitations of the review

As a scoping review, our study is subject to the same limitations as any literature review, including the potential omission of relevant sources of information and the dependence of the review on available information [publication bias]. To minimise this bias, a thorough search was performed and external experts in EP were contacted and requested to provide relevant literature. Due to the complexity of EP and its interactions with material deprivation, we may have excluded studies on deprivation and health that did not explicitly mention EP or any of its dimensions even though EP also played a key role. At the same time, the close coexistence of EP and other situations of deprivation and hardship may be related to a positive outcome bias and the greater likelihood of publishing positive, rather than negative or inconclusive results. Another limitation is the considerable heterogeneity of the studies: Our results highlight the difficulty in comparing different, heterogeneous studies. Notably, the results of the intervention studies may not be generalizable to the overall population living in EP because interventions were carried out among target groups defined by social class, sex, age, etc. Nevertheless, the large amount of information that was gathered, analysed, and synthesized in this review provides an important contribution to state-of-the-art of research on EP in relation to health. Other strengths of this study include the flexibility of the chosen design, which enabled us to include the maximum number of expressions of EP, and our efforts to analyse the information from an equity perspective.

4.4. Implications for policy and practice

Identifying the particular characteristics that EP displays in different geographic and cultural areas represents an important area of study for future research. The differences across European countries highlight the need to design several methods for ameliorating EP. More robust and in-depth data on EP are also needed to efficiently support related policies. This is especially important in the current context of incipient economic crisis due to COVID-19 pandemic, where health inequalities are expected to increase, as research on previous economic crisis shows [74]: the disadvantaged and lower income households are more vulnerable. This could drag many families into EP and aggravate its impact on health [75]. As recent studies on EP during COVID-19 pandemic discuss, knowledge on determinants of EP can help to design public policies in order to curtail EP situations [76,77].

Moreover, recent scientific evidence shows how human-drive climate change is already affecting the whole world [78]. We are in a climate emergency context where extreme temperatures and more frequent heatwaves and cold spells joined with economic crisis, may result in an increased group of population at risk of EP [79]. Energy prices are expected to rise due to increased energy consumption and households at risk of EP that could not afford rising costs of energy will be exposed to inadequate temperatures (both hot and cold), with increased effects on health of their inhabitants.

In conclusion, the present study shows that EP has an undoubtedly negative effect on people's health and well-being and that its distribution and the extent of its effects on health are closely linked to dimensions of inequity such as gender, age, race and ethnicity, social class, and territory. The scientific knowledge presented above could be used to ameliorate the complex and urgent problem of EP by combining structural policies with an equity perspective that targets energy and housing models alongside interventions to immediately improve the situations of people living under EP. To develop meaningful and adequate policies and interventions, further research should delve deeper into the direct and indirect mechanisms through which EP affects people's health and well-being, taking into account the perceptions and lived experiences of those affected, as well as the key role of the axis of inequality and their interaction, as well as contextualise relevant problems and solutions in the context of the post-pandemic economic crisis and global climate change.

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Figure 1. Selection process flowchart, adapted from PRISMA.

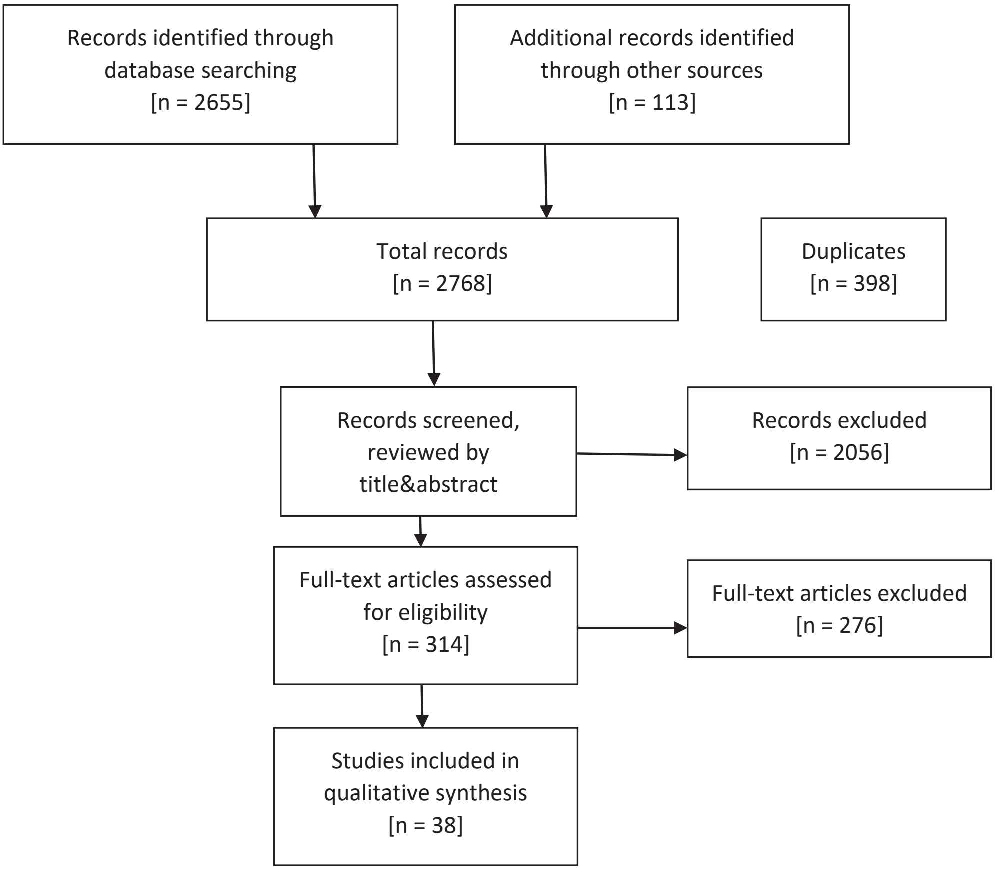

Table 1. Characteristics of studies.

Characteristic	N [%]
Number of studies reviewed	38
Region	
United Kingdom	18 [46.2]
Multi-European countries	6 [15.4]
USA	5 [12.8]
New Zealand	3 [7.7]
Spain	2 [5.13]
Greece	1 [2.6]
Ireland	1 [2.6]
Chile	1 [2.6]
Turkey	1 [2.6]
Type of study	
Observational	24 [63.2]
Interventions	14 [36.8]
Study design	
Quantitative	34 [89.5]
Cross-sectional	16 [47.1]
Longitudinal	7 [20.6]
Multiple time series	3 [8.8]
Trends study	1 [2.9]
Experimental	3 [8.8]
Quasi-experimental	2 [5.9]
Qualitative	3 [7.9]
Mixed methods	1 [2.6]
Energy poverty measure or type of intervention	
Inadequate temperature	12 [31.6]
Financial strain	6 [15.8]
Inadequate housing conditions	6 [15.8]
Index	7 [18.4]
Qualitative assessment	1 [2.6]
Energy efficiency improvements	11 [28.9]
Heating improvements	5 [13.2]
Health outcomes and health risks*	
Direct health outcomes	
General health status	18[47.4]
Mental health	14[36.8]
Respiratory health	14[36.8]
Chronic conditions	10[26.3]
Mortality	6[15.8]
Use of health services	4 [10.5]
Exposures to health risk	
Inadequate temperature	5[13.2]
Indoor air quality	2 [5.3]
Presence of dampness and/or mould	2 [5.3]

Food insecurity	1[2.6]
Inequality axis	
Yes	28 [73.7]
Inequality axis*	
Social class/ income	15 [39.5]
Gender	4 [10.5]
Territory	7 [18.4]
Age	12 [31.6]
Ethnicity/ race	1 [2.6]
Analyses**	
Disaggregated analysis	11 [28.9]
Target group	21 [55.3]
No	10[26.3]

*Non-exclusive categories, some studies include more than one option

**Four studies targeted a specific social group and provided disaggregated data for different subgroups

Table 2. Description of studies.

Observational studies							
Study	**Design**	**Location, year**	**Target population. Level of analysis [sample size]**	**Study aim**	**Inequality axis**	**EP exposure**	**Health outcome or risk exposure**
Oliveras et al. 2020 [12]	Quantitative, trends study	EU-27, 2007-2012-2016	People ≥18 years. Individual [n=95940]	The aim of this study was to analyse the time trend in the EU before and during the economic crisis in 1] the EP prevalence; 2] the association between EP and health; and 3] the impact of EP on health. We analysed trends among women and men in the two EU macro regions, defined by the degree of structural vulnerability to EP.	Sex[1,2] Social class / income[1] Territory[1]	**Inadequate temperature:** Cannot afford to keep the home adequately warm **Financial strain:** One or more arrears in utility bills such electricity, water, or gas during the past 12 months	**General health status:** Poor self-reported health status **Mental Health:** 5-item World Health Organisation Well-being Index, cut-offs of reduced well-being and depression
Llorca et al. 2020 [28]	Quantitative, longitudinal	Spain, 2011–2014	General population. Multilevel [24990 individuals in 11039 households]	To propose a latent class ordered probit model to control for subjectivity when analysing the influence of fuel poverty on self-reported health and apply to a Spanish population sample.	-	**Inadequate temperature:** Cannot afford to keep the home adequately warm **Index:** Expenditure based indicator	**General health status:** Poor self-reported health
Bosch et al. 2019 [22]	Quantitative, cross-sectional	EU-28 except Belgium and Ireland, plus Norway, Iceland and Switzerland, 2012	Low-income people ≥16 years. Individual [n=195643]	To examine the relationship between EP and poor health among the population in the two lower income quintiles in Europe using the 2012 EU-SILC dataset.	Social class / income[3] Territory[1,2]	**Inadequate temperature:** Cannot afford to keep the home adequately warm Dwelling not comfortably warm during wintertime. **Financial strain:** One or more arrears in utility bills such electricity, water, or gas during the past 12 months **Inadequate housing conditions:** Leaking roof, damp walls, floors or foundation, or rot in window frames of floor **Index:** Number of EP variables that an individual may suffer [ranging from 1 to 4].	**General health status:** Poor self-reported health status

Observational studies

Study	Design	Location, year	Target population. Level of analysis [sample size]	Study aim	Inequality axis	EP exposure	Health outcome or risk exposure
Kose et al. 2019 [30]	Quantitative, cross-sectional	Turkey, 2014	People ≥15 years. Individual [n=60533]	To contribute to the current literature by exploring the relationship between health outcomes and EP by providing empirical evidence from Turkey.	-	**Inadequate temperature:** Cannot afford to keep the home adequately warm **Financial strain:** One or more arrears in utility bills such electricity, water, or gas during the past 12 months	**General health status:** Health index based on two health measures: self-reported health and and self-reported limited daily activity.
Recalde et al. 2019 [5]	Quantitative, cross-sectional	EU-27, 2010-2016	- Aggregated	To analyse the Structural EP Vulnerability [SEPV] of the EU-27 countries through the creation of an index that considers the structural determinants of EP and related factors. A secondary aim was to propose country typologies according to their SEPV level.	Territory[1,2]	**Index:** Structural EP vulnerability index that comprises 13 indicators	**Mortality:** Excess winter mortality
Reyes et al. 2019 [57]	Quantitative, cross-sectional	Valdivia, Chile, 2017	80 households	To assess socio-economic variables, energy consumption and indoor environments and to monitor temperatures and indoor air pollution levels in households.	-	**Index:** Based on income spent on energy	**Inadequate temperature:** Monitoring of temperature **Indoor air quality:** Monitoring of fine particulate matter concentrations [$PM_{2.5}$]
Thomson et al. 2017 [29]	Quantitative, cross-sectional	32 European countries, 2012	People ≥18 years. Individual [n=41560]	To investigate the relationship between EP, health and well-being across 32 European countries, using 2012 data from the European Quality of Life Survey.	Territory[1,2]	**Inadequate temperature:** Cannot afford to keep the home adequately warm	**General health status:** Self-reported health status **Mental health:** 5-item World Health Organisation Well-being Index, cut-offs of reduced well-being and depression
Atsalis et al. 2016 [37]	Quantitative, multiple time series data	Greece, 2003-2014	- Aggregated	To analyse in quantitative terms the potential impact of EP on public health.	Social class / income[1] Territory[1]	**Inadequate temperature:** Cannot afford to keep the home adequately warm **Financial strain:** Expenditures undertaken for lighting and fuel to the total income exceeds the determined threshold of 10%	**Respiratory health:** Number of cases of respiratory infection treated by the two of the largest hospitals **Chronic conditions:** Number of cardiovascular diseases cases treated by the two of the largest hospitals

Observational studies							
Study	**Design**	**Location, year**	**Target population. Level of analysis [sample size]**	**Study aim**	**Inequality axis**	**EP exposure**	**Health outcome or risk exposure**
							Mortality: Number of deaths recorded at national level
Hernandez et al. 2016 [33]	Mixed-methods, cross-sectional	USA, 2012	Low-income population. Individual [20 individuals]	To examine associations between housing and energy-related issues and stress among participants using the Perceived Stress Scale [PSS], thematic analysis of in-depth interviews and other survey data.	Social class / income[3]	**Index:** Home Energy Insecurity Scale **Qualitative:** In-depth interviews	**Mental health:** Stress assessed through the Perceived Stress Scale and in-depth interviews
Tod et al. 2016 [36]	Qualitative, cross-sectional	UK, 2012-2013	Households with children with asthma. Individual [35 families and 25 health, education and social care staff]	To understand the influences and decisions of households with children with asthma regarding keeping warm and well at home in winter.	Age[3]	**Qualitative** Households with children vulnerable to cold homes	**Respiratory health** Households with children with asthma condition
Berkowitz et al. 2015 [39]	Quantitative, cross-sectional	USA, 2012-2013	People ≥21 years with diabetes mellitus. Individual [n=441]	To determine the association of food insecurity, cost-related medication underuse, housing instability, and energy insecurity with control of diabetes mellitus and the use of health care resources.	-	**Inadequate temperature:** Difficulty affording household heating or cooling	**Chronic conditions**: Poor diabetes control [composite measure of hemoglobin A1c level; low-density lipoprotein cholesterol level and blood pressure]] **Use of health services:** Outpatient visits and a composite of emergency department visits and acute care hospitalizations
Sharpe et al. 2015 [56]	Quantitative, cross-sectional	England, 2011	People living in social housing. Multilevel [n=671]	To assess how EP, occupants' risk perception and use of mechanical ventilation mediate the risk of mould contamination in social housing.	-	**EP behaviours** Derived by combining multiple measures, which summarized different facets of occupant's perception of risk, EP behaviours and	**Presence of dampness / mould:** Visible mould growth Mouldy/must odour

Observational studies							
Study	**Design**	**Location, year**	**Target population. Level of analysis [sample size]**	**Study aim**	**Inequality axis**	**EP exposure**	**Health outcome or risk exposure**
						use of mechanical ventilation	
de Vries et al. 2012 [25]	Quantitative, cross-sectional	England, 2008-2009	People ≥50 years. Multilevel [7160 individuals in 89 counties]	To check the hypothesis that both the risk of fuel poverty and the strength of its detrimental effects on health would be increased in areas of colder and wetter climate.	Age[3]	**Financial strain:** Total fuel spend exceeded 10% of total household income	**General health status:** Poor self-reported health status **Mental Health:** Depression measured with the Centre for Epidemiological Studies Depression scale **Respiratory health:** Objectively measured peak expiratory flow [PEF] **Chronic conditions**: Hypertension objectively measured
Webb et al. 2012 [38]	Quantitative, cross-sectional	England, 2004-2007	People ≥50 years. Individual [n=3763]	To investigate the relationship between housing and the respiratory health of older people in England, using data from a large-scale national survey.	Age[3]	**Financial strain:** Total fuel spend exceeded 10% of total household income	**Respiratory health:** Objectively measured peak expiratory flow [PEF], forced expiratory volume in 1 s [FEV1], forced vital capacity [FVC]
Critchley et al. 2007 [23]	Quantitative, cross-sectional	England, 2001-2003	Low-income population. Individual [n=79]	To investigate explanatory factors for persistent cold temperatures in homes which have received heating improvements. To analyse health effects of low temperatures.	Social class /income[3]	**Inadequate temperature** Mean bedroom temperature over the measuring period fell below 16 °C or where the mean living-room temperature fell below 18 °C.	**General health status:** Poor self-reported health status **Mental health:** Poor self-reported mental health **Chronic conditions:** Long-standing illness or disability
Nord et al. 2006 [59]	Quantitative, cross-sectional	USA, 1995-2001	Low-income people ≥15 years. Individual [n=20058]	To examine the extent to which greater proportions of poor households, especially poor elderly households, experienced very low food security [the more severe range of food insecurity] during times of the year when home heating and cooling costs were high, controlling for important covariates.	Age[1,2] Social class / income[3]	**Financial strain** Seasonally high home heating and cooling costs	**Food insecurity:** It refers to households that have reported multiple indications of reduced food intake and disrupted eating patterns due to inadequate resources for food.
Heyman et al. 2005	Quantitative, longitudinal	UK, 2000-2001	Low-income population.	To investigate relationships between home energy efficiency, socio-economic status and	Social class / income[3]	**Inadequate temperature:** Satisfaction with home heating	**General health status:**

Observational studies							
Study	**Design**	**Location, year**	**Target population. Level of analysis [sample size]**	**Study aim**	**Inequality axis**	**EP exposure**	**Health outcome or risk exposure**
[27]			Individual [n=535]	respondent health.		assessed through the National Energy Action 8-item scale **Inadequate housing conditions:** Home energy efficiency measured through SAP rating	Poor self-reported health status
Rudge et al. 2005 [35]	Quantitative, cross-sectional	UK 1993-1994-1995-1996 [4 waves]	People ≥65 years Aggregated [25 enumeration districts]	To examine the demonstrability of a relationship between older people's health and fuel poverty risk, using morbidity data.	Age[3]	**Index** Fuel Poverty Risk Index [FPR], including factors of energy inefficient housing, low income, householder age and under occupation.	**Respiratory health:** Excess winter morbidity based on emergency hospital episodes for all respiratory diagnosis codes
Wilkinson et al. 2004 [43]	Quantitative, longitudinal	UK, 1995-1998 follow up to 2001.	- Aggregated	To examine the determinants of vulnerability to winter mortality in elderly British people.	Sex[2] Social class / income[2]	**Inadequate temperature:** Difficulty keeping house warm	**Mortality:** Excess winter mortality
Butler et al. 2003 [34]	Quantitative, longitudinal	New Zealand, 2000	Mothers of newborns. Individual [n=1376]	To examine problems with dampness/mould and cold housing and any associations with postnatal depression and asthma among mothers of the Pacific Islands Families [PIF] cohort.	Sex[3] Age[1] Ethnicity / place of origin[1] Social class/ income[1]	**Inadequate temperature:** Having problems with cold housing **Inadequate housing conditions:** Having problems with housing dampness or mould	**Mental health:** Postnatal depression assessed through the Edinburgh Postnatal Depression Scale **Respiratory health:** Self-reported asthma
Healy et al. 2003 [41]	Quantitative, multiple time series data	14 European countries, 1988–1997	- Aggregated	To identify key relations between a variety of risk factors and seasonal-mortality patterns in 14 European countries.	Territory[1,2]	**Inadequate housing conditions:** Domestic thermal efficiency measures **Index:** Indicators of housing conditions, affordability of home heating and energy efficiency levels	**Mortality:** Excess winter mortality
Healy et al. 2002 [58]	Quantitative, cross-sectional	Ireland, 2001	General population. Aggregated [1500	Relationship between fuel poverty and thermal comfort and the extent of indoor cold strain resulting from inadequately heated housing.	-	**Index:** Inability to heat the home adequately and/or total fuel spend exceeded 10% of	**Inadequate temperature:** Self- reported and objective measures of thermal comfort

Observational studies

Study	Design	Location, year	Target population. Level of analysis [sample size]	Study aim	Inequality axis	EP exposure	Health outcome or risk exposure
			households]			total household income	
Gemmel et al. 2001 [26]	Quantitative, cross-sectional	Scotland, 1991	People aged 55-60 years old. Individual [n=858]	To assess the relation between housing characteristics and ill health focusing in particular on adequacy of indoor heating.	Age[3]	**Inadequate temperature:** House cold in winter **Inadequate housing conditions:** Several variables such as winter bedroom heating type	**General health status:** Poor self-reported health status **Chronic conditions:** Presence of one or more chronic condition[s] Presence of one or more limiting condition [s]
Evans et al. 2000 [24]	Quantitative, cross-sectional	England, 1997	People aged 18–64 years old. Individual [n= 8889]	To examine the association between damp housing and adult health, taking into account a wide range of other factors that may influence health and could confound this relation.	-	**Inadequate temperature:** Cannot afford to keep the home warm enough **Inadequate housing conditions:** Having serious problems with damp and condensation	**General health status:** SF-36 questionnaire **Mental health:** SF-36 questionnaire **Respiratory health:** Asthma **Chronic conditions:** Presence of longstanding illness, disability or infirmity **Use of health services:** Number of visits to the GP's surgery in the last 12 months Visited outpatients department in the last 3 months Visited casualty department in the last 3 months Hospital inpatient in the last 12 months

Intervention studies							
Study	**Design**	**Location, year**	**Target population. Level of analysis [sample size]**	**Study aim**	**Inequality axis**	**Intervention**	**Health outcome**
Grey et al. 2017 [44]	Qualitative, longitudinal	Wales, 2012-2015	Low-income population. Individual [28 individuals before the intervention and 22 after]	To obtain a better understanding of the views and experiences of low-income households who were at an increased risk of fuel poverty through living in cold, energy inefficient [hard-to-heat, hard-to-treat] houses and to explore the application of a longitudinal focus group approach as a qualitative method to explore the ways in which experiencing an energy efficiency intervention changed the views and experiences of residents.	Social class / income[3]	**Energy efficiency improvements**	**Mental health:** Qualitative data **Respiratory health:** Qualitative data **Chronic conditions:** Qualitative data
Peralta et al. 2017 [55]	Quantitative, time-stratified case-crossover analysis	Spain, 1986-2012	General population. Individual [2552 deaths]	To evaluate the impact energy efficiency façade retrofitting interventions in Barcelona on the association between cold outdoor temperatures and mortality.	Sex[2]	**Energy efficiency improvements**	**Mortality:** All natural causes and from neoplasms, circulatory system and respiratory system causes.
Poortinga et al. 2017 [52]	Quantitative, longitudinal	Wales, 2009-2011-2012-2014-2016 [4 waves]	People living in social housing. Multilevel [10009 individuals]	To examine [1] the changes in a range of social and health outcomes following upgrades to a national social housing standard, and [2] whether these outcomes can be linked to the specific measures that were part of the upgrade programme.	-	**Energy efficiency improvements**	**General health status:** Poor self-reported health status **Mental health:** Average of 4 questions about feeling nervous, down, calm and peaceful, downhearted and blue and happy **Respiratory health:** Presence of respiratory symptoms
Doll et al. 2016 [60]	Quantitative, longitudinal	USA, 2012-2015	Low-income population. Individual [54 households]	To quantify indoor environment parameters before and after weatherization in single-family, low- income housing.	Social class / income[3]	**Energy efficiency improvements**	**Inadequate temperature:** Monitoring of temperature and relative humidity **Indoor air quality:** Monitoring of carbon monoxide, carbon dioxide, nitrogen dioxide, formaldehyde, particulate matter and radon

Intervention studies							
Study	**Design**	**Location, year**	**Target population. Level of analysis [sample size]**	**Study aim**	**Inequality axis**	**Intervention**	**Health outcome**
Gilbertson et al. 2012 [32]	Quantitative, cross-sectional	England, 2001-2002, 2002-2003	Low-income population. Individual2685 individuals	To utilise quantitative data from the Warm Front evaluation model to elaborate psychosocial pathways to health and then, to gauge the relative impact of improved living conditions compared with the alleviation of fuel poverty.	Social class / income[3]	**Energy efficiency improvements**	**General health status:** EQ-5D, SF-36 **Mental health:** GHQ-12, EQ-5D, SF-36 **Chronic conditions:** Presence of longstanding illness or disability
Breysse et al. 2011 [51]	Quantitative, longitudinal	USA, 2006-2007	Low-income population. Individual [50 adults and 30 children in 31 homes]	To determine whether renovating low-income housing using "green" and healthy principles improved resident health and building performance.	Social class / income[3]	**Energy efficiency improvements**	**General health status:** Poor self-reported health status **Respiratory health:** Asthma Non-asthma respiratory problems
Heyman et al. 2011 [53]	Quantitative, experimental	UK 2002-2003	Households living in EP. Individual [237 households: 129 in the trial and 108 in the control group]	To discuss the outcomes of a four-year pragmatic randomised controlled trial with partial crossover. The study was designed to measure the impact of fuel efficiency interventions on room temperature, fuel expenditure, satisfaction with home warmth and a range of health indicators for households living in full or marginal fuel poverty.	-	**Energy efficiency improvements** **Heating improvements**	**General health status:** SF36 questionnaire
Free et al. 2010 [49]	Quantitative, experimental	New Zealand, 2006	Households containing an asthmatic child aged 6-12 years. Individual [269 households: 135 children in the intervention and 134 in the control group]	To determine whether more effective home heating affects school absence for children with asthma.	Age[3]	**Heating improvements**	**Days absent from school during winter in a group of asthmatic children**
El Ansari et al. 2008	Quantitative, multiple time	UK, 1993–2005	People >= 65 years.	To explore the challenges of measuring the health impacts of fuel poverty schemes,	Age[3]	**Energy efficiency improvements**	**Mortality:** Excess winter mortality

Intervention studies							
Study	**Design**	**Location, year**	**Target population. Level of analysis [sample size]**	**Study aim**	**Inequality axis**	**Intervention**	**Health outcome**
[54]	series data		Aggregated	assessing whether EWM could be an indicator of fuel poverty/indoor heating.			
Howden-Chapman et al. 2007 [50]	Quantitative, experimental	New Zealand, 2001-2002	Households in uninsulated dwellings with at least one member with respiratory problems. Individual [1128 households: 563 in the intervention [1689 individuals] and 565 in the control [1623 individuals] group]	To determine whether insulating existing houses increases indoor temperatures and improves occupants' health and well-being.	-	**Energy efficiency improvements**	**General health status:** SF-36 questionnaire Days off work and school **Mental health:** SF-36 questionnaire **Respiratory health:** Presence of respiratory symptoms **Use of health services:** Number of visits to general practitioner Hospital visits [number and length] **Days off work/school**
Shortt et al. 2007 [48]	Quantitative, quasi-experimental	North Ireland, 2000-2002	Rural communities. Individual [100 individuals: 54 in the intervention and 46 in the control group]	This paper focuses primarily on the installation of central heating in selected households and the immediate effect on the dwellings and their occupants.	Age[2] Territory[3]	**Energy efficiency improvements** **Heating improvements**	**General health status:** Number of illnesses reported **Mental health:** Self-reported stress/ mental illness **Respiratory health:** Self-reported asthma, chest infections/bronchitis, pneumonia/hypothermia **Chronic conditions:** Self-reported angina, arthritis/rheumatism, other **Inadequate temperature:** Self- reported and objective measures of thermal comfort **Presence of dampness and/or mould:** Self-reported problems of

Intervention studies

Study	Design	Location, year	Target population. Level of analysis [sample size]	Study aim	Inequality axis	Intervention	Health outcome
							condensation, mould and damp
Gilbertson et al. 2006 [45]	Qualitative, Cross-sectional	England, 2003	Low-income population. Individual [49 households]	To record the change in householders' perceptions and behaviours following Warm Front improvements: Focus: satisfaction with the Scheme, perceived changes in health and well-being, use of living space and social interactions.	Social class / income[3]	**Energy efficiency improvements**	**General health status:** Qualitative data **Mental health:** Qualitative data **Respiratory health:** Qualitative data **Chronic conditions:** Qualitative data
Sommerville et al. 2000 [47]	Quantitative, longitudinal	England, 1995-1997	Children with asthma living in damp council housing. Individual [72 children]	To evaluate if installing heating in their homes improve the health of children with asthma.	Age[3]	**Heating improvements**	**Respiratory health** Presence of respiratory symptoms Days lost from school due to asthma
Hopton et al. 1996 [46]	Quantitative, quasi-experimental	Glasgow, Scotland	Children <16 years living in an area of severe social disadvantage. Individual [132 children: 55 in the intervention and 77 in the control group]	To evaluate the effect of the new heating arrangements on the tenants assessment of their housing conditions and to assess the effects of the heating on indicators of the health status of children under the age of 16 years.	Age[3] Social class / income[3]	**Heating improvements**	**General health status:** Number of reported symptoms **Mental health:** Reported temper tantrums, irritability, feeling down **Respiratory health:** Reported wheezing sore throat, persistent cough, runny nose **Other symptoms:** Reported headaches, poor appetite, tiredness, diarrhoea, vomiting, fever/high temperature, earache **Inadequate temperature:** Reported cold housing **Presence of dampness and/or mould:** Reported presence of dampness and mould

NS, [-]: not specified; UK: United Kingdom; USA: United States of America; [1]: Analysis of EP according inequity axis; [2]: Health outcomes stratified according inequity axis; [3]: Study targeted on vulnerable group.

Table 3. Associations between EP and health in studies about direct health effects.

Observational			
Outcome	**Exposure factor**	**Association**	**References**
General health status	Inadequate temperature	↓*	Oliveras et al. 2020 [12] ; Llorca et al. 2020 [27]; Bosch et al. 2019 [21]; Kose et al. 2019 [29]; Thomson et al. 2017 [29][a]; Critchley et al. 2007 [23]; Evans et al. 2000 [24]
	Financial strain	↓*	Oliveras et al. 2020 [12] ; Bosch et al. 2019 [21]; Kose et al. 2019 [29]
		-	de Vries et al. 2012 [25]
	Inadequate housing conditions	↓*	Bosch et al. 2019 [21]; Kose et al. 2019 [29]; Heyman et al. 2005 [27]; Gemmel et al. 2001 [26]
	Index	↓*	Llorca et al. 2020 [27]; Bosch et al. 2019 [21]
Mental health	Inadequate temperature	↓*	Oliveras et al. 2020 [12] ; Thomson et al. 2017 [29][a]; Critchley et al. 2007 [23]; Butler et al. 2003 [34]; Evans et al. 2000 [24]
	Financial strain	↓*	Oliveras et al. 2020 [12] ; de Vries et al. 2012 [25]
		↓	Critchley et al. 2007 [23][c]
		Qualitative ↓	Hernandez et al. 2016 [33]
	Inadequate housing conditions	↓*	Butler et al. 2003 [34]
Respiratory health	Inadequate temperature	↓*	Atsalis et al. 2016 [37]; Butler et al. 2003 [34]; Evans et al. 2000 [24]
		Qualitative ↓	Tod et al. 2016 [36]
	Financial strain	↓*	de Vries et al. 2012 [25], Webb et al. 2012 [38][b]
	Inadequate housing conditions	↓*	Butler et al. 2003 [34]
	Index	↑*	Rudge et al. 2005 [35][d]
Chronic conditions	Inadequate temperature	↑*	Evans et al. 2000 [24]; Atsalis et al. 2016 [37]
		↑	Berkowitz et al. 2015 [39]; Critchley et al. 2007 [23]
	Financial strain	-	de Vries et al. 2012 [25]
	Inadequate housing conditions	↑*	Gemmel et al. 2001 [26]
Mortality	Inadequate temperature	↑*	Atsalis et al. 2016 [37]
		-	Wilkinson et al. 2004 [43]
	Index	↑*	Recalde et al. 2019 [5]; Healy et al. 2003 [41]
Use of health services	Inadequate temperature	↑*	Berkowitz et al. 2015 [39][b]; Evans et al. 2000 [24]

Interventions			
Outcome	**Exposure factor**	**Association**	**References**
General health status	Energy efficiency improvements	↑*	Poortinga et al. 2017 [52]
		↑	Gilbertson et al. 2012 [32]; Breysse et al. 2011 [51]; Howden-Chapman et al. 2007 [50], Gilbertson et al. 2006 [45][d]
		-	Heyman et al. 2011 [53]

Interventions			
Outcome	**Exposure factor**	**Association**	**References**
	Heating improvement	↑*	Shortt et al. 2007 [48]
		↓	Gilbertson et al. 2012 [32]
		-	Hopton et al. 1996 [46]
Mental health	Energy efficiency improvements	↑*	Gilbertson et al. 2012 [32][c]; Howden-Chapman et al. 2007 [50]; Poortinga et al. 2017 [52]
		↑	Grey et al. 2017 [44]; Gilbertson et al. 2006 [45][d]
	Heating improvement	↑	Gilbertson et al. 2012 [32]; Shortt et al. 2007 [48], Hernandez et al. 2016 [33]
		-	Hopton et al. 1996 [46]
Respiratory health	Energy efficiency improvements	↑*	Breysse et al. 2011 [51]; Howden-Chapman et al. 2007 [50]; Poortinga et al. 2017 [52]
		↑	Grey et al. 2017 [44]
	Heating improvement	↑*	Sommerville et al. 2000 [47]
		↑	Shortt et al. 2007 [48]
		-	Hopton et al. 1996 [46]
Chronic conditions	Energy efficiency improvements	↑	Grey et al. 2017 [44]; Gilbertson et al. 2012 [32]; Gilbertson et al. 2006 [45][d]
	Heating improvement	↓	Gilbertson et al. 2012 [32]; Shortt et al. 2007 [48]
Mortality	Energy efficiency improvements	*↑ m; ↓* w	Peralta et al. 2017 [55]
		-	El Ansari et al. 2008 [54]
Other symptoms	Heating improvement	-	Hopton et al. 1996 [46]
Use of health services	Energy efficiency improvements	↓*	Howden-Chapman et al. 2007 [50]
Days off school/work	Energy efficiency improvements	↓*	Howden-Chapman et al. 2007 [50]
	Heating improvement	↓*	Free et al. 2010 [49]

↑: Positive association; ↓: negative association; [-]: no association reported; a: Statistically significant association in most countries, but not in all; b Statistically significant association with increased outpatient visits, not with emergency department and inpatient visits; c Statistically significant association only with GHQ-12; d: qualitative study; m: men; w: women;

Table 4. Associations between energy poverty and health in studies about risk factors exposures.

Risk exposures	Exposure factor	Association	Reference
Observational			
Presence of dampness/mould	EP behaviours	↑*	Sharpe et al. 2015 [56]
Indoor air pollution	EP Index	↓	Reyes et al. 2019 [57]
Inadequate temperature	EP Index	↓	Reyes et al. 2019 [57]
		↑	Healy et al. 2002 [58]
Food insecurity	Financial strain	↑*	Nord et al. 2006 [59]
Interventions			
Presence of dampness/mould	Heating improvement	↓*	Shortt et al. 2007 [48], Hopton et al. 1996 [46],
Indoor air pollution	Energy efficiency improvements	↓	Doll et al. 2016 [60][a]
	Heating improvement	↓*	Free et al. 2010 [49]
Inadequate temperature exposure	Energy efficiency improvements	↓*	Gilbertson et al. 2012 [32],
		-	Doll et al. 2016 [60]
	Heating improvement	↓*	Shortt et al. 2007 [48][b], Hopton et al. 1996 [46], Free et al. 2010 [49]
Days off school	Heating improvement	↓*	Free et al. 2010 [49][c]

↑: Positive association; ↓: negative association; (-): no association reported. (*): significative association; a: the number of Indoor Environmental Quality compliant homes is the same or higher after intervention for all guidelines except CO_2 and PM2.5 in smoking homes.; b: self-reported satisfaction with indoor temperature; c: group of asmathic children:

Acknowledgments

We would like to thank Camila Higueras Callejón, public health research librarian at Andalusian School of Public Health, for her careful planning of the search strategy.

Appendices

Appendix A. Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist (from [19])

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3-4
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	4
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	4
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	5
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	4

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Appendix C
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	5, section 2.3
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	5-6
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	5-6
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	-
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	6
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	Page 6 and Figure 1
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	Table 1
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	-
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Table 2
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Table 3 and 4
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	11

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Limitations	20	Discuss the limitations of the scoping review process.	12
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	11-12
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	NA

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where sources of evidence (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with information sources (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

Appendix B. List of experts consulted

- Stefan Bouzarovski. University of Manchester. Professor of Geography and Director of the Centre for Urban Energy and Resilience. Oxford Road Manchester, M13 9PL United Kingdom.
- Peter Goldblatt. Professor, UCL Institute of Health Equity, Department of Epidemiology & Public Health, 1-19 Torrington Place. London WC1E 7HB.
- Matthias Braubach, Technical Officer, WHO European Centre for Environment and Health, Platz der Vereinten Nationen 1, D-53113 Bonn, Germany.
- John Hills, Richard Titmuss Professor of Social Policy, Department of Social Policy.
- Sergio Tirado Herrero Research Fellow of the Institute of Environmental Science and Technology (ICTA) at Universitat Autònoma de Barcelona (UAB)
- David Ormandy, Visiting Academic, Warwick Medical School - Health Sciences.

Appendix C. Medline search strategy

1	Adequate warmth.mp.	3
2	affordable warmth.mp.	4
3	Air conditioning.mp.	3278
4	climate change.mp.	17029

5 Climatization.mp. 21

6 Cold homes.mp. 9

7 Cold housing.mp. 12

8 Cold related.mp. 225

9 Cold temperature.mp. 47556

10 Cold waves.mp. 20

11 Domestic energy efficiency.mp. 0

12 Energy consumption.mp. 4100

13 Energy efficiency.mp. 1400

14 Energy insecurity.mp. 7

15 Energy poverty.mp. 6

16 Energy precariousness.mp. 0

17 Energy vulnerability.mp. 2

18 Fuel poor.mp. 2

19 Fuel poverty.mp. 41

20 Heat waves.mp. 541

21 heat.mp. 170384

22 Hot temperature.mp. 107025

23 Hot weather.mp. 403

24 Household energy needs.mp. 6

25 Indoor cold.mp. 7

26 Keep adequately warm.mp. 0

27 Poor termal performance.mp. 0

28 Thermal confort.mp. 1

29 Warm temperature.mp. 250

30 Household energy needs.mp. 6

31 Keep adequately warm.mp. 0

32 Warm weather.mp. 220

33 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 298808

34 affordability of heating.mp. 0

35 Affordable cost.mp. 201

36 Affordable energy.mp. 7

37 Energy affordability.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 0

38 Energy affordability.mp. 0

39 Energy cost.mp. 2434

40	Energy supply.mp.	2847
41	Housing affordability.mp.	25
42	Housing allowance.mp.	4
43	Housing instability.mp.	119
44	Inability of afford.mp.	80
45	Low income households.mp.	392
46	Low-income dwelling.mp.	0
47	Poverty line.mp.	508
48	Reasonable cost.mp.	856
49	Social inequalities.mp.	1626
50	Socioeconomic factors.mp.	138724
51	34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50	146553
52	Alcohol consumption.mp.	31419
53	anxiety.mp.	170858
54	Blood pressure.mp.	384665
55	Cancer.mp.	1209774
56	Cardiovascular diseases.mp.	143857
57	Cold-related mortality.mp.	43
58	Depression.mp.	303760
59	Diabetes.mp.	462744
60	Drug utilization.mp.	22632
61	General practitioner consultations.mp.	119
62	Health.mp.	2189452
63	Health care utilization.mp.	4673
64	Health services.mp.	355807
65	Hospital admissions.mp.	11584
66	Illness.mp.	405028
67	Limitations of activities of daily living.mp.	239
68	Mental health.mp.	133303
69	Morbility.mp.	425
70	Mortality.mp.	565351
71	Musculoskeletal diseases.mp.	11267
72	Obesity.mp.	227549
73	Quality of life.mp.	232696
74	Respiratory diseases.mp.	9845
75	Self-perceived health.mp.	1070

76 Self-rated health.mp. 4567

77 Stress.mp. 653486

78 Smoking.mp. 224512

79 Well-being.mp. 47510

80 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 5678943

81 33 and 51 and 80 469

10.3. Annex III: material suplementari article 1

Supplement 1. Age-adjusted prevalence ratio (PR) from Poisson regression models of poor self-reported health status, reduced well-being and depression in people with EP_T versus people without EP_T over time and p-values of year interactions (in bold when <0.05). Results are weighted and stratified by sex and region.

	Sample size	2007		2012		2016		p-value of years interaction		
		PR	95%IC	PR	95%IC	PR	95%IC	2012/ 2007	2016/ 2007	2016/ 2012
Poor self-reported health status										
Total										
EU27	94957	1.59	(1.50 - 1.68)	1.58	(1.52 - 1.65)	1.64	(1.53 - 1.76)	0.989	0.447	0.390
LSV	41166	1.59	(1.40 - 1.81)	1.69	(1.57 - 1.83)	1.54	(1.33 - 1.79)	0.405	0.773	0.282
HSV	53791	1.46	(1.37 - 1.56)	1.48	(1.41 - 1.55)	1.53	(1.42 - 1.66)	0.813	0.372	0.433
Women										
EU27	54270	1.53	(1.43 - 1.64)	1.52	(1.45 - 1.60)	1.60	(1.49 - 1.73)	0.902	0.369	0.253
LSV	22655	1.61	(1.39 - 1.86)	1.65	(1.51 - 1.81)	1.64	(1.38 - 1.94)	0.741	0.872	0.912
HSV	31615	1.35	(1.25 - 1.47)	1.38	(1.31 - 1.46)	1.45	(1.34 - 1.57)	0.659	0.243	0.361
Men										
EU27	40687	1.64	(1.49 - 1.81)	1.66	(1.55 - 1.79)	1.68	(1.48 - 1.91)	0.843	0.768	0.872
LSV	18511	1.56	(1.24 - 1.95)	1.73	(1.52 - 1.97)	1.44	(1.11 - 1.87)	0.423	0.660	0.219
HSV	22176	1.61	(1.45 - 1.80)	1.61	(1.48 - 1.76)	1.65	(1.42 - 1.92)	0.994	0.820	0.802
Reduced well-being										
Total										
EU27	93940	1.85	(1.72 - 1.99)	1.98	(1.88 - 2.09)	2.04	(1.88 - 2.22)	0.146	0.088	0.562
LSV	40937	1.81	(1.54 - 2.12)	2.02	(1.83 - 2.23)	1.98	(1.68 - 2.35)	0.235	0.427	0.841
HSV	53003	1.60	(1.47 - 1.74)	1.89	(1.77 - 2.02)	1.91	(1.73 - 2.10)	**0.002**	**0.008**	0.888
Women										
EU27	53655	1.80	(1.65 - 1.97)	1.86	(1.74 - 1.98)	1.86	(1.68 - 2.05)	0.599	0.668	0.996
LSV	22527	1.76	(1.45 - 2.12)	1.92	(1.71 - 2.16)	2.01	(1.65 - 2.44)	0.423	0.337	0.718
HSV	31128	1.54	(1.39 - 1.71)	1.75	(1.62 - 1.89)	1.71	(1.52 - 1.92)	0.056	0.198	0.718
Men										
EU27	40285	1.86	(1.64 - 2.12)	2.13	(1.94 - 2.33)	2.30	(2.00 - 2.66)	0.106	**0.032**	0.357
LSV	18410	1.86	(1.41 - 2.45)	2.13	(1.79 - 2.52)	1.99	(1.48 - 2.67)	0.410	0.733	0.702
HSV	21875	1.64	(1.41 - 1.90)	2.08	(1.86 - 2.31)	2.20	(1.86 - 2.61)	**0.011**	**0.010**	0.573

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	Sample size	2007		2012		2016		p-value of years interaction		
		PR	95%IC	PR	95%IC	PR	95%IC	2012/ 2007	2016/ 2007	2016/ 2012
Likely depression										
Total										
EU27	93940	2.65	(2.34 - 3.01)	2.88	(2.62 - 3.17)	2.73	(2.37 - 3.14)	0.304	0.755	0.542
LSV	40937	3.21	(2.50 - 4.13)	3.27	(2.75 - 3.88)	2.67	(2.01 - 3.56)	0.911	0.345	0.238
HSV	53003	2.02	(1.74 - 2.35)	2.53	(2.26 - 2.84)	2.48	(2.11 - 2.93)	**0.018**	0.067	0.845
Women										
EU27	53655	2.55	(2.20 - 2.96)	2.42	(2.15 - 2.72)	2.63	(2.21 - 3.12)	0.569	0.798	0.424
LSV	22527	3.24	(2.42 - 4.33)	2.70	(2.18 - 3.34)	2.85	(2.03 - 4.01)	0.323	0.579	0.786
HSV	31128	1.88	(1.57 - 2.25)	2.13	(1.86 - 2.46)	2.34	(1.92 - 2.86)	0.275	0.106	0.451
Men										
EU27	40285	2.70	(2.16 - 3.39)	3.62	(3.08 - 4.25)	2.84	(2.24 - 3.61)	**0.039**	0.762	0.100
LSV	18410	3.14	(1.99 - 4.93)	4.16	(3.14 - 5.50)	2.45	(1.48 - 4.06)	0.298	0.476	0.073
HSV	21875	2.16	(1.66 - 2.81)	3.18	(2.62 - 3.86)	2.65	(2.01 - 3.51)	**0.020**	0.292	0.293

EP_T: energy poverty indicator “Cannot afford to keep home adequately warm; PR: age-adjusted Prevalence Ratio; CI: confidence intervals; LSV: countries with lower structural vulnerability; HSV: countries with higher structural vulnerability

Supplement 2. Population attributable risk percent (PAR%) to EP_T of poor self-reported health status, reduced well-being and likely depression over time and differences between years (in bold if difference is statistically significant). Results are weighted and stratified by sex and region.

	2007		2012		2016		Differences between years (95% CI)			
	PAR%	95%CI	PAR%	95%CI	PAR%	95%CI	2007-2012		2012-2016	
Poor self-reported health status										
Total										
EU27	6.81	(5.83 - 7.76)	7.65	(6.73 - 8.46)	6.58	(5.51 - 7.62)	0.84	(-0.51 - 2.12)	-1.06	(-2.39 - 0.31)
LSV	2.82	(1.93 - 3.65)	4.23	(3.49 - 5.04)	2.82	(1.78 - 3.98)	**1.41**	**(0.34 - 2.60)**	**-1.40**	**(-2.70 - -0.07)**
HSV	9.38	(7.57 - 11.21)	10.23	(8.88 - 11.53)	8.56	(6.82 - 10.29)	0.85	(-1.23 - 3.06)	-1.66	(-4.09 - 0.50)
Women										
EU27	6.81	(5.55 - 8.08)	7.61	(6.55 - 8.63)	6.76	(5.48 - 8.05)	0.81	(-0.85 - 2.35)	-0.85	(-2.55 - 0.81)
LSV	3.12	(2.08 - 4.24)	4.40	(3.39 - 5.47)	3.56	(2.13 - 5.10)	1.28	(-0.23 - 2.78)	-0.83	(-2.57 - 0.94)
HSV	7.74	(5.60 - 10.18)	8.89	(7.16 - 10.48)	7.52	(5.64 - 9.53)	1.16	(-1.73 - 3.90)	-1.37	(-3.79 - 1.24)
Men										
EU27	6.41	(4.84 - 7.94)	7.28	(6.08 - 8.55)	6.10	(4.23 - 7.99)	0.87	(-1.25 - 2.92)	-1.17	(-3.55 - 1.07)
LSV	2.42	(1.10 - 3.83)	3.91	(2.74 - 5.04)	2.07	(0.53 - 3.72)	1.49	(-0.30 - 3.22)	-1.85	(-3.65 - 0.21)
HSV	10.83	(8.22 - 13.83)	11.37	(9.14 - 13.61)	9.57	(6.04 - 12.63)	0.54	(-3.06 - 3.97)	-1.80	(-6.13 - 1.83)
Reduced well-being										
Total										
EU27	9.17	(7.79 - 10.55)	11.90	(10.72 - 13.07)	9.72	(8.22 - 11.24)	**2.73**	**(0.78 - 4.58)**	**-2.18**	**(-4.07 - -0.17)**
LSV	4.00	(2.78 - 5.30)	6.40	(5.22 - 7.64)	4.88	(3.31 - 6.49)	**2.40**	**(0.70 - 4.18)**	-1.52	(-3.47 - 0.46)
HSV	10.72	(8.36 - 12.81)	16.70	(14.69 - 18.78)	12.88	(10.46 - 15.23)	**5.98**	**(3.03 - 9.24)**	**-3.81**	**(-6.88 - -0.64)**
Women										
EU27	9.48	(7.56 - 11.23)	11.62	(10.15 - 13.14)	8.82	(7.18 - 10.62)	2.14	(-0.24 - 4.46)	-2.80	(-5.12 - -0.44)
LSV	4.06	(2.52 - 5.70)	6.49	(4.96 - 7.89)	5.33	(3.39 - 7.29)	**2.43**	**(0.25 - 4.55)**	-1.16	(-3.69 - 1.15)
HSV	10.51	(7.34 - 13.56)	15.16	(12.68 - 17.49)	10.79	(8.05 - 13.73)	**4.65**	**(0.85 - 8.39)**	**-4.37**	**(-7.81 - -0.44)**
Men										
EU27	8.16	(6.12 - 10.17)	11.59	(9.80 - 13.49)	10.60	(7.99 - 13.19)	**3.43**	**(0.87 - 6.39)**	-0.99	(-4.01 - 2.09)
LSV	3.79	(1.86 - 5.79)	6.03	(4.20 - 7.91)	4.45	(2.10 - 6.93)	2.23	(-0.58 - 4.95)	-1.57	(-4.63 - 1.62)
HSV	10.03	(6.25 - 13.83)	17.78	(14.70 - 21.41)	15.18	(11.22 - 19.52)	**7.76**	**(3.01 - 13.04)**	-2.60	(-8.35 - 2.56)

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	2007		2012		2016		Differences between years (95% CI)			
	PAR%	95%CI	PAR%	95%CI	PAR%	95%CI	2007-2012		2012-2016	
Likely depression										
Total										
EU27	16.63	(13.94 - 19.52)	20.75	(18.08 - 23.08)	15.49	(12.51 - 18.38)	**4.12**	**(0.48 - 7.73)**	**-5.26**	**(-8.89 - -1.00)**
LSV	9.95	(6.91 - 13.13)	13.17	(10.37 - 16.03)	7.90	(4.71 - 11.47)	3.21	(-0.67 - 7.14)	**-5.26**	**(-9.54 - -0.86)**
HSV	17.11	(12.76 - 21.43)	25.41	(21.56 - 29.20)	19.85	(15.37 - 24.10)	**8.29**	**(2.46 - 14.36)**	**-5.56**	**(-11.36 - -0.24)**
Women										
EU27	17.11	(13.68 - 20.81)	18.00	(14.90 - 21.10)	15.83	(12.32 - 19.94)	0.89	(-3.61 - 5.62)	-2.17	(-6.99 - 2.70)
LSV	10.77	(7.15 - 14.88)	11.17	(7.94 - 14.75)	9.16	(4.78 - 14.24)	0.41	(-5.22 - 5.30)	-2.02	(-7.52 - 3.83)
HSV	16.08	(10.36 - 21.85)	21.28	(16.73 - 26.37)	19.30	(14.01 - 25.08)	5.20	(-1.65 - 12.33)	-1.98	(-9.04 - 5.30)
Men										
EU27	15.05	(10.60 - 20.12)	23.46	(19.45 - 27.63)	14.56	(10.16 - 18.95)	**8.41**	**(1.55 - 14.61)**	**-8.90**	**(-14.39 - -3.32)**
LSV	8.71	(3.96 - 13.70)	15.46	(10.90 - 20.35)	6.45	(1.93 - 11.56)	6.75	(-0.16 - 13.74)	**-9.00**	**(-16.01 - -2.18)**
HSV	17.14	(9.88 - 25.02)	29.87	(23.84 - 36.30)	19.85	(12.27 - 27.01)	**12.73**	**(3.37 - 22.28)**	**-10.02**	**(-19.28 - -0.51)**

EP_T: energy poverty indicator “Cannot afford to keep home adequately warm; PAR%: age-adjusted population attributable risk percent; CI: confidence intervals; LSV: countries with lower structural vulnerability; HSV: countries with higher structural vulnerability

Supplement 3. Age-adjusted prevalence ratio (PR) from Poisson regression models of poor self-reported health status, reduced well-being and likely depression in people with EP_A versus people without EP_A over time and p-values of year interactions (in bold when <0.05). Results are weighted and stratified by sex and region.

	Sample size	2007		2012		2016		p-value of years interaction		
		PR	95%IC	PR	95%IC	PR	95%IC	2012/ 2007	2016/ 2007	2016/ 2012
Poor self-reported health status										
Total										
EU27	95063	1.48	(1.39 - 1.56)	1.37	(1.30 - 1.43)	1.68	(1.57 - 1.80)	**0.042**	**0.004**	**<0.001**
LSV	41065	1.54	(1.39 - 1.70)	1.43	(1.31 - 1.56)	1.65	(1.40 - 1.93)	0.280	0.473	0.123
HSV	53998	1.37	(1.27 - 1.47)	1.29	(1.22 - 1.36)	1.57	(1.46 - 1.68)	0.213	**0.009**	**<0.001**
Women										
EU27	54409	1.46	(1.36 - 1.56)	1.34	(1.26 - 1.41)	1.59	(1.47 - 1.73)	**0.049**	0.109	**<0.001**
LSV	22615	1.68	(1.49 - 1.89)	1.38	(1.25 - 1.54)	1.68	(1.38 - 2.05)	**0.017**	0.975	0.085
HSV	31794	1.24	(1.14 - 1.36)	1.26	(1.18 - 1.34)	1.43	(1.31 - 1.56)	0.874	**0.024**	**0.015**
Men										
EU27	40654	1.48	(1.34 - 1.64)	1.40	(1.30 - 1.51)	1.80	(1.60 - 2.02)	0.397	**0.014**	**<0.001**
LSV	18450	1.38	(1.16 - 1.65)	1.48	(1.30 - 1.70)	1.60	(1.23 - 2.08)	0.526	0.371	0.625
HSV	95063	1.48	(1.39 - 1.56)	1.37	(1.30 - 1.43)	1.68	(1.57 - 1.80)	**0.042**	**0.004**	**<0.001**
Reduced well-being										
Total										
EU27	94027	1.80	(1.68 - 1.94)	1.64	(1.55 - 1.73)	2.09	(1.92 - 2.27)	**0.041**	**0.008**	**<0.001**
LSV	40839	1.85	(1.64 - 2.10)	1.61	(1.46 - 1.78)	1.91	(1.60 - 2.28)	0.088	0.794	0.102
HSV	53188	1.61	(1.47 - 1.76)	1.60	(1.50 - 1.72)	2.03	(1.85 - 2.23)	0.955	**<0.001**	**<0.001**
Women										
EU27	53775	1.75	(1.61 - 1.91)	1.53	(1.42 - 1.64)	1.94	(1.75 - 2.15)	**0.016**	0.125	**<0.001**
LSV	22486	1.86	(1.61 - 2.16)	1.47	(1.30 - 1.67)	1.93	(1.56 - 2.37)	**0.018**	0.800	**0.031**
HSV	31289	1.50	(1.35 - 1.67)	1.52	(1.39 - 1.65)	1.86	(1.66 - 2.08)	0.918	**0.007**	**0.004**
Men										
EU27	40252	1.85	(1.63 - 2.09)	1.78	(1.63 - 1.96)	2.28	(1.98 - 2.63)	0.645	**0.027**	**0.004**
LSV	18353	1.86	(1.50 - 2.31)	1.80	(1.53 - 2.11)	1.86	(1.37 - 2.52)	0.800	0.988	0.856
HSV	21899	1.73	(1.49 - 2.01)	1.73	(1.54 - 1.93)	2.27	(1.94 - 2.65)	0.965	**0.015**	**0.006**

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	Sample size	2007		2012		2016		p-value of years interaction		
		PR	95%IC	PR	95%IC	PR	95%IC	2012/ 2007	2016/ 2007	2016/ 2012
Likely depression										
Total										
EU27	94027	2.77	(2.44 - 3.14)	2.12	(1.92 - 2.35)	2.90	(2.50 - 3.35)	**0.001**	0.647	**0.001**
LSV	40839	3.12	(2.50 - 3.89)	2.10	(1.75 - 2.53)	2.92	(2.19 - 3.90)	**0.007**	0.722	0.060
HSV	53188	2.28	(1.96 - 2.66)	2.03	(1.80 - 2.29)	2.61	(2.21 - 3.07)	0.231	0.246	**0.016**
Women										
EU27	53775	2.56	(2.20 - 2.98)	1.90	(1.68 - 2.15)	2.73	(2.27 - 3.28)	**0.003**	0.602	**0.001**
LSV	22486	2.52	(1.94 - 3.29)	1.80	(1.44 - 2.26)	2.97	(2.07 - 4.28)	0.059	0.477	**0.022**
HSV	31289	2.21	(1.84 - 2.65)	1.87	(1.61 - 2.17)	2.41	(1.97 - 2.97)	0.161	0.525	**0.047**
Men										
EU27	40252	3.06	(2.45 - 3.81)	2.45	(2.07 - 2.90)	3.11	(2.46 - 3.93)	0.116	0.915	0.103
LSV	18353	4.09	(2.86 - 5.86)	2.55	(1.90 - 3.43)	2.79	(1.76 - 4.43)	**0.045**	0.197	0.748
HSV	21899	2.29	(1.75 - 3.01)	2.26	(1.85 - 2.77)	2.88	(2.19 - 3.78)	0.935	0.248	0.164

EP_A: energy poverty indicator “One or more arrears in utility bills during the past 12 months”; PR: age-adjusted Prevalence Ratio; CI: confidence intervals; LSV: countries with lower structural vulnerability; HSV: countries with higher structural vulnerability

Supplement 4. Population attributable risk percent (PAR%) to EP_A of poor self-reported health status, reduced well-being and likely depression over time and differences between years (in bold if difference is statistically significant). Results are weighted and stratified by sex and region.

	2007		2012		2016		Differences between years (95% CI)			
	PAR%	95%CI	PAR%	95%CI	PAR%	95%CI	2007-2012		2012-2016	
Poor self-reported health status										
Total										
EU27	5.08	(4.15 - 6.00)	4.45	(3.74 - 5.18)	5.73	(4.81 - 6.65)	-0.64	(-1.77 - 0.55)	**1.29**	**(0.09 - 2.55)**
LSV	3.75	(2.71 - 4.92)	3.22	(2.37 - 4.07)	3.11	(1.94 - 4.26)	-0.53	(-1.94 - 0.73)	-0.11	(-1.62 - 1.19)
HSV	5.56	(4.14 - 6.97)	5.05	(3.92 - 6.19)	6.90	(5.60 - 8.37)	-0.51	(-2.26 - 1.34)	**1.86**	**(0.04 - 3.80)**
Women										
EU27	5.29	(4.18 - 6.38)	4.29	(3.37 - 5.16)	5.31	(4.09 - 6.48)	-1.00	(-2.36 - 0.37)	1.02	(-0.46 - 2.44)
LSV	4.82	(3.49 - 6.18)	2.95	(1.98 - 4.04)	3.54	(1.99 - 5.25)	**-1.86**	**(-3.60 - -0.20)**	0.58	(-1.28 - 2.53)
HSV	4.02	(2.24 - 5.78)	4.58	(3.24 - 6.02)	5.31	(3.82 - 6.84)	0.56	(-1.69 - 2.82)	0.73	(-1.30 - 2.74)
Men										
EU27	4.64	(3.31 - 6.05)	4.57	(3.43 - 5.73)	6.12	(4.52 - 7.62)	-0.06	(-1.92 - 1.76)	1.55	(-0.37 - 3.58)
LSV	2.63	(1.09 - 4.33)	3.51	(2.18 - 4.95)	2.64	(0.97 - 4.31)	0.88	(-1.18 - 2.98)	-0.87	(-3.03 - 1.18)
HSV	7.18	(4.52 - 9.72)	5.64	(3.77 - 7.55)	9.03	(6.55 - 11.52)	-1.53	(-4.79 - 1.76)	**3.39**	**(0.33 - 6.52)**
Reduced well-being										
Total										
EU27	8.65	(7.46 - 9.93)	8.10	(6.92 - 9.13)	9.50	(8.10 - 11.00)	-0.55	(-2.23 - 1.11)	1.41	(-0.26 - 3.21)
LSV	6.51	(4.87 - 8.08)	5.23	(3.98 - 6.47)	4.98	(3.29 - 6.83)	-1.28	(-3.23 - 0.72)	-0.24	(-2.23 - 1.82)
HSV	8.78	(6.75 - 10.83)	10.38	(8.62 - 12.09)	12.48	(10.51 - 14.59)	1.60	(-1.23 - 4.17)	2.10	(-0.45 - 5.08)
Women										
EU27	8.69	(7.15 - 10.27)	7.12	(5.73 - 8.55)	8.79	(6.98 - 10.63)	-1.57	(-3.63 - 0.46)	1.67	(-0.57 - 3.89)
LSV	6.89	(5.03 - 8.90)	4.28	(2.73 - 5.87)	5.56	(3.41 - 7.92)	**-2.61**	**(-5.17 - -0.26)**	1.28	(-1.44 - 3.99)
HSV	7.85	(5.39 - 10.34)	9.16	(7.04 - 11.34)	10.61	(8.32 - 13.15)	1.31	(-2.03 - 4.46)	1.45	(-1.70 - 4.65)
Men										
EU27	8.32	(6.27 - 10.53)	9.19	(7.31 - 10.93)	10.27	(7.90 - 12.54)	0.87	(-2.00 - 3.64)	1.08	(-1.89 - 4.09)
LSV	6.18	(3.56 - 8.89)	6.34	(4.38 - 8.39)	4.22	(1.70 - 7.06)	0.17	(-3.02 - 3.66)	-2.12	(-5.46 - 1.20)
HSV	9.40	(6.25 - 12.64)	11.91	(8.96 - 15.35)	14.88	(11.42 - 18.45)	2.51	(-1.72 - 7.06)	2.97	(-1.80 - 7.65)

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	2007		2012		2016		Differences between years (95% CI)			
	PAR%	95%CI	PAR%	95%CI	PAR%	95%CI	2007-2012		2012-2016	
Likely depression										
Total										
EU27	17.02	(14.23 - 19.87)	13.05	(10.74 - 15.12)	15.05	(12.13 - 17.82)	**-3.97**	**(-7.79 - -0.57)**	2.00	(-1.59 - 5.67)
LSV	14.35	(10.40 - 18.24)	8.67	(6.19 - 11.37)	9.61	(6.01 - 13.72)	**-5.67**	**(-10.03 - -0.96)**	0.94	(-3.85 - 5.95)
HSV	16.58	(12.73 - 20.40)	15.87	(12.55 - 19.40)	17.50	(13.24 - 21.37)	-0.72	(-5.94 - 4.24)	1.63	(-3.98 - 6.97)
Women										
EU27	16.32	(13.10 - 19.93)	11.26	(8.73 - 14.07)	14.65	(10.91 - 18.33)	**-5.05**	**(-9.38 - -1.01)**	3.38	(-1.39 - 7.85)
LSV	11.48	(7.22 - 16.07)	6.73	(3.93 - 9.88)	10.97	(6.05 - 16.37)	-4.75	(-10.09 - 0.54)	4.23	(-1.63 - 10.60)
HSV	16.76	(12.12 - 21.41)	14.08	(10.32 - 18.15)	15.52	(10.67 - 20.59)	-2.68	(-9.11 - 3.58)	1.44	(-5.01 - 7.99)
Men										
EU27	17.69	(13.03 - 22.62)	15.34	(11.69 - 18.88)	15.39	(10.86 - 20.37)	-2.35	(-8.63 - 3.68)	0.06	(-6.05 - 5.90)
LSV	18.46	(11.44 - 25.13)	11.27	(6.80 - 15.97)	7.76	(2.52 - 13.10)	-7.19	(-15.58 - 1.57)	-3.51	(-11.02 - 3.24)
HSV	15.13	(8.50 - 21.81)	18.31	(12.44 - 24.47)	20.20	(12.78 - 27.70)	3.18	(-5.40 - 11.88)	1.89	(-7.95 - 11.11)

EP_A: energy poverty indicator “One or more arrears in utility bills during the past 12 months”; PAR%: age-adjusted population attributable risk percent; CI: confidence intervals; LSV: countries with lower structural vulnerability; HSV: countries with higher structural vulnerability

Supplement 5. Weighted prevalence of energy poverty (EP) and health outcomes by EP over time stratified by country. In bold if p-values of chi-square test assessing change over time are statistically significant (<0.05)

	Cannot afford to keep home adequately warm								Arrears in utility bills during the past 12 months							
	EP_T		Poor self-reported health		Reduced well-being		Likely depression		EP_A		Poor self-reported health		Reduced well-being		Likely depression	
	N	%	EP_T	nEP_T	EP_T	nEP_T	EP_T	nEP_T	N	%	EP_A	nEP_A	EPA	nEP_A	EP_A	nEP_A
Austria																
2007	38	3.8	**46.8**	**33.0**	37.0	**26.0**	17.1	**7.5**	91	8.0	**56.3**	**31.9**	**65.3**	**22.9**	**35.2**	5.8
2012	22	2.0	**36.6**	**25.4**	22.7	**17.5**	5.4	**5.1**	75	7.1	**29.3**	**25.1**	**20.5**	**17.2**	**5.9**	4.8
2016	31	4.3	**13.7**	**24.7**	11.8	**16.9**	4.0	**4.2**	69	5.4	**42.3**	**23.4**	**45.3**	**15.0**	**9.7**	3.8
Belgium																
2007	70	6.8	55.4	32.3	38.2	17.0	14.7	5.0	150	**16.2**	39.8	32.8	27.7	**16.7**	9.7	4.9
2012	72	7.1	57.2	33.0	51.0	19.2	19.6	4.8	134	**13.6**	42.1	33.7	31.8	**19.9**	8.3	5.5
2016	73	6.6	48.4	28.8	33.2	15.5	9.4	4.6	97	**8.8**	39.9	29.0	39.4	**14.5**	19.4	3.6
Bulgaria																
2007	328	**31.5**	50.9	**36.7**	46.3	**31.0**	25.4	**12.5**	245	25.8	**48.7**	**39.3**	45.7	**32.5**	25.2	**13.2**
2012	245	**22.9**	56.6	**32.8**	41.5	**19.0**	21.9	**7.7**	216	22.6	**47.2**	**36.3**	37.7	**20.9**	19.8	**8.6**
2016	202	**19.2**	52.0	**26.1**	46.0	**16.7**	25.0	**5.4**	201	23.7	**40.0**	**28.4**	40.7	**16.8**	16.1	**7.0**
Cyprus																
2007	287	**27.1**	**44.8**	19.9	45.2	**31.4**	21.8	11.9	240	**23.0**	37.1	23.8	51.3	30.8	22.6	12.5
2012	367	**35.2**	**38.4**	20.0	42.3	**26.1**	23.0	11.7	376	**37.1**	33.8	22.6	43.2	25.1	23.4	11.2
2016	189	**19.1**	**30.0**	21.7	46.2	**24.3**	32.0	10.5	158	**21.0**	26.8	22.5	40.4	25.4	24.8	12.0
Czech Republic																
2007	68	**5.2**	69.1	34.4	62.5	22.3	25.8	5.4	78	**7.0**	42.5	35.8	48.3	22.5	19.1	5.6
2012	54	**5.4**	54.5	39.6	47.1	23.9	18.5	5.7	129	**12.6**	45.0	40.0	38.6	23.1	11.4	5.7
2016	46	**2.7**	78.4	34.6	44.4	19.6	6.5	5.9	52	**6.5**	52.5	35.0	33.6	19.6	15.1	5.4
Denmark																
2007	26	2.0	42.4	**30.8**	20.3	14.8	5.8	4.1	27	3.2	**26.2**	**31.2**	21.9	14.6	2.8	4.3
2012	21	2.1	44.1	**34.2**	29.0	13.0	27.6	2.3	30	3.4	**35.8**	**34.6**	19.4	13.1	9.0	2.6
2016	30	3.5	61.6	**26.6**	37.8	12.8	30.6	3.3	25	2.6	**47.5**	**27.4**	23.1	13.4	11.1	4.1

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	Cannot afford to keep home adequately warm								Arrears in utility bills during the past 12 months							
	EP_T		Poor self-reported health		Reduced well-being		Likely depression		EP_A		Poor self-reported health		Reduced well-being		Likely depression	
	N	%	EP_T	nEP_T	EP_T	nEP_T	EP_T	nEP_T	N	%	EP_A	nEP_A	EPA	nEP_A	EP_A	nEP_A
Estonia																
2007	123	**11.5**	**63.6**	54.1	43.0	30.4	13.8	7.4	74	**7.6**	59.1	55.2	44.0	31.1	14.3	7.7
2012	254	**24.7**	**76.0**	48.6	44.3	28.5	11.1	5.9	78	**8.9**	65.2	55.4	40.2	32.4	8.5	7.6
2016	67	**5.5**	**80.4**	51.0	50.3	26.6	15.5	6.2	47	**5.3**	72.4	51.8	40.1	27.2	4.4	7.0
Finland																
2007	13	1.0	55.9	33.0	12.8	15.2	0.0	2.8	97	**9.4**	41.9	32.3	25.0	14.0	5.6	2.5
2012	15	1.5	58.0	35.8	19.3	15.5	0.0	3.3	51	**5.5**	45.4	35.8	31.2	14.7	7.4	3.0
2016	19	1.3	41.7	31.2	5.1	14.2	0.0	2.4	94	**9.0**	35.8	30.6	17.2	14.1	2.8	2.3
France																
2007	91	**5.9**	**31.7**	**26.9**	32.2	**22.2**	13.4	6.2	114	7.2	**34.9**	**26.7**	42.3	**21.2**	14.9	**5.9**
2012	187	**8.2**	**46.1**	**29.7**	38.4	**25.6**	18.2	8.3	203	9.4	**39.2**	**30.3**	38.9	**25.4**	15.7	**8.4**
2016	138	**9.1**	**28.9**	**22.8**	31.5	**18.0**	12.4	6.0	112	8.7	**24.8**	**23.1**	29.5	**18.5**	12.7	**6.3**
Germany																
2007	108	**5.1**	54.1	**32.2**	33.2	15.4	18.7	**3.7**	236	**12.1**	**37.8**	32.8	22.8	15.3	10.8	**3.5**
2012	181	**6.2**	48.8	**35.9**	33.3	17.7	15.1	**5.1**	355	**12.4**	**38.1**	36.5	27.5	17.4	10.4	**5.1**
2016	35	**2.2**	63.7	**32.4**	47.6	18.3	21.7	**6.4**	59	**3.8**	**38.8**	33.0	30.8	18.5	19.9	**6.2**
Greece																
2007	187	**18.0**	**45.1**	20.5	**44.5**	24.4	22.3	8.6	167	**15.4**	40.8	22.1	**50.6**	24.0	**24.4**	8.7
2012	277	**28.3**	**35.7**	21.0	**52.8**	27.1	27.7	6.0	390	**39.6**	26.4	24.1	**43.2**	28.6	**17.7**	8.4
2016	345	**32.6**	**32.0**	17.8	**41.9**	21.3	20.4	5.7	504	**48.1**	24.0	21.0	**34.0**	22.4	**13.1**	8.1
Hungary																
2007	114	**9.7**	53.6	**44.6**	**33.6**	**22.1**	9.9	**6.6**	217	**24.2**	46.5	45.2	**35.1**	**19.4**	**10.1**	**5.8**
2012	150	**15.3**	62.7	**38.6**	**49.5**	**23.2**	23.3	**7.7**	240	**25.3**	52.3	39.7	**42.7**	**21.7**	**17.9**	**7.5**
2016	106	**9.3**	71.4	**39.2**	**33.8**	**14.3**	18.4	**3.3**	134	**13.7**	60.9	39.3	**24.4**	**14.8**	**7.2**	**4.2**

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	Cannot afford to keep home adequately warm								Arrears in utility bills during the past 12 months							
	EP_T		Poor self-reported health		Reduced well-being		Likely depression		EP_A		Poor self-reported health		Reduced well-being		Likely depression	
	N	%	EP_T	nEP_T	EP_T	nEP_T	EP_T	nEP_T	N	%	EP_A	nEP_A	EPA	nEP_A	EP_A	nEP_A
Ireland																
2007	41	**4.1**	40.4	**16.4**	49.5	**14.3**	**17.0**	5.3	84	**7.8**	**42.7**	**15.1**	**50.4**	**12.9**	24.1	4.1
2012	99	**8.8**	49.5	**22.2**	48.8	**19.5**	**31.2**	5.6	138	**14.1**	**37.4**	**22.4**	**42.9**	**18.6**	17.8	6.3
2016	62	**5.0**	37.9	**14.9**	36.7	**13.8**	**11.7**	5.3	72	**6.9**	**31.3**	**14.9**	**25.3**	**14.1**	10.4	5.1
Italy																
2007	142	**9.1**	**44.6**	27.8	42.7	**28.7**	**15.8**	**8.8**	271	**18.1**	36.5	28.5	**34.1**	**29.7**	**14.2**	**8.5**
2012	203	**8.9**	**42.3**	29.1	38.2	**19.1**	**11.0**	**4.6**	563	**25.0**	34.0	29.8	**26.9**	**19.1**	**8.0**	**4.3**
2016	238	**11.8**	**57.6**	28.7	50.5	**26.1**	**24.0**	**10.9**	324	**16.1**	46.2	29.5	**47.7**	**25.6**	**22.4**	**10.7**
Latvia																
2007	171	**15.8**	73.4	58.9	54.7	**36.6**	22.7	**11.4**	125	**12.8**	60.2	61.8	**50.7**	**38.8**	18.0	**12.8**
2012	203	**19.0**	70.9	56.0	52.5	**30.6**	22.9	**10.8**	219	**22.5**	63.1	57.8	**46.8**	**31.3**	18.7	**11.3**
2016	90	**6.8**	85.2	58.4	48.3	**23.3**	18.7	**6.1**	117	**13.4**	64.3	60.0	**30.5**	**24.2**	9.9	**6.5**
Lithuania																
2007	418	**39.8**	67.3	52.6	41.3	27.3	14.4	6.7	122	**11.9**	58.9	**58.2**	39.2	**31.9**	11.7	9.4
2012	277	**23.3**	69.9	55.2	46.7	28.9	19.1	7.2	93	**9.3**	62.4	**58.7**	41.4	**32.3**	17.8	9.1
2016	157	**14.1**	68.7	49.7	38.9	24.2	18.1	7.1	62	**7.6**	70.9	**51.2**	43.4	**25.1**	15.9	8.1
Luxembourg																
2007	22	1.8	57.5	**33.1**	43.8	23.2	9.7	6.6	40	**4.5**	**51.9**	**32.5**	36.2	23.2	**12.1**	6.5
2012	24	2.1	47.0	**30.3**	58.3	21.9	28.4	6.7	44	**4.4**	**32.1**	**30.8**	46.5	21.3	**32.0**	6.1
2016	28	2.7	64.4	**23.5**	42.9	21.5	23.5	5.0	68	**7.2**	**31.3**	**23.8**	25.2	22.0	**7.6**	5.3
Malta																
2007	183	**17.9**	59.6	**34.4**	49.8	**38.2**	26.5	**12.0**	65	6.9	**60.9**	**37.1**	51.0	**39.8**	27.6	**13.5**
2012	263	**27.1**	49.5	**28.5**	46.4	**26.4**	16.7	**9.1**	89	9.1	**38.1**	**34.7**	50.4	**30.2**	20.0	**10.5**
2016	153	**14.5**	45.5	**28.2**	48.2	**23.5**	16.4	**6.9**	62	7.1	**36.4**	**30.8**	43.4	**26.3**	17.0	**7.8**
Netherlands																
2007	21	1.9	35.1	**27.1**	33.8	**13.2**	14.9	**3.3**	66	**5.7**	**42.0**	**26.6**	29.1	**12.7**	9.6	**3.2**
2012	21	2.1	65.5	**33.8**	34.3	**19.7**	17.8	**5.5**	95	**10.2**	**40.7**	**33.8**	29.0	**19.2**	11.7	**5.2**
2016	36	3.0	48.4	**26.5**	42.0	**19.4**	17.1	**7.3**	24	**2.2**	**38.8**	**26.8**	26.5	**19.2**	11.0	**7.4**

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	Cannot afford to keep home adequately warm								Arrears in utility bills during the past 12 months							
	EP_T		Poor self-reported health		Reduced well-being		Likely depression		EP_A		Poor self-reported health		Reduced well-being		Likely depression	
	N	%	EP_T	nEP_T	EP_T	nEP_T	EP_T	nEP_T	N	%	EP_A	nEP_A	EPA	nEP_A	EP_A	nEP_A
Poland																
2007	272	**17.3**	64.4	**37.5**	47.4	**27.8**	22.6	**10.1**	303	**19.3**	**56.0**	**38.7**	48.4	**27.3**	25.2	**9.7**
2012	521	**23.9**	67.2	**40.1**	51.5	**27.6**	24.5	**11.2**	506	**23.6**	**58.1**	**43.3**	43.7	**30.0**	20.6	**12.2**
2016	134	**11.8**	62.3	**32.1**	43.9	**21.1**	24.9	**7.1**	124	**9.8**	**66.2**	**32.6**	50.8	**20.9**	27.3	**7.2**
Portugal																
2007	199	**18.2**	59.6	**41.0**	40.9	**27.9**	20.5	**14.2**	124	**12.1**	**50.8**	**44.1**	**50.8**	**28.5**	**32.6**	**13.7**
2012	338	**32.3**	59.6	**42.3**	32.7	**12.9**	12.9	**4.9**	105	**11.0**	**58.8**	**46.5**	**29.0**	**18.0**	**13.2**	**6.8**
2016	296	**24.8**	53.6	**31.7**	35.0	**16.6**	15.0	**4.4**	85	**7.4**	**54.8**	**35.8**	**35.2**	**20.3**	**17.2**	**6.2**
Romania																
2007	242	22.0	**57.6**	43.4	60.6	**34.2**	33.4	**15.8**	238	**25.3**	50.1	44.3	53.6	**34.4**	26.2	**16.9**
2012	302	18.4	**73.5**	44.4	61.1	**30.7**	35.0	**12.7**	313	**21.5**	55.1	48.5	44.1	**34.4**	23.8	**14.7**
2016	189	17.2	**72.0**	44.0	57.5	**24.1**	23.7	**8.3**	196	**18.0**	66.2	44.6	43.5	**26.4**	17.6	**9.4**
Slovakia																
2007	123	**10.4**	42.1	34.5	**34.8**	**28.8**	**15.9**	**8.2**	146	**12.6**	47.2	34.0	**37.4**	**28.3**	19.6	**7.6**
2012	113	**10.6**	53.2	36.9	**64.6**	**26.6**	**38.7**	**8.5**	117	**12.2**	50.4	37.3	**56.7**	**26.8**	28.1	**9.5**
2016	38	**3.1**	61.5	35.0	**23.1**	**15.8**	**6.4**	**3.7**	46	**3.7**	76.4	34.6	**35.9**	**15.5**	17.8	**3.4**
Slovenia																
2007	30	2.3	75.6	38.7	**66.2**	26.1	**27.8**	6.6	102	9.3	52.2	38.3	51.6	24.5	18.2	6.0
2012	20	2.3	81.8	37.0	**73.5**	28.4	**56.4**	9.4	98	11.1	63.6	34.9	50.3	26.6	24.9	8.6
2016	37	3.5	52.5	35.6	**34.8**	25.1	**21.2**	8.2	83	8.9	36.4	36.2	34.7	24.5	16.1	7.9

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	Cannot afford to keep home adequately warm								Arrears in utility bills during the past 12 months							
	EP_T		Poor self-reported health		Reduced well-being		Likely depression		EP_A		Poor self-reported health		Reduced well-being		Likely depression	
	N	%	EP_T	nEP_T	EP_T	nEP_T	EP_T	nEP_T	N	%	EP_A	nEP_A	EPA	nEP_A	EP_A	nEP_A
Spain																
2007	111	**11.1**	45.5	**21.6**	32.2	18.2	9.5	5.7	78	**8.1**	27.6	24.4	28.7	18.9	15.0	5.6
2012	260	**17.3**	37.3	**27.0**	30.8	18.7	9.2	6.4	184	**12.8**	32.3	28.5	33.0	19.1	12.4	6.1
2016	129	**13.4**	43.3	**23.9**	30.9	16.4	10.7	4.7	78	**7.2**	34.8	26.2	38.1	16.9	14.6	4.9
Sweden																
2007	7	**0.7**	63.3	**31.8**	76.7	**15.2**	24.5	3.8	32	**3.3**	**50.3**	**31.6**	36.6	**15.1**	18.7	3.5
2012	12	**1.3**	65.7	**35.9**	70.4	**20.5**	25.1	4.7	31	**3.3**	**51.7**	**35.8**	47.0	**20.4**	7.5	4.9
2016	28	**2.3**	56.4	**30.0**	39.7	**21.4**	2.2	5.6	11	**1.3**	**89.8**	**29.9**	63.0	**21.3**	31.0	5.2
United Kingdom																
2007	79	**4.4**	**48.7**	**30.7**	**40.2**	**26.0**	27.8	**10.0**	144	**9.6**	**50.1**	**29.7**	49.7	**24.4**	29.1	**9.0**
2012	260	**12.0**	**61.2**	**33.9**	**57.3**	**29.0**	29.0	**9.5**	193	**9.9**	**50.3**	**35.7**	50.2	**30.4**	22.7	**10.7**
2016	86	**5.9**	**44.3**	**24.0**	**44.9**	**22.3**	23.2	**7.0**	83	**6.9**	**36.5**	**24.5**	46.4	**21.9**	20.5	**7.0**

EP_T: energy poverty indicator "Cannot afford to keep home adequately warm; nEP_T: no energy poverty measured with EP_T; EP_A: energy poverty indicator "One or more arrears in utility bills during the past 12 months"; nEP_A: No energy poverty measured with EP_A

Supplement 6. Age-adjusted prevalence ratio (PR) from Poisson regression models of poor self-reported health status in people with EP_T versus people without EP_T over time and p-values of year interactions (in bold when <0.05). Results are weighted and stratifies by country.

	Sample	2007		2012		2016		p-value of years interaction		
	size	PR	95% CI	PR	95% CI	PR	95% CI	2012/07	2016/07	2016/12
Austria	3239	1.38	(0.89 - 2.13)	1.16	(0.66 - 2.03)	0.81	(0.34 - 1.92)	0.635	0.276	0.485
Belgium	3030	1.74	(1.35 - 2.23)	1.69	(1.32 - 2.15)	1.87	(1.39 - 2.51)	0.867	0.716	0.602
Bulgaria	2965	1.14	(1.00 - 1.32)	1.47	(1.26 - 1.71)	1.53	(1.22 - 1.91)	**0.018**	**0.029**	0.756
Cyprus	3005	1.86	(1.55 - 2.25)	1.84	(1.52 - 2.23)	1.43	(1.10 - 1.87)	0.930	0.108	0.130
Czech Republic	3230	1.50	(1.23 - 1.82)	1.18	(0.88 - 1.58)	2.06	(1.66 - 2.56)	0.181	**0.033**	**0.003**
Denmark	3038	1.36	(0.75 - 2.44)	1.31	(0.82 - 2.07)	2.48	(1.70 - 3.62)	0.922	0.091	**0.035**
Estonia	2959	1.13	(0.96 - 1.32)	1.37	(1.23 - 1.53)	1.27	(1.09 - 1.47)	**0.047**	0.296	0.406
Finland	3067	0.93	(0.60 - 1.45)	1.17	(0.78 - 1.76)	1.41	(0.90 - 2.21)	0.459	0.202	0.549
France	4980	1.28	(0.93 - 1.75)	1.58	(1.33 - 1.87)	1.27	(0.93 - 1.74)	0.244	0.996	0.236
Germany	6656	1.85	(1.51 - 2.25)	1.54	(1.31 - 1.82)	1.93	(1.49 - 2.51)	0.178	0.775	0.151
Greece	3072	1.58	(1.27 - 1.96)	1.65	(1.36 - 2.01)	1.73	(1.39 - 2.16)	0.754	0.556	0.759
Hungary	3045	0.99	(0.83 - 1.17)	1.46	(1.26 - 1.68)	1.80	(1.48 - 2.19)	**0.001**	**0.000**	0.092
Ireland	3041	2.77	(1.73 - 4.44)	2.19	(1.71 - 2.80)	2.32	(1.55 - 3.46)	0.380	0.568	0.808
Italy	5670	1.40	(1.12 - 1.74)	1.33	(1.12 - 1.59)	1.67	(1.40 - 1.98)	0.735	0.215	0.073
Latvia	2951	1.22	(1.08 - 1.39)	1.16	(1.04 - 1.31)	1.26	(1.09 - 1.46)	0.558	0.771	0.398
Lithuania	3086	1.20	(1.06 - 1.35)	1.16	(1.04 - 1.29)	1.24	(1.05 - 1.45)	0.713	0.736	0.514
Luxembourg	3010	1.79	(1.22 - 2.63)	1.76	(1.10 - 2.81)	2.72	(1.90 - 3.88)	0.950	0.120	0.147
Malta	2923	1.62	(1.39 - 1.88)	1.53	(1.29 - 1.81)	1.44	(1.18 - 1.75)	0.620	0.351	0.645
Netherlands	3026	1.33	(0.71 - 2.49)	2.06	(1.45 - 2.92)	1.75	(1.22 - 2.53)	0.233	0.453	0.536
Poland	4659	1.40	(1.24 - 1.58)	1.46	(1.33 - 1.60)	1.50	(1.24 - 1.80)	0.611	0.558	0.800
Portugal	3047	1.21	(1.04 - 1.40)	1.33	(1.18 - 1.51)	1.33	(1.14 - 1.54)	0.320	0.400	0.952
Romania	3521	1.17	(1.01 - 1.36)	1.40	(1.27 - 1.54)	1.40	(1.19 - 1.64)	0.052	0.119	0.986
Slovakia	3120	1.06	(0.86 - 1.29)	1.20	(0.98 - 1.47)	1.48	(1.06 - 2.09)	0.375	0.093	0.294
Slovenia	3038	1.52	(1.14 - 2.04)	1.97	(1.35 - 2.88)	1.19	(0.92 - 1.54)	0.287	0.211	**0.030**
Spain	3500	1.97	(1.48 - 2.61)	1.41	(1.19 - 1.68)	1.92	(1.40 - 2.63)	0.051	0.917	0.094
Sweden	3051	2.13	(1.16 - 3.89)	1.59	(0.98 - 2.61)	1.68	(1.13 - 2.49)	0.468	0.521	0.869
United Kingdom	5028	1.59	(1.21 - 2.09)	1.86	(1.64 - 2.12)	1.94	(1.44 - 2.62)	0.305	0.344	0.816

EP_T: Energy poverty indicator “Cannot afford to keep home adequately warm”; PR: age-adjusted prevalence ratio; CI: Confidence intervals

Supplement 7. Age-adjusted prevalence ratio (PR) from Poisson regression models of reduced well-being in people with EP_T versus people without EP_T over time and p-values of year interactions (in bold when <0.05). Results are weighted and stratifies by country.

	Sample	2007		2012		2016		p-value of years interaction		
	size	PR	95% CI	PR	95% CI	PR	95% CI	2012/07	2016/07	2016/12
Austria	3211	1.40	(0.78 - 2.51)	1.22	(0.50 - 2.97)	0.77	(0.30 - 2.00)	0.809	0.299	0.486
Belgium	3030	2.24	(1.59 - 3.17)	2.65	(2.01 - 3.50)	2.15	(1.41 - 3.28)	0.458	0.881	0.416
Bulgaria	2846	1.32	(1.11 - 1.56)	1.88	(1.53 - 2.32)	2.25	(1.64 - 3.08)	**0.009**	**0.003**	0.354
Cyprus	2980	1.32	(1.10 - 1.60)	1.59	(1.31 - 1.94)	1.93	(1.52 - 2.44)	0.185	**0.015**	0.221
Czech Republic	3186	2.35	(1.85 - 2.97)	1.82	(1.31 - 2.52)	2.12	(1.42 - 3.16)	0.213	0.670	0.556
Denmark	3028	1.39	(0.62 - 3.13)	2.20	(0.99 - 4.93)	2.87	(1.63 - 5.03)	0.428	0.150	0.598
Estonia	2891	1.38	(1.07 - 1.78)	1.42	(1.16 - 1.74)	1.64	(1.23 - 2.19)	0.850	0.375	0.430
Finland	3047	0.90	(0.23 - 3.49)	1.29	(0.41 - 4.04)	0.35	(0.08 - 1.62)	0.695	0.367	0.184
France	4947	1.47	(1.06 - 2.05)	1.51	(1.21 - 1.87)	1.74	(1.27 - 2.39)	0.913	0.472	0.456
Germany	6617	2.18	(1.59 - 2.98)	1.89	(1.48 - 2.42)	2.60	(1.74 - 3.88)	0.491	0.498	0.190
Greece	3073	1.62	(1.28 - 2.05)	1.92	(1.62 - 2.28)	1.92	(1.57 - 2.37)	0.248	0.282	0.995
Hungary	3029	1.40	(1.03 - 1.91)	2.02	(1.62 - 2.52)	2.36	(1.56 - 3.55)	0.058	**0.047**	0.516
Ireland	3017	3.47	(2.24 - 5.37)	2.49	(1.92 - 3.23)	2.64	(1.69 - 4.13)	0.199	0.388	0.829
Italy	5633	1.43	(1.11 - 1.85)	1.94	(1.56 - 2.41)	1.82	(1.51 - 2.19)	0.075	0.137	0.657
Latvia	2887	1.47	(1.21 - 1.79)	1.62	(1.35 - 1.95)	1.89	(1.38 - 2.58)	0.475	0.182	0.409
Lithuania	3032	1.44	(1.16 - 1.78)	1.50	(1.25 - 1.80)	1.47	(1.09 - 1.97)	0.767	0.908	0.904
Luxembourg	2987	1.89	(1.11 - 3.22)	2.61	(1.79 - 3.82)	2.00	(1.16 - 3.47)	0.330	0.880	0.435
Malta	2871	1.28	(1.07 - 1.53)	1.71	(1.39 - 2.10)	2.00	(1.57 - 2.56)	**0.037**	**0.004**	0.339
Netherlands	3013	2.57	(1.31 - 5.06)	1.75	(0.92 - 3.32)	2.14	(1.39 - 3.31)	0.417	0.657	0.606
Poland	4541	1.54	(1.28 - 1.86)	1.74	(1.52 - 1.98)	1.84	(1.40 - 2.42)	0.306	0.289	0.701
Portugal	3018	1.27	(1.02 - 1.59)	2.43	(1.90 - 3.12)	1.75	(1.36 - 2.26)	**<0.001**	0.064	0.070
Romania	3440	1.60	(1.36 - 1.88)	1.74	(1.51 - 1.99)	2.11	(1.65 - 2.70)	0.440	0.063	0.172
Slovakia	3092	1.13	(0.87 - 1.48)	2.20	(1.80 - 2.70)	1.30	(0.64 - 2.67)	**<0.001**	0.719	0.168
Slovenia	3007	2.22	(1.58 - 3.10)	2.45	(1.78 - 3.36)	1.22	(0.80 - 1.86)	0.670	**0.031**	**0.010**
Spain	3477	1.68	(1.14 - 2.48)	1.67	(1.34 - 2.08)	1.95	(1.37 - 2.78)	0.981	0.583	0.474
Sweden	3046	5.00	(3.25 - 7.69)	3.73	(2.53 - 5.50)	2.01	(1.17 - 3.45)	0.323	**0.010**	0.069
United Kingdom	4994	1.55	(1.13 - 2.11)	1.97	(1.71 - 2.28)	2.01	(1.48 - 2.74)	0.165	0.240	0.911

EP_T: Energy poverty indicator “Cannot afford to keep home adequately warm”; PR: age-adjusted prevalence ratio; CI: Confidence intervals

Supplement 8. Age-adjusted prevalence ratio (PR) from Poisson regression models of likely depression in people with EP_T versus people without EP_T over time and p-values of year interactions (in bold when <0.05). Results are weighted and stratifies by country.

	Sample	2007		2012		2016		p-value of years interaction		
	size	PR	95% CI	PR	95% CI	PR	95% CI	2012/07	2016/07	2016/12
Austria	3211	2.18	(0.94 - 5.03)	0.90	(0.14 - 5.89)	1.26	(0.24 - 6.71)	0.399	0.566	0.793
Belgium	3030	2.97	(1.53 - 5.78)	4.09	(2.28 - 7.34)	2.06	(0.82 - 5.19)	0.482	0.528	0.221
Bulgaria	2846	1.74	(1.29 - 2.34)	2.36	(1.69 - 3.29)	3.61	(2.06 - 6.35)	0.181	**0.024**	0.200
Cyprus	2980	1.62	(1.19 - 2.21)	1.93	(1.44 - 2.60)	3.09	(2.20 - 4.34)	0.415	**0.005**	**0.041**
Czech Republic	3186	3.58	(2.16 - 5.95)	2.88	(1.51 - 5.46)	1.00	(0.40 - 2.53)	0.595	**0.018**	0.066
Denmark	3028	1.40	(0.31 - 6.20)	12.12	(4.95 - 29.65)	9.08	(4.44 - 18.53)	**0.015**	**0.026**	0.619
Estonia	2891	1.77	(0.93 - 3.36)	1.61	(0.97 - 2.68)	1.93	(1.00 - 3.74)	0.815	0.852	0.665
Finland	3047	0.00	(0.00 - 0.00)	0.00	(0.00 - 0.00)	0.00	(0.00 - 0.00)	0.787	0.778	0.579
France	4947	2.21	(1.23 - 3.97)	2.20	(1.53 - 3.17)	2.04	(1.18 - 3.52)	0.995	0.842	0.813
Germany	6617	5.10	(3.13 - 8.32)	2.97	(1.90 - 4.65)	3.39	(1.70 - 6.78)	0.109	0.345	0.754
Greece	3073	2.19	(1.44 - 3.32)	4.55	(3.18 - 6.52)	3.45	(2.31 - 5.15)	**0.009**	0.121	0.314
Hungary	3029	1.32	(0.73 - 2.41)	2.77	(1.88 - 4.09)	5.64	(2.76 - 11.53)	**0.041**	**0.002**	0.084
Ireland	3017	3.29	(1.46 - 7.39)	5.55	(3.60 - 8.57)	2.13	(0.88 - 5.19)	0.264	0.480	0.058
Italy	5633	1.68	(1.01 - 2.79)	2.28	(1.46 - 3.57)	2.00	(1.47 - 2.73)	0.373	0.560	0.635
Latvia	2887	1.93	(1.30 - 2.87)	1.90	(1.36 - 2.66)	2.50	(1.44 - 4.34)	0.950	0.453	0.403
Lithuania	3032	1.95	(1.27 - 3.00)	2.33	(1.63 - 3.32)	2.16	(1.32 - 3.54)	0.532	0.757	0.810
Luxembourg	2987	1.46	(0.38 - 5.66)	4.17	(1.94 - 8.98)	4.72	(1.76 - 12.67)	0.185	0.170	0.847
Malta	2871	2.13	(1.56 - 2.93)	1.74	(1.15 - 2.63)	2.26	(1.32 - 3.84)	0.440	0.860	0.450
Netherlands	3013	4.49	(1.35 - 14.95)	3.25	(1.24 - 8.50)	2.32	(1.10 - 4.89)	0.679	0.360	0.588
Poland	4541	1.90	(1.41 - 2.58)	1.96	(1.54 - 2.49)	2.87	(1.84 - 4.47)	0.881	0.132	0.137
Portugal	3018	1.21	(0.88 - 1.67)	2.51	(1.64 - 3.84)	2.71	(1.66 - 4.43)	**0.007**	**0.007**	0.810
Romania	3440	1.84	(1.41 - 2.39)	2.31	(1.84 - 2.91)	2.42	(1.54 - 3.81)	0.189	0.292	0.853
Slovakia	3092	1.76	(1.10 - 2.82)	3.98	(2.74 - 5.79)	1.48	(0.40 - 5.41)	**0.008**	0.803	0.150
Slovenia	3007	3.32	(1.78 - 6.20)	5.40	(3.45 - 8.43)	2.10	(1.16 - 3.83)	0.212	0.302	**0.013**
Spain	3477	1.56	(0.66 - 3.67)	1.48	(0.94 - 2.31)	2.35	(1.25 - 4.39)	0.914	0.452	0.240
Sweden	3046	6.58	(1.27 - 34.08)	5.17	(1.78 - 15.06)	0.39	(0.05 - 2.82)	0.810	**0.031**	**0.024**
United Kingdom	4994	2.77	(1.83 - 4.20)	3.09	(2.38 - 4.00)	3.38	(2.06 - 5.54)	0.668	0.550	0.751

EP_T: Energy poverty indicator "Cannot afford to keep home adequately warm"; PR: age-adjusted prevalence ratio; CI: Confidence intervals

Supplement 9. Age-adjusted population attributable risk percent (PAR%) to EP_T of poor self-reported health status over time and differences between years (in bold if difference is statistically significant). Results are weighted and stratified by country.

	2007		2012		2016		Differences between years (95% CI)			
	PAR%	95% CI	PAR%	95% CI	PAR%	95% CI	2007-2012		2012 - 2016	
Austria	1.32	(-0.57 - 2.98)	0.39	(-0.68 - 1.45)	-0.48	(-1.23 - 0.35)	-0.93	(-2.86 - 1.16)	-0.87	(-2.38 - 0.82)
Belgium	4.77	(4.05 - 7.64)	4.72	(2.05 - 6.54)	5.21	(2.15 - 8.87)	-0.05	(-2.62 - 2.24)	0.49	(-2.95 - 4.97)
Bulgaria	5.20	(1.77 - 6.32)	11.70	(8.78 - 17.58)	11.69	(1.28 - 17.10)	6.50	(2.55 - 15.81)	-0.01	(-11.15 - 5.08)
Cyprus	21.72	(18.89 - 27.00)	23.71	(20.86 - 28.46)	7.67	(2.63 - 12.84)	1.99	(-6.14 - 7.34)	-16.03	(-22.63 - -8.61)
Czech Republic	3.26	(2.44 - 4.39)	1.11	(-0.71 - 2.73)	5.00	(2.62 - 6.67)	-2.15	(-3.88 - -0.50)	3.89	(1.02 - 6.59)
Denmark	0.90	(-0.17 - 2.92)	0.61	(-0.37 - 1.74)	4.00	(2.64 - 6.32)	-0.29	(-2.57 - 1.38)	3.40	(2.39 - 5.55)
Estonia	1.56	(-0.05 - 3.65)	9.45	(6.68 - 12.94)	1.97	(0.79 - 3.30)	7.89	(3.57 - 10.36)	-7.48	(-12.15 - -3.39)
Finland	-0.14	(-0.65 - 0.90)	0.33	(-0.24 - 1.14)	0.82	(0.14 - 2.44)	0.46	(-0.39 - 1.61)	0.49	(-0.69 - 2.06)
France	1.50	(-0.71 - 3.82)	4.47	(2.25 - 6.17)	3.06	(0.04 - 6.65)	2.97	(-0.32 - 5.99)	-1.41	(-4.77 - 4.40)
Germany	3.99	(2.98 - 5.88)	2.81	(1.32 - 3.79)	1.98	(0.64 - 3.72)	-1.18	(-3.11 - -0.02)	-0.83	(-2.47 - 1.15)
Greece	12.65	(7.44 - 20.10)	15.82	(10.61 - 24.73)	19.50	(16.42 - 23.13)	3.17	(-3.56 - 16.29)	3.68	(-6.83 - 9.26)
Hungary	-0.20	(-2.52 - 1.94)	6.86	(4.80 - 8.39)	7.93	(4.34 - 9.68)	7.06	(5.24 - 9.60)	1.07	(-4.05 - 3.83)
Ireland	6.51	(2.32 - 11.29)	9.79	(6.80 - 12.41)	7.89	(2.12 - 11.52)	3.28	(-1.16 - 7.12)	-1.90	(-7.36 - 2.32)
Italy	4.12	(-0.01 - 6.87)	3.15	(2.55 - 4.23)	8.57	(4.73 - 11.37)	-0.97	(-3.49 - 3.11)	5.42	(1.64 - 7.21)
Latvia	3.87	(2.02 - 5.00)	3.46	(0.85 - 6.04)	2.60	(0.97 - 2.86)	-0.41	(-2.76 - 2.27)	-0.86	(-3.18 - 0.12)
Lithuania	7.78	(3.35 - 11.41)	4.01	(0.94 - 5.28)	4.01	(2.93 - 6.72)	-3.77	(-10.47 - 1.93)	0.00	(-1.08 - 4.02)
Luxembourg	1.68	(0.56 - 3.90)	1.54	(0.04 - 2.92)	4.49	(4.07 - 7.44)	-0.15	(-2.09 - 1.70)	2.96	(1.69 - 5.41)
Malta	10.67	(8.22 - 13.04)	13.61	(9.30 - 18.36)	7.11	(5.05 - 14.54)	2.94	(-1.80 - 9.43)	-6.50	(-12.18 - -0.88)
Netherlands	0.68	(-1.17 - 1.59)	2.01	(1.04 - 2.83)	2.71	(0.24 - 5.59)	1.33	(0.19 - 3.46)	0.70	(-0.81 - 3.40)
Poland	7.95	(5.46 - 11.61)	10.50	(10.03 - 14.48)	7.29	(5.85 - 10.17)	2.55	(0.32 - 6.20)	-3.21	(-7.11 - -1.72)
Portugal	4.75	(1.83 - 8.05)	10.31	(8.29 - 13.71)	9.98	(4.70 - 16.14)	5.56	(1.08 - 10.44)	-0.33	(-8.05 - 4.45)
Romania	4.51	(0.57 - 7.45)	8.16	(6.28 - 9.58)	7.88	(5.85 - 10.58)	3.65	(-1.17 - 7.40)	-0.28	(-2.95 - 3.31)
Slovakia	0.68	(-1.55 - 2.35)	2.51	(0.69 - 5.05)	1.86	(0.42 - 2.78)	1.83	(-0.42 - 5.75)	-0.65	(-3.78 - 2.10)
Slovenia	1.83	(0.50 - 3.96)	2.28	(1.22 - 2.83)	0.81	(-0.20 - 1.31)	0.45	(-1.30 - 2.30)	-1.47	(-3.00 - -0.70)
Spain	10.14	(7.88 - 14.92)	6.64	(2.97 - 8.96)	9.84	(5.08 - 12.22)	-3.51	(-11.43 - -0.03)	3.21	(-1.64 - 5.45)
Sweden	0.69	(-0.03 - 1.35)	0.78	(-0.22 - 2.03)	1.94	(0.44 - 3.81)	0.09	(-0.65 - 0.90)	1.16	(-0.02 - 3.48)
United Kingdom	2.92	(1.68 - 4.40)	8.71	(7.19 - 11.18)	5.60	(4.03 - 7.85)	5.78	(3.00 - 9.49)	-3.11	(-5.33 - -0.86)

EP_T: Energy poverty indicator “Cannot afford to keep home adequately warm”; PAR%: age-adjusted population attributable risk percent; CI: Confidence intervals

Supplement 10. Age-adjusted population attributable risk percent (PAR%) to EP_T of reduced well-being over time and differences between years (in bold if difference is statistically significant). Results are weighted and stratified by country.

	2007		2012		2016		Differences between years (95% CI)			
	PAR%	95% CI	PAR%	95% CI	PAR%	95% CI	2007-2012		2012 - 2016	
Austria	1.42	(-0.41 - 5.81)	0.49	(-1.46 - 2.34)	-0.59	(-2.17 - 0.34)	-0.93	(-4.57 - 2.38)	-1.08	(-4.30 - 1.80)
Belgium	7.92	(4.27 - 13.29)	10.57	(7.30 - 19.04)	7.60	(2.67 - 15.36)	2.64	(-0.44 - 14.77)	-2.97	(-13.16 - 2.51)
Bulgaria	10.47	(7.12 - 15.00)	19.74	(14.42 - 32.67)	22.95	(20.30 - 30.53)	9.27	(3.12 - 21.74)	3.20	(-8.07 - 15.45)
Cyprus	8.95	(2.81 - 10.47)	17.87	(13.50 - 23.27)	14.93	(12.34 - 20.66)	8.92	(5.23 - 17.72)	-2.94	(-9.98 - 0.21)
Czech Republic	7.66	(4.20 - 11.44)	4.51	(2.60 - 7.11)	5.12	(0.07 - 10.42)	-3.15	(-7.47 - 1.81)	0.61	(-5.27 - 7.76)
Denmark	1.00	(-0.59 - 5.21)	2.44	(0.08 - 5.39)	5.29	(0.73 - 12.08)	1.45	(-4.93 - 4.29)	2.85	(-0.62 - 11.80)
Estonia	4.47	(1.44 - 7.11)	10.44	(4.44 - 14.14)	4.47	(0.55 - 8.84)	5.97	(0.37 - 11.79)	-5.97	(-10.89 - -0.04)
Finland	-0.12	(-1.50 - 0.75)	0.41	(-0.81 - 1.21)	-1.18	(-2.13 - 0.88)	0.53	(-0.71 - 1.79)	-1.59	(-3.02 - 1.33)
France	2.68	(1.02 - 4.07)	3.99	(3.10 - 6.82)	7.93	(3.14 - 14.18)	1.32	(0.09 - 4.25)	3.94	(-0.55 - 9.92)
Germany	5.94	(3.70 - 9.19)	5.01	(2.91 - 7.24)	3.33	(1.23 - 4.37)	-0.93	(-5.50 - 1.63)	-1.68	(-3.29 - 0.44)
Greece	11.49	(6.14 - 17.85)	20.85	(13.93 - 25.98)	22.99	(13.21 - 27.12)	9.36	(-0.32 - 14.42)	2.14	(-7.84 - 8.75)
Hungary	4.74	(-0.87 - 6.81)	13.61	(8.58 - 16.59)	12.43	(2.10 - 15.38)	8.87	(1.77 - 17.26)	-1.18	(-6.57 - 3.10)
Ireland	9.24	(4.52 - 13.63)	12.33	(6.12 - 15.36)	9.21	(7.07 - 13.58)	3.10	(-5.07 - 6.56)	-3.12	(-6.23 - 1.32)
Italy	4.04	(1.84 - 7.06)	8.11	(6.48 - 13.21)	9.33	(7.59 - 12.48)	4.07	(1.74 - 8.30)	1.22	(-3.74 - 3.35)
Latvia	7.67	(1.97 - 11.63)	11.74	(7.11 - 19.43)	8.01	(2.82 - 11.87)	4.08	(-2.61 - 14.88)	-3.73	(-11.35 - 2.85)
Lithuania	15.88	(8.48 - 19.32)	11.45	(7.54 - 15.97)	7.46	(5.55 - 13.33)	-4.43	(-11.78 - 4.11)	-3.99	(-7.71 - 2.32)
Luxembourg	1.93	(-0.03 - 5.50)	3.81	(0.75 - 5.23)	2.71	(1.36 - 6.62)	1.89	(-1.57 - 3.47)	-1.10	(-3.02 - 3.28)
Malta	5.07	(1.16 - 8.35)	16.66	(10.94 - 24.34)	13.73	(8.12 - 20.58)	11.59	(4.59 - 17.97)	-2.93	(-13.92 - 4.60)
Netherlands	3.17	(0.94 - 11.00)	1.53	(-1.11 - 3.54)	3.95	(0.99 - 5.81)	-1.64	(-12.11 - 1.02)	2.42	(-0.08 - 6.56)
Poland	9.82	(3.90 - 13.59)	15.35	(14.18 - 20.30)	10.87	(6.77 - 15.57)	5.54	(2.88 - 10.79)	-4.48	(-12.23 - -0.69)
Portugal	5.86	(0.51 - 8.70)	32.91	(28.09 - 38.61)	19.63	(8.60 - 35.88)	27.06	(22.57 - 34.14)	-13.28	(-30.01 - 1.56)
Romania	13.86	(8.24 - 17.97)	13.83	(9.81 - 15.01)	18.95	(16.72 - 26.90)	-0.03	(-3.26 - 6.76)	5.12	(4.04 - 13.85)
Slovakia	1.53	(-1.42 - 4.03)	12.80	(9.24 - 15.13)	1.16	(-0.70 - 3.10)	11.27	(6.84 - 16.54)	-11.64	(-14.35 - -7.76)
Slovenia	3.80	(2.11 - 5.93)	3.11	(1.42 - 6.35)	0.90	(-0.53 - 1.68)	-0.70	(-3.65 - 4.21)	-2.21	(-6.69 - -0.05)
Spain	7.27	(2.22 - 13.97)	10.41	(3.81 - 14.00)	10.54	(6.88 - 16.91)	3.13	(-7.95 - 10.74)	0.13	(-5.22 - 13.11)
Sweden	2.85	(0.45 - 3.61)	3.00	(2.46 - 4.58)	2.46	(0.85 - 5.01)	0.15	(-0.24 - 2.55)	-0.54	(-2.57 - 2.54)
United Kingdom	2.79	(0.78 - 6.57)	10.20	(6.85 - 12.14)	6.30	(2.45 - 8.95)	7.41	(3.71 - 10.09)	-3.90	(-7.87 - -0.13)

EP_T: Energy poverty indicator “Cannot afford to keep home adequately warm”; PAR%: age-adjusted population attributable risk percent; CI: Confidence intervals

Supplement 11. Population attributable risk percent (PAR%) to EP_T of likely depression over time and differences between years (in bold if difference is statistically significant). Results are weighted and stratified by country.

	2007		2012		2016		Differences between years (95% CI)			
	PAR%	95% CI	PAR%	95% CI	PAR%	95% CI	2007-2012		2012 - 2016	
Austria	4.03	(-0.85 - 12.00)	-0.24	(-3.01 - 4.42)	0.63	(-2.99 - 7.63)	-4.26	(-12.85 - 2.70)	0.87	(-5.07 - 8.77)
Belgium	12.00	(1.22 - 22.63)	18.10	(6.86 - 31.13)	6.96	(-3.30 - 20.00)	6.11	(-9.50 - 22.50)	-11.14	(-28.00 - 6.52)
Bulgaria	21.89	(9.52 - 33.96)	27.74	(16.59 - 39.81)	39.33	(20.17 - 57.20)	5.85	(-9.78 - 23.00)	11.59	(-11.04 - 33.79)
Cyprus	16.02	(5.28 - 26.81)	25.52	(13.07 - 37.31)	28.41	(18.81 - 39.19)	9.51	(-6.46 - 26.11)	2.89	(-12.54 - 18.08)
Czech Republic	14.43	(6.00 - 24.32)	10.19	(1.65 - 20.78)	0.01	(-3.94 - 6.11)	-4.23	(-16.81 - 8.83)	-10.18	(-20.90 - 0.48)
Denmark	1.02	(-2.82 - 8.25)	18.62	(4.01 - 36.02)	19.28	(5.52 - 33.57)	17.60	(2.33 - 35.28)	0.66	(-21.93 - 21.51)
Estonia	8.91	(-2.11 - 21.43)	14.76	(-3.16 - 30.87)	6.68	(-1.39 - 16.09)	5.86	(-16.04 - 25.69)	-8.08	(-26.17 - 11.18)
Finland	-1.31	(-2.19 - -0.65)	-1.50	(-2.42 - -0.78)	-1.84	(-2.83 - -1.03)	-0.18	(-1.27 - 0.87)	-0.34	(-1.63 - 0.85)
France	6.47	(0.53 - 13.67)	8.97	(4.01 - 15.45)	10.72	(0.23 - 21.65)	2.50	(-5.99 - 11.26)	1.75	(-10.61 - 13.56)
Germany	18.03	(9.08 - 27.84)	10.42	(3.86 - 17.41)	4.91	(0.63 - 10.35)	-7.61	(-19.53 - 4.03)	-5.51	(-13.78 - 2.41)
Greece	20.69	(8.02 - 33.87)	50.41	(38.14 - 61.80)	44.42	(30.96 - 59.77)	29.72	(11.76 - 47.30)	-5.99	(-23.64 - 14.20)
Hungary	4.01	(-4.76 - 15.58)	21.84	(11.51 - 32.15)	33.01	(12.37 - 52.08)	17.83	(1.16 - 32.37)	11.17	(-10.65 - 32.38)
Ireland	8.53	(0.14 - 20.42)	29.96	(18.53 - 42.14)	6.63	(-2.65 - 18.15)	21.43	(5.21 - 36.61)	-23.33	(-38.44 - -7.37)
Italy	6.37	(-0.20 - 14.56)	10.86	(3.43 - 19.40)	11.49	(5.10 - 18.09)	4.49	(-6.35 - 15.79)	0.63	(-9.84 - 10.16)
Latvia	14.41	(4.84 - 24.74)	16.70	(7.30 - 27.19)	13.72	(3.67 - 25.55)	2.29	(-11.76 - 16.28)	-2.98	(-17.67 - 12.80)
Lithuania	29.17	(9.65 - 47.75)	26.09	(14.10 - 37.66)	17.53	(4.14 - 31.27)	-3.07	(-24.16 - 20.79)	-8.56	(-26.58 - 9.83)
Luxembourg	1.00	(-2.50 - 5.92)	7.15	(0.90 - 15.12)	9.36	(-1.80 - 21.17)	6.15	(-1.98 - 14.90)	2.21	(-11.02 - 15.00)
Malta	17.83	(9.10 - 27.16)	17.49	(2.92 - 31.68)	17.07	(3.81 - 30.95)	-0.35	(-17.61 - 16.15)	-0.42	(-20.13 - 18.62)
Netherlands	6.77	(-1.88 - 17.29)	4.44	(-0.80 - 11.87)	4.52	(-0.55 - 11.44)	-2.33	(-14.74 - 9.30)	0.09	(-8.52 - 9.08)
Poland	15.88	(7.58 - 24.72)	19.50	(11.30 - 27.55)	22.13	(9.91 - 34.15)	3.62	(-8.17 - 15.21)	2.63	(-12.64 - 16.67)
Portugal	4.74	(-3.23 - 13.61)	34.11	(17.69 - 51.12)	36.66	(18.93 - 55.89)	29.38	(11.68 - 47.90)	2.54	(-21.38 - 28.95)
Romania	18.85	(9.90 - 27.69)	22.78	(15.07 - 30.67)	23.66	(9.24 - 37.84)	3.93	(-7.92 - 15.94)	0.88	(-15.98 - 16.80)
Slovakia	8.39	(0.03 - 17.22)	27.17	(17.12 - 38.01)	1.82	(-3.43 - 10.92)	18.78	(5.03 - 33.03)	-25.35	(-37.15 - -10.85)
Slovenia	7.58	(0.90 - 15.48)	9.47	(3.82 - 15.61)	4.51	(-0.35 - 10.04)	1.90	(-7.98 - 10.78)	-4.96	(-13.18 - 3.12)
Spain	6.07	(-7.16 - 20.66)	7.61	(-1.44 - 17.07)	14.18	(1.27 - 28.45)	1.54	(-14.73 - 18.04)	6.57	(-9.66 - 24.01)
Sweden	3.62	(-0.99 - 11.06)	4.90	(-0.88 - 12.80)	-1.70	(-3.59 - 1.36)	1.29	(-8.33 - 11.52)	-6.60	(-14.92 - -0.20)
United Kingdom	8.43	(3.38 - 14.28)	19.24	(13.25 - 25.91)	13.41	(5.97 - 22.46)	10.81	(2.92 - 18.99)	-5.83	(-15.75 - 5.28)

EP_T: Energy poverty indicator “Cannot afford to keep home adequately warm”; PAR%: age-adjusted population attributable risk percent; CI: Confidence intervals

Supplement 12. Age-adjusted prevalence ratio (PR) from Poisson regression models of poor self-reported health status in people with EP_A versus people without EP_A over time and p-values of year interactions (in bold when <0.05). Results are weighted and stratifies by country.

	Sample	2007		2012		2016		p-value of years interaction		
	size	PR	95% CI	PR	95% CI	PR	95% CI	2012/07	2016/07	2016/12
Austria	3226	1.88	(1.52 - 2.32)	1.36	(0.98 - 1.91)	2.86	(2.07 - 3.94)	0.113	**0.031**	**0.002**
Belgium	3017	1.28	(1.02 - 1.61)	1.35	(1.07 - 1.69)	1.76	(1.28 - 2.42)	0.764	0.109	0.176
Bulgaria	2984	1.33	(1.14 - 1.54)	1.41	(1.20 - 1.67)	1.47	(1.16 - 1.85)	0.570	0.475	0.805
Cyprus	2994	1.56	(1.28 - 1.90)	1.66	(1.37 - 2.01)	1.72	(1.29 - 2.31)	0.655	0.575	0.833
Czech Republic	3227	1.38	(1.07 - 1.77)	1.21	(0.97 - 1.51)	2.11	(1.35 - 3.31)	0.449	0.105	**0.030**
Denmark	3027	1.12	(0.51 - 2.46)	1.27	(0.71 - 2.26)	2.17	(1.27 - 3.70)	0.796	0.170	0.178
Estonia	3018	1.23	(0.99 - 1.52)	1.39	(1.16 - 1.67)	1.56	(1.19 - 2.04)	0.381	0.180	0.501
Finland	3066	1.37	(1.07 - 1.75)	1.69	(1.21 - 2.36)	1.38	(0.94 - 2.05)	0.318	0.964	0.448
France	4989	1.70	(1.28 - 2.25)	1.60	(1.32 - 1.94)	1.54	(1.07 - 2.23)	0.742	0.693	0.865
Germany	6642	1.24	(1.05 - 1.48)	1.21	(1.03 - 1.41)	1.51	(1.10 - 2.09)	0.790	0.295	0.212
Greece	3092	1.68	(1.33 - 2.13)	1.50	(1.23 - 1.82)	1.52	(1.22 - 1.89)	0.460	0.534	0.930
Hungary	3032	1.21	(1.04 - 1.42)	1.63	(1.41 - 1.88)	1.79	(1.49 - 2.15)	**0.007**	**0.002**	0.417
Ireland	3020	3.11	(2.21 - 4.38)	2.20	(1.67 - 2.89)	2.41	(1.56 - 3.73)	0.123	0.371	0.717
Italy	5699	1.31	(1.08 - 1.61)	1.21	(1.06 - 1.39)	1.74	(1.50 - 2.03)	0.512	**0.028**	**0.001**
Latvia	2990	1.04	(0.87 - 1.24)	1.19	(1.05 - 1.35)	1.20	(1.01 - 1.43)	0.226	0.250	0.922
Lithuania	3136	1.05	(0.86 - 1.27)	1.34	(1.12 - 1.61)	1.50	(1.17 - 1.93)	0.068	**0.026**	0.470
Luxembourg	2985	1.96	(1.35 - 2.83)	1.33	(0.81 - 2.17)	1.61	(1.06 - 2.43)	0.212	0.482	0.559
Malta	2928	1.91	(1.56 - 2.35)	1.10	(0.80 - 1.53)	1.52	(1.07 - 2.16)	**0.005**	0.263	0.191
Netherlands	3012	1.45	(1.06 - 1.99)	1.28	(0.97 - 1.68)	1.63	(0.95 - 2.80)	0.563	0.716	0.438
Poland	4710	1.38	(1.22 - 1.55)	1.29	(1.17 - 1.42)	1.84	(1.54 - 2.18)	0.411	**0.007**	**0.001**
Portugal	3058	1.24	(1.02 - 1.50)	1.55	(1.30 - 1.86)	1.36	(1.05 - 1.76)	0.096	0.569	0.417
Romania	3492	1.16	(0.99 - 1.37)	1.32	(1.17 - 1.49)	1.49	(1.27 - 1.76)	0.223	**0.034**	0.232
Slovakia	3127	1.39	(1.14 - 1.70)	1.47	(1.17 - 1.83)	1.96	(1.59 - 2.41)	0.738	**0.020**	0.061
Slovenia	3018	1.47	(1.16 - 1.85)	1.81	(1.47 - 2.23)	1.18	(0.89 - 1.56)	0.189	0.233	**0.016**
Spain	3493	1.26	(0.83 - 1.89)	1.41	(1.13 - 1.74)	1.83	(1.34 - 2.51)	0.628	0.150	0.171
Sweden	3062	1.75	(1.21 - 2.53)	1.72	(1.18 - 2.51)	3.16	(2.32 - 4.29)	0.948	**0.016**	**0.014**
United Kingdom	5019	1.95	(1.59 - 2.40)	1.67	(1.41 - 1.98)	1.94	(1.39 - 2.72)	0.254	0.978	0.435

EP_A: energy poverty indicator "One or more arrears in utility bills during the past 12 months"; PR: age-adjusted prevalence ratio; CI: confidence intervals

Supplement 13. Age-adjusted prevalence ratio (PR) from Poisson regression models of reduced well-being in people with EP_A versus people without EP_A over time and p-values of year interactions (in bold when <0.05). Results are weighted and stratifies by country.

	Sample	2007		2012		2016		p-value of years interaction		
	size	PR	95% CI	PR	95% CI	PR	95% CI	2012/07	2016/07	2016/12
Austria	3201	2.88	(2.30 - 3.61)	1.24	(0.74 - 2.05)	3.32	(2.31 - 4.78)	**0.003**	0.512	**0.002**
Belgium	3016	1.67	(1.22 - 2.29)	1.61	(1.19 - 2.18)	2.79	(1.96 - 3.95)	0.864	**0.033**	**0.019**
Bulgaria	2860	1.49	(1.24 - 1.78)	1.90	(1.53 - 2.36)	2.51	(1.81 - 3.49)	0.086	**0.006**	0.164
Cyprus	2969	1.62	(1.35 - 1.95)	1.77	(1.45 - 2.15)	1.80	(1.39 - 2.33)	0.532	0.515	0.906
Czech Republic	3186	2.28	(1.72 - 3.02)	1.71	(1.31 - 2.22)	2.03	(1.21 - 3.40)	0.142	0.699	0.559
Denmark	3017	1.36	(0.53 - 3.50)	1.39	(0.58 - 3.31)	1.61	(0.73 - 3.55)	0.978	0.794	0.808
Estonia	2944	1.53	(1.12 - 2.08)	1.37	(1.01 - 1.85)	1.57	(1.01 - 2.44)	0.618	0.918	0.611
Finland	3046	1.78	(1.19 - 2.65)	2.07	(1.28 - 3.35)	1.20	(0.69 - 2.08)	0.633	0.257	0.142
France	4955	2.15	(1.65 - 2.79)	1.63	(1.32 - 2.01)	1.77	(1.22 - 2.56)	0.103	0.398	0.705
Germany	6603	1.49	(1.12 - 1.99)	1.59	(1.29 - 1.97)	1.69	(1.08 - 2.65)	0.718	0.648	0.816
Greece	3093	2.02	(1.62 - 2.52)	1.68	(1.42 - 2.00)	1.65	(1.33 - 2.04)	0.204	0.200	0.891
Hungary	3016	1.99	(1.54 - 2.57)	2.17	(1.75 - 2.68)	1.76	(1.18 - 2.61)	0.612	0.601	0.354
Ireland	2997	3.96	(2.85 - 5.51)	2.38	(1.84 - 3.09)	1.82	(1.11 - 2.99)	**0.017**	**0.011**	0.342
Italy	5664	1.16	(0.92 - 1.46)	1.43	(1.19 - 1.71)	1.94	(1.64 - 2.29)	0.170	**<0.001**	**0.016**
Latvia	2923	1.36	(1.05 - 1.76)	1.56	(1.29 - 1.90)	1.35	(0.92 - 1.99)	0.387	0.983	0.504
Lithuania	3082	1.26	(0.94 - 1.71)	1.53	(1.16 - 2.00)	1.84	(1.23 - 2.75)	0.360	0.144	0.452
Luxembourg	2963	1.50	(0.93 - 2.42)	2.09	(1.43 - 3.08)	1.11	(0.69 - 1.78)	0.287	0.377	**0.040**
Malta	2875	1.31	(1.00 - 1.70)	1.65	(1.27 - 2.15)	1.73	(1.18 - 2.52)	0.216	0.236	0.856
Netherlands	2999	2.25	(1.43 - 3.55)	1.53	(1.06 - 2.20)	1.40	(0.69 - 2.86)	0.194	0.273	0.832
Poland	4577	1.71	(1.45 - 2.02)	1.42	(1.24 - 1.63)	2.30	(1.79 - 2.96)	0.094	0.056	**0.001**
Portugal	3027	1.87	(1.45 - 2.41)	1.88	(1.37 - 2.59)	1.58	(1.08 - 2.32)	0.979	0.477	0.501
Romania	3414	1.59	(1.33 - 1.89)	1.45	(1.24 - 1.69)	1.66	(1.26 - 2.19)	0.436	0.792	0.396
Slovakia	3101	1.33	(1.02 - 1.74)	2.18	(1.74 - 2.74)	2.11	(1.23 - 3.62)	**0.005**	0.135	0.907
Slovenia	2988	2.19	(1.66 - 2.88)	1.87	(1.45 - 2.41)	1.54	(1.11 - 2.14)	0.404	0.108	0.366
Spain	3469	1.58	(1.01 - 2.49)	1.92	(1.50 - 2.45)	2.64	(1.83 - 3.82)	0.465	0.083	0.151
Sweden	3056	2.31	(1.35 - 3.97)	2.13	(1.42 - 3.18)	2.89	(1.79 - 4.65)	0.806	0.546	0.335
United Kingdom	4986	2.04	(1.65 - 2.53)	1.66	(1.39 - 1.99)	2.12	(1.56 - 2.88)	0.142	0.840	0.170

EP_A: energy poverty indicator “One or more arrears in utility bills during the past 12 months”; PR: age-adjusted prevalence ratio; CI: confidence intervals

Supplement 14. Age-adjusted prevalence ratio (PR) from Poisson regression models of likely depression in people with EP_A versus people without EP_A over time and p-values of year interactions (in bold when <0.05). Results are weighted and stratifies by country.

	Sample	2007		2012		2016		p-value of years interaction		
	size	PR	95% CI	PR	95% CI	PR	95% CI	2012/07	2016/07	2016/12
Austria	3201	6.31	(4.00 - 9.94)	1.36	(0.50 - 3.71)	3.43	(1.31 - 8.98)	**0.006**	0.263	0.191
Belgium	3016	2.01	(1.09 - 3.71)	1.55	(0.80 - 3.01)	5.79	(3.05 - 11.01)	0.573	**0.021**	**0.005**
Bulgaria	2860	2.05	(1.51 - 2.78)	2.48	(1.75 - 3.51)	2.41	(1.34 - 4.35)	0.416	0.626	0.937
Cyprus	2969	1.76	(1.28 - 2.42)	2.20	(1.63 - 2.95)	2.52	(1.75 - 3.65)	0.317	0.147	0.563
Czech Republic	3186	3.83	(2.35 - 6.23)	2.12	(1.17 - 3.83)	3.81	(1.60 - 9.07)	0.129	0.990	0.274
Denmark	3017	0.62	(0.14 - 2.79)	3.36	(1.10 -10.23)	2.60	(0.77 - 8.72)	0.075	0.141	0.758
Estonia	2944	2.18	(1.23 - 3.86)	1.37	(0.64 - 2.93)	0.71	(0.25 - 2.00)	0.336	0.062	0.314
Finland	3046	2.21	(0.89 - 5.50)	2.50	(0.72 - 8.67)	1.21	(0.31 - 4.77)	0.879	0.472	0.442
France	4955	2.93	(1.71 - 5.04)	2.11	(1.47 - 3.03)	2.48	(1.36 - 4.52)	0.317	0.678	0.656
Germany	6603	3.08	(1.88 - 5.05)	2.04	(1.37 - 3.04)	3.26	(1.72 - 6.18)	0.206	0.887	0.224
Greece	3093	2.65	(1.77 - 3.96)	2.49	(1.77 - 3.52)	1.84	(1.25 - 2.71)	0.827	0.203	0.256
Hungary	3016	2.00	(1.20 - 3.34)	2.79	(1.91 - 4.08)	1.88	(0.78 - 4.58)	0.308	0.907	0.427
Ireland	2997	6.15	(3.41-11.09)	3.08	(1.90 - 5.00)	2.15	(0.87 - 5.27)	0.073	0.054	0.482
Italy	5664	1.71	(1.08 - 2.71)	1.88	(1.28 - 2.76)	2.22	(1.66 - 2.96)	0.760	0.345	0.498
Latvia	2923	1.55	(0.95 - 2.56)	1.87	(1.30 - 2.69)	1.82	(0.92 - 3.63)	0.554	0.713	0.946
Lithuania	3082	1.33	(0.78 - 2.28)	2.96	(1.83 - 4.78)	2.27	(1.10 - 4.71)	**0.030**	0.245	0.553
Luxembourg	2963	1.82	(0.65 - 5.07)	5.15	(2.89 - 9.20)	1.40	(0.65 - 3.04)	0.083	0.688	**0.008**
Malta	2875	2.15	(1.39 - 3.33)	1.89	(1.11 - 3.21)	2.43	(1.19 - 4.95)	0.709	0.778	0.581
Netherlands	2999	2.91	(1.17 - 7.24)	2.28	(1.15 - 4.51)	1.51	(0.48 - 4.70)	0.671	0.375	0.541
Poland	4577	2.49	(1.87 - 3.29)	1.63	(1.27 - 2.10)	3.48	(2.27 - 5.34)	**0.029**	0.198	**0.003**
Portugal	3027	2.55	(1.78 - 3.65)	2.39	(1.42 - 4.02)	2.50	(1.48 - 4.22)	0.836	0.949	0.903
Romania	3414	1.58	(1.17 - 2.14)	1.91	(1.49 - 2.45)	1.90	(1.15 - 3.13)	0.341	0.544	0.977
Slovakia	3101	2.61	(1.65 - 4.11)	3.11	(2.04 - 4.76)	4.62	(1.68 - 12.68)	0.578	0.310	0.479
Slovenia	2988	3.28	(1.81 - 5.96)	2.86	(1.84 - 4.46)	2.39	(1.43 - 4.00)	0.719	0.431	0.602
Spain	3469	2.81	(1.32 - 5.96)	2.33	(1.48 - 3.66)	3.66	(1.94 - 6.88)	0.676	0.599	0.255
Sweden	3056	5.42	(2.34-12.53)	1.61	(0.41 - 6.29)	6.04	(1.79 - 20.31)	0.135	0.887	0.157
United Kingdom	4986	3.47	(2.46 - 4.91)	2.30	(1.68 - 3.15)	3.32	(1.98 - 5.57)	0.082	0.886	0.229

EP_A: energy poverty indicator "One or more arrears in utility bills during the past 12 months"; PR: age-adjusted prevalence ratio; CI: confidence intervals

Supplement 15. Age-adjusted population attributable risk percent (PAR%) to EP_A of poor self-reported health status over time and differences between years (in bold if difference is statistically significant). Results are weighted and stratified by country.

	2007		2012		2016		Differences between years (95% CI)			
	PAR%	95% CI	PAR%	95% CI	PAR%	95% CI	2007-2012		2012 - 2016	
Austria	6.79	(3.41 - 9.36)	2.14	(-0.36 - 3.03)	7.11	(4.77 - 10.65)	-4.65	(-7.91 - -1.99)	4.97	(1.74 - 8.35)
Belgium	3.89	(2.03 - 8.46)	4.16	(1.16 - 6.49)	5.38	(4.58 - 9.94)	0.26	(-5.47 - 3.35)	1.23	(-0.87 - 6.95)
Bulgaria	7.19	(4.23 - 11.64)	7.70	(6.29 - 10.89)	8.18	(4.40 - 13.14)	0.50	(-1.72 - 6.66)	0.48	(-6.18 - 6.85)
Cyprus	11.35	(6.38 - 16.77)	18.63	(13.44 - 25.79)	7.29	(3.98 - 12.62)	7.27	(1.50 - 16.21)	-11.33	(-18.49 - -1.79)
Czech Republic	2.05	(0.96 - 3.80)	2.45	(1.07 - 4.07)	4.59	(1.66 - 6.61)	0.40	(-1.36 - 2.05)	2.14	(-1.54 - 2.87)
Denmark	0.24	(-1.02 - 1.66)	0.63	(-0.90 - 1.89)	2.24	(1.01 - 4.28)	0.40	(-1.72 - 1.74)	1.61	(-0.34 - 5.18)
Estonia	1.45	(0.09 - 2.57)	2.39	(1.21 - 3.37)	2.25	(1.14 - 4.38)	0.94	(-0.43 - 3.29)	-0.13	(-1.07 - 3.11)
Finland	3.22	(0.92 - 5.99)	2.74	(1.35 - 3.70)	2.87	(-1.44 - 7.13)	-0.48	(-3.57 - 1.51)	0.12	(-4.89 - 4.50)
France	3.67	(1.39 - 5.61)	4.11	(1.81 - 5.72)	3.84	(0.85 - 8.90)	0.45	(-2.56 - 4.33)	-0.27	(-2.33 - 5.74)
Germany	2.64	(0.47 - 3.90)	2.06	(0.27 - 4.63)	1.55	(0.24 - 2.72)	-0.58	(-3.02 - 1.68)	-0.52	(-3.73 - 2.10)
Greece	10.27	(6.85 - 15.51)	13.61	(10.72 - 16.38)	16.99	(10.86 - 27.46)	3.34	(-4.38 - 9.35)	3.38	(-5.26 - 11.58)
Hungary	3.95	(-0.14 - 5.54)	11.25	(7.78 - 15.29)	8.07	(5.57 - 12.19)	7.30	(2.72 - 13.19)	-3.18	(-8.98 - 0.02)
Ireland	14.28	(8.85 - 16.35)	10.38	(8.04 - 15.48)	7.85	(1.58 - 13.03)	-3.90	(-6.08 - 2.63)	-2.53	(-8.57 - 1.67)
Italy	5.17	(0.97 - 10.39)	4.87	(1.77 - 8.56)	10.01	(7.01 - 12.61)	-0.30	(-7.24 - 5.07)	5.14	(1.58 - 8.10)
Latvia	0.43	(0.02 - 2.24)	3.62	(1.31 - 5.65)	1.94	(-0.34 - 4.11)	3.19	(0.64 - 4.03)	-1.68	(-4.19 - 1.14)
Lithuania	0.55	(-0.37 - 2.61)	2.08	(0.72 - 3.21)	2.65	(0.06 - 4.97)	1.53	(-0.26 - 3.01)	0.57	(-2.60 - 3.47)
Luxembourg	3.05	(1.31 - 4.64)	1.12	(-0.45 - 3.46)	3.32	(-0.03 - 4.55)	-1.92	(-3.86 - 0.69)	2.20	(-2.59 - 4.74)
Malta	5.01	(2.90 - 5.63)	0.98	(-0.78 - 3.02)	2.52	(0.73 - 3.99)	-4.03	(-6.32 - -1.35)	1.54	(-0.49 - 2.30)
Netherlands	2.95	(-0.68 - 6.59)	2.45	(-1.16 - 5.81)	1.29	(0.28 - 2.85)	-0.50	(-3.57 - 4.01)	-1.15	(-4.88 - 2.52)
Poland	7.22	(6.29 - 8.13)	6.18	(4.87 - 8.69)	10.07	(5.46 - 14.78)	-1.04	(-2.64 - 1.59)	3.89	(-0.45 - 8.50)
Portugal	2.79	(0.94 - 3.70)	4.41	(2.49 - 6.60)	3.20	(1.57 - 5.76)	1.62	(-1.00 - 4.39)	-1.21	(-3.89 - 1.43)
Romania	3.86	(-0.37 - 8.81)	5.43	(3.65 - 6.19)	8.79	(6.13 - 10.73)	1.57	(-4.01 - 5.42)	3.36	(1.11 - 5.75)
Slovakia	4.74	(2.56 - 7.91)	4.51	(2.44 - 7.17)	4.04	(1.90 - 5.98)	-0.24	(-3.74 - 1.82)	-0.46	(-2.83 - 2.29)
Slovenia	4.15	(1.82 - 5.79)	7.46	(4.07 - 8.62)	1.25	(0.08 - 3.23)	3.31	(-1.41 - 6.08)	-6.20	(-7.80 - -0.85)
Spain	1.65	(-0.55 - 3.65)	3.92	(2.80 - 5.48)	4.70	(2.29 - 6.44)	2.27	(-0.85 - 5.17)	0.78	(-2.84 - 1.64)
Sweden	2.12	(0.22 - 2.73)	1.82	(1.00 - 3.22)	2.09	(-0.19 - 3.19)	-0.30	(-1.73 - 2.16)	0.27	(-3.42 - 1.47)
United Kingdom	7.44	(4.69 - 9.97)	4.57	(3.59 - 6.13)	4.39	(1.31 - 5.08)	-2.87	(-5.35 - -0.45)	-0.19	(-4.08 - 0.94)

EP_A: energy poverty indicator “One or more arrears in utility bills during the past 12 months”; PAR%: age-adjusted population attributable risk percent; CI: confidence intervals

Supplement 16. Age-adjusted population attributable risk percent (PAR%) to EP_A of reduced well-being over time and differences between years (in bold if difference is statistically significant). Results are weighted and stratified by country.

	2007		2012		2016		Differences between years (95% CI)			
	PAR%	95% CI	PAR%	95% CI	PAR%	95% CI	2007-2012		2012 - 2016	
Austria	14.05	(10.40 - 16.58)	1.63	(-0.78 - 5.45)	11.18	(5.11 - 17.81)	-12.42	(-17.13 - -6.14)	9.55	(0.17 - 17.87)
Belgium	9.08	(2.90 - 11.95)	7.47	(3.71 - 11.65)	14.23	(10.98 - 24.67)	-1.61	(-5.67 - 4.40)	6.77	(3.52 - 15.49)
Bulgaria	10.44	(3.82 - 15.28)	15.62	(9.84 - 24.62)	22.50	(12.74 - 28.39)	5.18	(-0.87 - 13.49)	6.88	(-3.84 - 12.21)
Cyprus	12.97	(8.16 - 17.93)	21.96	(16.06 - 28.20)	9.92	(6.73 - 14.27)	8.99	(0.64 - 15.88)	-12.04	(-19.86 - -1.79)
Czech Republic	7.11	(3.26 - 11.15)	8.11	(5.23 - 12.96)	4.66	(-0.48 - 6.33)	1.00	(-4.03 - 7.77)	-3.45	(-10.23 - 0.11)
Denmark	1.06	(-1.62 - 2.37)	1.21	(-2.42 - 3.02)	1.58	(-0.65 - 3.56)	0.15	(-3.11 - 2.55)	0.36	(-3.11 - 5.11)
Estonia	3.40	(1.28 - 6.66)	2.42	(-0.11 - 5.30)	2.42	(-0.11 - 5.49)	-0.98	(-4.85 - 2.04)	0.00	(-4.96 - 3.68)
Finland	7.04	(3.32 - 14.72)	5.18	(-0.87 - 10.59)	1.78	(-0.51 - 8.64)	-1.86	(-10.92 - 4.38)	-3.40	(-9.23 - 4.29)
France	7.22	(5.48 - 11.10)	5.00	(2.75 - 7.58)	6.31	(4.33 - 8.78)	-2.22	(-4.78 - -0.64)	1.30	(-2.80 - 4.77)
Germany	5.48	(2.66 - 9.50)	6.45	(5.09 - 7.82)	2.42	(0.64 - 6.55)	0.97	(-1.69 - 3.49)	-4.03	(-5.80 - -0.93)
Greece	14.61	(12.15 - 22.10)	19.85	(14.01 - 23.90)	22.33	(18.54 - 32.02)	5.24	(-1.00 - 10.14)	2.48	(-2.69 - 10.11)
Hungary	16.75	(11.77 - 22.65)	20.55	(12.75 - 25.59)	8.32	(4.52 - 10.49)	3.79	(-4.15 - 13.82)	-12.23	(-19.98 - -2.59)
Ireland	20.04	(13.87 - 30.45)	14.98	(8.14 - 20.88)	5.45	(2.09 - 10.72)	-5.06	(-15.23 - 0.40)	-9.53	(-15.32 - -0.10)
Italy	2.79	(-0.62 - 6.54)	9.60	(3.61 - 11.49)	12.83	(9.47 - 15.99)	6.81	(-0.02 - 9.26)	3.23	(-0.33 - 10.63)
Latvia	4.14	(0.79 - 5.64)	10.47	(8.90 - 15.17)	3.59	(0.40 - 8.53)	6.33	(3.26 - 12.49)	-6.88	(-14.78 - -2.93)
Lithuania	3.04	(2.23 - 6.88)	3.38	(2.04 - 5.94)	4.47	(1.15 - 8.51)	0.35	(-3.94 - 2.24)	1.09	(-2.21 - 4.67)
Luxembourg	2.06	(0.83 - 5.55)	4.81	(1.18 - 7.10)	0.76	(-1.76 - 2.40)	2.75	(-4.18 - 5.01)	-4.05	(-7.46 - 0.58)
Malta	1.94	(0.25 - 3.10)	5.85	(3.10 - 10.09)	4.15	(1.78 - 7.72)	3.91	(2.25 - 9.84)	-1.69	(-5.90 - 3.10)
Netherlands	7.64	(0.71 - 12.98)	4.72	(0.33 - 8.48)	0.93	(-0.42 - 2.50)	-2.92	(-11.31 - 6.10)	-3.79	(-8.42 - 0.70)
Poland	12.82	(9.94 - 15.77)	8.73	(6.43 - 12.36)	14.36	(10.84 - 20.32)	-4.08	(-8.02 - -0.22)	5.63	(-1.52 - 9.45)
Portugal	9.54	(4.44 - 15.74)	7.16	(2.70 - 11.19)	4.93	(1.23 - 8.68)	-2.38	(-7.19 - 3.62)	-2.23	(-8.03 - 2.52)
Romania	12.57	(9.72 - 14.97)	7.56	(3.98 - 10.06)	11.44	(1.79 - 19.10)	-5.01	(-10.34 - -2.07)	3.88	(-6.80 - 13.84)
Slovakia	4.12	(1.38 - 9.20)	11.40	(9.46 - 13.47)	4.76	(0.29 - 7.75)	7.28	(0.59 - 10.42)	-6.64	(-10.67 - -4.17)
Slovenia	10.22	(6.17 - 12.82)	7.94	(4.32 - 12.22)	3.98	(1.33 - 6.94)	-2.28	(-4.69 - 4.71)	-3.96	(-9.10 - 0.78)
Spain	3.94	(0.51 - 12.84)	9.21	(6.91 - 11.20)	10.07	(5.71 - 14.61)	5.28	(-4.21 - 8.89)	0.86	(-3.15 - 5.65)
Sweden	4.15	(2.57 - 8.81)	3.66	(1.14 - 5.49)	1.98	(0.23 - 3.84)	-0.50	(-6.04 - 2.92)	-1.68	(-5.18 - 1.31)
United Kingdom	9.10	(4.79 - 12.91)	5.38	(3.61 - 7.63)	6.67	(4.39 - 10.80)	-3.72	(-5.72 - -1.18)	1.29	(-2.54 - 3.61)

EP_A: energy poverty indicator “One or more arrears in utility bills during the past 12 months”; PAR%: age-adjusted population attributable risk percent; CI: confidence intervals

Supplement 17. Age-adjusted population attributable risk percent (PAR%) to EP_A of likely depression over time and differences between years (in bold if difference is statistically significant). Results are weighted and stratified by country.

	2007		2012		2016		Differences between years (95% CI)			
	PAR%	95% CI	PAR%	95% CI	PAR%	95% CI	2007-2012		2012 - 2016	
Austria	31.01	(19.78 - 36.71)	2.25	(-2.42 - 6.84)	10.09	(0.24 - 17.13)	-28.76	(-34.61 - -18.63)	7.84	(-3.07 - 13.98)
Belgium	13.00	(1.48 - 20.02)	6.73	(-3.96 - 14.67)	30.00	(23.03 - 50.49)	-6.27	(-16.14 - 12.48)	23.27	(17.79 - 39.51)
Bulgaria	19.92	(8.49 - 29.92)	22.89	(9.28 - 26.79)	21.22	(11.14 - 32.72)	2.97	(-13.70 - 18.04)	-1.67	(-13.93 - 12.49)
Cyprus	15.25	(10.88 - 26.94)	30.15	(21.35 - 35.51)	16.27	(7.80 - 22.51)	14.90	(-5.59 - 19.97)	-13.87	(-27.71 - -2.90)
Czech Republic	13.77	(10.22 - 20.00)	11.86	(6.94 - 15.44)	11.04	(4.17 - 17.77)	-1.91	(-11.56 - 3.16)	-0.82	(-6.99 - 9.57)
Denmark	-1.09	(-3.11 - 2.86)	6.71	(2.79 - 25.62)	3.91	(-1.68 - 13.64)	7.79	(4.41 - 24.83)	-2.80	(-21.97 - 0.66)
Estonia	6.83	(4.87 - 12.43)	2.17	(-4.38 - 7.17)	-1.18	(-3.28 - -0.65)	-4.66	(-13.51 - 2.29)	-3.35	(-8.74 - 2.12)
Finland	10.53	(3.56 - 25.19)	6.96	(-3.27 - 11.95)	1.87	(-9.66 - 10.95)	-3.57	(-21.95 - 8.39)	-5.09	(-17.79 - 9.87)
France	10.73	(2.03 - 22.67)	8.05	(2.68 - 11.26)	10.77	(1.74 - 21.75)	-2.68	(-16.30 - 4.17)	2.72	(-1.87 - 19.07)
Germany	19.60	(10.44 - 31.74)	10.75	(4.22 - 18.23)	7.49	(1.16 - 14.93)	-8.84	(-20.32 - -1.63)	-3.26	(-17.07 - 8.93)
Greece	21.70	(11.12 - 28.53)	34.23	(18.99 - 44.16)	26.60	(10.37 - 40.96)	12.53	(-2.64 - 30.21)	-7.63	(-30.96 - 12.94)
Hungary	16.50	(8.94 - 26.77)	27.45	(15.68 - 37.28)	9.24	(-0.29 - 26.27)	10.95	(-4.88 - 23.78)	-18.20	(-31.91 - -1.79)
Ireland	29.94	(14.12 - 44.99)	19.82	(7.99 - 28.00)	7.16	(4.66 - 12.95)	-10.12	(-33.58 - 8.84)	-12.65	(-21.33 - 1.66)
Italy	11.25	(-3.43 - 24.48)	17.86	(8.52 - 33.58)	15.91	(11.33 - 22.94)	6.61	(-15.01 - 27.93)	-1.95	(-18.90 - 10.09)
Latvia	5.94	(-0.10 - 9.76)	14.48	(4.17 - 26.59)	7.04	(-1.23 - 22.76)	8.55	(-2.76 - 26.69)	-7.44	(-18.89 - 6.79)
Lithuania	3.65	(1.07 - 9.56)	9.02	(3.41 - 12.31)	5.93	(0.67 - 13.93)	5.38	(-4.45 - 9.84)	-3.09	(-11.64 - 6.03)
Luxembourg	3.26	(0.06 - 10.93)	15.79	(10.19 - 20.96)	2.67	(-4.66 - 12.33)	12.53	(3.02 - 18.02)	-13.11	(-23.27 - -3.52)
Malta	6.75	(2.44 - 13.54)	7.82	(3.47 - 16.37)	7.42	(0.75 - 11.63)	1.07	(-10.07 - 10.97)	-0.40	(-11.59 - 3.48)
Netherlands	11.23	(3.81 - 23.91)	10.72	(-3.92 - 14.96)	1.17	(-0.00 - 7.87)	-0.51	(-12.29 - 4.32)	-9.56	(-12.48 - 4.02)
Poland	23.50	(13.03 - 31.55)	12.58	(6.10 - 16.33)	24.64	(16.51 - 40.23)	-10.91	(-25.45 - 0.38)	12.06	(3.32 - 26.48)
Portugal	15.58	(12.54 - 20.53)	10.35	(5.56 - 17.71)	12.09	(4.94 - 17.73)	-5.23	(-13.44 - 3.25)	1.74	(-3.96 - 6.93)
Romania	12.49	(3.02 - 18.03)	13.85	(8.54 - 18.85)	14.93	(11.26 - 25.65)	1.36	(-7.95 - 12.83)	1.08	(-3.12 - 12.46)
Slovakia	17.05	(7.43 - 29.22)	18.10	(17.08 - 28.01)	13.89	(8.15 - 22.28)	1.05	(-8.03 - 12.93)	-4.20	(-19.86 - 2.76)
Slovenia	17.41	(7.92 - 27.25)	15.64	(9.61 - 22.16)	9.14	(1.67 - 17.72)	-1.77	(-12.13 - 8.93)	-6.49	(-15.18 - -1.37)
Spain	11.06	(3.01 - 26.83)	12.49	(3.57 - 17.10)	14.82	(2.50 - 32.62)	1.43	(-23.26 - 12.65)	2.33	(-8.71 - 21.59)
Sweden	11.94	(3.56 - 29.50)	1.75	(-0.55 - 5.60)	4.93	(-0.86 - 12.77)	-10.19	(-23.90 - -3.14)	3.18	(-1.07 - 9.18)
United Kingdom	18.18	(16.40 - 22.43)	9.25	(5.46 - 15.60)	11.49	(3.26 - 23.46)	-8.93	(-13.84 - -3.02)	2.24	(-12.33 - 15.37)

EP_A: energy poverty indicator "One or more arrears in utility bills during the past 12 months"; PAR%: age-adjusted population attributable risk percent; CI: confidence intervals

10.4. Annex IV: material suplementari article 2

Supplementary table 1. Energy poverty distribution according to age, country of birth and social class, stratified by sex. Subpopulation of individuals unable to meet an unforeseen expenditure of 750€ with their own resources. Barcelona, 2016.

	Women (n=491)			Men (n=356)			p-value[a]
	cases	**%**	**95%CI**	**cases**	**%**	**95%CI**	
Total	194	39.8	(35.4 - 44.2)	140	39.3	(34.2 - 44.4)	0.866
Age (years)							
Less than 65	130	39.1	(33.8 - 44.3)	119	39.6	(34.0 - 45.2)	0.890
65 or older	64	41.7	(33.7 - 49.7)	21	37.4	(24.8 - 50.0)	0.573
p-value[b]		0.582			0.755		
Country of birth							
HI	119	36.5	(31.2 - 41.8)	79	37.4	(30.9 - 44.0)	0.830
LMI	75	46.4	(38.6 - 54.2)	61	42.3	(34.2 - 50.5)	0.480
p-value[b]		0.038*			0.361		
Social class							
Non-manual	42	28.8	(21.3 - 36.3)	36	37.9	(28.0 - 47.7)	0.149
Manual	135	43.0	(37.4 - 48.5)	99	39.9	(33.8 - 46.0)	0.467
p-value[b]		0.004*			0.734		

n: sample size; cases: number of energy poverty cases; CI: Confidence interval; HI: High income: LMI: Low and middle-income;*: statistically significant p-value (< 0.05); [a]Chi-square test assessing sex differences within each category; [b]Chi-square test assessi differences between categories within each sex; there were 9 missing values in the EP indicator; the final sample consisted of 84 individuals.

Supplementary table 2. Prevalence of health status indicators among people with and without energy poverty, crude prevalence ratios (cPR), adjusted prevalence ratios (aPR) and adjusted population attributable risk percent (PAR%), stratified by sex. Subpopulation of individuals unable to meet an unforeseen expenditure of €750 with their own resources Barcelona, 2016

Women

	Energy poverty (n=194)			No energy poverty (n=297)								
	c	%	95%CI	c	%	95%CI	cPR	95%CI	aPR	95%CI	PAR%	95%CI
Poor self-reported health	103	51.6	44.5 - 58.7	103	35.0	29.4 - 40.6	1.5	1.2 - 1.8	1.5	1.2 - 1.8	16.0	7.5 - 24.8
Poor mental health	80	44.5	37.1 - 51.9	86	31.2	25.7 - 36.7	1.4	1.1 - 1.8	1.5	1.2 - 1.9	16.5	6.6 - 26.9
Poor quality of life	148	75.5	69.3 - 81.8	204	68.7	63.3 - 74.0	1.1	1.0 - 1.2	1.1	1.0 - 1.2	4.0	-0.5 - 8.5
High blood pressure	63	31.1	24.6 - 37.6	82	27.0	21.8 - 32.1	1.2	0.9 - 1.5	1.2	0.9 - 1.5	6.1	-4.4 - 16.8
Myocardial infarction and/or stroke	14	6.8	3.3 - 10.3	10	3.5	1.3 - 5.8	1.9	0.9 - 4.4	1.8	0.8 - 4.0	23.4	-10.4- 58.5
Asthma	22	11.1	6.6 - 15.5	18	6.0	3.2 - 8.7	1.9	1.0 - 3.4	1.7	0.9 - 3.4	23.0	-4.5 - 50.6
Chronic bronchitis	21	10.3	6.1 - 14.6	14	4.6	2.2 - 6.9	2.3	1.2 - 4.4	2.3	1.2 - 4.6	34.2	6.4 - 61.8
Arthrosis, arthritis, rheumatism	67	32.7	26.1 - 39.3	86	28.5	23.3 - 33.7	1.1	0.9 - 1.5	1.1	0.9 - 1.4	4.5	-5.6 - 14.7
Allergies	51	26.0	19.7 - 32.3	51	16.7	12.4 - 21.0	1.6	1.1 - 2.2	1.6	1.1 - 2.2	17.8	3.0 - 32.5
Migraine or frequent headaches	75	38.8	31.8 - 45.8	76	25.6	20.6 - 30.7	1.5	1.2 - 2.0	1.5	1.1 - 2.0	16.7	5.3 - 28.4
Overweight	103	52.4	45.2 - 59.6	136	46.8	41.0 - 52.6	1.1	0.9 - 1.3	1.1	0.9 - 1.3	3.6	-4.0 - 11.4
Diabetes	28	14.3	9.4 - 19.2	22	8.1	4.7 - 11.5	1.8	1.0 - 3.1	1.7	1.0 - 2.9	21.5	-1.4 - 45.7
Domestic injuries	20	9.5	5.5 - 13.6	23	7.8	4.6 - 10.9	1.2	0.7 - 2.2	1.2	0.7 - 2.3	7.7	-17.3 - 33.1

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Men

	Energy poverty (n=140)			No energy poverty (n=216)								
	c	%	95%CI	c	%	95%CI	cPR	95%CI	aPR	95%CI	PAR%	95%CI
Poor self-reported health	48	34.1	26.1 - 42.0	51	22.7	17.1 - 28.3	1.5	1.1 - 2.1	1.6	1.1 - 2.2	18.6	4.7 - 33.2
Poor mental health	50	40.2	31.6 - 48.8	61	29.7	23.4 - 36.1	1.4	1.0 - 1.8	1.3	1.0 - 1.8	11.1	-1.5 - 23.9
Poor quality of life	90	64.5	56.6 - 72.5	123	56.4	49.7 - 63.1	1.1	1.0 - 1.4	1.2	1.0 - 1.4	5.8	-1.2 - 12.9
High blood pressure	29	21.4	14.4 - 28.3	40	17.6	12.6 - 22.7	1.2	0.8 - 1.9	1.3	0.8 - 2.0	10.4	-7.1 - 28.5
Myocardial infarction and/or stroke	11	7.3	3.1 - 11.5	12	4.8	2.1 - 7.4	1.5	0.7 - 3.4	1.4	0.6 - 3.1	13.0	-18.9 - 46.4
Asthma	17	11.9	6.5 - 17.3	11	5.1	2.1 - 8.1	2.3	1.1 - 4.9	2.0	1.0 - 4.3	28.8	-2.4 - 60.3
Chronic bronchitis	10	7.0	2.8 - 11.3	12	5.5	2.4 - 8.6	1.3	0.6 - 2.9	1.4	0.6 - 3.3	14.1	-21.7 - 50.3
Arthrosis, arthritis, rheumatism	22	16.3	10.0 - 22.6	22	9.9	5.9 - 13.8	1.7	0.9 - 2.9	1.9	1.1 - 3.2	24.6	2.2 - 47.8
Allergies	31	22.4	15.4 - 29.5	23	10.4	6.3 - 14.4	2.2	1.3 - 3.6	2.0	1.2 - 3.3	28.6	7.5 – 50.0
Migraine or frequent headaches	33	23.3	16.2 - 30.3	35	16.9	11.7 - 22.0	1.4	0.9 - 2.1	1.4	0.9 - 2.2	14.2	-4.0 - 33.0
Overweight	81	57.4	49.1 - 65.7	127	58.7	52.0 - 65.3	1.0	0.8 - 1.2	1.0	0.8 - 1.2	-1.7	-9.1 - 5.6
Diabetes	9	6.2	2.3 - 10.2	22	9.7	5.8 - 13.7	0.6	0.3 - 1.4	0.5	0.2 - 1.2	-21.4	-47.9 - 5.7
Domestic injuries	12	8.9	4.1 - 13.8	13	5.8	2.7 - 8.9	1.5	0.7 - 3.3	1.5	0.7 - 3.3	17.5	-14.4 - 49.4

n= sample size; c=number of cases with the health outcome; CI: Confidence interval

Supplementary table 3. Prevalence of health services and medication use indicators among people with and without energy poverty, crude prevalence ratios (cPR), adjusted prevalence ratios (aPR) and adjusted population attributable risk percent (PAR%), stratified by sex. Subpopulation of individuals unable to meet an unforeseen expenditure of €750 with their own resources. Barcelona, 2016.

Women

	Energy poverty (n=194)			No energy poverty (n=297)								
	c	%	95%CI	c	%	95%CI	cPR	95%CI	aPR	95%CI	PAR%	95%CI
Use of health services in the last 12 months												
Emergency services*	62	31.3	24.7 - 37.9	62	21.0	16.3 - 25.7	1.5	1.1 - 2.0	1.5	1.1 - 2.1	16.2	3.2 - 29.5
Hospitalisations	34	17.3	12.0 - 22.7	34	12.0	8.1 - 15.9	1.4	0.9 - 2.3	1.4	0.9 - 2.3	14.2	-4.7 - 33.7
Primary health care	174	89.0	84.3 - 93.6	253	84.9	80.8 - 89.1	1.0	1.0 - 1.1	1.1	1.0 - 1.1	2.1	-0.7 - 4.9
Nursing	78	39.1	32.2 - 46.0	83	28.6	23.3 - 33.9	1.4	1.1 - 1.8	1.4	1.1 - 1.8	12.6	2.1 - 23.4
Psychiatry	28	14.4	9.4 - 19.5	18	6.4	3.5 - 9.2	2.3	1.3 - 4.0	2.3	1.3 - 4.2	33.0	9.9 - 56.2
Psychology	25	12.8	8.0 - 17.6	17	5.5	2.9 - 8.1	2.3	1.3 - 4.2	2.8	1.5 - 5.2	39.6	16.1 - 63.0
Social work	29	15.5	10.3 - 20.8	33	11.5	7.6 - 15.3	1.4	0.8 - 2.2	1.4	0.9 - 2.3	14.0	-5.9 - 34.1
Unmet medical need	54	29.7	23.1 - 36.3	68	23.3	18.5 - 28.1	1.3	0.9 - 1.7	1.3	1.0 - 1.8	11.3	-1.1 - 24.0
Medication use in the last two days												
Painkillers	108	54.3	47.1 - 61.4	144	48.9	43.1 - 54.7	1.1	0.9 - 1.3	1.2	1.0 - 1.4	5.9	-1.2 - 13.2
Allergy medication	19	9.1	5.1 - 13.1	13	4.2	1.9 - 6.4	2.2	1.1 - 4.4	2.4	1.1 - 5.0	34.1	3.7 - 63.1
Antibiotics	16	8.6	4.4 - 12.7	9	2.9	1.0 - 4.9	2.9	1.3 - 6.5	3.2	1.4 - 7.2	45.0	14.7 - 73.4
Asthma medication	14	6.8	3.3 - 10.3	9	3.1	1.1 - 5.1	2.2	1.0 - 5.1	2.5	1.0 - 6.2	37.0	0.7 - 73.8
Psychotropic drugs	72	35.3	28.5 - 42.1	76	25.1	20.1 - 30.1	1.4	1.1 - 1.9	1.5	1.1 - 1.9	14.9	3.6 - 26.6

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Men

	Energy poverty (n=140)			No energy poverty (n=216)								
	c	%	95%CI	c	%	95%CI	cPR	95%CI	aPR	95%CI	PAR%	95%CI
Use of health services in the last 12 months												
Emergency services*	31	22.0	15.1 - 29.0	30	14.0	9.3 - 18.6	1.6	1.0 - 2.5	1.5	1.0 - 2.4	17.4	-1.7 - 36.9
Hospitalisations	26	18.5	12.1 - 25.0	32	14.6	9.9 - 19.4	1.3	0.8 - 2.0	1.4	0.9 - 2.2	12.6	-6.5 - 31.9
Primary health care	112	80.3	73.7 - 86.9	172	80.1	74.7 - 85.5	1.0	0.9 - 1.1	1.0	0.9 - 1.1	-0.1	-4.4 - 4.1
Nursing	38	27.3	19.8 - 34.8	49	22.1	16.6 - 27.7	1.2	0.8 - 1.8	1.2	0.9 - 1.8	8.4	-6.7 - 23.9
Psychiatry	17	11.5	6.3 - 16.7	22	10.3	6.2 - 14.5	1.1	0.6 - 2.0	1.2	0.6 - 2.2	6.0	-18.9 - 32.3
Psychology	10	6.8	2.7 - 10.9	16	7.5	3.9 - 11.1	0.9	0.4 - 2.0	1.0	0.5 - 2.1	-0.8	-31.1 - 31.1
Social work	23	17.0	10.6 - 23.4	27	12.8	8.3 - 17.3	1.3	0.8 - 2.2	1.3	0.8 - 2.3	10.8	-11.6 - 33.6
Unmet medical need	33	24.0	17.0 - 31.1	43	20.3	15.0 - 25.7	1.2	0.8 - 1.8	1.2	0.8 - 1.7	5.9	-11.0 - 22.8
Medication use in the last 2 days												
Painkillers	67	48.0	39.6 - 56.4	66	30.9	24.6 - 37.2	1.6	1.2 - 2.0	1.5	1.2 - 2.0	17.3	6.1 - 28.8
Allergy medication	9	5.8	2.1 - 9.5	7	3.3	0.9 - 5.7	1.8	0.7 - 4.7	1.6	0.6 - 4.2	17.9	-24.3 - 62.9
Antibiotics	7	4.6	1.3 - 8.0	9	4.1	1.4 - 6.8	1.1	0.4 - 3.0	1.3	0.5 - 3.6	10.5	-32.6 - 54.2
Asthma medication	9	6.5	2.3 - 10.6	4	1.9	0.0 - 3.8	3.4	1.0 - 11.1	3.4	1.0 - 11.1	48.3	2.9 - 89.2
Psychotropic drugs	33	23.6	16.4 - 30.7	38	16.9	11.9 - 21.9	1.4	0.9 - 2.1	1.5	0.9 - 2.2	15.0	-2.7 - 32.7

n= sample size; c=number of cases with the health outcome; CI: Confidence interval; *Two or more visits to emergency services

10.5. Annex V: material suplementari article 4

Rmarkdown document with the data analysis for the paper: 'Geographical inequalities of energy poverty in a Mediterranean city: using small area Bayesian spatial models'

The *R* code in this document is provided as supplementary material to the paper: *Geographical inequalities of energy poverty in a Mediterranean city: using small area Bayesian spatial models.* Note that some results in this document may slightly differ from those shown in the paper due to MCMC sampling variability.

Libraries loading

Load the following libraries:

- *RColorBrewer*: Color palettes for choropleth maps.
- *sp*: Classes and methods for SpatialPolygonsDataFrame (Barcelona map).
- *spdep*: Functions for calculating Barcelona neighborhoods' neighbors.
- *Pbugs*: Allows WinBUGS to be called from R, simulating each chain in a different core processor (parallel computing).
- *abind*: Use of the *abind* function for some array operations.
- *Hmisc*: Use of the *cut2* function.
- *openxlsx*: throw some outputs to excel files.

```
pkgs <- c(
  "RColorBrewer",
  "sp",
  "spdep",
  "abind",
  "Hmisc",
  "openxlsx"
)

invisible(sapply(pkgs, function(x) {
  if (!x %in% installed.packages()[, 1])
    install.packages(x)
  suppressPackageStartupMessages(require(x, character.only = TRUE))
}))

if (!"pbugs" %in% installed.packages() || packageVersion("pbugs") < "0.1.4") {
  install_github(repo = "fisabio/pbugs")
}
library(pbugs)
```

Data loading

Load the data required to run this document. Data are not provided for privacy reasons (individual data in some cases). In fact some of the data outputs of the following chunk have been slightly modified in order to preserve data privacy.

The *data.Rdata* file below contains 4 objects: *carto*, *surveys*, *Pop_Lev_Ind* and *ProbsBarcelona*.

- *carto*: contains an SpatialPolygonsDataFrame object with the Barcelona neighborhoods.
- *surveys*: matrix object. Each row corresponds to each surveyed person in the Barcelona Health Survey. Columns correspond, in this order, to the neighborhood ID; the 6 indicators composing the energy poverty index (1 means yes and 0 no); and 5 auxiliary demographic and socioeconomic variables, with information at the neighborhood level in the 2016 Barcelona Census.
- *Pop_Lev_Ind*: data.frame object. Each row corresponds to aggregated information, from the 2016 Barcelona Census, for each Barcelona neighborhood. Columns correspond to the population proportions for each of the values of the auxiliary variables in the *surveys* object.
- *ProbsBarcelona*: vector. Average values of each EP indicator for the entire city.

```
load("data.Rdata")
ls()
```

```
## [1] "carto"          "pkgs"           "Pop_Lev_Ind"    "ProbsBarcelona"
## [5] "surveys"
```

```
# Carto: SpatialPolygonsDataFrame object with the Barcelona neighborhoods cartography
neigh <- nb2WB(poly2nb(carto))
# neighborhood structure of the Barcelona neighborhoods for WinBUGS

# surveys
dim(surveys)
```

```
## [1] 3378   12
```

```
head(surveys,3)
```

```
##   Neigh ind_Temp_cold ind_Temp_hot ind_Arrears ind_Conditions ind_Heating
## 1    60             0            0           0              0           0
## 2    31             0            0           0              1           0
## 3    18             0            0          NA              0           0
##   ind_Air_cond Age_gr Education_gr Low_Inc_Country Housing_tenure Unemployed
## 1            0      2            5               1              0          0
## 2            0      2            5               0              0          0
## 3            1      2            5               0              0          0
```

```
# Pop_Lev_Ind
dim(Pop_Lev_Ind)
```

```
## [1] 73 14
```

```
head(Pop_Lev_Ind,3)
```

```
##   Neigh  prop_Edu1 prop_Edu2 prop_Edu3 prop_Edu4 prop_Edu5 prop_Unemployed
## 1     1 0.02720130 0.3247604 0.2305811 0.1819350 0.2355223      0.08395448
## 2     2 0.02386194 0.1795327 0.1774022 0.2354946 0.3837085      0.06744171
## 3     3 0.04766154 0.2380103 0.2438099 0.2087144 0.2618039      0.08178837
##   prop_Age1 prop_Age2 prop_Age3 prop_Age4  prop_Age5 prop_Housing_tenure
## 1 0.1679301 0.3849743 0.2876116 0.1160920 0.04339196           0.1956399
## 2 0.1109256 0.4253324 0.2786306 0.1318646 0.05324684           0.1819954
## 3 0.1169266 0.3748745 0.2738103 0.1591594 0.07522923           0.2571044
##   prop_Low_Inc
## 1    0.4586879
## 2    0.2637934
## 3    0.2023961
```

WinBUGS model

We define now the WinBUGS model used to estimate the smoothed small area estimates for the variables composing the energy poverty (EP) index. The index is composed of 6 variables (energy poverty problems), which correspond to the columns of the Y matrix. Each row of this matrix correspond to each of the variables in the Barcelona Health Survey (BHS). Since all the variables used for the EP index are binary, we model them as:

$$Y_{ij} \sim Bernoulli(P_{ij}),\ i = 1, ..., I,\ j = 1, ..., J,$$

for I(=3378) the number of surveys in the BHS and J(=6) the number of variables composing the index. We model the logit of the corresponding probabilities as a linear function of the auxiliary covariates and a spatial random effect for each neighborhood:

$$logit(P_{ij}) = (\beta_0)_j + \sum_{k=1}^{K} (\beta_k)_{cov_k[i],j} + \theta_{Neigh[i]j},$$

where K is the number of auxiliary variables available and $\beta_k (k = 1, ..., K)$ denotes the effect of the k-th auxiliary variable, which is a matrix with as many rows as levels of the corresponding covariate and J columns, one for each modelled indicator. In the latest expression $cov_k[i]$ denotes the value of the k-th covariate for the i-th survey. Finally, $\theta_{ij},\ i = 1, ..., I,\ j = 1, ..., J$ denotes a matrix of random effects with as many rows as Barcelona neihgborhoods. This random effects term models the spatial effects on each outcome that cannot be explained by the auxiliary variables. This matrix is assumed to follow a multivariate spatial process. Specifically, we use an M-model (Botella-Rocamora, Martinez-Beneito, and Banerjee 2015) with underlying Leroux's spatial processes (Leroux, Lei, and Breslow 1999) in order to induce multivariate and spatial dependence, respectively, on the cells of $\boldsymbol{\theta}$. A row variance adaptive version of the M-model (Corpas-Burgos, Botella-Rocamora, and Martinez-Beneito 2019) will be considered in order to reproduce heteroscedasticity for the outcomes, if this was required. A multivariate process is assumed for $\boldsymbol{\theta}$ since, otherwise, we would be assuming prior independence on the spatial distribution of the outcomes. This could have an impact on the subsequent principal component analysis, that will be done of those indicators in order to build the EP index.

The proposal above allows estimating the probability of prevalence for each energy poverty indicator (indicator to be equal to 1) for each combination of the auxiliary variables and neighborhoods. Once obtained these smoothed indicators, overall prevalence probabilities for each neighborhood are obtained by averaging the probabilities for all the combinations of the auxiliary variables according to the prevalence of these auxiliary variables for each neighborhood. This procedure is undertaken as described in (Vergara-Hernández et al. 2021).

```
model_EPindex <- function() {
  for (j in 1:nVar) {
    for (i in 1:nIndiv) {
      Y[i, j] ~ dbern(p[i, j])
      logit(p[i, j]) <- beta.0[j] +
        beta.age[AgeGr[i], j] +
        beta.edu[Edu[i], j] +
        beta.lowInc[LowInc[i] + 1, j] +
        beta.housing[Housing[i] + 1, j] +
        beta.unemp[Unemployed[i] + 1, j] +
        theta[Neigh[i], j]
    }

    # Reference groups for fixed effects
    beta.age[3, j]     <- 0
    beta.edu[3, j]     <- 0
    beta.lowInc[1, j]  <- 0
    beta.housing[1, j] <- 0
```

```
    beta.unemp[1, j]    <- 0

    # Prior distributions for fixed effects
    for (k in 1:2) {
      beta.age[k, j] ~ dflat()
    }
    for (k in 4:nAge) {
      beta.age[k, j] ~ dflat()
    }
    for (k in 1:2) {
      beta.edu[k, j] ~ dflat()
    }
    for (k in 4:nEdu) {
      beta.edu[k, j] ~ dflat()
    }
    beta.lowInc[2, j]   ~ dflat()
    beta.housing[2, j] ~ dflat()
    beta.unemp[2, j]    ~ dflat()

    beta.0[j] ~ dflat()
    lambda[j] ~ dunif(0, 1)
    sd.phi[j] ~ dunif(0, 10)

    # M-model for theta with Leroux distribution for the underlying random effects (phi)
    for (k in 1:nNeigh) {
      theta[k, j]      <- inprod2(phi[k,], M[, j])
      phi[k, j]         ~ dnorm(phi.mean[k, j], phi.prec[k, j])
      phi.prec[k, j]  <- (1 - lambda[j] + lambda[j] * nNeighbors[k])
      phi.mean[k, j] <- (lambda[j] / (1 - lambda[j] + lambda[j] * nNeighbors[k])) *
        sum(phi.map[(index[k] + 1):index[k + 1], j])
    }

    for (k in 1:nNeighbors.tot) {
      phi.map[k, j] <- phi[map[k], j]
    }

    # Row Variance Adaptive (RVA) M-model
    for (k in 1:nVar) {
      M[j, k] ~ dnorm(0, prec.m[j])
    }
    prec.m[j] <- pow(sd.m[j], -2)
    sd.m[j]     ~ dunif(0, 10)
  }

  # Probability estimates for each of the original variables and neighborhoods
  # accounting for auxiliary variables.
  for (iVar in 1:nVar) {
    for (iNeigh in 1:nNeigh) {
      for (iUnemployed in 1:nUnemployed) {
        for (iHousing in 1:nHousing) {
          for (iLowInc in 1:nLowInc) {
            for (iEdu in 1:nEdu) {
              for (iAge in 1:nAge) {
```

```
              # probabilities for each combination of auxiliary variables and neighborhood
              logit(pi.pred[iAge, iEdu, iLowInc, iHousing, iUnemployed, iNeigh, iVar]) <-
                beta.0[iVar] +
                beta.age[iAge, iVar] +
                beta.edu[iEdu, iVar] +
                beta.lowInc[iLowInc, iVar] +
                beta.housing[iHousing, iVar] +
                beta.unemp[iUnemployed, iVar] +
                theta[iNeigh, iVar]
            }
            # Probabilities averaging across ages
            pi.pred2[iEdu, iLowInc, iHousing, iUnemployed, iNeigh, iVar] <- inprod2(
              pi.pred[, iEdu, iLowInc, iHousing, iUnemployed, iNeigh, iVar],
              p.age[iNeigh, ]
            )
          }
          # Probabilities averaging across education groups
          pi.pred3[iLowInc, iHousing, iUnemployed, iNeigh, iVar] <- inprod2(
            pi.pred2[, iLowInc, iHousing, iUnemployed, iNeigh, iVar],
            p.edu[iNeigh, ]
          )
        }
        # Probabilities averaging across origin countries
        pi.pred4[iHousing, iUnemployed, iNeigh, iVar] <- inprod2(
          pi.pred3[, iHousing, iUnemployed, iNeigh, iVar],
          p.lowInc[iNeigh, ]
        )
      }
      # Probabilities averaging across house owning
      pi.pred5[iUnemployed, iNeigh, iVar] <- inprod2(
        pi.pred4[, iUnemployed, iNeigh, iVar],
        p.housing[iNeigh, ]
      )
    }
    # Probabilities averaging across unemployment levels
    p.neigh[iNeigh, iVar] <- inprod2(pi.pred5[, iNeigh, iVar], p.unemployed[iNeigh, ])
  }
 }
}
```

WinBUGS call

WinBUGS call arrangements

```
TheData <- list(
  Y              = as.matrix(
    surveys[, dimnames(surveys)[[2]][grep("ind_", dimnames(surveys)[[2]])]]),
  AgeGr           = as.integer(surveys[, "Age_gr"]),
  Edu             = as.integer(surveys[, "Education_gr"]),
  LowInc          = as.integer(surveys[, "Low_Inc_Country"]),
  Housing         = as.integer(surveys[, "Housing_tenure"]),
  Unemployed      = as.integer(surveys[, "Unemployed"]),
  Neigh           = as.integer(surveys[, "Neigh"]),
  nNeigh          = length(neigh$num),
```

```r
  nNeighbors.tot  = length(neigh$adj),
  nNeighbors      = neigh$num,
  map             = neigh$adj,
  index           = c(0, cumsum(neigh$num)),
  nIndiv          = nrow(surveys),
  nVar            = length(grep("ind_", dimnames(surveys)[[2]])),
  nAge            = length(unique(as.integer(surveys[, "Age_gr"]))),
  p.age           = as.matrix(Pop_Lev_Ind[, grep("prop_Age", names(Pop_Lev_Ind))]),
  nEdu            = length(unique(surveys[, "Education_gr"])),
  p.edu           = as.matrix(Pop_Lev_Ind[, grep("prop_Edu", names(Pop_Lev_Ind))]),
  nLowInc         = length(unique(surveys[!is.na(surveys[, "Low_Inc_Country"]),
                                      "Low_Inc_Country"])),
  p.lowInc        = cbind(1 - Pop_Lev_Ind$prop_Low_Inc, Pop_Lev_Ind$prop_Low_Inc),
  nHousing        = length(unique(surveys[!is.na(surveys[, "Housing_tenure"]),
                                      "Housing_tenure"])),
  p.housing       = cbind(1 - Pop_Lev_Ind$prop_Housing_tenure,
                          Pop_Lev_Ind$prop_Housing_tenure ),
  nUnemployed     = length(unique(surveys[!is.na(surveys[, "Unemployed"]),
                                      "Unemployed"])),
  p.unemployed    = cbind(1 - Pop_Lev_Ind$prop_Unemployed,
                          Pop_Lev_Ind$prop_Unemployed )
)

inits    <- function() {
  list(
    beta.0            = rnorm(TheData$nVar, 0, 0.1),
    beta.unemp        = matrix(
            data      = c(rep(NA, TheData$nVar), rnorm(TheData$nVar, 0, 0.1)),
            byrow     = TRUE,
            ncol      = TheData$nVar
    ),
    beta.housing      = matrix(
            data      = c(rep(NA, TheData$nVar), rnorm(TheData$nVar, 0, 0.1)),
            byrow     = TRUE,
            ncol      = TheData$nVar
    ),
    beta.lowInc       = matrix(
            data      = c(rep(NA, TheData$nVar), rnorm(TheData$nVar, 0, 0.1)),
            byrow     = TRUE,
            ncol      = TheData$nVar
    ),
    beta.edu          = matrix(
            data      = c(rnorm(2 * TheData$nVar), rep(NA, TheData$nVar),
                          rnorm(2 * TheData$nVar)),
            byrow     = TRUE,
            ncol      = TheData$nVar
    ),
    beta.age          = matrix(
            data      = c(rnorm((TheData$nAge - 3) * TheData$nVar),
                          rep(NA, TheData$nVar),
                          rnorm((TheData$nAge - 3) * TheData$nVar)),
            byrow     = TRUE,
            ncol      = TheData$nVar
```

```
    ),
    sd.m              = runif(TheData$nVar),
    lambda            = runif(TheData$nVar),
    phi               = matrix(rnorm(TheData$nVar * TheData$nNeigh, 0, 1),
                               nrow = TheData$nNeigh),
    M                 = matrix(rnorm(TheData$nVar * TheData$nVar, 0, 0.1),
                               nrow = TheData$nVar)
  )
}
parameters <- c(
  "beta.0", "beta.unemp", "beta.housing", "beta.lowInc", "beta.edu", "beta.age",
  "theta", "sd.m", "lambda", "p.neigh"
)

set.seed(1)
results <- pbugs(
  data               = TheData,
  inits              = inits,
  parameters.to.save = parameters,
  model.file         = model_EPindex,
  n.chains           = 3,
  n.iter             = 5000,
  n.burnin           = 2000,
  DIC                = FALSE,
  save.history       = FALSE,
  bugs.seed          = 1
)
```

Energy poverty index calcutions

```
p.neigh<-results$sims.list$p.neigh

# Posterior mean of the EP components
p<-apply(p.neigh,c(2,3),mean)
logit.p<-log(p/(1-p))
# Principal components analysis of the (logit transformated) smoothed indicators
ACP<-princomp(logit.p)
EPindex<-ACP$scores[,1]
# Component loadings of the indicators in the EP index (shown in Table 1)
Loadings<-ACP$loadings[,1]

# EP index for each MCMC iteration
EPindex.sim<-matrix(nrow=dim(p.neigh)[1],ncol=nrow(logit.p))
for(i in 1:dim(p.neigh)[1]){
  x<-log(p.neigh[i,,]/(1-p.neigh[i,,]))
  x<-scale(x, center = TRUE, scale = FALSE)
  EPindex.sim[i,]<-as.vector(x%*%matrix(Loadings,ncol=1))
}

# EP index ICs
ICs<-t(apply(EPindex.sim,2,function(x){quantile(x,c(0.025,0.975))}))

# EP index posterior mean
```

```r
EPindex.pm <- t(apply(EPindex.sim,2,mean))

# Prob(EPindex of each neighborhood> EP of the entire city)
P.EPindex<-apply(EPindex.sim,2,function(x){mean(x>0)})

# Gathering of index summaries
df.index <- data.frame("post.mean"=as.vector(EPindex.pm),
                       "ic.lo"= ICs[,"2.5%"],
                       "ic.hi"= ICs[,"97.5%"],
                       "prob"=P.EPindex)
index <- as.matrix(df.index)

# EP index indicators summaries
post.mean<-apply(p.neigh,c(2,3),mean)
ic.lo <- apply(p.neigh,c(2,3),function(x){quantile(x,c(0.025))})
ic.hi <- apply(p.neigh,c(2,3),function(x){quantile(x,c(0.975))})
# Probabilities of excess (with respect to Barcelona) for each EP indicator
ProbExcess <- matrix(NA, nrow=73, ncol=6)
for(i in 1:6){
  ProbExcess[,i]<-apply(p.neigh[,,i],2,function(x){mean(x>ProbsBarcelona[i])})
}

# Final array with all the information above
data.all <- abind(post.mean, ic.lo, ic.hi, ProbExcess, along=3)
data.all <- abind(data.all, index, along=2)
data.all <- aperm(data.all, c(1,3,2))
dimnames(data.all)[[3]] <- c("Temp_cold", "Temp_hot", "Arrears", "Conditions", "Heating",
```

Figure 1

```r
data.plot <- as.data.frame(data.all[,,7])
data.plot$OBJECTID <- as.numeric(row.names(data.plot))
data.plot <- merge(carto, data.plot, by="OBJECTID")

par(oma = c(0, 0, 0, 0), mfrow=c(1,2))

par(mar=c(1,0,3,0))
MyCut <- cut2(data.plot@data$post.mean, g=5, digits=2, m=0, oneval=FALSE)
values<-as.numeric(MyCut)
mypalette<-rev(brewer.pal(5,"BrBG"))
fgs<-mypalette[values]
plot(data.plot,col=fgs,border="grey",xlab="",ylab="",axes=F,lwd=0.75)
title("Energy poverty index")
legend("bottomright", title="",legend=levels(MyCut),fill=mypalette, y.intersp=0.9,
       cex= 1.1, bty="n",inset=0.05)
mtext("(a)", line=-0.5, adj=0.1)

par(mar=c(1,0,3,0))
MyCut<-cut2(data.plot@data$prob,c(0,0.025,0.05,0.95,0.975,1),digits=2,m=0, oneval=F)
values<-as.numeric(MyCut)
mypalette<-rev(brewer.pal(5,"RdYlGn"))
fgs <- mypalette[values]
plot(data.plot,col=fgs,border="grey",xlab="",ylab="",axes=F,lwd=0.75)
```

```
title("Probability energy poverty is higher than Barcelona's average energy poverty\n(Prob
legend("bottomright", title="",legend=levels(MyCut),fill=mypalette, y.intersp=0.9,
       cex= 1.1, bty="n",inset=0.05)
mtext("(b)", line=-0.5, adj=0.1)
```

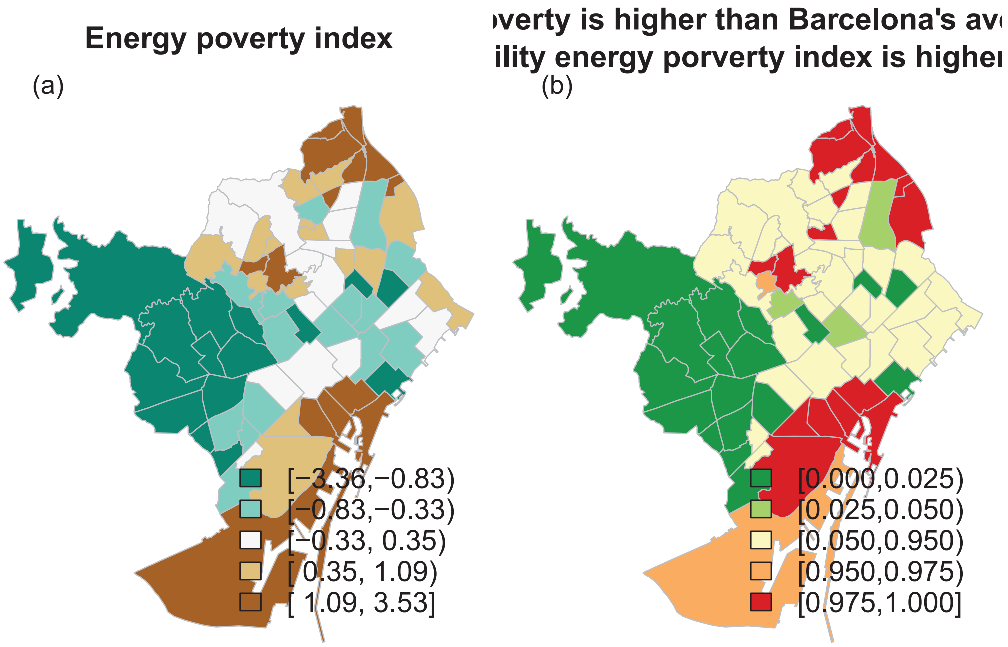
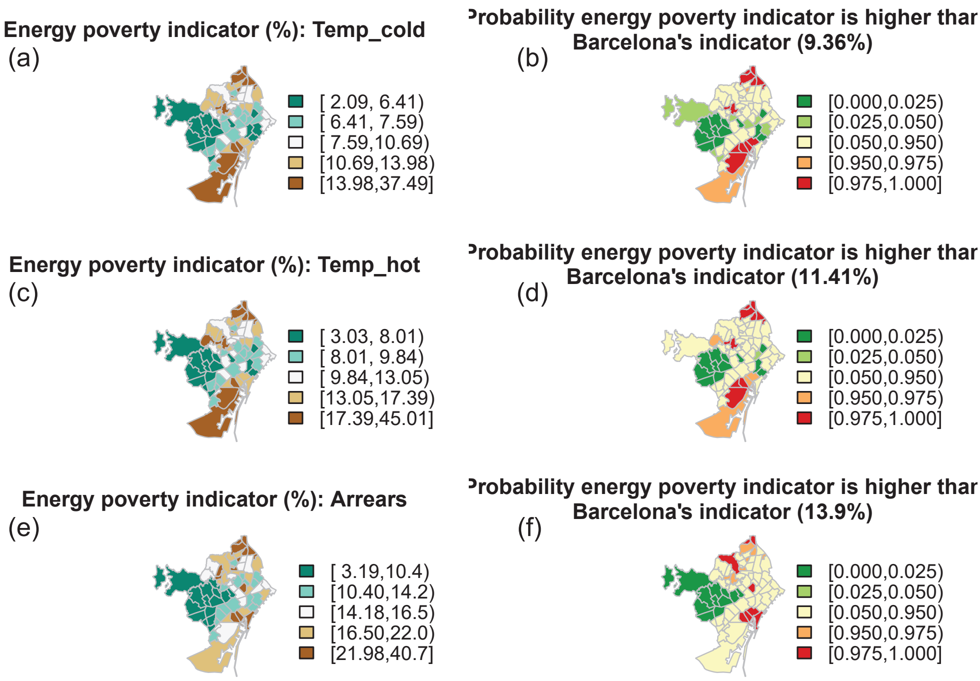


Figure 2

```
par(oma = c(0, 0, 0, 0), mfrow=c(3,2))

l <- 0
for (i in 1:6){

data.plot <- as.data.frame(data.all[,,i])
data.plot$OBJECTID <- as.numeric(row.names(data.plot))
data.plot <- merge(carto, data.plot, by="OBJECTID")
data.plot$post.mean <- round(data.plot$post.mean*100,2)

par(mar=c(1,0,3,0))
MyCut <- cut2(data.plot@data$post.mean, g=5, digits=3, m=0, oneval=FALSE)
values<-as.numeric(MyCut)
mypalette<-rev(brewer.pal(5,"BrBG"))
fgs<-mypalette[values]
plot(data.plot,col=fgs,border="grey",xlab="",ylab="",axes=F,lwd=0.75)
title(paste0("Energy poverty indicator (%): ",dimnames(data.all)[[3]][i]))
legend("bottomright", title="",legend=levels(MyCut),fill=mypalette, y.intersp=0.9,
```

```
       cex= 1.1, bty="n",inset=0.05)

l <- l+1
mtext(paste0("(",letters[l],")"), line=-0.5, adj=0.1)

par(mar=c(1,0,3,0))
MyCut<-cut2(data.plot@data$prob,c(0,0.025,0.05,0.95,0.975,1),digits=2,m=0, oneval=F)
values<-as.numeric(MyCut)
mypalette<-rev(brewer.pal(5,"RdYlGn"))
fgs <- mypalette[values]
plot(data.plot,col=fgs,border="grey",xlab="",ylab="",axes=F,lwd=0.75)
title(paste0("Probability energy poverty indicator is higher than\nBarcelona's indicator",
legend("bottomright", title="",legend=levels(MyCut),fill=mypalette, y.intersp=0.9,
       cex= 1.1, bty="n",inset=0.05)
l <- l+1
mtext(paste0("(",letters[l],")"), line=-0.5, adj=0.1)
}
```



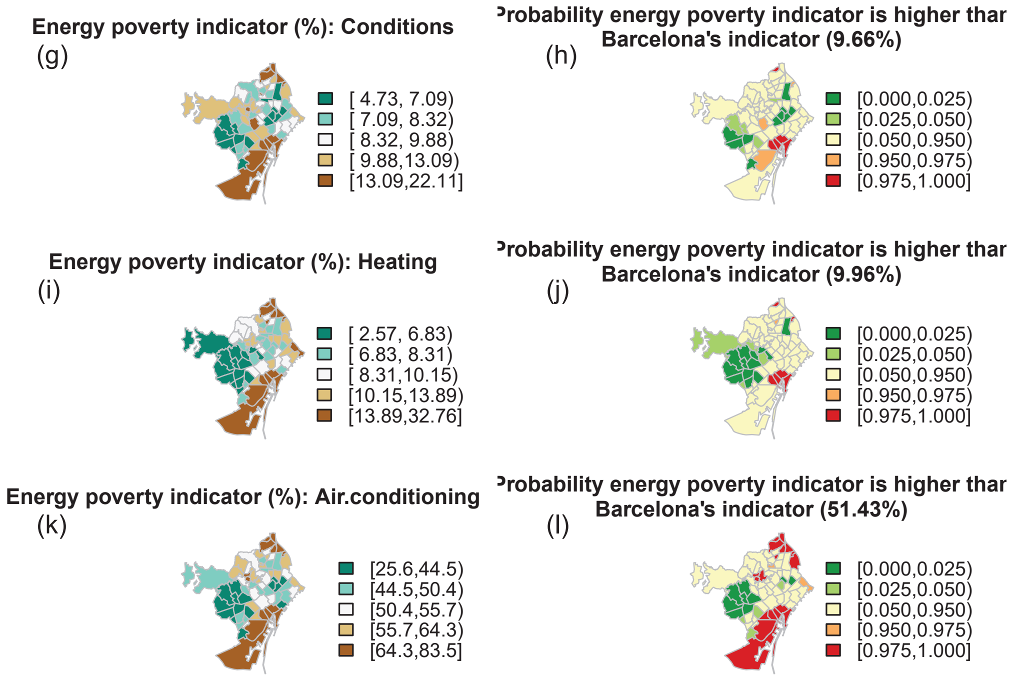


Table 2

Code not run, its output is an excel file. Code included for illustrative purposes.

```
PostMeans <- data.all[,"post.mean",]
table2.min <- apply(PostMeans,2,min)
table2.min[-7] <- table2.min[-7]*100
table2.max <- apply(PostMeans,2,max)
table2.max[-7] <- table2.max[-7]*100
table2.q <- apply(PostMeans,2,function(x){quantile(x,c(0.25,0.5,0.75))})
table2.q[,-7] <- table2.q[,-7]*100
table2.corr <- cor(PostMeans, method="spearman")
table2.w <- Loadings

table2 <- data.frame("Indicador"=row.names(table2.corr),
                     "Minimum" = table2.min, t(table2.q),
                     "Maximum" = table2.max, table2.corr,
                     "Loadings"=c(Loadings,NA))
table2[,-1] <- format(round(table2[-1],2),nsmall=2)

wb2 <- createWorkbook()

addWorksheet(wb2, "Table_2")

hs <- createStyle(textDecoration = "BOLD", fontColour = "#FFFFFF", fontSize=12,
                  fontName="Arial", fgFill = "#4F80BD", halign= "center")
```

```r
writeData(wb2, sheet = "Table_2", table2, colNames=TRUE, headerStyle = hs)

setColWidths(wb2, sheet = "Table_2", cols=1:14, widths = "auto")

saveWorkbook(wb2, file = "Table_2.xlsx", overwrite = TRUE)
```

Table 3

Code not run, its output is an excel file. Code included for illustrative reasons.

```r
indicators <- c()
colors.excel <- c()

for (i in 1:7){
  aux <- data.all[,,i]

  if(i==7){
    indicators <- cbind(indicators, paste0(format(round(aux[,"post.mean"],2), nsmall=2),
                                           " (", format(round(aux[,"ic.lo"],2), nsmall=2),
                                           ", ", format(round(aux[,"ic.hi"],2), nsmall=2),
                                           ")"))
  }else{
    indicators <- cbind(indicators, paste0(format(round(aux[,"post.mean"]*100,2), nsmall=2),
                                           " (", format(round(aux[,"ic.lo"]*100,2), nsmall=2),
                                           ", ", format(round(aux[,"ic.hi"]*100,2), nsmall=2),
                                           ")"))
  }

  MyCut<-cut2(aux[,"prob"],c(0,0.025,0.05,0.95,0.975,1),digits=1,m=0, oneval=F)
  mypalette<-rev(brewer.pal(5,"RdYlGn"))

  colors.excel <- cbind(colors.excel, mypalette[MyCut])
}

indicators <- as.data.frame(indicators)
names(indicators) <- dimnames(data.all)[[3]]
indicators$OBJECTID <- as.numeric(row.names(indicators))
indicators <- data.frame(indicators, "ind"=data.all[,,7][,"post.mean"])
indicators <- merge(carto, indicators, by="OBJECTID")
indicators <- indicators@data[order(indicators@data$ind, decreasing = T),]
indicators <- subset(indicators, select=c("NBarri",dimnames(data.all)[[3]]))

colors.excel <- as.data.frame(colors.excel)
names(colors.excel) <- dimnames(data.all)[[3]]
colors.excel$OBJECTID <- as.numeric(row.names(colors.excel))
colors.excel <- data.frame(colors.excel, "ind"=data.all[,,7][,"post.mean"])
colors.excel <- merge(carto, colors.excel, by="OBJECTID")
colors.excel <- colors.excel@data[order(colors.excel@data$ind, decreasing = T),]
colors.excel <- subset(colors.excel, select=c("NBarri",dimnames(data.all)[[3]]))

wb <- createWorkbook()

addWorksheet(wb, "Table_3")
```

```r
hs <- createStyle(textDecoration = "BOLD", fontColour = "#FFFFFF", fontSize=12,
                  fontName="Arial", fgFill = "#4F80BD", halign= "center")

writeData(wb, sheet = "Table_3", indicators, colNames=TRUE, headerStyle = hs)

setColWidths(wb, sheet = "Table_3", cols=1, widths = 42)
setColWidths(wb, sheet = "Table_3", cols=2:8, widths = 17)


colors.excel$NBarri <- "white"
colors.excel <- rbind("#4F80BD",colors.excel)

for(i in 1:dim(colors.excel)[1]){
  for(j in 1:dim(colors.excel)[2]){
    bodyStyle <- createStyle(fgFill = colors.excel[i,j])
    addStyle(wb, sheet = "Table_3", bodyStyle, rows = i, cols = j, gridExpand = F, stack=T)
  }
}

saveWorkbook(wb, file = "Table_3.xlsx", overwrite = TRUE)
```

Bibliography

Botella-Rocamora, Paloma, Miguel A. Martinez-Beneito, and Sudipto Banerjee. 2015. "A Unifying Modeling Framework for Highly Multivariate Disease Mapping." *Statistics in Medicine* 34 (9): 1548–59. https://doi.org/10.1002/sim.6423.

Corpas-Burgos, F, P Botella-Rocamora, and M A Martinez-Beneito. 2019. "On the Convenience of Heteroscedasticity in Highly Multivariate Disease Mapping." *TEST* 28: 1229–50. https://doi.org/https://doi.org/10.1007/s11749-019-00628-8.

Leroux, Brian G., Xingye Lei, and Norman Breslow. 1999. "Estimation of Disease Rates in Small Areas: A New Mixed Model for Spatial Dependence." In *Statistical Models in Epidemiology, the Environment and Clinical Trials*, edited by M E Halloran and D Berry. Berlin Heidelberg New York: Springer.

Vergara-Hernández, Carlos, Marc Marí-Dell'Olmo, Laura Oliveras, and Miguel A. Martinez-Beneito. 2021. "Taking Advantage of Sampling Designs in Small Area Inference of Survey Sudies." Archive.

Figure S1.A. Energy poverty indicator (%): Temp_cold

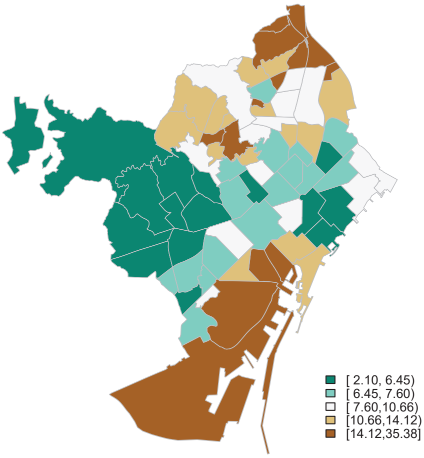


Figure S1.B. Probability energy poverty indicator is higher than the indicator for Barcelona overall (9.36%)

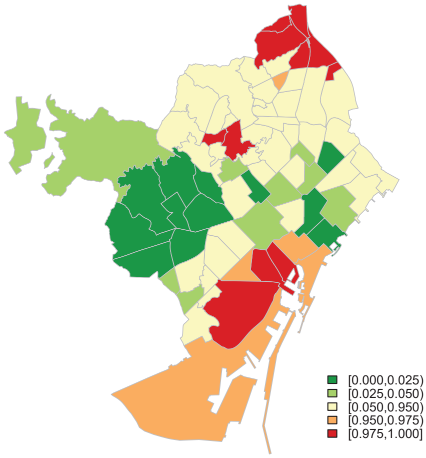


Figure S2.A. Energy poverty indicator (%): Temp_hot

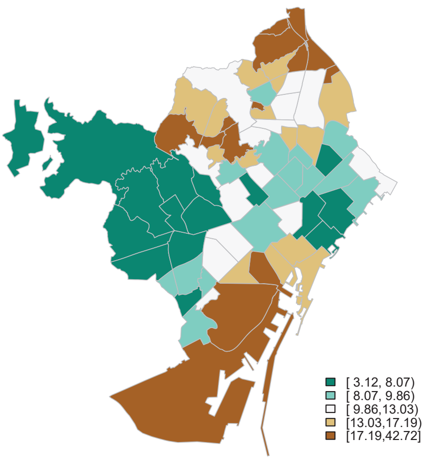


Figure S2.B. Probability energy poverty indicator is higher than the indicator for Barcelona overall (11.41%)

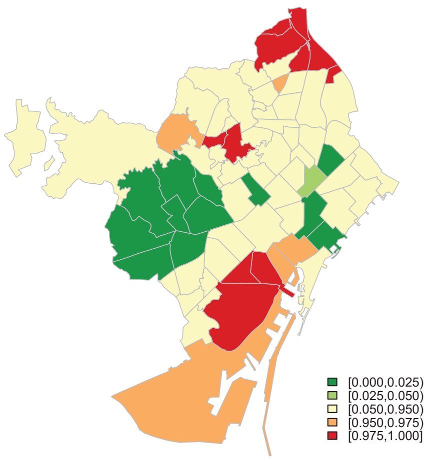


Figure S3.A. Energy poverty indicator (%): Arrears

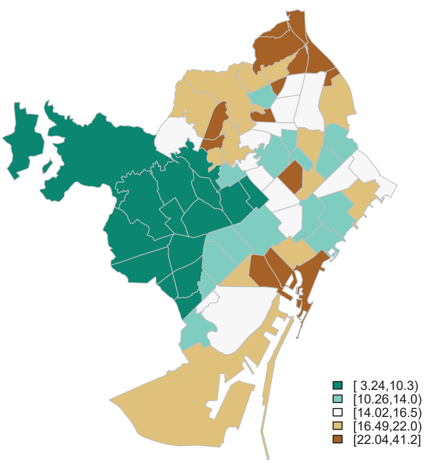


Figure S3.B. Probability energy poverty indicator is higher than the indicator for Barcelona overall (13.9%)

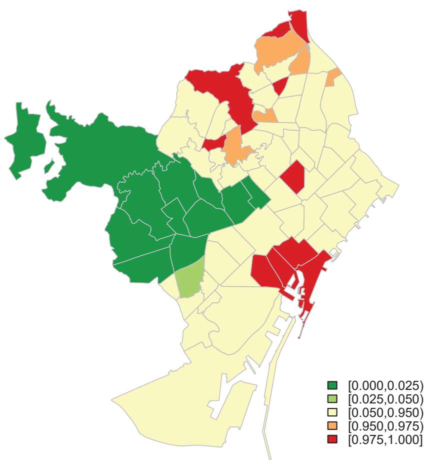


Figure S4.A. Energy poverty indicator (%): Conditions

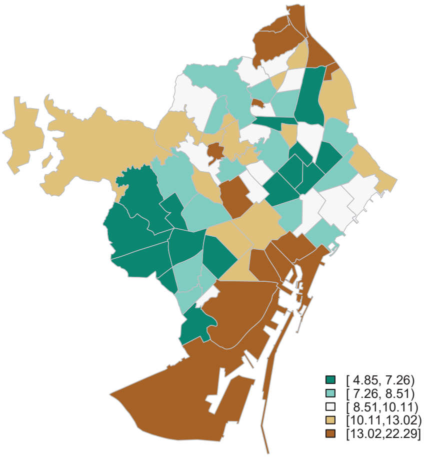


Figure S4.B. Probability energy poverty indicator is higher than the indicator for Barcelona overall (9.66%)

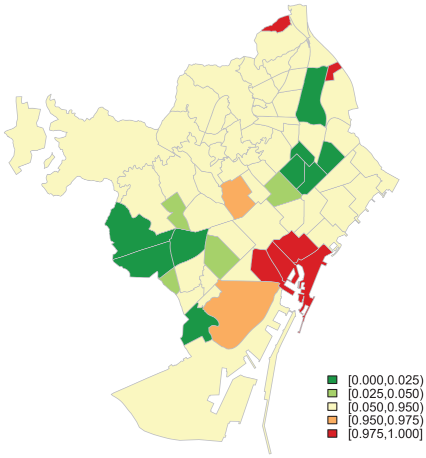


Figure S5.A. Energy poverty indicator (%): Heating

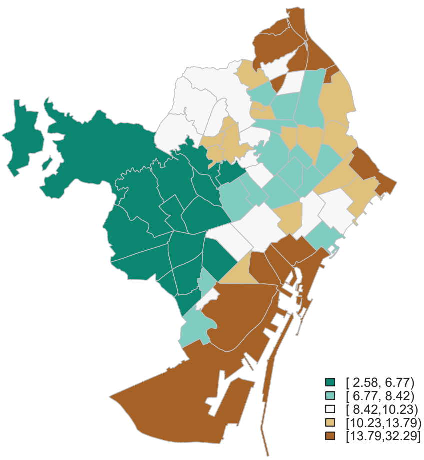


Figure S5.B. Probability energy poverty indicator is higher than the indicator for Barcelona overall (9.96%)

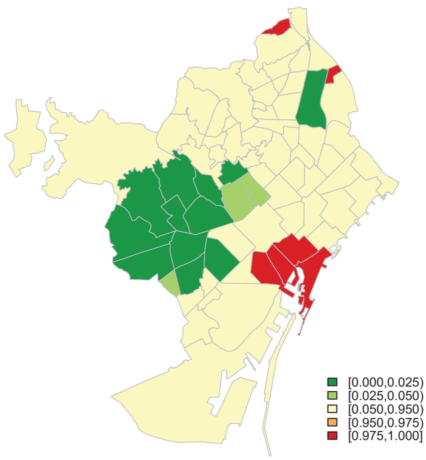


Figure S6.A. Energy poverty indicator (%): Air_cond

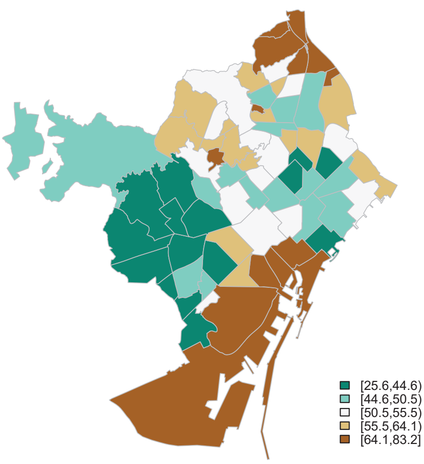


Figure S6.B. Probability energy poverty indicator is higher than the indicator for Barcelona overall (51.43%)