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Review

Much broader than health: Surveying the diverse co-benefits of energy demand reduction in Europe

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ABSTRACT

Demand-side energy reduction measures that aim to reduce energy usage are an effective tool in reducing greenhouse gas emissions as part of a net zero emissions push in Europe. However, often barriers within policymaking hinder deployment. Co-benefits - the secondary benefits of climate change mitigation action - offer an opportunity to reframe energy reduction as financially advantageous and also address a wide range of other policy goals. In support, we survey the type, frequency, and scale of energy demand reduction (EDR) co-benefits in Europe, and assess how these co-benefits can be accounted for in future EDR policymaking.

We conduct a review of co-benefits associated with EDR literature. From 53 selected papers, 86 unique co-benefits are identified across five different categories: Health, Energy Security, Economy, Social, and Environment. Economic co-benefits represent the highest proportion. Health/environmental impacts of air quality are the most cited individual co-benefit. While quantification methodology is discussed frequently, only a fifth of the papers attempt primary quantification of energy reduction co-benefits, with most of those concerned only with air quality. Lastly, a matrix framework is developed that conveys quantifiability and required timescales for key individual co-benefits.

We propose a four-step plan for improving the use of co-benefits, deepening the evidence base to improve climate change mitigation policy: (1) Work on standardisation of co-benefit terms to aid understanding and quantification, (2) Greater focus on cross-disciplinary co-benefit research to avoid research siloes, (3) Greater research on primary quantification of EDR co-benefits to establish functional methodologies and raise awareness of policymakers, and (4) Given high barriers to entry on co-benefits, greater efforts are needed to take co-benefits to policy-makers.

1. Introduction

1.1. Climate change and the importance of demand-side energy reduction

Human activity has had an unequivocal impact on global temperatures, causing rapid cascading changes throughout the atmosphere, ocean, and land [1]. As a common concern of humankind, the urgent risks and impacts posed by climate change require a significant reduction in global greenhouse gas (GHG) emissions over the next thirty years, in order to hold the global average surface temperature to well below 2 °C relative to pre-industrial levels [1–3].

Global emissions modelling scenarios (e.g. Fig. 2.4 [3]) typically propose four main mitigation 'levers': 1) reducing energy use via energy efficiency and other avoided demand measures; 2) decarbonising energy production via mainly renewables-based displacement of incumbent fossil fuels; 3) low-carbon fuel switching at the end use stage mainly via electrification, and 4) CO_2 sequestration via natural and mechanical means. The first mitigation lever – reducing energy use – is the focus of this paper, as its relative success will dictate how hard the other levers have to work, noting that energy-related emissions currently account for around 73 % of global GHG emissions annually [4]. The European Union (EU) for example has a current target to reduce primary energy consumption by at least 32.5 % by 2030 (from a 2007 baseline projection), mainly through the adoption of energy efficiency measures [5]. In the United Kingdom (UK), a reduction in energy use per capita is acknowledged to be essential, mainly achieved in the transport and building sectors which together account for 47 % of terrestrial emissions [6]. Specific policy measures include investment in public transport

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infrastructure and home energy efficiency improvements [6].

Three key issues make demand-side energy reduction particularly challenging. First is historical precedent - absolute energy-GDP decoupling has not been achieved at a global level to date [7]. Advertised country-level energy reductions in more developed nations are largely attributable to 'offshoring' rather than a changed need effect – meaning more stringent and varied demand-side measures are required [8]. Second is the extent and coverage of energy policy itself - while net zero emissions pledges cover countries that currently account for around 70 % of global GDP, less than a quarter are solidified in binding domestic legislation, and even less underpinned by the specific measures and mechanisms required [3]. Third, demand-side energy policy success is largely dependent on how well the socio-technical challenges are confronted, these include financial feasibility, political credibility, and social acceptability [7,9]. These factors are incredibly important in producing regime-scale change [10], since the energy transition involves many complex policy feedbacks between technology and politics [11]. Convincing the public and policymakers of the necessity of such changes also requires overcoming powerful and entrenched ideological obstacles [12].

1.2. The need for a better inclusion of the co-benefits of demand-side energy reduction

Reducing energy demand is often seen as not only one of the fastest, cheapest, and safest means to reduce GHG emissions, it can also promote additional benefits beyond just climate and emission targets. Known commonly as co-benefits, these additional benefits are both diverse and extensive across various fields [13,14]. Specific examples related to reducing energy demand include improved energy security and reduced fuel poverty, although the full scale of potential associated co-benefits is much larger [5,13]. The term 'co-benefit' emerged in the academic literature in the 1990s, and has since been defined in a variety of ways that are both scale and context dependent. Partly as a result, clarifying and implementing the co-benefit concept in policymaking has proved challenging [15]. Co-benefits are often either not identified or overlooked, resultantly they lack inclusion in policymaking where they could demonstrate substantial economic savings, and potentially encourage an increase in climate mitigation action [12,16]. While sometimes acknowledged in official documentation, co-benefits are rarely articulated or incorporated explicitly in decision making and the quantitative analysis of climate policy outcomes. Co-benefit inclusion within the UK's Committee on Climate Change's sixth carbon budget [17] for example is minimal, limited to general comments about health and environmental co-benefits.

1.3. The response: collating the broadest co-benefits of energy demand reduction policy

Energy demand reduction (EDR) is a growing term within the literature [14,18], which reflects measures that aim to reduce energy use through demand-side interventions, with associated reductions in GHG emissions. The most well-known EDR measure is energy efficiency, but also includes avoided demand (e.g. through sufficiency), and shifting to lower intensity energy consumption (e.g. modal shift to buses). A broader inclusion of co-benefits could accelerate EDR policies, yet a fundamental barrier lies in the disparate nature of the co-benefit literature itself within the EDR field. Currently, the majority of co-benefit literature focuses on the health/air pollution co-benefits of lower fossil fuel combustion, with other EDR co-benefits largely absent [19]. In addition, EDR particularly is not frequently identified – making it hard for policymakers to distinguish EDR-related co-benefits - instead it is usually subsumed by general mitigation and adaptation discourse.

An effort to collate the broad set of co-benefits of EDR policies would help improve the evidence base to make the social and political case for the implementation of a deeper set of EDR policies. This is the focus and goal of our paper, through a structured literature review approach, which helps "provide an approach that can help academics to discover under-investigated topics and methods" [20]. The main aim and contribution of the paper is therefore to collate the type, frequency, and scale of EDR policy co-benefits in Europe, and to understand how these co-benefits can be accounted for in future EDR policymaking.

There are three objectives that look to fulfill the central aim:

1. Categorise EDR co-benefits into particular policy-relevant categories, and to gain further comprehension of their collective impact
2. Collation of the most commonly cited co-benefits associated with EDR
3. Assess the state of methods of quantification for EDR co-benefits, and to understand the potential for standardisation of methodologies.

The structure of the paper is as follows. In Section 2 we provide an overview of demand-side policy associated co-benefit areas. In Section 3 we outline our structured literature review methodology, provide results in Section 4, leading to the Discussion in Section 5, before closing with Conclusions in Section 6.

2. Demand-side energy policy and associated co-benefits: a background

2.1. Energy demand and economic growth

The growth of modern industrial society has demonstrated that as economic systems become larger, wealthier, more populous, and more complex, they require larger energy flows to sustain them [13]. For every 1 % increase in per capita GDP, on average there is around a 0.75 % increase in per capita energy consumption [13,21]. While global energy demand was set to increase by 4.6 % in 2021, offsetting the 4 % contraction in 2020 due to the Covid pandemic, energy use in advanced economies was on track to be 3 % below pre-Covid levels [3]. However, longer term demand among the advanced economies is expected to recover across most sectors and follow IEA and other baseline forward energy projections [3]. Therefore, achieving global climate targets cannot depend on economic stagnation and disruption. To effectively deliver significant climate change mitigation, there will likely need to be a rapid large-scale transformation in the sociotechnical systems that provide energy services across the economy [13].

2.2. Approaches to EDR policy

A reduction in energy demand can be conducted through a variety of policy instruments. One of the most cited is altering consumer behaviour through behavioural nudges, examples include congestion charging and home smart metering [14,22]. However there are serious doubts about the scale of change this type of policy can deliver [14]. This is not to say that information flows are unimportant, as the information structure of the energy system can improve feedbacks and aid other EDR policy initiatives [23]. The other most commonly utilised EDR policy is energy efficiency improvement, particularly in both personal mobility and the residential sector [13].

The Avoid-Shift-Improve (ASI) framework offers a useful context by which EDR policy can be understood, as a common framework it allows for transdisciplinary collaboration and to establish focal points in discussion of demand-side solutions [24]. Originating in Germany in the 1990s, the term has served as a way to structure policy measures that reduce the environmental impact (and thus energy requirements) of transport [25]. ASI is becoming increasingly adopted beyond transport, to other demand-side reduction services, such as buildings and food systems [24], and more recently across all economic sectors in a net zero framework analysis of the UK [26].

Transport modal shift remains perhaps the most prominent example of an EDR measure, whereby car traffic is shifted towards lower carbon intensity modes of transport, such as trains, walking and cycling [27]. Transport modal shift can therefore be understood clearly through the ASI components: avoiding excessive journeys (e.g. densifying urban structure and carpooling), shifting traffic towards better modes (e.g. more extensive public transport infrastructure and congestion charges), and improving energy efficiency through more fuel-efficient vehicles [25,27]. ASI frameworks also encapsulate the two aspects of EDR referenced earlier: behavioural nudges (primarily through avoid) and energy efficiency (primarily through shift and improve). In this sense, when EDR is viewed through the three broad ASI components (avoid, shift, improve), we also see how 'energy efficiency' in the strictest sense is a subset of the broader EDR classification, most closely associated with 'improve', and sometimes 'shifting' components of ASI frameworks. This is also reflective of a shift in time: EDR is the newer term (compared to energy efficiency), representing a broader set of actions to reduce energy demand and thereby energy-related GHG emissions.

However, even providing efficiency gains at the scale required requires a bold direction for future investment, while also overcoming the inertia of historic policy [13]. Royston *et al.* [18] assert that existing demand-side approaches of technological efficiency and informed individual consumption are not adequate in achieving the reductions required to curtail immediate emissions.

Finally, a lack of understanding of the consequences of non-energy policy on energy demand means that EDR objectives currently remain invisible in policy areas where it may not be as obviously present [18]. By understanding the complex synergies beyond energy policy, one can facilitate greater understanding of how demand for energy is constituted, understand how to improve energy governance and awareness of potential interventions, and subsequently identify and inform policymakers of the relevant co-benefits [18,28].

2.3. EDR policy by sector

Energy demand reduction is only one part of broader climate change mitigation policy, and therefore to equate the two would be to associate co-benefits that do not have relevance to any particular EDR policy. However, a large portion of climate change mitigation is concerned with energy savings, and therefore there is significant overlap between the two concepts. Sharifi [22] discusses both climate mitigation and adaptation policy in reference to relevant policy areas, as well as how the measure contributes to mitigation (i.e., energy savings). As a result, the relevant EDR measures can be identified to present a clear view of EDR policy by sector, as shown in Table 1. (Note that the adapted Sharifi [22] Table 1 is only intended to serve as an example of how EDR policies may be viewed by sector and through an ASI framework lens. Other sector-divided EDR examples include Creutzig *et al.* [24]).

2.4. The complexity of co-benefits

Miyatsuka and Zusman [15] posit that at its core, the co-benefit approach is the idea of a win-win strategy, whereby a single climate mitigation policy achieves objectives beyond just climate change related targets. Karlsson *et al.* [19] also identify co-benefits as the benefits of climate policy in addition to the avoided climate change costs (e.g., lowered private and societal costs for health problems, or the decreased threats to biodiversity). There is however no single exact understanding of the term co-benefit across the literature, with differences in usage relating to intentionality and the type of benefits included [15,19]. This lack of consensus means that there is no clear understanding of the best entry point to integrate co-benefits into policy, nor is there agreement on the methodologies used to account for these benefits [15]. If properly synthesised and understood, co-benefits can ameliorate or even exceed the potential costs of mitigation policy, in this case demand-side measures are usually some of the least considered in contemporary climate policy and therefore would most benefit from such inclusion [14,19]. Key challenges include accounting for the scale of co-benefits that exist, how they interact with specific policy measures, as well as the lower order impacts that they can have within a system.

In Europe, there have already been two large projects to attempt to synthesise, account and identify methods of quantification looking at the co-benefits (referenced as multiple benefits in these studies) of energy efficiency measures; Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe (COMBI)[1] and Multiple Benefits of Energy Efficiency (M-BENEFITS).[2] This represents an attempt to

Table 1
Example of energy demand reduction policy by sector, adapted from Sharifi [22] with reference to ASI framework. Note – the categorisation of planning/policy measures into ASI categories is based on author's own assessment of whether the measure mostly Avoids (energy use), Shifts (to lower energy intensity) or Improves (energy efficiency).

Sector	Planning/policy measure	Avoid	Shift	Improve
Urban Design/ Land Use Planning	Appropriate levels of density	A		
	Improved physical accessibility to amenities	A		
	Land use mix	A		
	Improved connectivity		S	
	Cool roofs and pavements			I
	Passive urban design (shading, orientation, natural ventilation, etc.)			I
	Appropriate design of streets, street networks and street canyons	A		
Transportation	Transit-Oriented Development		S	
	Transportation demand management	A		
	Promotion of public transport and active transport modes		S	
	Congestion pricing		S	
	Single tariff public transport policy		S	
	Car sharing	A		
	Electrification of urban transport			I
	Improvement of vehicle efficiency standards			I
	Parking demand management	A		
	Vehicles and fuel tax policies	A		
	Adoption of high occupancy vehicle (HOV) lanes	A		
Building	Passive building design	A		
	Insulation			I
	Green building programs and policies	A		
	Building retrofit	A		
	Enhance building energy efficiency (i.e., home appliances, light bulbs, etc.)			I
	Improved air conditioning techniques			I
	Providing smoke-free kitchens to poor households		S	
	Building material durability improvement	A		
Waste	Wastewater recycling and treatment/management			I
Energy	Distribution and decentralisation of energy systems (district cooling and heating, CHP plants, microgrids, etc.)	A		I
	Electric power transmission and distribution management	A		I
Green Infrastructure	Water-sensitive urban design (permeable surfaces, bioswales, etc.)	A		

[1] https://combi-project.eu/.
[2] https://www.mbenefits.eu/.

address some of the challenges faced in co-benefit research and integration (within energy efficiency policy). Both projects had aims of understanding how energy efficiency improvement not only reduces overall energy consumption but is also a means to address major future energy challenges and produce non-energy multiple benefits. While limited to energy efficiency, such projects are examples of efforts to research the scale of EDR co-benefits by creating tools that facilitate the quantification and visibility of co-benefits for policy makers. They both help to refine methods of quantification and monetisation, use this knowledge to incorporate into decision-support frameworks for policy-making, bolster investment proposals and increase communication and awareness of the growing co-benefit evidence base. These studies together represent a positive example of how to overcome some of these complexities in a European policy context, and provide important lessons for the direction of travel for co-benefits research.

To illustrate the complexity and interrelationships of co-benefits, Fig. 1 provides an example representation of some of the positive and negative feedback loops that could occur after the implementation of EDR policy, and the potential co-benefits that arise.

Fig. 1 acknowledges the potential variety of co-benefits available, affecting different aspects of the system with economic impacts in a range of sectors. Air pollution is a co-benefit that is often cited within co-benefit literature, the health impacts/savings of reduced air pollution as a result of mitigation policy representing a dominant portion of literature [19]. The prominence of health co-benefits may be due to the relative ease of quantification, or it is a more mature field - better developed for quantification. However even within this most-researched sector, uncertainty as well as the large complexity of confounding factors raises difficulties [19]. In addition, Harlan and Ruddell [29] state that estimating the monetary savings of co-benefits is redundant if appropriate research and predetermination of ancillary factors is not present. Therefore, there is a driving need to account for and expand the current knowledge of EDR co-benefits beyond just health.

Categorisation offers a method of simplifying the complexity of EDR co-benefits into defined policy areas that contain the most immediate interactions [29]. The precedent for categorisation is itself related to encouraging inclusion in policy, it therefore is an adaptable process to specific contexts. The Institute for Advanced Sustainability Studies (IASS) [30] highlight that forming accepted co-benefit categories allows for the establishment of a common denominator with regards to policy areas, which is advantageous for political discourse. In addition, IASS suggest co-benefit groupings that are too heterogeneous may become too diverse to address specific interest groups [30].

2.5. Co-benefits as incentive for EDR policy

The desired outcome of increased awareness and inclusion of co-benefits within any given EDR policy area is as a further motivator of such action, in motivating stakeholders that would not be encouraged by climate risk alone. Bain *et al.* [12] discuss the positive effect that co-benefits can have on the likelihood of climate mitigation action occurring independent of the belief that climate change is important.

A significant barrier in the progression of EDR policy (and mitigation generally) is that the effective communication of climate science has not been sufficient to increase policy action [12]. It was found that development (economic and scientific advancement) and benevolence (a more moral and caring community) co-benefits motivated public, private, and financial climate action at the same level as a belief in climate change [12]. What Bain *et al.* [12] call dysfunction co-benefits relating to, for example, pollution and disease are some of the weakest motivators of action, Amelung *et al.* [31] however indicate that raising the direct health co-benefits increases willingness to adopt food and housing measures (e.g., reduced red meat diet, retrofitting homes etc.) at the household level. Petrovic *et al.* [32] also highlight that public health is usually a high priority at the national level, and that public health messaging about the benefits of mitigation action rather than climate change was more effective in changing attitudes across most issues.

Framing beyond a climate lens, which is what co-benefits provide, allows policymakers and politicians to overcome the ideological divides that previously hindered adoption of such measures [12,32]. It is unclear however how the degree of motivation relates to particular co-benefits and directly to EDR policy, it is also the case that convincing members of the public is a different task to convincing policymakers.

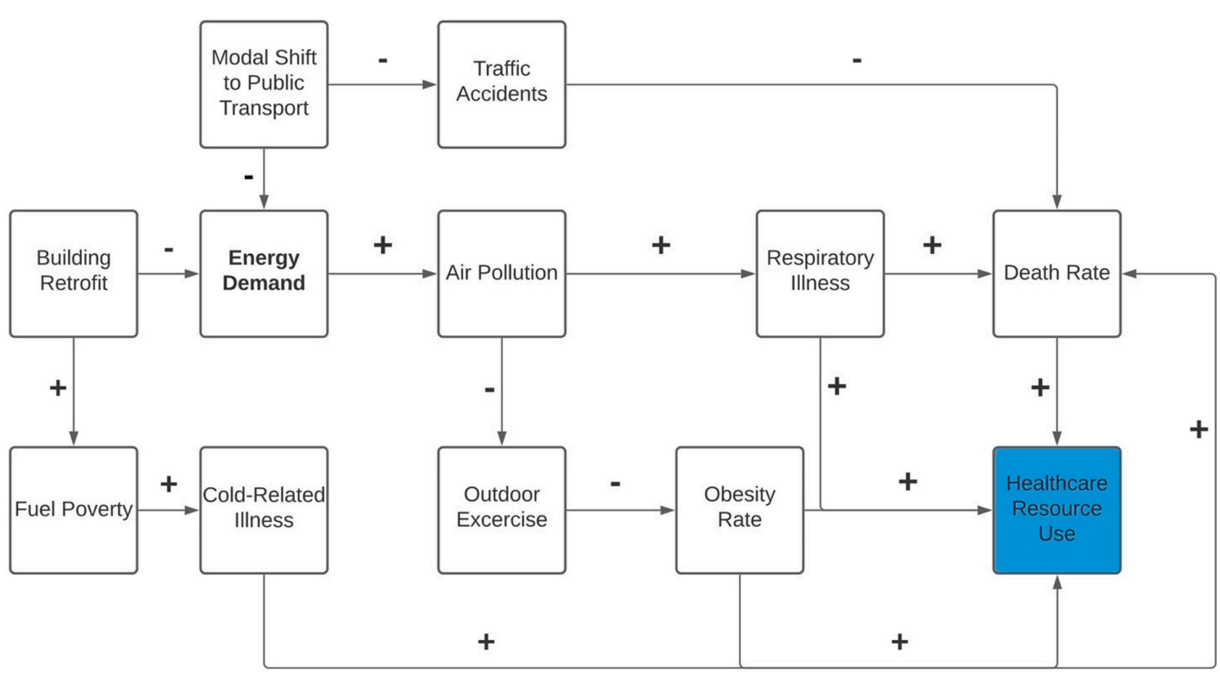

Fig. 1. Example system feedback map of energy demand co-benefit interaction impacting healthcare resource use, to illustrate interrelationships. Authors own construction. Note: +/− sign denotes positive/negative feedback relationship respectively.

3. Methodology

3.1. Overview of the literature review process

In order to acount for the full extent of potential EDR co-benefits, a structured literature review utilising 'co-benefit' and associated terms in conjunction with relevant phraseology was carried out. A structured literature review contains aspects of a conventional systematic literature review, however it does not fulfill all of the critieria traditionally associated with a full systematic approach [33]. It differs namely in that it is smaller in scale and scope [34]. In this case the structured review shares many similarities with a rapid evidence assessment: the completeness of the search is determined by the time available; the synthesis is both narrative and tabular, and the analiysis expresses the quantities of literature as well as its overall quality and direction [35]. For our paper, which is an exploratory synthesis of the existing co-benefit literature across a broad range of fields, the structured literature review is a suitable choice.

3.2. Iterative/responsive nature of the review process

3.2.1. Establishing relevant definitions

Taking a taxonomic approach to co-benefit literature is a challenging endeavour because of the large range of established terms and definitions used by authoritative organisations and persons [36,37]. The application of significantly different concepts under the same terminology, or vice-versa, ensures that the integration of co-benefits into policymaking at scale is difficult, however this does not mean the term is redundant or without some underlying consistency [19,38]. Mayrhofer and Gupta [38] identify that all uses of the term co-benefit are an elaboration of a 'win-win' strategy, by which more than one objective is achieved through a single policy action (specifically in the context of climate policy). Much previous discourse has raised the importance of intentionality in relation to the terminology used, distinguishing co-benefits as intentional positive effects, while for example using other terms such as ancillary benefits to describe unintended positive effects [36,39]. Intentionality now has reduced relevance to the use of co-benefit and associated terms, since it is acknowledged that they are used interchangeably, as well as the fact that unintentional benefits are in many cases due to a lack of suitable accounting methods within policymaking [36].

3.2.2. Non-energy benefits and other alternate co-benefit terminology

An issue arose in initial exploratory searches focusing on just the terms 'co-benefit' and 'ancillary benefit', since it excluded many relevant articles that discussed co-benefits but did not use these terms specifically (e.g., using more focused terminology or overlapping/parallel terms rather than directly referencing co-benefits). The literature discussing climate change mitigation and using the term 'co-benefit' is largely dominated by health and specifically air pollution/quality related discussion, this is likely due to the well-established methods of quantification and inclusion in policymaking compared to other co-benefits [19,39–41]. Therefore, further searches were conducted that focussed specially on energy systems, to identify relevant literature that did not directly engage with co-benefits. As a result, it was considered pertinent to include literature that used the term 'non-energy benefit' (NEB), this is an umbrella term that focuses on the range of benefits associated with energy efficiency programs which are not directly energy related [42]. This has direct relevance to both energy demand reduction as an aspect of demand reduction policy, it is also a related term to co-benefits and can also be viewed legitimately as a sub-concept within co-benefits more broadly [42–44]. Rasmussen [43] views NEBs and co-benefits as overlapping concepts, with co-benefits representing the international, national, and sectoral levels, while NEBs cover just the sectoral and individual contexts. In this review, only NEBs relevant to demand reduction policy and policymaking in general are included in the analysis as appropriately identified co-benefits.

There is also a clear overlap between terminology as well as the effects of energy efficiency measures and EDR measures more broadly. NEBs also have a direct relationship with the 'energy benefit' of a certain policy, i.e., the desired outcome the energy system/usage change. The energy benefit of energy efficiency (e.g., demand reduction) has a cascading effect producing multiple dependent co-benefits associated to the policy. It is important that the complex relationship between efficiency, EDR and the resultant co-benefits is understood so as to identify all the NEBs correctly (also see Fig. 1).

The same precautions as for non-energy benefits were taken with the terms 'co-benefit', 'multiple benefit', 'multiple impact', and 'coeffect', specifically in energy efficiency literature, i.e. we ensured there was a clear link between the policy, efficiency impacts and the resulting co-benefits before including in our analysis (see Fig. 1 for process example). This was to ensure a direct relationship was drawn between the policy measure and the subsequent co-benefit before inclusion.

NEBs as a concept are not as comprehensive in their scope in comparison to co-benefits, the amount of literature is also relatively limited and mainly focused on the scale of industry [42–44], though the pioneering work of Skumatz [45] provides a notable exception. In contrast, 'multiple benefit' and other terms generally have a broader scale of focus. As acknowledged however, altering the energy flows within industry is and will be a significant part of reducing energy demand more broadly, therefore NEBs are important in contributing to a strong financial case for energy efficiency measures within industry directly [43,46]. Industrial leaders are important stakeholders in transitioning the energy system. NEBs focus mainly on energy efficiency means it only addresses one component of EDR policy, however the synergies across policy mean that many NEBs identified have the potential for broader applicability across other EDR measures. Merging aspects of NEB literature with co-benefits in the context of energy demand reduction is justified as it accesses a larger potential base of secondary benefits for which to utilise in EDR policy across sectors.

3.2.3. 'Energy demand reduction' and alternatives

During the iterative searching process (see Section 3.3), three terms became most closely associated with the co-benefit literature: 'Energy efficiency'; 'energy demand' (reduction/response etc) and 'climate change mitigation', and were therefore included as the main EDR terms in the literature search, in conjunction with the final use (after iteration too) of six 'co-benefit' terms. 'Energy efficiency' and 'energy demand' appear commonly in energy-sided journals e.g. [18,28,47], with EDR becoming more prevalent recently, as the energy literature broadens beyond energy efficiency to include a fuller range of avoid-shift-improve interventions (see Section 2.2). Conversely, 'climate change mitigation' is linked with co-benefits more commonly in climate-sided journals [24,31,32] and within government/NGO reports in the grey literature [30,36,41].

3.3. Initial literature review process

3.3.1. Literature collection and review

In order to find literature related directly to our aims and objectives, we follow the approach laid out in Fig. 2:

The summary of the main searches conducted is given in Table 2. Peer-reviewed publications were obtained via search terms from the journal database Google Scholar. Relevant non peer-reviewed 'grey' literature was also included, due to its relevance to the policy process, which was found through supplementary searches using Google. Effective search terms and strings were established through iteration. In addition, foundational literature - already identified as relevant before the search and review process began – was subsequently also included in the full review [19,22].

Six relevant terms were used as the basis of any search criteria as it would produce the largest breadth of search results relevant to a limited

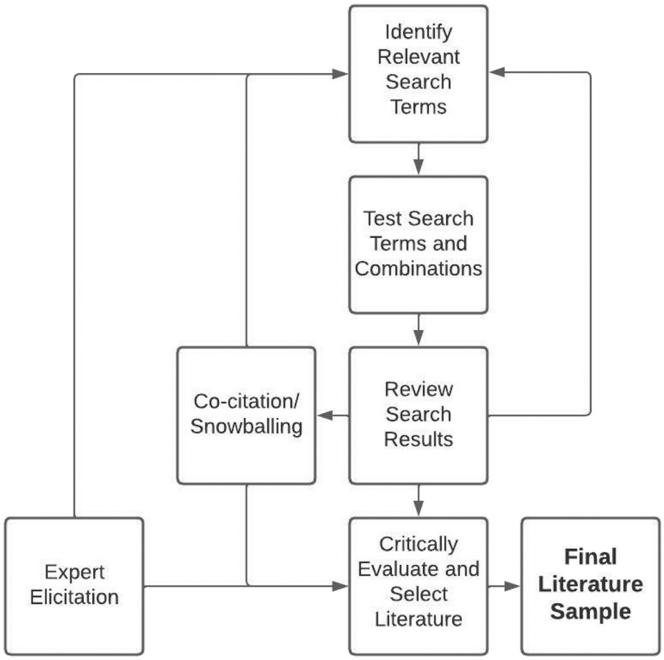

Fig. 2. Flowchart representation of the structured literature reviews' iterative process.

Table 2
Overview search terms used during the structured literature review process.

Search term	Peer-reviewed literature (Google scholar results)	Grey literature (Google results)
"climate change mitigation" AND "co-benefit" OR "ancillary benefit" OR "non-energy benefit" OR "multiple benefit" OR "multiple impact" OR "coeffect"	4830	53,400
"energy demand" AND "co-benefit" OR "ancillary benefit" OR "non-energy benefit" OR "multiple benefit" OR "multiple impact" OR "coeffect"	2990	32,400
"energy efficiency" AND "co-benefit" OR "ancillary benefit" OR "non-energy benefit" OR "multiple benefit" OR "multiple impact" OR "coeffect"	5520	76,400
Total	13,340	162,200

literature base surrounding energy demand co-benefits. With regard to Google searches, identical strings were used with the inclusion of all six terms. To widen the search, in conjunction the terms "climate change mitigation", "energy demand" and "energy efficiency" were used to capture key areas of relevant literature, as shown in Table 2. Through the process of snowballing, checking reference lists and expert elicitation, additional references were added into the literature review. Overall, therefore, we have good confidence that the six 'co-benefit' terms used in this review correspond to the overwhelming majority of literature addressing EDR co-benefits.

The inclusion criteria for a paper to be selected for further screening was as follows:

1. Have a focus on the co-benefits of energy demand reduction (or use of a similar related term in the same context).
2. Be published from the year 2000–2022 (up to time of submission, to collate the most recent results).
3. Have a geographical focus on Europe/a European nation, or have a significant portion of literature relevant to Europe within a global analysis.
4. Contain either categorisation of EDR co-benefits, or explicate the relevant accounting methods (or both).
5. Not have repeated elements or significant overlap with previously chosen literature.

3.3.2. Literature inclusion and selection by terminology

Next, to narrow down to the selected references for study, papers were sorted on the journal database search results by relevance as well as by citations to bring the most relevant papers to the forefront. In order to capture the most relevant literature, the first twenty pages (200 articles) sorted by most relevant (100) and most cited (100) for each search were taken into the next stage of sifting. This was a form of algorithmic sifting to ensure the most relevant articles were extracted. This consideration was taken because of the small scale of current literature relevant to EDR co-benefits, as well as to capture enough co-citation through going through the references of more relevant papers. Following the initial sifting, the screening process then followed a three step process: 1. title, 2. abstract, 3. full article (see Fig. 3).

As a result, papers that utilised terminology adjacent to "co-benefit" (or included co-benefit but not as the preferred term for the concept) as the primary term were included on the basis of significant overlap between their use in the context of energy demand reduction. Beyond Google and Google Scholar searches therefore, co-citation of papers already selected was undertaken in order to find associated literature that had high applicability to the research aims. This task was carried out either through the cited by function on Google Scholar, or by looking through the citations of the papers themselves. This process facilitated the inclusion of many journal articles that used an alternative term to describe 'co-benefits', and throughout the search, familiarity with other terms grew and those in popular use were identified. Additional papers were also gathered through a process of expert elicitation in the co-benefit academic field, suggested papers went through the same sifting process as those found through literature search and provided supplementary literature (see Fig. 3).

A total of five diffent primary terms were included within the review, after a preliminary selection of 57 papers, four were not included in the final sample because of the overlap between the literature. This was primarily down to the same authors in different papers, this led to a repetition nearly verbatim of the same points and therefore the inclusion was not deemed to add anything new to the review. If two papers had similar content, the one which contained the most relevance to the research aims was included.

3.4. Methodological limitations

While the methodology is grounded in solid literature review principles, there are certain limitations that must be acknowledged. A general criticism of the literature review process is that there can be little obvious intent to maximise or analyse data collected, there is also potential bias (even inadvertantly) to omit certain sections of literature, or by not questioning the validity of certain statements made [35]. The other concessions made during the structured literature review process include using broader and less sophisticated search strategies and performing only relatively simple quality appraisal [35]. In this review only the first 20 pages of a database search were analysed for each combination of search terms. Also, we included (based on our iteration) a set of six alternate terms associated with co-benefit (co-benefit, ancillary benefit, non-energy benefit, multiple benefit, multiple impact, coeffect) in the search process (see Fig. 3). There could be a number of potential alternative terms that we may have inadvertently excluded, but the focus was made on terms that had the highest perceived quantity and quality of literature a priori and throughout the process.

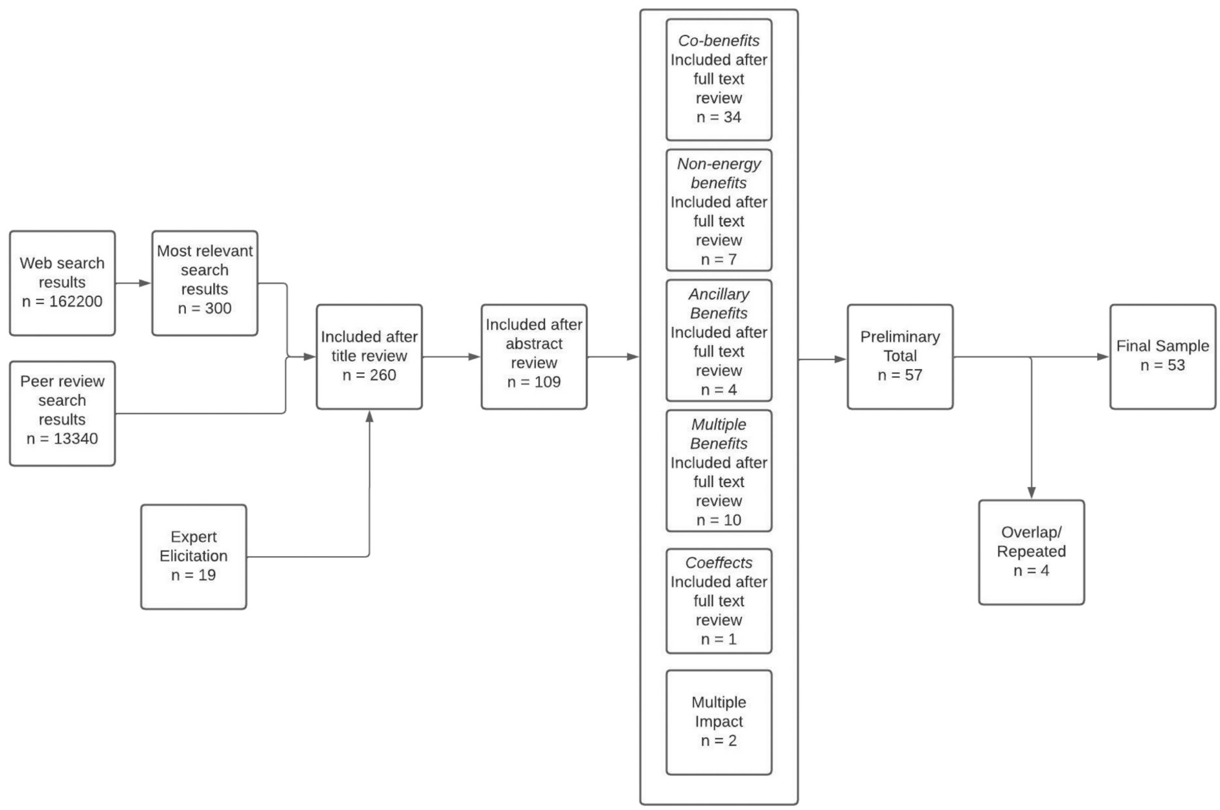

Fig. 3. Representation of the structured literature review sample by term.

4. Results

After the completing the literature review process, 53 articles/reports were selected for final use within the review. Section 4.1 presents an overview of the literature used, the scope of the literature, and the primary terminology used within each article. Section 4.2 collates the co-benefits across five key categories: Health, Energy security, Economy, Social and Environment. Section 4.3 details the most common listed individual co-benefits (such as air pollution). Last, Section 4.4 outlines the potential for common EDR co-benefit quantification.

4.1. Literature summary

Table 3 highlights the 53 papers/reports selected for use within the literature review. 41 were peer-reviewed journal articles, 9 were reports from thinktanks, NGOs, or government and 3 were conference or working papers.

Viewing the third column, 31 of the 53 articles prioritised the use of the term ‘co-benefit’ to describe the positive externalities of climate change policy. The second most prevalent term was multiple benefits (10No.), this term is primarily used in the context of energy efficiency specifically rather than climate change mitigation, much like the term non-energy benefits [43]. Non-energy benefit (5No.), ‘ancillary benefit’ (4No.), ‘multiple impact’ (2No.), and ‘coeffect’ (1No.) were the other three terms favoured in the additional ten papers. Other than non-energy benefit and multiple impact which share a use similar to multiple benefit, the additional two terms have a direct interchangeability with co-benefit in this context.

The geographic scope (in the fifth column) of the literature review naturally focused (due to search / inclusion criteria) on European literature, with 21No. sources from either a European-wide study or from a particular country within Europe. The inclusion of literature that had global elements (30No.) was justified because it included components that heavily focused on Europe, or that it had relevance to the policymaking debate within Europe. To be too Eurocentric would be to exclude important literature that had a wider focus, it would also fail to acknowledge the broad applicability that other co-benefit accounting and classification methods can have to a European context.

4.2. Research objective 1: categorising co-benefits

Floater *et al.* [36] acknowledge that the use of categorisation is to build a framework from which cities or countries can understand co-benefits in relation to their policy needs, or in the case of academic literature as a means to simplify the enormous scope of potential co-benefits available [38]. This is evident in the simplification of the thirteen categories initially present within Floater *et al.* [36] into five strategic categories. Hence, there should be a balance between the potentially infinitesimal number of categories, and finding an appropriate resolution that demonstrates nuance and relevance. The division of priorities between different government departments exacerbates the challenge of incorporating co-benefits and allowing for collaboration where priorities intersect, due to the competition for funding which can lead to simple cost-benefit analysis of energy and climate issues, at the expense of a broader co-benefits inclusion, which has been endemic to a lot of contemporary thought [64]. Urge-Vorsatz *et al.* [39] highlight that a taxonomy provides a framework with which analysts can identify the area specific impacts of particular policies, however there must be understanding of the interaction among different impacts across sectors. Rather than compile a universal taxonomy which is neither possible given the complexity nor desirable, it is more appropriate to focus on creating broad categories from which lower-order co-benefit categories can be further elaborated to specific policy [39].

Jennings *et al.* [64] suggest four key categories of co-benefits: health and the NHS, Immigration and Energy security, Economy and unemployment, and Poverty, housing, and inequality. Evidently while it is only UK focused, its rationale is important as it aims to explicitly correlate the co-benefit areas to governmental departments and

Table 3
Summary of literature review.

Author(s)	Year	Preferred co-benefit term	Document type	Geographic scope
Bachra *et al.* [48]	2020	Co-benefit	Journal Article	Global (inc. Europe)
Bisello *et al.* [49]	2017	Co-benefit	Conference Paper	Global (inc. Europe)
Bleyl *et al.* [47]	2019	Multiple Benefit	Journal Article	Europe
Bollen *et al.* [50]	2009	Co-benefit	Working Paper	Global (inc. Europe)
Cassen *et al.* [51]	2015	Co-benefit	Journal Article	Global (inc. Europe)
Chatterjee and Urge-Vorsatz [52]	2021	Multiple Impact	Journal Article	Germany and Hungary
Cooremans and Schönenberger [53]	2019	Non-energy Benefit	Journal Article	Switzerland
Creutzig *et al.* [54]	2012	Co-benefit	Journal Article	Europe
Creutzig *et al.* [55]	2022	Co-benefit	Journal Article	Global (inc. Europe)
Deng *et al.* [56]	2017	Co-benefit	Journal Article	Global (inc. Europe)
Fawcett and Killip [37]	2019	Multiple Benefit	Journal Article	Europe
Ferreira *et al.* [57]	2017	Co-benefit	Journal Article	N/A
Floater *et al.* [36]	2016	Co-benefit	Report	Global (inc. Europe)
Frankowski and Herrero [58]	2021	Co-benefit	Journal Article	Poland
Freed and Felder [42]	2017	Non-energy Benefit	Journal Article	Global (inc. Europe)
Giles-Corti *et al.* [59]	2010	Co-benefit	Journal Article	Global (inc. Europe)
Hamilton and Akbar (World Bank) [60]	2010	Co-benefit	Report	Global (inc. Europe)
Heffner and Campbell [61]	2011	Co-benefit	Report	Global (inc. Europe)
International Energy Agency (IEA) [62]	2014	Multiple Benefit	Report	Global (inc. Europe)
Jakob [63]	2006	Co-benefit	Journal Article	Switzerland
Jennings *et al.* [64]	2019	Co-benefit	Report	UK
Jochem and Madlener [65]	2003	Ancillary Benefit	Working Paper	Global (inc. Europe)
Kamal *et al.* [66]	2019	Multiple Benefit	Journal Article	Global (inc. Europe)
Karlsson *et al.* [19]	2020	Co-benefit	Journal Article	Global (inc. Europe)
Killip *et al.* [67]	2020	Multiple Benefit	Journal Article	Global (inc. Europe)
Krook Riekkola *et al.* [68]	2011	Ancillary Benefit	Journal Article	Sweden
Kwan and Hashim [69]	2016	Co-benefit	Journal Article	Global (inc. Europe)
Longo *et al.* [70]	2012	Ancillary Benefit	Journal Article	Basque Country, Spain
Lung *et al.* [71]	2019	Multiple Benefit	Journal Article	Global (inc. Europe)
Maione *et al.* [72]	2016	Co-benefit	Journal Article	Europe
Markandya and Rubbelke [40]	2004	Ancillary Benefit	Journal Article	Europe
Mayrhofer and Gupta [38]	2016	Co-benefit	Journal Article	Global (inc. Europe)
New Climate Institute [73]	2021	Co-benefit	Report	Global (inc. Europe)
Nehler *et al.* [44]	2018	Non-energy Benefit	Journal Article	Sweden
Payne *et al.* [74]	2015	Multiple Benefit	Journal Article	UK
Pye and McKane [46]	2000	Non-energy Benefit	Journal Article	Global (inc. Europe)
Rashidi *et al.* [75]	2019	Co-benefit	Journal Article	Global (inc. Europe)
Rasmussen [43]	2017	Non-energy Benefit	Journal Article	Global (inc. Europe)
Rosenow and Bayer [76]	2017	Multiple Benefit	Journal Article	Europe
Russell *et al.* [77]	2015	Multiple Benefit	Report	Global (inc. Europe)
Sharifi [22]	2021	Co-benefit	Journal Article	Global (inc. Europe)
Schwanitz *et al.* [78]	2015	Co-benefit	Journal Article	Europe
Smith *et al.* [41]	2016	Co-benefit	Report	UK
Smith and Haigler [79]	2008	Co-benefit	Journal Article	Global (inc. Europe)
Sovacool *et al.* [80]	2020	Co-benefit	Journal Article	Europe
Thema *et al.* [81]	2019	Multiple Benefit	Journal Article	Europe
UNECE [82]	2016	Co-benefit	Report	Europe
Urge-Vorsatz *et al.* [39]	2014	Co-benefit	Journal Article	Global (inc. Europe)
Urge-Vorsatz *et al.* [83]	2016	Multiple Impact	Journal Article	Global (inc. Europe)
Von Stechow *et al.* [84]	2015	Coeffect	Journal Article	Global (inc. Europe)
World Health Organisation [85]	2012	Co-benefit	Report	Global (inc. Europe)
Workman *et al.* [86]	2019	Co-benefit	Journal Article	Europe
Younger *et al.* [87]	2008	Co-benefit	Journal Article	Global (inc. Europe)

priorities, such categories can also be mapped down from the national level to local and regional levels of government [64]. With no universal consensus in how co-benefits can be categorised, we used the Jennings *et al.* [64] framework as a basis for classification of EDR co-benefits identified within this literature review as shown in Table 4:

The four Jennings *et al.* [64] categories were re-defined due to simplicity and clarity as: Health, Energy security, Economy, and Social. Our addition of a fifth (Environment) category was also made due to the large potential environmental co-benefits discussed within the literature that would not realign well within the other categories, the direct link to many governmental departments at various scale across Europe, as well as its common inclusion within other papers analysed [19,36,38,51,81]. Caution was also taken in relation to identifying specific co-benefits as a result of energy demand reduction policy, this was done by either correlating directly to policy within the paper, or to reference each potential co-benefit in relation to the policy detailed in Table 1. Finally, we note that the placement of co-benefits into our five categories is sometimes subjective – for example some health aspects can be placed into either/both of social or economic parameters. However, such subjectivity does not interfere with our original intention (Section 1.3) to survey the broad literature space and highlight the main types and frequency of co-benefits.

Fig. 4 shows that the most prevalent of co-benefit term used is 'co-benefit' within each of the five classes of EDR categories:

4.3. Research objective 2: individual EDR co-benefit collation and trends

In total, 533 co-benefits were cited within the 53 papers/reports in the review (see Table 4), of these, a total of 86No. unique co-benefits were identified (see Table 5). Floater *et al.* [36] had the most EDR co-benefits cited at 22No., while Smith and Haigler [79], Maione *et al.* [72] and Workman *et al.* [86] jointly only identified 2No., the lowest number in a single paper. The most commonly cited co-benefit category was economy with 153 occurrences, closely followed by social with 143

Table 4
Summary of energy demand reduction co-benefits identified by category (based on four Jennings *et al.* [64] categories, plus fifth category (Environment) added by authors).

Author(s)	Year	Health	Energy security	Economy	Social	Environment	Total
Bachra *et al.* [48]	2020	1	1	3	4	2	11
Bisello *et al.* [49]	2017	2	1	8	8	2	21
Bleyl *et al.* [47]	2019	1	2	7	2	–	12
Bollen *et al.* [50]	2009	1	–	2	–	–	3
Cassen *et al.* [51]	2015	2	–	3	3	2	10
Chatterjee and Urge-Vorsatz [52]	2021	2	–	1	2	–	5
Cooremans and Schönenberger [53]	2019	–	2	4	3	1	10
Creutzig *et al.* [54]	2012	3	–	–	3	1	7
Creutzig *et al.* [55]	2022	2	3	–	8	3	16
Deng *et al.* [56]	2017	1	1	2	3	3	10
Fawcett and Killip [37]	2019	2	2	5	1	2	12
Ferreira *et al.* [57]	2017	3	1	5	2	2	13
Floater *et al.* [36]	2016	3	3	5	6	5	22
Frankowski and Herrero [58]	2021	1	–	–	4	–	5
Freed and Felder [42]	2017	1	1	2	2	3	9
Giles-Corti *et al.* [59]	2010	3	1	1	5	–	10
Hamilton and Akbar (World Bank) [60]	2010	2	–	–	1	5	8
Heffner and Campbell [61]	2011	3	–	5	3	1	12
IEA [62]	2014	2	2	7	2	1	14
Jakob [63]	2006	1	–	1	2	–	4
Jennings *et al.* [64]	2019	5	1	4	2	1	13
Jochem and Madlener [65]	2003	2	–	6	–	2	10
Kamal *et al.* [66]	2019	1	–	9	4	2	16
Karlsson *et al.* [19]	2020	2	1	1	–	3	7
Killip *et al.* [67]	2020	1	–	5	4	2	12
Krook Riekkola *et al.* [68]	2011	1	1	2	–	1	5
Kwan and Hashim [69]	2016	4	–	–	3	1	8
Longo *et al.* [70]	2012	1	1	1	3	1	7
Lung *et al.* [71]	2019	2	–	3	3	3	11
Maione *et al.* [72]	2016	1	–	–	–	1	2
Markandya and Rubbelke [40]	2004	2	–	–	3	1	6
Mayrhofer and Gupta [38]	2016	2	4	3	4	5	18
New Climate Institute [73]	2021	2	–	1	1	–	4
Nehler *et al.* [44]	2018	1	1	3	4	2	11
Payne *et al.* [74]	2015	4	1	4	3	–	12
Pye and McKane [46]	2000	1	1	4	1	2	9
Rashidi *et al.* [75]	2019	1	1	5	1	–	8
Rasmussen [43]	2017	2	2	4	5	3	16
Rosenow and Bayer [76]	2017	1	2	3	2	–	8
Russell *et al.* [77]	2015	3	0	3	4	0	10
Sharifi [22]	2021	2	2	2	5	4	15
Schwanitz *et al.* [78]	2015	1	1	2	1	2	7
Smith *et al.* [41]	2016	3	3	3	4	3	16
Smith and Haigler [79]	2008	1	–	1	–	–	2
Sovacool *et al.* [80]	2020	2	1	5	4	2	14
Thema *et al.* [81]	2019	1	1	2	1	2	7
UNECE [82]	2016	1	–	1	–	2	4
Urge-Vorsatz *et al.* [39]	2014	3	1	3	4	2	13
Urge-Vorsatz *et al.* [83]	2016	4	2	5	1	–	11
Von Stechow *et al.* [84]	2015	2	1	3	4	4	14
World Health Organisation [85]	2012	3	–	2	7	–	12
World Bank	2010	2	–	–	1	5	8
Workman *et al.* [86]	2019	1	–	1	–	–	2
Younger *et al.* [87]	2008	5	–	1	1	1	8
Total		104	48	153	143	85	533

instances. Health co-benefits were the third most prevalently cited with 104 occurrences. Hence, while still significant, the disproportionate focus on air quality health effects does not translate into a relatively higher number of unique EDR co-benefits when other health co-benefits are included. [82].

The weighting of each co-benefit category was heavily dominated by the use of the term 'co-benefit' as the dominant term used in the literature (see Table 3). However, the order of each category by size does not correspond directly to the number of EDR co-benefits under the 'co-benefit' term, as the social category cited the most using this term. The relatively large number of 'multiple benefits' cited within the economy category (48No.) - the highest cited category under this term - led to economy being the largest category when all six co-benefit terms are aggregated. The distribution of NEBs also differs marginally, with the largest nominal and proportional number of NEB-derived co-benefits also found within the economy category. Many NEBs discussed within the literature related to the industry and local scale, there was also a significant identification of reduced stressors in industry (such as noise and comfort) which meant the social category still had the second highest total of NEBs per category [42–44,46].

The range of individual co-benefits counted within a single category was from 153No. (economy) to 48No. (energy security), a large difference that may indicate the weakness of energy security as a category for EDR co-benefits in and of itself. Energy sovereignty (i.e. reliance on imported energy supplies/materials/products) represented the largest EDR co-benefit within the energy security category (26No.), and was also the largest as a proportion of a single category at 54 % of all energy security co-benefits. Concerning individual co-benefits more broadly, air

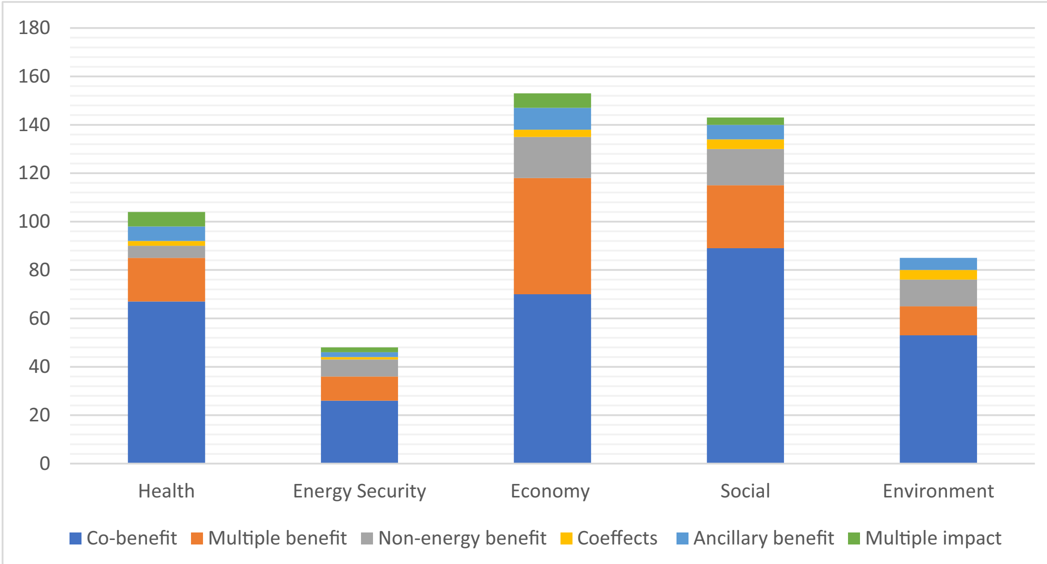

Fig. 4. Representation of the six co-benefit terms within the five co-benefit categories: Health, energy security, economy, social, and environment.

pollution/quality was the top cited co-benefit in both the health (52No., from 53 papers/reports) category in relation to cardiovascular/respiratory illness and healthcare costs, and the environment (26No.) category concerning damage to infrastructure and natural environment, making it the most substantial EDR co-benefit by a large margin. Overall, air quality/pollution accounted for approximately 15 % of the total co-benefits cited. The large extent to which air quality extends as the major co-benefit relates clearly to the high concentration of literature focused solely on the co-benefits of air pollution [19]. The environmental aspect of air quality benefits however is much less exclusively discussed in comparison to the health impacts, it is also much more heterogenous and disparate in the location of its effects which raises difficulties for incorporation into policy, for example the weathering of materials and deposition of substances [70]. Ecosystems and biodiversity (16No.) was the second highest environmental co-benefit, illustrating the broader reach of environmental impacts.

Improving fuel poverty represented the largest EDR co-benefit within the social category at 15 %, as a co-benefit it is heavily associated with two major EDR policy sectors, transport and residential [22,36,54,70]. The subsequent two most cited co-benefits (noise and thermal comfort) also relate explicitly to these two sectors and account for 24 % of co-benefit citations within the category, combined they convey that reduced stressors within urban environments are prominent EDR co-benefit stemming especially from these two policy fields as well as at the industrial firm level.

In terms of economic co-benefits, employment accounted for the largest co-benefit (22No.) at 14 % of the economy co-benefits, while productivity was second (21No.). It is important to highlight that both productivity and employment co-benefits are sectoral, and are therefore relevant to specific economic sectors that benefit from EDR policy (e.g., public transport, retrofitting old housing stock etc.) [84]. It could also be potentially misleading, as sectoral gains in both productivity and employment could be offset by general losses triggered by enacting EDR policy. However, Ferreira *et al.* [57] suggest that certain policy such as a large-scale deep renovation programme for housing would have a net gain in terms of jobs at a rate of thirty to one in the energy sector. Such understanding of the macro impacts, job implications especially, have to be assessed on a policy-by-policy basis. It is also a question as to whether economic growth is a desirable/universal co-benefit in and of itself, or rather dependent on certain political objectives (see also Discussion – Section 5).

4.4. Research objective 3: quantification of EDR co-benefits

Rasmussen [43] identifies a four stage process by which co-benefits are eventually accounted for in policymaking by quantitative means. Firstly, qualitative descriptions and studies of potential co-benefits are made so as to identify their potential effects, secondly the effects of the co-benefit are quantified into physical units, which are thirdly transformed into monetary units, and finally the economic valuation is offset from the costs of the policy action so as to understand the overall net impact of related co-benefits [43]. In order to understand the extent of quantification within the literature, each paper/report was categorised in relation to its inclusion of the quantification of (EDR) co-benefits. As most papers were addressing climate change mitigation more broadly, a paper was only categorised as including quantification if it related directly to a co-benefit of EDR policy. The results are collated in Fig. 5.

Fig. 5 is a classification of the papers in the review in terms of their inclusion of the methodologies involved in co-benefit quantification. This ranged from no discussion at all to a full quantification of certain co-benefits. Methodology discussion implies that different methods of quantification were discussed but not executed, while physical unit quantification implies that the paper conducted co-benefit quantification into physical units (e.g., avoided sick days/year), rather than monetary savings.

Fig. 5 also shows most literature (60 %) contained only a conceptual discussion of methodology relating to co-benefit accounting (32No.), which did not attempt actual quantification calculations. These papers included discussion of previous quantification attempts, suggestion of potential methods for overall inclusion in policy (net impact equations), individual co-benefits methods (specific equations to derive physical units), or how modelling can and has integrated co-benefits previously (integrated assessment models specifically). In terms of actual quantification, eleven documents (21 % of the reviewed papers) contained primary monetary quantification [46,47,52,58,63,68,70,78,79,81,84] while two [54,73] contained quantification of physical units (i.e., indicators for individual co-benefits). Of the eleven that contained primary monetary quantification, six contained a multiple co-benefit calculation that assessed net co-benefit impact [46,47,63,78,81,84]. Longo *et al.* [70] assessed the willingness to pay for climate policy using different combinations of potential co-benefits. Frankowski and Herrero [58] analysed the qualitative benefits of home retrofit while Krook Riekkola *et al.* [68] had a specific focus on economic co-benefits (cap and trade benefits). Smith and Haigler [79] (air quality) and Chatterjee and

Table 5
Most cited energy demand reduction co-benefits by category.

Category (and number of distinct co-benefit types)	Co-benefits in order of cited frequency (Max. possible = 53No, i.e. the literature survey total)			
	Most cited co-benefit	2nd most cited co-benefit	3rd most cited co-benefit	Sum of remaining co-benefits
Health (12No. distinct co-benefits)	Reduced Air Pollution, Related Morbidity and Mortality (52No.)	Improved Physical Activity and Wellbeing (19No.)	Reduced Transport Accidents (10No.)	Heat-Island/Thermal Stress (6No.); Mental Health (6No.); Worker Safety (6No.); Less illness-related absences (3No.); Sanitation (2No.); Sleep Efficiency (1No.); Nutrition (1No.); Disease Reduction (1No.); Healthcare System Resilience (1No.)
Energy Security (14No. distinct co-benefits)	Greater Energy Sovereignty (26No.)	Reduced Load Management (4No.)	Greater Water Resources Security (3No.); Improved Energy Delivery (3No.)	Political Stability (2No.); Resource Stability (2No.); International Competitiveness (2No.); Interregional Collaboration (1No.); Democratic Quality of Governance (1No.); Infrastructure Failure (1No.); Production Risks (1No.); Economic Stability (1No.); Personal Security (1No.); Reserve Requirements (1No.)
Economy (24No. distinct co-benefits)	Higher Employment (22No.)	Greater Productivity (21No.)	Lower Infrastructure Operation and Maintenance Costs (16No.)	Asset Values (14No.); Economic Growth (13No.); Energy Prices (10No.); Local Microeconomy Benefits and Competition (8No.); Circular Economy (7No.); Tax Effects (5No.); Technological Spillover (5No.); Energy Subsidies (4No.); Non-energy Cost Reductions (4No.); Fiscal Sustainability (3No.); Abatement Costs (3No.); Quality, Durability and Waste (3No); Utility System Infrastructure Capacity Costs (2No.); Macroeconomic Impacts (2No.); Cap and Trade Benefits (2No.); Greening the Economy (1No.); Capacity Utilisation (1No.); Rental Income (1No.); Reduced Capital Stock/Pooling Trade (1No.); Public Balance (1No.); Loan Conditions (1No.)
Social (26No. distinct co-benefits)	Reduced Fuel Poverty (22No.)	Greater Thermal Comfort (18No.)	Reduced Noise (16No.)	Congestion (14No.); Social Connectivity (9No.); Accessibility of Mobility Services (8No.); Aesthetics (8No.); Energy Access (6No.); Skills, Education and Awareness (5No.); Social Justice (4No.); Image and Reputation (4No.); Road Damage (2No.); Resource Equity (2No.); Worker Morale (2No.); Social Cohesion (3No.): Product Quality/Access (3No.); Sustainable Behaviour (1No.); Cost of Travel (1No.); Equipment and Facilities Wear (1No.); Shelter (1No.); Communication (1No.); Decision making (1No.); Public Services (1No.); Reliability of Services (1No.); Lower Vacancy Rates (1No.); Reduced Odour (1No.);
Environment (10No. distinct co-benefits)			Higher Resource Quality and Management (13No.)	Waste Reduction (11No.); Soil and Water Quality (9No.);

(continued on next page)

Table 5 (*continued*)

Category (and number of distinct co-benefit types)	Co-benefits in order of cited frequency (Max. possible = 53No, i.e. the literature survey total)			
	Most cited co-benefit	2nd most cited co-benefit	3rd most cited co-benefit	Sum of remaining co-benefits
	Reduced Air Pollution Effects on Urban and Natural Improved Environments (26No.)	Greater Ecosystem and Biodiversity Enhanced Preservation (16No.)		Greenspace (4No.); Natural Buffers (2No.); Fire Safety (1No.); Food (1No.); Water Consumption/Resilience (1No.)
Total = 86No. distinct co-benefits				

Urge-Vorsatz [52] (working hours and sick days due to air quality) solely focused on the health co-benefits. Lastly, eight of the papers (15 %) did not discuss quantification at all, or no further than raising the difficulties that quantification poses for co-benefit inclusion.

That only around a fifth of studied papers/reports attempted actual quantification calculations is interesting. Floater *et al.* [36] mention that the lack of clear definition hinders the integration of co-benefits, but even where they are well-defined there are some co-benefits that are very difficult to monetise or even quantify into physical units. In this review, comfort is a prominent example of a rather subjective and therefore hard to account for EDR co-benefit. In response to the difficulties raised, Rasmussen [43] acknowledge that in order to include both tangible and less tangible benefits, that a scale of quantifiability is much preferred in comparison to a binary separation into quantifiable or not quantifiable (as shown in Fig. 5). Scaling benefits in this way prevents benefits not easily quantified from being rejected from analysis entirely, this requires application as well as understanding of the potential of qualitative inclusion further [43].

There is significant consensus however within the literature that quantification methodologies have not been utilised and standardised on a scale relevant enough to make an impact on policy. The barriers for quantitative inclusion of EDR co-benefits remain numerous, much of the discussion of methodology within the literature relates directly to the difficulties involved. Fawcett and Killip [37] posit that quantitative data on co-benefits is currently patchy by sector, issue, and geography. Data availability on co-benefits is therefore an issue for quantitative evaluation, especially relating to macroeconomic impacts. Fawcett and Killip [37] therefore suggest there must be more use of case studies, to make the benefits more salient to policy-makers, not because they make them more quantifiable.

Evidence of the relevance of EDR co-benefits, as it relates to the first component of Rasmussen's [43] accounting process (qualitative understanding of the potential), is crucial to develop and bring forth the process of quantitative integration into cost-benefit analyses [57]. Heffner and Campbell [61] simply acknowledge the complexity and cost barriers currently observed when quantifying co-benefits, in the example of fuel poverty it is posed that a needs-based analysis which provides an indicative range of values can overcome some of these issues to inform decision-making in relation to social co-benefits. Karlsson *et al.* [19] instead consider that the issue of poor co-benefit accounting is due to the way policymaking currently operates, that is because it is conducted within siloed ministries and committees, therefore co-benefits that transcend these distinct boundaries become less visible.

5. Discussion

5.1. Insights from the research objectives

5.1.1. Research objective 1: categorisation of EDR co-benefits

The literature documented clearly that categorisation as a process is malleable to specific needs and contexts as there was a large range of categorisation methods present. Therefore the five categories identified here are not a universal taxonomy but rather a suggestion relative to a European policy context [39]. The identification of the individual co-benefits here can be rearranged, this flexibility is useful for the consideration of EDR co-benefits by a wide array of actors. Within our review, social benefits had the highest number of distinct co-benefits (26No. see Table 5). At first this appears in contrast to previous literature which suggests health has much more focus. However the dominance of air quality health benefits may obscure the actual quantities in each

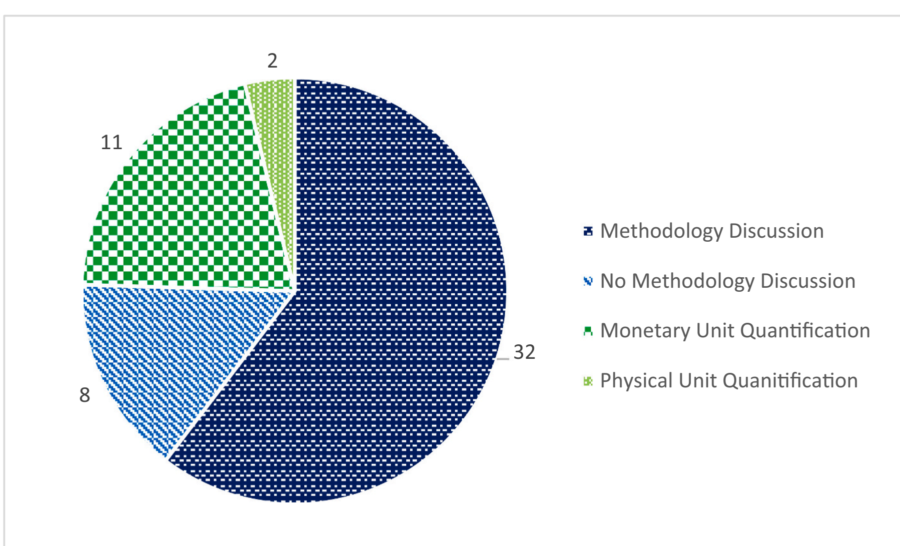

Fig. 5. Literature sorted by level of numerical quantification of co-benefits included: blue = no (discussion only); green = yes (mainly monetary in dark green).

category (especially in the health category itself) [19].

The social co-benefits as a category were also the least easily linked to a single governmental department or body, one of the most common suggestions arising from the literature is in the breaking down of departmental silos and of the proliferation of truly interdisciplinary government [87]. The compartmentalisation of government may act as a barrier to co-benefit inclusion into EDR policy, as mentioned by Karlsson *et al.* [19], especially of those that do not so clearly fit into specific categories. However co-benefits themselves could act as enablers of policy and professional synergies, especially at the city level where EDR policy is highly present [87].

5.1.2. Research objective 2: EDR co-benefit identification and collation

The occurrence of air quality as a health co-benefit was high and consistent with previous observations made in the literature [15,19]. In fact, it was cited in 52 of the 53 papers/reports obtained for our survey, supporting a legitimate concern that such focus on only one co-benefit of EDR policy could 'crowd out' research into other co-benefits. The amount of co-benefit literature already available on the health impacts of air quality improvement act as a catalyst for further research by already establishing standard methodologies and successful practice, a lack of literature focused on other EDR co-benefits could increase significantly if a threshold value of interest and already published literature is reached [19]. The effectiveness of raising the health impacts of mitigation policy in increasing support as highlighted by Amelung *et al.* [31] may account for some of the air quality (and specifically health impacts) focus within the literature.

The identification of EDR co-benefits as a research objective was established as important due to the suggestion from previous literature that an understanding of the totality of EDR co-benefits would translate into a motivating force for EDR policy. Smith *et al.* [41] state that co-benefits can emphasise the importance of demand-side measures to policymakers, since they occur in a wide range of fields and have few adverse impacts. Therefore, identification is the first step towards quantification which makes the economic benefits explicit. Bachra *et al.* [48] qualified this view in relation to city-level action, stating cities that cited co-benefits in policy were 2.5 times more likely to take climate mitigation action than those that did not. This corroborates well with research by Bain *et al.* [12], who found inclusion and identification of co-benefits can increase the likelihood of the success and support for policy in government where there are differing dispositions towards EDR policy [70]. This also demonstrates that there are other methods to promote EDR policy other than through the framing of climate change mitigation, one way of overcoming the challenge of the climate change communication (Bain *et al.* [12]). This research therefore offers a basis for the identification of obvious and frequently observed EDR co-benefits in policymaking, and that in doing so raise awareness of potential co-benefits which government(s) can look at integrating in even elementary ways. As the first attempt at a register of EDR co-benefits, there is no doubt potential for the inclusion of further EDR benefits given more resources. However, the review process identified some of the most important EDR co-benefits of the contemporary literature and can act as a platform for future compilation of EDR co-benefits, as well as begin the first step in the process of quantitative integration into decision-making [43].

5.1.3. Research objective 3: assess the state of EDR co-benefits quantification

Robust quantification of the positive impacts across a range of co-benefits could be a significant advance in signing off EDR policies, by viewing them beyond simply a policy/implementation cost and resultant energy savings. Therefore assessing the state of quantification of EDR co-benefits is an important first step. To include EDR co-benefits within policymaking directly, one must utilise relevant accounting methods that appeal and integrate into the decision-making process. In order to fully understand the scale and relevance of a specific co-benefits impacts, as well as the cumulative impact of related co-benefits, indicators must be quantified in either absolute or relative terms [81]. Floater *et al.* [36] state that there are three primary data sources that have the potential for co-benefit quantification: numerical data, case studies, and models.

There are two potential methods of quantification. First is with respect to the physical units of a co-benefit (e.g., savings in quality adjusted life-years or tonnes of air pollutants), enabling the comparison of impacts in physical units, which can itself be of great value to policymakers in providing clarity [81]. Monetary-based indicators are a second option, found as more prevalent in our literature survey (see Fig. 5), aligning well with inclusion in cost-benefit analyses of EDR policy, which can make the co-benefit's impact more explicit. For example, Workman *et al.* [86] recognise that cost-effectiveness remains a key principle in the European Commission's economic analysis of environmental policymaking. This crude economic understanding could however lead to ineffective and uninspired policy if EDR co-benefits are not included.

Discussion of the challenges of quantification was common throughout the literature review, however only a minority of papers actually attempted primary quantification. Health and air quality are highly mentioned co-benefits within the broad mitigation co-benefit space, possibly because the methodologies may be more established [19], in what is a more mature field. Conversely, barriers to wider quantification beyond health/air quality could simply be the lack of maturity (or data availablity) in those other fields. In such a case, more primary quantification research would benefit the progression of co-benefits over the longer term. The estimation of physical units in Creutzig *et al.* [54] raise the profile of co-benefits and encourage monetary quantification as a future step [43].

Quantifiable co-benefits can make investments in EDR measures like energy efficiency more financially attractive and therefore increase their priority against other competing investment opportunities [43]. The dominance of the quantitative (versus qualitative) approach relates directly to the dominance of cost-benefit analysis in co-benefit study [38,43]. This is also reflective of the high level of economy benefits, and beyond that the need for co-benefit terminology to resonate with decision makers and the analyses and evaluation of policy at all scales [67]. Regarding quantification methodology, the majority of discussions relate to the health impacts of air pollution [39,72,79,82,86]. An example of a well-established method of quantification in relation to air pollution health impacts is Disability Adjusted Life Years (DALYs). In turn, because of the widely used and document methodology for determining the DALY impacts, there is a relatively simple conversion of the health impact (physical unit) to monetary value [79]. Established quantification of EDR co-benefits that are not related to broader economic metrics do not extend well beyond air pollution and health, as uncertainties surrounding the accuracy of co-benefit quantification become much more pervasive as the focus shifts from sectoral and local economies to national and supernational scales [51,84].

An important way of promoting co-benefits across Europe could be through the creation of open-access tools that are aimed directly at policy makers, such as the COMBI and M-BENEFITS projects discussed previously. This approach provides direct visualisation of the multiple impacts of common energy efficiency measures at both a national and European scale in monetary and physical terms. Through promoting and creating tools like this, modelling approaches can be standardised across Europe and knowledge shared on co-benefits across different categories including emissions, resources, social welfare, macro economy and the energy system itself. This open approach could overcome the barrier of uncertainty at larger scales and encourage further national and sub-national understanding/research on certain metrics. Beyond COMBI/M-BENEFITS, tools need to be developed that address the wider co-benefits in the EDR space, rather than solely energy efficiency.

The other main methodologies used to quantify co-benefits are via integrated assessment models (IAMs) and life-cycle assessments [61], which can be used to explore beyond just air pollution [72].

5.2. Wider co-benefit aspects

5.2.1. Challenges in assessing co-benefit terminology

In total, 86 unique EDR co-benefits were identified, which is a significant step forward in highlighting co-benefits for inclusion in the policy debate surrounding demand-side measures. This paper represents - to our knowledge - the first time that EDR co-benefits have been collated independently of general climate change mitigation or solely energy efficiency (in the case of NEBs and multiple benefits). Key challenges in the identification of further EDR co-benefits include the fact that the co-benefits aren't identified within literature, are identified as general mitigation benefits (and therefore the link between policy and co-benefit is less clear), or that they are identified under different terminology. The lack of convergence in terms of language used is indicative that the field is still in early stages of development in its own right.

Moving forward, it will be important to utilise a single definition of co-benefit that implicates a 'win-win' strategy for academic and policy usage, and to overcome the inconsistent usage of the term that has led to previous confusion [15,19]. One pathway could be via standardisation of terminology within the EU, which has the opportunity to make its understanding of co-benefits explicit with respect to its energy efficiency and eco-design proposals for example. The term is gradually gaining clarity, engagement, and understanding [19]. Use of the concept by interdisciplinary scholars as well as in non-academic spaces will increase the collated knowledge of EDR co-benefits, and prevent the term from becoming a sterile technological instrument [19,38]. The normative nature of co-benefits should also be understood, the value systems and norms underpinning the co-benefits concept at present should be made explicit [38]. For example, while economic growth is considered a co-benefit in this instance, this is under the assumptions of an economy whereby growth is seen in and of itself desirable. If translating co-benefits to a different economic context, such as under a steady-state or degrowth economy, economic growth as a co-benefit would no longer be considered as such [88].

5.2.2. A quantifiability framework for EDR co-benefits

In order to demonstrate the potential for quantification among the most prevalant EDR co-benefits identified within the review, Fig. 6 shows a matrix developed to present some of the potential and challenges faced in quantifying key co-benefits across varying time scales. The framework offers an ability to understand the temporal and quantitative challenges facing individual EDR co-benefit accounting, co-benefits can have considerably different magnitudes as well as varying durations at which the actual benefit are realised and should be estimated [43,61]. Such a framework potentially offers future research guidance in domains where EDR co-benefits are less quantified, and so lead research into areas where quantification is less prevalent. It may be the case that some of the least quantified co-benefits offer significant financial benefit (especially those of heterogeneous nature), which could further promote EDR policy if competent methods are established.

The lower quantifiability co-benefits stem from complications in attempting a quantitative approach either due to the heterogeneous nature of impacts and therefore the large array of indicators and measurements required (e.g., air pollution on different environments and surfaces), or because of the primarily subjective and qualitative nature of potential indicators (e.g., comfort) which lack clear ways of standardisation. Especially for more challenging EDR co-benefits to incorporate but also in general, the epistemic community still observe that there are methodological complications in establishing exact causality between a specific policy and the scale of co-benefits associated [38]. This extends to monetisation, the interaction between different impacts, and also in avoiding double-counting [38]. Considerable caution should therefore be taken in establishing a standard methodology to consider these issues, and potentially standardisation is not a near goal for the near-term because of the underdeveloped nature of the co-benefit space.

5.2.3. Scales of EDR co-benefit integration

The application of the co-benefit framework must be at a scale relevant to the level at which demand-side measures are implemented most prominently, as well as the scale at which the co-benefits are realised and can be accounted for (i.e., via metrics). There is no single political entity that covers the entirety of Europe despite the EU's large influence, however co-benefits can also have an impact that applies to multiple levels of government. While important to set targets at higher levels of governance such as the EU, a significant challenge is to ensure a more coordinated approach at multiple levels of governance that results in visible action. Methods for carrying out impact assessments that include co-benefits must be adjusted to encourage accounting at EU, national and local level [76]. Urge-Vorsatz *et al.* [83] proposes the use of impact pathways to understand the clear link between policy to an impact so as to ease the process of quantifying externalities, one of the key issues in addressing co-benefits at different scales. Despite the

Fig. 6. Framework classifying some of the most prevalent EDR Co-benefits in terms of quantifiability and time frame, adapted from Rasmussen [43].

variability in the magnitude of co-benefits, accounting for and integrating EDR co-benefits at the city and regional level should be explored as the degree of uncertainty in quantification beyond a local context becomes much larger, and the resources/collaboration required vastly increase [51,84]. Jennings *et al.* [64] propose integration at the regional and city level because co-benefits can be most quickly incorporated, it is where EDR co-benefits mostly manifest, and logically therefore where most EDR policy intervention takes place. Floater *et al.* [36] support this in suggesting that at the city level, co-benefit potential and awareness is particularly high because citizens can more directly witness the consequences of EDR policy on their daily lives within the built urban environment (where most EDR policy measures are enacted).

A co-benefit approach at the city level must be supported by local powers and funds to carry out EDR policy, as well as feasibility studies that incorporate relevant co-benefits. As the state of local power differs by nation within Europe quite drastically, devolved powers have to be sufficient at the local level of government (especially in relation to transport, planning, and environmental policy) to enable the interests of EDR policy proliferation. The UK is an example where increased devolved power in city regions offers relevant functions and context whereby co-benefits can be included within the policy decision-making process. For example, studies of social housing such as Boomsma et al., [89] have a direct relevance to the local council level where social housing is owned and managed, understanding energy conservation norms and the effect of housing retrofit have large implications for future co-benefit inclusion here. In discussing aggressive driving and the potential economic, environmental and health co-benefits of reducing such behaviour, Faria *et al.* [90] also discuss its direct relevance to urban planners and policy makers at the city level. Disaggregated impacts of co-benefits at local scales can provide much more clarity and motivation to policy makers and industry to act, however the role of tools like COMBI/M-BENEFITS are still vital in providing a national and European framework that creates an environment that is receptive and aware of co-benefits generally.

There is also the case of addressing co-benefits at the industrial firm level, often a scale at which economic calculation and economy co-benefits are prominent. There is however a lack of knowledge in companies to identify co-benefits and develop a consistent analytical approach [67]. Work must be done therefore to educate energy experts and those in industry to ensure that the language of energy efficiency and strategic value are more unified, so decision-makers can be more engaged [67].

The incentives at higher levels of governance must be so that accounting for co-benefits and making the relevant investments at the level of industry is encouraged and easy. Understanding the extent of co-benefits at scale, as well as methods of quantification and inclusion in cost-benefit analyses, will ultimately empower industry and political actors to enact reform and legislate policy that otherwise would be undervalued and discarded.

5.2.4. A growing focus on co-benefits

A key motivation for this paper is the desire for better inclusion of EDR co-benefits in policymaking though identifying key co-benefits which can go on to incentivise actors to account for them, and to ultimately pursue EDR policy as a result of their positive impact (Bain *et al.* [12]). The lack of literature that captured and categorised these benefits was the research gap initially identified, and what this current paper attempts to address.

That said, there is growing focus and attention on co-benefits: 32 of our 53 studies (published between 2000 and 2022) are from 2016 to 2022. Chatterjee *et al.* [91] provides a very recent (2022) example of a meta-review of co-benefits in climate mitigation, but was not included in our literature survey results (Section 4), so as not to have a disproportionate effect on the results of our paper due to its aim as a meta-review of co-benefits. In fact, the study is quite different in nature: Chatterjee *et al.* [91] undertake a more detailed (semi-systematic) review of 'Energy Efficiency' AND 'co-benefits' OR 'multiple impacts'. Our current paper is a lighter (structured) literature review, but aims to be much broader, with three alternative energy reduction terms (EDR, energy efficiency, climate mitigation) and six 'co-benefit' alternates (co-benefit, ancillary benefit, non-energy benefit, multiple benefit, multiple impact, coeffect). Thus our paper is distinct from Chatterjee *et al.* [91] in that it covers EDR more broadly and not just energy efficiency. As stated previously, there is a strong relationship between EDR and energy efficiency, however EDR covers a broader range of measures and also takes into account the wider link and feedbacks between co-benefits and energy benefits. Our paper also identifies significantly more European co-benefits (86No. compared to 12No. in the main text of Chatterjee *et al.* [91]), as well as creating a classification and quantifiability framework for these benefits. Both papers raise the profile of important co-benefits and provide important insight on the future for co-benefit inclusion going forwards.

Despite their different natures, there are some important points to highlight from Chatterjee *et al.* [91]. Their results suggest that there is a wide array of co-benefits due to energy efficiency measures, and that the EU is well placed to explore the magnitude of certain co-benefits (e.g., health and productivity) due to the large degree of secondary data available for these indicators. The results reflect similar findings in this paper, that there is a large number of co-benefits and that quantifiability is a priority to promote the cost-effectiveness of energy efficiency measures, the main lens through which co-benefits are looked at in Europe (and the Global North in general) [91]. This finding is directly relevant to the both the COMBI and M-BENEFITS tools developed for the EU context and suggests that tools like this can provide a platform for the growth of energy efficiency measures because of data-driven evidence of the impacts of certain policies in certain countries.

An important point raised in Chatterjee *et al.* [91] is the context dependency of co-benefits, that not just political objectives and values shape ultimately what is defined as a 'benefit' as raised in our paper (see Section 5.1), but also the method of implementation for energy efficiency measures (relevant to EDR more broadly, dependent on economic and political factors) is impacted by what incentives are relevant to a government or an economy at any given time. This can differ especially across socio-economic contexts.

5.3. General limitations

There were general limitations of the research, other than those strictly associated with the type of methodology (see Section 3.4). Human error in the identification and classification of co-benefits was a possibility throughout, co-benefits may have been misidentified, double-counted, or completely missed while reading the literature. There was potential error to include a co-benefit identified within the mitigation literature that was not associated with EDR policy, although links were drawn from the policies highlighted in Table 1 throughout the review process. There is also an inherent difficulty in reclassifying co-benefits from the literature that are associated with a different classification system, reassigning co-benefits from categories that were not used within this review was an inherently subjective endeavour and therefore prone to error and debate.

6. Conclusion

6.1. Overall conclusions

This literature review presents a high-level summary of the co-benefits associated with reducing energy demand, in five categories: Health, Energy Security, Economy, Social and Environment. From our review, we propose four key insights. First, we collated a wider-than-expected array of Energy Demand Reduction (EDR) co-benefits (86No.) within the current climate change mitigation literature.

Second, we found a high prevelance of economy and social co-benefits, with a much more even distribution of co-benefits beyond the narrow picture of air quality / health co-benefits conventionally held in the literature [19]. Third, classification of EDR co-benefits offers ways to quickly inform practitioners of the immediate relevance and interactions between EDR policies. That said, a universal taxonomy of EDR co-benefits is not desirable or possible: while our five category classification has relevance to some European contexts, it may not be appropriate for others and therefore adaptability of such frameworks is actively encouraged so as to increase EDR policy engagement and integration [39]. Fourth, quantification of co-benefits is still in its early stages of methodological development and full inclusion within cost-benefit assessments, but its growth and accuracy can only benefit from further research in the field.

6.2. Further research and recommendations

It is clear that the EDR co-benefit space - outside of health impacts - is in its infancy. This present work can act as a foundation for co-benefit research specific to demand-side measures and independent of general mitigation discourse. Increasing the quantity and diversity of the literature will enable further research and expand the scope of EDR co-benefits identified and researched.

Beyond those generalities, our specific recommendations below form a four-step plan for improving the use of co-benefits, to ultimately improve climate change mitigation policy:

1. **Step 1: Working towards standardisation of co-benefit terms.** The array of co-benefit terms in common usage (e.g. co-benefits, multiple benefits, non-energy benefits, ancillary benefits, multiple impact, co-effects) may provide a serious barrier for their greater use. Therefore, working to develop a set of standard terms (including individual co-benefits – for example we identified 86No. but some overlapped) would make understanding and quantification easier. This could be set out at a policy-making (EU-27, UK) level.
2. **Step 2: Improving cross-disciplinary research efforts.** We found the literature from quite siloed places (e.g. energy, economics, climate). Given the diverse nature of the co-benefit literature we found, broadening to achieve more cross-disciplinary co-benefit research teams will lead to better research, and allow access to more diverse places to disseminate the literature.
3. **Step 3: Greater research effort on primary quantification of EDR co-benefits.** An increase in literature focused on quantifying the benefits, especially those without established methodologies and ideally from a wider array of contexts within Europe (such as Eastern Europe), is encouraged in order to establish functional methodologies and to raise the awareness of policymakers. Addressing questions such as *'Is monetisation the only or best approach to evaluating the different benefits?'* are vital to address in this next research phase.
4. **Step 4: Bringing co-benefits to policy-makers.** Given the barriers to entry on co-benefits combined with an urgent need for greater EDR policy as part of climate change mitigation efforts, greater efforts to bring co-benefits to the attention of policy makers is vital. First, greater utilisation of case studies, as suggested by Fawcett and Killip [37], can provide an ideal method for policy makers to engage with co-benefits, by demonstrating the real-world impacts of co-benefits more clearly. Second, following on, deeper engagement at a regional/city level can create the means and potential to implement EDR policy and ultimately improve inclusion and quantification methods through reducing abstraction and having more certainty of outcomes.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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