Energy Research & Social Science 49 (2019) 143–157

Contents lists available at ScienceDirect

Energy Research & Social Science

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

More priorities, more problems? Decision-making with multiple energy, development and climate objectives

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ARTICLE INFO

Keywords:
Development
Climate change
Multiple objectives
Co-benefits

ABSTRACT

The Sustainable Development Goals and the Paris Agreement pose new conceptual challenges for energy decision makers by compelling them to consider the implications of their choices for development and climate mitigation objectives. This is a nontrivial exercise as it requires pragmatic consideration of the interconnections between energy systems and their social and environmental contexts and working with a plurality of actors and values. There are an increasing number of indices, frameworks and academic studies that capture these interconnections, yet policy makers have relatively few *ex-ante* tools to pragmatically aid decision-making. This paper, based on a collation of 167 studies, reviews how multi-criteria decision approaches (MCDA) are used in energy policy decisions to explicitly consider multiple social and environmental objectives, and the conceptual usefulness of doing so. First, MCDA can be used to distil a finite set of objectives from those of a large number of actors. This process is often political and objectives identified are aligned with vested interests or institutional incentives. Second, MCDA can be used to build evidence that is both qualitative and quantitative in nature to capture the implications of energy choices across economic, environmental, social and political metrics. Third, MCDA can be used to explore synergies and trade-offs between energy, social and environmental objectives, and in turn, make explicit the political implications of choices for actors. The studies reviewed in this paper demonstrate that the use of MCDA is so far mainly academic and for problems in the Global North. We argue for a mainstreaming of such a multi-criteria and deliberative approaches for energy policy decisions in developing countries where trade-offs between energy, development and climate mitigation are more contentious while recognizing the data, capacity and transparency requirements of the process.

1. Introduction

The introduction of the Sustainable Development Goals (SDGs) and the mainstreaming of climate objectives through the Paris Agreement pose new conceptual challenges to energy research and policy-making. While debates over energy have always implicitly been embedded in broader social and environmental contexts, these introductions force more explicit consideration of energy-development linkages in decision-making. Indeed, there is increasing work seeking to document these overlaps, for example, between climate policy and social and environmental co-benefits [1] and between climate change focused "Nationally Determined Contributions" (NDCs) and the full slew of social and environmental goals included in the SDGs [2]. Recent academic work further explores these linkages, studying energy through the lens of the social sciences [3–6] and humanities [7], including political economy [8], history [9], geography [10] and using cross-disciplinary analytical categories such as energy transitions [11–17]. This work makes evident the importance of social and environmental understanding to energy policy making and governance [12,14,18–20].

While the dense theoretical and conceptual linkages between energy on the one hand and social and environmental objectives on the other increasingly receive play, policymakers have relatively few tools on hand with which to negotiate this new terrain. Yet, this *ex ante*, or pre-policy assessment is necessary if energy decision-making is to appropriately internalize the range of possible synergies and trade-offs with social and environmental goals. This requirement is even greater in developing countries, which are rapidly building both energy supply and demand infrastructure, with long-term lock-in effects [21–23].

This paper reviews a family of analytical approaches that are used to explicitly considere multiple objectives of energy decision making and

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https://doi.org/10.1016/j.erss.2018.11.003
Received 7 June 2018; Received in revised form 8 November 2018; Accepted 8 November 2018

interaction across these objectives – multi-criteria decision approaches (MCDA). It aims to tease out the conceptual usefulness of multi-criteria approaches to energy problems where multiple social, environmental and climate objectives are considered. We thus limit studies reviewed to those that use MCDA to explicitly consider social and environmental criteria in energy problems. Studies were collated using a key-word search in Google Scholar and ScienceDirect coupled with a 'snowball' approach and were then characterised by geography and level of application, type of study and type of problems considered.

This review is intended to complement the comprehensive reviews of MCDA applications to energy problems already available in the literature [24–37] by uniquely privileging studies that explicitly consider social and environmental criteria. Admittedly, the boundary between social and non-social and environmental and non-environmental criteria can be fuzzy and one at which we neither stake authority nor comprehensiveness but rather our judgement on whether the study illuminates the conceptual usefulness of multi-criteria approaches for today's energy problems. Further, the review tends to privilege academic and successful applications in practice, allowing only general comment on the influence of academic studies in actual decision-making and challenges in application.

Instead, in this review, we focus on the conceptual suitability of these approaches for tackling today's complex energy problems that are embroiled in climate and political implications and have no definite answer. These approaches are particularly suited to today's open-ended problems as they do not presume to provide unitary answers, but instead provide mechanisms to structure deliberations that take into account multiple objectives, different preferences of actors, and therefore, different political implications of energy choices. After detailing the conceptual challenges facing today's energy choices, the rise and political salience of multi-objective frameworks in development and energy indices, in the following sections we review multi-objective and multi-criteria approaches to energy decision-making when social and environmental factors are in play, organized by the three stages of the approach.

First, we show how decision makers have used multi-objective approaches to identify a set of finite objectives from seemingly infinitely complex decision-making environments. The objectives consider a plurality of values and are identified as part of a political process of prioritization where objectives identified are those aligned with vested interests and institutional incentives.

Second, we analyse how decision makers build evidence for their choices. Multiple objective based decisions require evidence that simultaneously capture outcomes across a variety of energy, economic, environmental, social and political metrics, and also the perspectives of multiple actors with a stake in the decision. This is nontrivial as it involves the usage and synthesis of methods that capture both qualitative and quantitative implications which is a data and methods intensive process.

Third, choices entail different synergies and trade-offs between the energy, social, and environmental objectives, and in turn different winners and losers. Decision makers have not only used the approach to make evident and deliberate these synergies and trade-offs, but also to untangle and resolve conflicts of interest amongst actors. In the concluding section, we draw evidence from the review to suggest that while intensive, multi-criteria approaches are a useful approach for decision makers grappling with today's energy problems, especially in developing countries.

2. Conceptual challenges of today's energy choices

Today's energy decisions are implicated with more than just energy outcomes. First, there is a growing awareness of the social and political repercussions of energy choices. This is especially the case in developing countries where energy access is low and the provision of modern energy is politically linked with development and increased welfare. Second, the global imperative to respond to climate change, exemplified by the rapid entry into force of the Paris Agreement, mainstreams the objective of reducing greenhouse gas emissions, alongside nationally determined development priorities.

A multi-objective approach to development, energy and climate change is by no means new. The Sustainable Development Goals highlight a multi-faceted understanding of development. The 17 SDG Goals, and 169 associated targets are interdependent and cannot be considered in isolation [38–48]. Understandings of energy considerations such as security have evolved from a supply-security oriented approach, to one which includes availability, accessibility, affordability, equity and acceptability [49]. The World Energy Council's Energy Trilemma Index frames national energy planning across three dimensions – energy security, energy equity, and environmental sustainability [50]. Similar indices highlighting domestic priorities are also developed for the national-level [51]. Sectoral frameworks are also taking a multi-objective approach. The IEA has proposed an approach to capture the "multiple benefits" of energy efficiency such as energy savings, poverty alleviation, employment and health and well-being [52]. The World Commission on Dams' decision-making framework integrates socio-economic, development, and environmental considerations following sustained critiques of the high costs of displacement and environmental damage of hydro mega-projects [53].

Recent developments in the climate regime also reinforce the need for a multiple objectives perspective. Notably, the NDCs framework of the Paris Agreement explicitly allows countries to simultaneously consider national priorities and global climate objectives [54]. This joint consideration has a genealogy in climate governance with the term 'co-benefits' used to make explicit the benefits of climate actions across multiple sectors and objectives. Though the term was initially intended to denote the ancillary benefits of climate change mitigation actions, more recent understanding has stressed the "multi-directionality" of the term, and has explored the climate and development benefits of any decision [55–57]. This gains significance for developing countries, where the context of development is important for making energy and climate decisions. The formulation of these NDCs allow countries to determine independent mitigation and adaptation pathways as per their own objectives and contextual challenges [58,59]. For example, contemporary energy decision makers in developing countries will give more importance to options which simultaneously help increase access to affordable modern energy, allow reliable supply of energy for growth, and provide climate and environment benefits than those that have climate benefits alone.

Energy decision makers are increasingly held accountable to terms of development and climate change. However, they have few appropriate tools which can aid in the decision-making for social and environmental ends. These additional considerations have trade-offs and synergies which differ from the status quo, requiring additional deliberation. This intertwined relationship with society and environment makes energy systems complex in two particular ways [60]. First, energy systems have enormous, intricate and often little understood interdependencies with climate change and other social, ecological, and technical systems [60–65]. Addressing only one portion of the system tends not to resolve problems as they are culminations of multiple factors [61]. Solutions then need to address multiple factors. Second, today's energy and climate problems also impact multiple actors whose values and objectives are at stake and often in conflict [66,67]. Solutions to these complex problems involve the difficult process of both building a political consensus amongst various and differing actors and understanding trade-offs that arise [68,69]. This complexity is only heightened when we look at energy and climate decisions in the context of development, where even more relevant objectives and actors can make the problem even more complex [61]. We break both of these conceptual challenges down in more detail.

2.1. Interconnectedness

First, energy systems are interconnected with other environmental, social, and political systems [12,20,63] to the extent that it is hard to speak of one without the others. Social science and humanities scholars have articulated this intimate entanglement and argued that it is useful to speak not just of energy but "socio-energy" [12] systems and "energo-power" – the energy basis of political power – to characterise the interconnectedness of society, politics and energy systems [70]. Cherp et al. propose that energy transitions should be viewed through multiple and nested techno-economic, social-technical, and political perspectives to capture these wide-ranging connections [71]. Ürge-Vorsatz et al. map the multiple impact pathways and indirect effects energy choices have on environmental, social and political spheres [55]. A host of more policy-oriented work has also charted the interconnectedness between the multiple SDGs and energy systems [38–48].

Collectively, these make clear that energy systems, beyond the fuels, conversion technologies, distribution infrastructure and electrons, are part of broader chains linking systems to resources, natural cycles, and institutional and social arrangements. For example, scholars working to understand the causes of energy poverty point to interrelated factors of growing socio-economic deprivation, strangling shifts in land and housing tenure, changes in political economy, and ill-suited building design as factors contributing to a household's inability to use energy [72]. This relationship between energy and social and political forms is bidirectional, as energy systems can influence institutional forms, political action, and social life [73]. This implies that decisions on energy have multiple non-energy implications across many facets of social and political life. For example, the seemingly trivial determination of the height of a hydroelectric dam has implications on power produced, construction costs, and affordability to the end-user, but also upstream and downstream impacts on displacement, biodiversity, silting and even aesthetic impacts on landscape and riverine features. The dam height is in turn impacted by the social and political forces of regulation, market imperatives and social resistance. These interconnections between energy, society, and environment are complex, often hidden, simultaneous, ever-shifting and contextual.

This can also apply to strategic planning of energy systems, especially for planning energy transitions in developing countries. Countries, in their NDCs to greenhouse gas mitigation as part of the Paris Agreement, seek to devise pathways which achieve nationally relevant aims such as access to energy, affordability, economic growth, and energy security, alongside a mitigation imperative. Choices bring differing sets of trade-offs and synergies. A fossil fuel heavy strategy, while ensuring affordability and access currently, will adversely affect local environment and health and exacerbate climate change. A strategy with renewables brings its own dynamics. As prices of renewable energy technologies drop globally, the objectives of emission reduction, affordability and access can be synergistically met, but perhaps at the cost of increased import dependence and domestic job creation if local manufacturing is not bolstered. Deliberations on future energy transitions require an understanding of these various interconnected implications.

The feasibility of planned energy transitions is also dependent on political buy-in and compatibility with, or at least consideration of, the practices of energy producers and users [9,12,18,20,73]. Decisions which are seemingly technical or economic have multiple implications, rendering decisions taken from single or limited vantage inadequate. Of interest to decision makers is how these multiple elements relate to each other in their decision-making context. Crucially as well, the social and environmental implications often also become grounds of political support or contest.

2.2. Multiple actors and multiple values

An understanding of the impacts energy decisions have on other spheres is further complicated as these implications are valued differently by different actors [18,61,68,74–76]. Even the same implication can be interpreted differently dependant on the values of the actor. For example, climate change deniers will give short shrift to increased carbon emissions, while climate concerned actors will make it their primary concern. These values are plural [77], often legitimate [74] - in the sense of political standing - and incommensurable [78], in that they cannot be reduced simply to economic cost-benefit. These values can either be in contest or consensus and are often negotiated. Decisions have winners and losers, and often due to the density of the interconnections most energy choices have with other sectors, working out who is impacted, and how, is difficult, but critical.

Decisions makers often have to navigate and reconcile this political field of established incentives and alliances, conflicts of interest and values [68,69,79–82]. They seek to find pragmatic decisions which reconcile various interests and build coalitions of critical mass. Often this is done by identifying synergies and grounds for consensus. While important for all settings, the consideration of multiple values is especially critical if these energy decisions are made in democratic environments, and subject to pressures and demands from constituencies of varying values including those seemingly unrelated to energy such as livelihoods [62]. Further there should be scepticism of any process that conceals rather than makes explicit these relationships [62]. Indeed, control over a decision's objectives itself is an exercise of power.

Actors in the energy space are aplenty. These can include organized interests, such as civil society and environmental activists, explicit energy related constituencies such as distribution utilities, suppliers, and consumers, and existing institutions and regulators including departments of various motivations. For example, in India, each of the different energy related Ministries of Power; New and Renewable Energy; Coal; and Environment, Forestry and Climate Change promote different transition strategies, conditioned by their incentives. Civil and political society can advocate for concerns such as equity, reduced displacement, environmental protection and climate change mitigation. User alliances such as resident associations, farmers, transport unions, or industrial associations campaign for increased access and affordability of energy, while also resisting alternatives that are not compatible with their behaviour and usage patterns. These values also shift in context, dependent on developmental needs, political cycles and opportunity, and even differing cultures. While this complexity can be overwhelming, decision makers have the pragmatic need to cut through this complexity to make a decision.

2.3. Pragmatic need for decision-making

Traditional decision-making often flattens this complexity, reducing concerns to technical and economic terms. Such flattening is no longer tenable as the omission of climate and development considerations can lead to the worsening of outcomes, often as society and environment are not considered during a decision-making process, leading to unintended consequences. Addressing singular or discrete factors in these interconnected fields can often lead to many crucial elements left unaddressed and even externalised [61]. A purely technical and economic understanding can also omit a much-needed understanding of the political levers which can lead to change and reinforce structural impacts such as social disbenefit, environmental damage and climate change [9,12,18,20]. But such complexity can arrest decision-making by introducing too much noise and requiring decision makers to juggle too many considerations.

While coping with the plurality of systems and values is critical to the success of decision-making when addressing climate and development considerations, often contestations of values and need for analysis across multiple factors can lengthen decision-making processes. This too is inadequate as the imperative to respond to climate change and alleviate energy poverty is urgent [19]. The urgency to address development deficits and climate change implies that decision makers need to have a degree of pragmatism of "closing down" this often "messy, intractable and conflict prone" complexity [83,84]. Decision makers seek the "right reduction" of the complexity allowing them to make a justifiable choice [85].

Ideally, energy decision makers need a way to act, but one that does not omit these additional considerations. Hulme advocates for a solution which "demands multiple values, multiple frameworks, and multiple voices be harnessed together" [61]. While the need for a focus on multiple objectives of development and climate planning is increasingly recognized, the availability of tools and frameworks with which to do so have lagged behind. Existing decision-making approaches available to policy makers, tend to emphasize *ex-post* accounting tools, such as the SDGs accounting tools and energy security indices, which can track the performance of policies across multiple objectives. While these lay out the plethora of objectives to be pursued, and are useful indices to tally achievement, they do not *per se* enable decision makers to untangle the synergies and trade-offs particular to their decisions, and to which they are held accountable. Simultaneously needed are *ex-ante* analogues to these *ex-post* accounting tools, which can aid decision makers to internalize the possible synergies and trade-offs with social and environmental goals to make prescriptive energy choices. Decision makers can use such tools to incorporate multiple considerations, navigate plural values and make the right reductions.

3. Multi-objective approaches in use

Multiple criteria decision approaches are a family of formal tools salient for decision-making for complex problems. The tools structure and inform decision-making processes aimed at achieving multiple objectives. Decision makers and academics have frequently utilised these to untangle problems by exploring relations between interconnected systems and contested values. A study of the decisions made by government agencies in the United States of America from 2000 to 2016 indicated that the usage of MCDA was on the rise [86], though there is little equivalent evidence for other geographies and especially the Global South for which these methods are, perhaps, even more pertinent.

Applications of MCDA have included a wide range of sectors such as infrastructure planning, sustainability, water, land, and of course energy [24–28,87–95]. Decision makers can use the approach to reduce the various complex inter-relationships to a set of discrete objectives and then deliberate on how alternative choices impact the multiple objectives. The tools are also used to identify which objectives should be prioritized, possible synergies and unavoidable trade-offs [96]. MCDA processes rarely result in a single definitive answer, but instead structure deliberations on a range of alternatives [97].

For energy, past reviews indicate that MCDA is primarily used to untangle planning and management problems [25,27] and most studies which incorporate social and environmental goals are conducted as part of environmental impact assessments [26,28]. Figs. 1 and 2 summarise the energy applications reviewed in this paper where social and environmental criteria are explicitly considered. Studies reviewed are sorted by their application in the Global North or South, by their level of study from the international down to a specific site, by the attribute of being academic or aimed at informing practice, and by different types of problems: energy planning, energy planning with climate and sustainability objectives, rural energy planning, urban energy planning, siting, investments and corporate decisions [98–101] and appraisals of technologies or projects [102–108].

As indicated by Fig. 1, MCDA has been applied most prominently at the national level in energy planning [109–118], appraisals of technologies and projects [119–141], and siting, investments and corporate decisions. Regional and local planning, including in rural and urban settings, are also represented [142–164]. Fig. 2 shows that the majority of published applications are on the Global North and are academic exercises. While in the Global North, energy planning applications dominate, in the Global South appraisals of technologies or projects are more prevalent. In practice, applications of MCDA are primarily in energy planning. A recent review of MCDAs for energy decision-making found that less than 5% of papers addressed "energy sustainability" and none whatsoever in Global South and development settings [26]. However, based on this review, Fig. 2 indicates that there are energy planning exercises which incorporate climate change and sustainability considerations in both the Global South and North. While it is clear that MCDA has been applied to problems of different types, levels and geography, this review, as limited to the subset of published academic and practice applications, does not provide the basis to comment on whether MCDA is more suitable to problems of a particular type or level.

The following three sections explore how practitioners and academics utilizing multi-objective and multi-criteria decision approaches tackle the conceptual challenges of energy, climate and development decision-making in complex environments characterized by their interconnectedness, the values of multiple actors at stake, and the pragmatic need for decision-making. Complementing the more comprehensive reviews of multi-objective and multi-criteria decision-making for energy and various tools available in the literature [24–37,87,92,96,97,165–173], these sections detail the conceptual usefulness of these methods to problems where social and environmental criteria are considered drawing from formal methodologies, select case studies, and reviews.

These sections individually explore the three conceptual stages of an MCDA process [26,165]. First, decision makers use the approach to identify and catalogue a set of objectives. However, this is not a trivial task as decision makers have to reduce complex environments and a variety of related concerns to discrete and finite objectives. How does one adequately capture the plurality and breadth of the context while also pursuing practically achievable goals?

Second, MCDA users build evidence for their decisions. Addressing multi-objectives, decision makers face the challenge of having to capture the multiple and varied outcomes of their decisions. Single methods are often inadequate to do so. What are the challenges of using multiple methods of evidence generation, including the usage of qualitative and quantitative methods to elicit information and preferences? And, are these multiple framings useful for decision-making, or cluttering?

Finally, decision makers use the approach to make explicit the synergies and trade-offs of their decisions across a variety of outcomes and actors. Deliberation in these terms is often lacking during energy decision-making but is also difficult due to the complexity of relations and the political nature of discussions. How can one mediate and structure the engagement of the multiple values and associated actors that have a stake in and influence the decision?

These conundrums open up questions of methodology – on how best to analyse problems which are simultaneously social, ecological and technical – and of politics – on structuring deliberations between multiple values and actors and navigating relations of power. Though the tools offer differing techniques and outputs, their purpose is common. They are used to elucidate how the objectives relate to one another. The methods also help make explicit the objectives of a decision-making process and build evidence. These features help structure a decision-making process in which policy makers can consider multiple objectives simultaneously. Unpacking the characteristics and experiences of MCDA approaches further sheds light on how they can be relevant for addressing the complex problems of making energy decisions for development and climate ends.

4. Distilling objectives from a complex field

Decision-making in complex interconnected fields such as energy can potentially address a wide range of objectives ranging from political feasibility, to technical and economic viability and compliance with

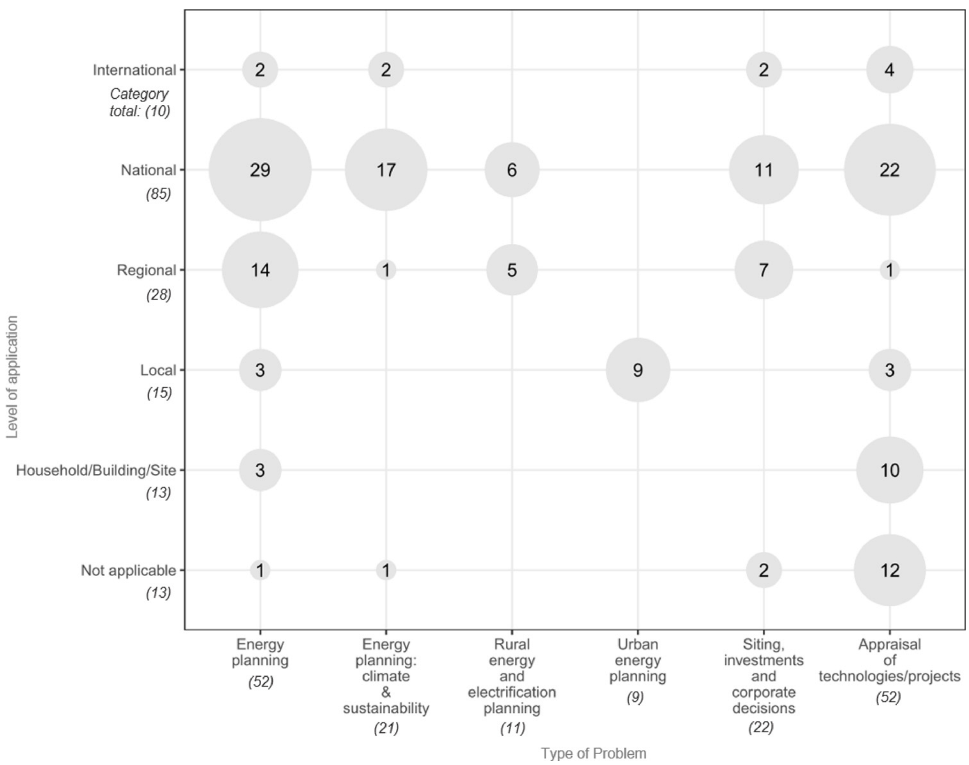

Fig. 1. Summary of 167 reviewed applications of MCDA by level of application (vertical axis) and problem type (horizontal axis). Each circle corresponds to the papers of that row and column category. The number of articles for that category combination is printed in the circle. Category totals are bracketed and below category axis labels.

ecological constraints [174]. However, it is rarely feasible to consider all possible objectives, especially with issues of high urgency such as climate change and development, as it can prolong and over-complicate decision-making. Instead decision makers have to practically limit goals to those that are feasible and relevant. Neither feasibility nor relevancy of goals is self-apparent but is deemed through a political process, and often one that is contextual. For energy decision makers, frameworks such as the SDGs, energy trilemmas and multi-dimensional energy security and sustainability indices provide multiple objectives that in abstract they should address. However, decision objectives are also rooted within political environments and relations of power. The selection of objectives of a decision-making process is dictated by prevailing institutional incentives and political arrangements and is subject to pressures from actors with a stake in the decision. These actors can demand that decision makers widen their ambit and consider the various values at stake or those important to the actors themselves. Multi-criteria decision-making tools can help decision makers distil a set of objectives from a complex field, reducing the complexity to tractable

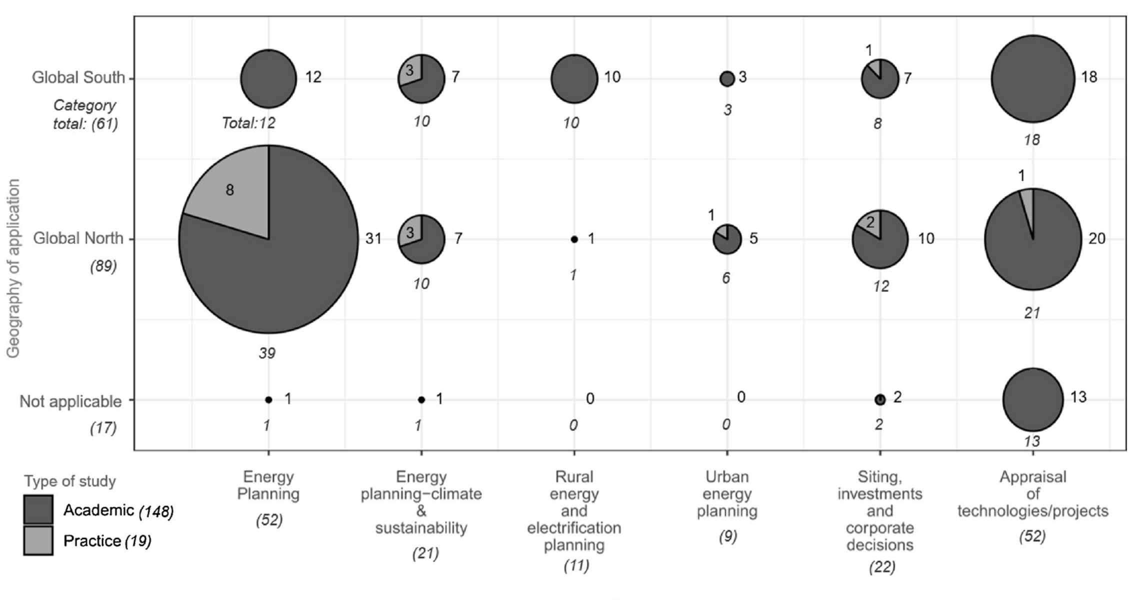

Fig. 2. Summary of 167 reviewed applications of MCDA by geography of application (vertical axis), problem type (horizontal axis) and study type (pie share). Each pie-chart corresponds to the papers of that row and column category. The number of academic articles for that category combination is to the right of the pie-chart and share of academic articles are in the darker grey. The number of practice articles is either in the pie-wedge, or offset. Practice share of articles is in a lighter grey. Total number of articles, the sum of academic and practice articles, is below the pie charts and italicized and depicted by the size of the pie-chart itself. Category totals are bracketed and below category axis labels.

terms, but also while considering the plurality of values at stake.

Objectives considered in MCDA approaches are not standardized but can be suited as per the decision-making environment. In MCDA applications limited in scope to the plan or site level, only technical and economic objectives are considered [25,27]. For instance, Afgan and Carvalho [175] undertake a multi criteria assessment for renewable energy plants considering objectives of efficiency, costs, emissions, and area required for these plants and Dinca et al. [176] conduct a technical evaluation of district-scale natural gas systems using criteria of technical efficiency, cost, operational costs and lifetime. Some approaches to evaluate such technical choices have used MCDA to minimally incorporate one or two environmental and social considerations [119,177–181]. A review of MCDA for energy decisions shows that the most popular criteria are: investment cost, CO_2 emissions, technical efficiency, and operation and maintenance cost [28]. These are either technical and economic considerations or easily quantifiable social and environmental criteria. Amongst the environmental criteria, apart from CO_2 or other greenhouse gases, land use NO_X and SO_x were most often considered [87]. For social objectives, job creation and social and user “acceptability” were most often included [87].

But MCDA’s novel benefit is shown in analyses where more complex interconnections with social and environmental systems are considered, as is the focus of this review. While MCDA can be used to assess *ex-post* energy systems [182–185], decision makers can use MCDA *ex-ante* to consider political, social, technical, and economic objectives simultaneously to help meet developmental goals while enabling sustainable energy choices [26,165,169,186]. For example, Beck et al. [187] use MCDA to show how decision-making agents can shift preferences of biomass based regional electricity generation alternatives when they take into account consequences such as rural electrification and CO_2 emissions. Jangid et al. [188] identify potential sites for wind farms balancing considerations of land use, social consent, wind speed, accessibility to roads and ease of construction, a method applied to siting problems in a variety of contexts [189–203]. A range of studies have used MCDA to identify appropriate rural electrification options [204] in contexts as diverse as Brazil [205], Venezuela [206], Bangladesh [207], Bhutan [208] and the Indian Himalayas [209,210], collectively making the case that local social factors and consent as well as environmental consequences are key upfront considerations when either extending the grid or installing decentralized systems. In demand-side examples, Zhang et al. [211] model the provincial-level energy savings, CO_2 mitigation and air pollution reduction of energy efficiency measures in China’s cement plants and Tzeng et al. [212] evaluate alternative fuels for public buses with criteria of availability and reliability of supply, energy efficiency, air and noise pollution, alignment of technology with industrial production, costs of implementation and maintenance, suitability to existing road features and speed of traffic flow and comfort. MCDA has been used to incorporate locally specific considerations into problems as diverse as evaluating future energy and heating options in European cities [145,147], energy planning in Asian cities [153,158,161,163,164] or providing energy to informal settlements that are ineligible for basic service provision, such as those in South Africa’s Western Cape Province [213].Academics have also used MCDA to evaluate household energy choices [214–216], as in a case study in India, incorporating considerations of household costs, maintenance burden and safety [217–219].

An “objective tree” can be constructed to make explicit and categorize the various objectives identified. This is a useful decision-making aid which makes the complexity of the decision more tractable. Fig. 3 is an example of an objective tree which is constructed for deciding India’s building efficiency policy [165]. Buildings have an impact on electricity consumption and savings conditioning not only future emissions but also expenditure and welfare of households. They are also intimately related with the job market due to the importance of the construction industry to employment, and tied up in complex institutional and regulatory frameworks. The objective tree makes handling this messy complexity more manageable, while integrating the plurality of concerns. It involves the identification of discrete objectives such as “maximise electricity saved”, “maximise jobs created”, “minimise GHG emissions”, and “minimise political economy *ex-ante* resistance” for this complex case and grouping them in economic, environment, social and institutional categories [165].

Objectives not only arise from the decision-making contexts but are often conditioned by who the involved actors are. In a multi-objective analysis of rural cooking fuel transitions in India, objectives identified arose from bureaucratic mandates at national and local levels, philanthropic aims of local NGOs, profit imperatives of the private sector and user concerns [220]. National government objectives considered included GHG reduction and energy security. At the local level, departments most concerned about the clean energy transition were, perhaps unconventionally, the Forestry and Tribal Affairs departments as the transition would lead to less usage of protected forests as a source of cooking fuel, and increase the welfare of tribal groups concentrated in the area. At the household-level, the analysis also integrated the considerations of the women in the households not only in the usual terms considered such as drudgery and air pollution exposure, but also cultural preferences such as taste and position while cooking. Alongside policy goals, these more quotidian and also qualitative factors are critical determinants of the adoption of new technologies and can be integrated into decision-making analysis with MCDA [220].

The objectives of any decision are situated in a specific economic, technological, social and environmental milieu, and are conditioned by institutions, with particular mandates, jurisdictions and orbiting political interests. But, this also makes multi-objective approaches prone to “information pollution” where far too many aspects considered can actually detract from pragmatic decision-making [89]. How have practitioners of MCDA dealt with this, and limited their selection of objectives? A strategy often used is embedding the decision’s objectives within prevailing institutional incentives. An analysis of transitioning Beijing’s taxi fleet to more sustainable technologies involved considering institutional objectives such as alignment with tax levies and incentives by the Beijing Department of Transportation and achieving existing road emission limits [221]. In the Italian island of Sardinia, Beccali et al. use MCDA to identify renewable technologies that are more suited to local political, legislative and administrative arrangements [222]. With MCDA, decision makers can also integrate such locally-specific concerns alongside internationally decided objectives such as the SDGs and climate mitigation.

This is especially pertinent when devising national energy strategies, which MCDA is often utilized for [223–228], including in the context of climate change [25,28,92,160,229–241]. Reflecting the United Arab Emirates’ domestic strategy to focus more on sustainable development and the adoption of renewable technologies, an academic study utilized a multi-objective approach to evaluate the impact of alternative scenarios on key economic sectors, job growth, GDP, electricity consumption and carbon emissions [242]. In Europe, academics have used multi-objective approaches to evaluate how sustainable development and climate change targets will impact the national economy and social welfare. Switzerland’s GHG emissions reduction target motivated an analysis of various carbon reducing technologies in the context of this climate goal alongside other social objectives such as human health, conflict potential and energy security [243]. Another study for Lithuania used a multi-objective framework to analyse a variety of climate change mitigation policies in the context of European Union (EU) and domestic goals [244]. In Austria, an MCDA approach was used to test between multiple sustainable energy pathways and their impact on local environment, GHG emissions, financial costs but also qualitative aspects such as employment, social cohesion, noise, quality of landscape, social justice, ecological justice and technological advantage [245]. In Turkey, in order to evaluate a transition to a more renewables dependant energy system, five renewable sources were evaluated across nineteen criteria including economic development, job

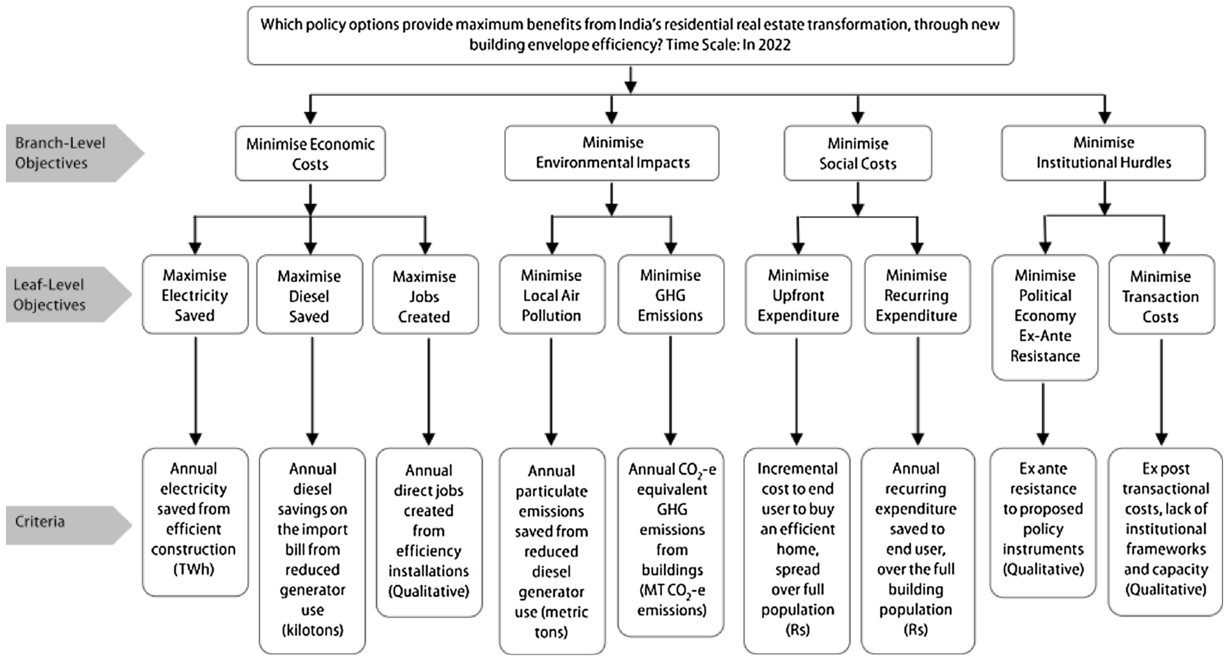

Fig. 3. Objective tree.
Source: [165]

creation, investment, operational, land use and ecological costs, suitability of sites, alignment with international regulations, dependency on foreign technology, technological maturity and social resistance [246].

Such analyses are especially pertinent for developing countries where development needs are still to be met. In one case, a United Nations Environment Programme (UNEP) study utilized the approach to devise Nationally Appropriate Mitigation Actions for the Philippines where climate change mitigation was simultaneously considered alongside economic growth, defined in terms of employment generation, GDP growth, regional equity, (absolute) poverty reduction, improvement in access to basic services, increase in ethnic and gender equality and strengthening institutions [247]. In Brazil, Santos et al. assess various scenarios for Brazil's power sector in light of the international goal to reduce GHG emissions and towards domestic objectives of jobs, energy dependency, income, health and environmental pollution amongst others [232]. Rahman et al. conduct a similar analysis for Bangladesh, assessing future energy system profiles on technical and economic criteria as well as lifecycle GHG emissions and local environmental impact, social considerations such as local employment, public and political acceptance, policy and regulation factors such as local ownership, interference with utilities, tax incentives and land acquisition requirements [233],

Such multi-objective approaches provide a framework by which developing countries can strategically meet national development objectives while also addressing climate mitigation goals. These studies set their agenda by an explicit definition of the multiple objectives of an energy decision, chosen for their relevance and feasibility. MCDA can be used by decision makers to integrate the plurality of values affected including social and environmental considerations. However, for practical decision-making purposes objectives considered need to be limited, and this limitation is often a political process where choices of objectives are conditioned by pressures from relevant actors. Pragmatic concerns often lead to only objectives aligned with institutional incentives to be considered. However, multi-objective approaches can be used *ex ante* to make this selection process explicit, transparent, and open to deliberation, rather than obscure and ad hoc. This unambiguous identification of objectives also sets the terms by which the project, plan or strategy can be justified. The usefulness and challenges of justifying choices by generating evidence for multiple objectives is the subject of the next section.

5. Building evidence for multiple objectives

Decisions have to be justified. The burden of justification is especially high when decisions set out to achieve multiple objectives; the more objectives considered, the more evidence is needed. This makes building evidence for multiple objectives a data and methods intensive challenge, but also one that involves various types of evidence. Tasked with evaluating their choices across a variety of metrics, decision makers use a variety of methods to capture the multiple implications of their choices. The metrics upon which choices are evaluated need not be of the same type but can be "divergent…[and] unconstrained by methodological preferences" [83]. Decision makers can use MCDA to incorporate both qualitative and quantitative evidence into their decision-making.

Both types of information are critical when integrating a variety of social values which rarely can be represented quantitatively, even by proxy. Social factors such as acceptability, culture, taste and aesthetics are often critical in the approval of a policy or the adoption of a technology but decision makers find it difficult to incorporate these qualitative factors in their decision-making. For example, studies that look to understand household's adoption of modern cooking energy services often fail to incorporate qualitative factors such as gendered dynamics and bargaining power within households, social value associated with cooking fuels and stoves, cooking styles, and taste preferences, all of which influence a household's decision to purchase and use clean cooking fuels [248]. Such considerations such as preferences of taste and position of cooking, which are cultural and irreducible to monetary terms, were incorporated into an analysis of alternative cooking fuel choices in rural India using MCDA [220]. A similar approach was taken to evaluate building ventilation options, incorporating the qualitative consideration of occupant comfort alongside indoor air quality and energy consumption [249]. As MCDA is methodologically syncretic, users can evaluate alternatives with a variety of methods, across disciplines, including quantitative and qualitative approaches [91,250].

In more politicized decisions, practitioners have stressed the value of using MCDA to incorporate the positions of differing actors, especially when their viewpoints can be subjective, inconsistent and opaque [31,251]. “Stakeholder” based or “participatory” approaches are utilized by decision makers to understand and incorporate the variety of perspectives [24,89,92,118,140,147,252–258]. In an analysis of the installations of renewable energy in the island of Crete, Tsoutsos et al. [259] assessed the various alternatives across economic, technical, social and environmental criteria identified by the relevant actors in energy planning including local authorities, investors, local communities, academics, environmental groups and upper levels of government including the EU. Using a multi-criteria approach, one can identify the priorities of the various actors and grounds on which there is convergence and divergence. In Crete, upper levels of government and potential investors prioritized lower investment and operating costs. Only investors were interested in maturity of technology, while local authorities and communities prioritized social acceptability. The broadest consensus, inclusive of local authorities, the EU, academics, and environmental groups, was for reducing carbon emissions. While there was divergence in which criteria were prioritized, ultimately the choice of installing wind farms, photovoltaics, and oilstone biomass emerged as the preferred alternative amongst most groups [259]. The transparency of such varying positions can be crucial evidence towards designing energy policy that is political viable and social acceptable.

While there is a benefit to framing evidence through qualitative methods, often MCDA methods do not give adequate attention to how they frame evidence. Evidence is rarely neutral. This is especially the case in complex systems, where epistemological framings cannot capture the entirety of the phenomenon but only a portion of it [85]. This framing is produced as part of a “regime” of knowledge which highlights only a certain aspect of the phenomenon, reinforcing a particular perspective.

MCDA users frame evidence by choosing both metrics to represent objectives and methodologies to evaluate alternatives. This becomes especially critical when defining social objectives as they have no particular measure. A meta-review of social objectives considered by MCDA for energy studies indicates that job creation is most widely considered [28]. But this only captures one of the many social implications of energy decisions. In an example which captured multiple social objectives, UNEP utilized a multi-criteria approach to inform South Africa’s Integrated Resource Plan [169]. A multi-faceted understanding of social objectives was developed through the selection of multiple social criteria such as job creation, reduction in poverty, reduction in inequality and improved health. While these were also political priorities, they were also indicators for which numeric data was available [220]. This can often be a limitation for MCDA analyses as it is a data intensive exercise. The availability of data can constrain how evidence is framed.

The challenge of framing can reduce the legitimacy of any decision-making process [89]. However, like in the South Africa case, MCDA practitioners have resolved this by analysing objectives with multiple metrics and methods and capturing different perspectives. Seemingly similar objectives are interpreted and valued differently as in the case of health impacts of pollution [260] highlighted by Marttunen et al. [90] where “participants systematically overweighted the proxy attribute, emissions level, compared to the fundamental objective, illness level.” Actor preferences diverged when similar objectives were assessed by different criteria. Using multiple methods and metrics, decision makers can assign a more precise value to the objective [97]. In a study of demand side planning for BC Gas in Canada, Hobbs and Horn [261] used multiple methods to better understand the perspectives of various stakeholders, recognizing that methods can suit actors differently.

MCDA, with the strength of making evident preferences, relations and trade-offs, can also be complemented with other appraisal methods which provide more definitive results. Corroborating analyses of the Greek [262] and European [263] power sectors show how MCDA can also be used in conjunction with cost-benefit and externality analysis respectively, creating complementary evaluations of the alternatives on a single quantitative criterion. A similar MCDA analysis of energy policy scenarios for an Irish region complemented its qualitative and quantitative multi-criteria assessment with discrete environmental data from an ecological footprint analysis [264]. MCDA has also frequently been used compatibly with other analytical tools such as life cycle analyses [35,137,138,221,237] and geographical information systems (GIS) in siting applications [180,188,191,192,195,203]. Miragedis and Diakoulaki term this compatibility a “methodological affinity” between MCDA and other appraisal methods [263].

Multi-objective approaches involve assessing each alternative across objectives, making it a data and methods intensive exercise. However, as it involves different methods, it can be used by decision makers to incorporate qualitative considerations along quantitative ones. Often, qualitative insights and factors such as political economy, institutional hurdles, social behaviour and cultural norms are critical to the success of a policy decision. MCDA can be used to analyse each dimension separately, and thus present information and value judgements in intuitive forms rather than in obscured or transformed quantitative terms [97,265]. This can enhance the transparency of a decision’s implications, especially in more contested political decisions where evidence remains open to interpretation by actors with varied perspectives. A better understanding of the various perspectives at stake and the potential trade-offs can help structure deliberation on the decision.

6. Exploring relations, synergies and trade-offs

Decisions have winners and losers along different dimensions or objectives, yet the trade-offs across choices are often not systematically deliberated [67]. Doing so is a central benefit of MCDA, as decision makers can use the approach to explore the impact of alternative choices on different actors by unpacking the relations between objectives [89]. Methodologically, MCDA processes relate objectives by aggregating criteria on a single scale, keeping objectives distinct but comparing them, or asking actors to share perspectives on the differences [266]. More than simply comparing relations, MCDA can be used to identify those that are most critical to either agreement or conflict, and thus can reduce a field of complex relations to a fewer set of flashpoints by identifying synergies or trade-offs.

Due to their sprawling social, political and environmental implications, addressing contestation over energy mega-projects such as hydroelectric dams is particularly suited to MCDA approaches. In Paraguay, a study explored the trade-off between the benefit of a hydroelectric scheme to geopolitical strategy and national coffers – by exporting energy to its neighbours – with domestic welfare and economic growth – by dedicating the source to local industry [267]. In a more conventional study in Sri Lanka, the trade-off between inundated land, resettlement, biodiversity and affordable electricity generation was explored for the country’s different dams [268]. In Portugal, the trade-off between preservation of cultural heritage and the local environment and economic expansion and energy production was explored in a case study on the Foz Coa dam, during construction of which a set of ancient rock engravings were discovered [77]. A multi-criteria approach was used by academics to compare relations which are often seen as incommensurable and unrelated such as energy provision, economic value and cultural heritage.

Trade-off analysis is also pertinent for renewables-based and low-carbon transitions [24]. In India, the trade-off between coal and solar based generation was explored in terms of impact on carbon emissions, but also land use, water use, costs, reliability and energy returns [269]. A similar exercise was carried for energy transition in Portugal where trade-offs between economic growth, energy security and resilience, jobs, CO_2 emissions, land use and public health among other criteria for multiple energy scenarios were outlined [270]. MCDA is also used to evaluate demand-side transitions. Jain et al.’s [271] case-study on the trade-offs between private and public transport in Delhi, India highlighted that customers choose modes with the objectives of safety, reliability, affordability, and comfort, preferring metro rail services compared to buses and other public transport options.

Navigating these trade-offs in policy-planning, in turn, involves making a series of decisions on who wins and loses. In contexts where different actors are involved in the decision-making process, a clear exploration of the trade-offs can help design compensation and wider benefits. In two similar cases in Alaska and Greece, local groups opposed the installation of renewable technologies in a form of "NIMBYism" [Not In My Back-Yard-ism]. Decision makers used MCDA to identify alternatives which accrued more local benefits and had community approval [252–254]. In the case of Alaska, MCDA was also used to identify the variances in concerns of constituencies. Inhabitants with closer connections to the tourism industry were against the development due to aesthetic reasons, compared to those in agriculture who were more concerned with economic benefit and affordability of energy [252]. Near Italy's Mt. Amiata, where opposition against geothermal technology was mounting, Borzoni et al. used MCDA to make evident the differences in positions of residential associations, local political parties, municipalities and energy companies [272]. However, it is not always politically useful or feasible to articulate trade-offs. As Lootsma et al. [273] noted after a long process of deliberating Netherlands' energy strategy using MCDA, decision makers often preferred unanimous approval of technologies and pathways rather than exploring trade-offs which made hard choices tangible but no easier. Decision-making ultimately remains a political rather than methodological process.

As the multiple interests can map onto the multiple objectives, decisions makers using MCDA can identify issues that are contentious and ones which can be the basis of consensus. This process reduces the variety of concerns that were initially identified to a fewer set of critical ones. Decision makers can identify issues that should be prioritized for discussions, those that are the most contested and those that generate consensus which can be the basis to build coalition amongst actors. Often in settings where interests are opposing, MCDA is used to resolve conflict [24,87,91,96,242,273–277].

Seeing differences amongst key constituencies, Keeney et al. [276] convened multiple institutions to deliberate on West Germany's energy objectives including industrial and professional associations, environmental research and protection groups, electricity supply companies, religious institutions and labour unions. Each of the institutions developed their own objective trees which were synthesized into a combined tree, which participants met with broad consensus. This mapping has also been conducted for promoting energy efficiency in Portugal [278,279] and waste to energy in Germany [280]. In a comparable analysis of solar and mobility transitions in India and Thailand, Raven et al. [281], gathering the various perspectives on energy and sustainability transitions, utilised MCDA to map variation in sectoral perspectives of academics, government, NGOs, industries and consultancies. The analysis helped identify issues where there was a high degree of disagreement and uncertainty such as with decentralised solar systems, and therefore where further research and policy deliberation should be dedicated. In highly contested decisions, decision makers can use the objective tree to identify potential areas of consensus and conflict towards which more analysis and deliberations can be dedicated. This process allowed decision makers to identify "fundamental", "critical" or "swing" objectives upon which the decision hinges [97].

Such critical or swing metrics have disproportionate influence over a decision-making process. However, with MCDA, these are not identified *ex-ante* but as part of the process. The benefit of critical objectives is the distilling of the complex multiple values to fewer flashpoints which can be investigated further. For example. Punia Sindhu et al. [282] use MCDA to show that political and regulatory barriers such as multi-tiered government approvals and non-functioning agencies are the most pressing barriers for the uptake of solar energy in India. This is especially pertinent as conditions can shift during the decision-making process and the identification of these swing parameters can ensure decision makers respond quickly to these shifts.

MCDA has been used to explore South Africa's mitigation options [283]. The analysis sought to quantify emissions reduction potential and cost associated with various mitigation opportunities across the economy. It identified various objectives or co-benefits of mitigation technologies such as contribution to GDP, jobs, impact on water sources, amongst others. The analysis involved both quantitative and qualitative methods which allowed stakeholders to explore the multiple impacts of mitigation technologies. In one example, four technologies – solar PV, onshore wind, nuclear power, and coal-based power using Carbon Capture and Storage – were considered. A sensitivity analysis demonstrated that when net social benefit was considered, recommended technologies shifted [284].

Often these "critical" factors are social or political. In an analysis exploring the sustainability of a Swiss utility's current and future electricity supply technology portfolio, Roth et al. [186] show how preferences change when social concerns are considered. Studying numerous indicators on environment, social, and economic criteria, their results show that while nuclear power had the lowest estimated total costs, renewables emerged favourably when social criteria were included. Similarly, an analysis of renewable energy provision in a local area in Yorkshire, United Kingdom indicates that while large scale projects are more financially viable, if local social, economic and environmental benefits are factored in, smaller scale projects became more favourable [143]. In an assessment of bioenergy options in Uganda, social criteria were also consistently decisive [136]. This points to the usefulness of MCDA to political contexts where social outcomes of energy matter, especially the case in developing country settings. The swing factors are also useful as part of scenario modelling where the effect of changes, especially exogenous factors such as oil prices or renewable technology penetration, on the decision can be modelled.

Better deliberations on our energy choices can be structured by making trade-offs evident. Explicitly laying out the implications of each choice on each objective and considering how actors value each objective differently, MCDA can be used to develop a sense of which actors win or lose, and in what terms. The complex implications of decisions need not be considered *ad infinitum*, but with the use of MCDA be reduced to a set of trade-offs and synergies which can serve as the basis of building coalitions around issues where there is consensus or identifying contentious issues which require more deliberation. Understanding *ex-ante* the trade-offs of choices, decision makers can iterate their designs or begin to develop terms of compensation to losing parties upfront. The merit of the MCDA method is that users can integrate a plurality of considerations, but also relate them to each other. Social and environmental, quantitative and qualitative factors are not considered in isolation to the terms of decision-making, but in integration with them.

7. Conclusion

MCDA parses the intricate complexity and politics of today's energy decisions by making legible and tractable the various perspectives different actors bring to a decision, the multiple objectives and values at stake, and the trade-offs across them. By characterizing and making evident the perspectives of various actors and the trade-offs and synergies of choices, the method can structure deliberations to work through conflicts of interest and help arrive at decisions that are socially and politically viable. MCDA can be used by decision makers, in affinity with other methods, to integrate essential qualitative and non-monetary considerations such as behaviour, institutional alignment, and political buy-in, which are often not included yet are hurdles of policy implementation. By making multiple objectives explicit upfront, decision makers can transparently represent and deliberate the values at stake. An understanding of trade-offs and synergies entailed in the decision can also help prioritize areas of research and deliberation.

This *ex-ante* method complements ongoing initiatives that are tracking, *ex-post*, the impact of energy decisions upon multiple objectives. It is suited to the implementation challenges of the SDGs and the Paris Agreement which create incentives for energy decision makers to simultaneously consider development and climate needs. Such decisions often involve trade-offs which MCDA can help manage, though more research is needed to understand how MCDA's role or usefulness changes by project type, level and context. Applications reviewed here indicate that MCDA has been applied across problem type, level and context though most applications were academic, for energy planning and project appraisals, at the national-level and in the Global North.

While the potential gains of this approach are substantial, it is also important to be aware of the challenges in its application. Energy decisions for climate and development outcomes can be particularly complex, aiming to address many objectives across a large scope of inter-linked decision arenas. For such decisions, the method is not yet mainstream due to the high capacity and data requirements to implement it in full. This is the case both for strategic problems, where complex interconnections between various sectors have to be explored, but also, for all sorts of problems in developing countries where the availability of local data and capacity is limited.

Moreover, the conceptual complexities of today's energy problems pose an obstacle to full implementation of the approach. Doing so requires mapping the various interconnections between energy systems and social, political, environmental, and climate outcomes as well as the value trade-offs between objectives. This, in turn, requires both quantitative and qualitative analysis and data. These requirements can make the method cumbersome to implement and even the results difficult to reconcile. Insights into existing trade-offs need not always enable decision-making, and can only perhaps make a point of conflict more visible and protracted. Working through contradictory objectives and conflicts between multiple actors can be contentious and requires a high amount of co-ordination and transparency amongst actors, often against their self-interests. Making a decision's objectives, process and trade-offs transparent, in themselves, can have high political resistance. MCDA could even risk replicating the complexity it aims to make tractable [97] Possibly, as a result, MCDA has mostly been implemented in academic settings.

While there has been academic uptake of the method in the Global South, its full ability is yet to be explored in decision-making exercises where trade-offs between energy, development, and climate concerns are more contentious and are implicitly being made in fast-moving policy contexts. Developing tools to manage these unwieldy applications in data-scarce environments is a challenge. However, there has been a welcome increase in the availability of MCDA tools to decision makers [87,97,165–168,285], including those aimed at helping developing country decision makers to find synergies between development and climate goals and the SDGs more broadly [92,96,165,170]. These tools provide an opportunity to incentivise decision makers to systematically work through the trade-offs and synergies that are often made implicitly, especially as part of strategic, multi-sectoral deliberations such as when formulating energy plans or NDCs. Incentivizing decision makers will require MCDA practitioners to engage more with the political context of the decisions they intend to inform. As pressures to implement international pledges such as the SDGs and NDCs grow, decision makers may increasingly seek productive ways to engage these political contexts, and make them tractable. MCDA provides one useful way to structure these discussions.

Declaration of interest

None.

Acknowledgements

We thank the John D. and Catherine T. MacArthur Foundation (grant number: 16-1603-150748-CLS), Oak Foundation (grant number: OCAY-15-519) and the Swiss Agency for Development and Co-operation (grant number: 81045724) for grant support during this project. We also thank Deepaboli Chatterjee, Babu Lal and Rimjhim Saxena for their assistance with data visualisation. All opinions and errors are those of the authors alone.

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