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Prevalence of plastic waste as a household fuel in low-income communities of the Global South

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Anecdotal evidence suggests that households burn plastics to manage waste and help satisfy their energy demand. To examine the prevalence, extent, and reasons for using plastic waste as household fuel, we report on a survey with 1018 key informants from cities in 26 countries in the Global South. Informants were purposively selected due to their familiarity with the living conditions in their communities. One-third of respondents reported being aware of plastic waste burning, with some reporting that their households engaged in this practice. Analyses of the data reveal significant correlations of plastic waste burning with both supply factors, such as, the massive amount of waste generated ($p = 0.000$), expensive clean fuels ($p = 0.004$), and demand factors, including self-management of waste ($p = 0.000$). Expanding essential public waste management services and implementing programs that enhance the affordability of clean energy technologies, especially among marginalized and low-income communities, could reduce this health- and environment-damaging practice.

The management of plastic waste, with over half a billion tons of plastic produced annually and rising, is a major global environmental challenge[1–3]. Meanwhile, in cities across much of the Global South, waste management systems are grossly inadequate, with the quantity of unmanaged plastic waste therefore increasing[4,5]. The term Global South, as used in this study, refers to the low- and middle-income countries in the regions of Latin America, Asia, Africa, and Oceania[6]. These trends are thought to contribute to the

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increased burning of plastic waste. While some governments are now introducing policies and regulations to limit plastic use and disposal, including targeting its combustion, the gap between policy formulation and effective enforcement, especially in marginalized areas, is substantial[7]. Most mitigation efforts have thus far proven ineffective or inadequate. Plastic continues to accumulate in many settings[8], and households need to find new ways to manage the waste surrounding them.

At the same time, clean fuels and technologies whose emissions meet the fine particulate matter (PM2.5) and carbon monoxide(CO) levels recommended in the World Health Organization's (WHO) global air quality guidelines[9], such as electricity, liquefied petroleum gas (LPG), biogas, natural gas, and ethanol, remain largely unaffordable for people living in extreme poverty. This compels them to depend on traditional solid biomass fuels such as firewood, charcoal, crop residues, and animal dung[10]. However, many urban residents with lower socioeconomic status in the Global South are finding biomass fuels to be increasingly scarce, due to population growth and limited access to these traditional fuels[11].

Thus, there are growing concerns that energy-poor, solid fuel-dependent households who must self-manage their own and their communities' plastic waste may turn to burning plastic waste as a no or low-cost alternative for cooking and heating[12]. For instance, Nigeria's Multi-Tier Framework for Energy Access survey data reveals that roughly 13% of 3511 surveyed households reported garbage as one of their household fuels over the prior 12-month period[13], and similar practices have been reported in other locations[14]. While it is generally believed that plastic is used primarily to ignite cooking fires[15–17], households living through humanitarian crises and in urban settings more generally, have reported burning plastic waste as a primary cooking fuel[18,19].

Despite the considerable potential health, environmental, and socioeconomic risks associated with plastic waste burning[4,19,20], the extent and prevalence of its use as a household fuel remain poorly understood[12]. The scarcity of data and evidence limits a comprehensive understanding of the issue, complicating the design of effective strategies to mitigate its impacts[21]. To address this gap, we conducted a primary survey among purposively selected key informants across 26 countries in the Global South. All participants were familiar with urban living conditions, particularly those of low-income communities, where the practice of burning plastic waste is suspected to be most common. Although this approach does not yield a population-representative sample in the settings considered, the survey does reveal that the burning of plastic waste is widespread. It offers a starting point for future research on the underlying drivers and impacts of this behavior[21]. As such, it represents a crucial step towards developing targeted programs to counteract the harmful effects of global plastic waste burning.

Results

Context

The Global South is urbanizing at an unprecedented rate, creating an urgent demand for rapid expansion of infrastructure, services, and economic opportunities. However, many low-income countries face acute resource constraints that hinder their ability to keep pace with this growth[22,23]. By 2050, an estimated two-thirds of the global population is expected to reside in urban areas, with much of this growth occurring in low- and middle-income countries (LMICs)[24]. Historically, this rapid urbanization has led to the proliferation of informal settlements within these nations. Access to reliable energy, effective waste management systems, and modern water and sanitation services remains very low in some cities in the Global South[25,26]. These infrastructure deficiencies pose serious health and environmental risks and exacerbate social inequalities and unrest[27]. In response to these systemic gaps, informal solutions, such as plastic waste burning, have emerged as a means to address the lack of proper waste management and energy access needs[28].

Continued use of traditional stoves enables the burning of waste plastic as fuel. Low-income households migrating to informal settlements to escape high rental costs often face barriers in accessing affordable, clean fuels. Moreover, the rapid growth of densely populated settlements intensifies pressure on local forests and other natural resources, driving up the costs of traditional fuels such as wood and charcoal[29]. One notable consequence is the increased scarcity of biomass fuels, which has become a contributing factor to accelerating the energy transition in many urban environments. This transition is occurring at a highly unequal rate[30]. However, it is leaving lower socioeconomic status and marginalized communities behind[31], and exacerbating energy insecurity for those least able to afford clean commercial fuels[10] and forcing them to look for no- or low-cost fuels, which can include unmanaged solid waste.

As a readily available waste product that combusts easily, plastic is a potentially attractive fuel source for low-income households struggling to meet their energy needs. Plastic waste is difficult to manage as it does not decay like organic waste, nor does it have the resale value that metals have; this makes burning or incineration a widely accepted method of management[1,28]. Unfortunately, burning waste, particularly plastic waste, releases many harmful toxins that negatively affect household environments and spill over to contribute to poor urban air quality[20,32]. The harms from plastic burning extend beyond direct human exposure to toxic emissions via inhalation. Secondary impacts, including ingestion of contaminated food, documented in environmental analyses, underscore additional risks associated with plastic combustion[33]. For example, chicken egg samples from an electronic waste site in Ghana, where plastic and cables were burnt in an open fire, have been found to contain toxins[34,35]. Additionally, the technologies and tools used to burn plastic waste, along with how individuals interact with these tools, likely play a critical role in influencing the environmental and health impacts of this practice, both within households and across broader communities.

While systematic evidence on the prevalence and extent of plastic waste burning as a household fuel remains limited, anecdotal and localized studies indicate that the practice could be widespread[15,16,36]. Systematic and comprehensive data gathering on this topic, including results from this survey, is needed to advance understanding of the complex dynamics of plastic waste burning and to inform policies and targeted programs aimed at mitigating its risks[21].

Survey results

Responses were obtained from 1018 key informants familiar with the context of their cities were analysed in this study; see Table 1 for sample summary statistics (and "Methods" for additional details). Respondents were asked about the general prevalence of plastic waste burning in their city. Among 931 responses for this question, 22% indicated that plastic burning was slightly prevalent, 35% reported it was moderately prevalent, 26% responded it was very prevalent, and 8% described it as extremely prevalent (Fig. 1a).

Respondents were also asked about the use of plastic waste as a household fuel through three questions. Among the 989 respondents who answered a first question on burning of plastic cooking fuel as a replacement for other fuels, 19% somewhat agreed and 8% strongly agreed, indicating notable agreement to this practice (Fig. 1b). Meanwhile, 22% neither agreed nor disagreed, while the remaining respondents either disagreed (21%) or strongly disagreed (30%) with the statement.

In a second question, 32% of participants somewhat agreed, and 24% strongly agreed that burning plastic waste in traditional stoves is common practice ($N = 985$). By contrast, 16% disagreed, and 13% strongly disagreed (Fig. 1c). These responses suggest a higher prevalence of plastic waste burning compared to the first survey question,

Table 1 | Summary statistics of respondents

Variable	N	Percentage
Gender		
Male	908	54.3%
Female	908	43.1%
Non-binary/ third gender	908	0.7%
Prefer not to say	908	2.0%
What type of organization do you work?		
University or Polytechnical	904	38.8%
Commercial entity	904	9.5%
Government agency	904	23.3%
Not-for-profit (NGO)	904	11.2%
Other	904	17.1%
Education		
Up to Grade 12	904	9.1%
Post-secondary qualifications	904	5.2%
Bachelor's degree	904	39.0%
Master's degree	904	32.7%
PhD	904	13.2%
Other	904	0.8%
How long (in years) have you been engaged in your current field of work/ research		
Less than 2 years	897	31.2%
Less than 5 years	897	26.1%
Less than 10 years	897	14.5%
More than 10 years	897	28.2%
What is the geographical coverage of your work?		
Multinational	904	17.9%
National	904	44.6%
City level	904	20.5%
Community	904	17.0%
What area does your work fall under?		
Natural sciences	904	15.9%
Engineering and technical	904	25.0%
Medical and health services	904	8.2%
Agricultural science	904	10.2%
Social sciences	904	18.9%
Arts and humanities	904	4.3%
Other	904	17.5%
Type of institution		
University or Polytech	904	38.8%
Commercial entity	904	9.5%
Government agency	904	23.3%
Not-for-profit (NGO	904	11.2%
Other	904	17.1%
To which of the following categories do you belong?		
Researcher	904	35.5%
Local government and civil servant	904	20.8%
Socially engaged professional	904	6.7%
Community leader	904	1.9%
NGO or CBO	904	9.4%
Private operators	904	11.6%
Others	904	14.0%

Note: Socio-demographic questions were asked in the concluding section of the survey.

which may indicate that plastic burning is used primarily to manage household plastic waste, rather than as a primary or preferred energy source for cooking.

The third question asked respondents whether they were aware that plastic waste was used as a household fuel in their cities, with three response options: yes, unsure and no. Affirmative answers to this question appear to lie between those on the two other questions: out of 998 respondents who answered the question, 37% reported being aware of this practice, 37% were unsure, and 27% were unaware (Fig. 1d).

The 365 respondents who indicated awareness of plastic waste burning for energy purposes in their city, from the final question 'Are you aware of burning waste plastic as fuel', were also asked follow-up questions regarding the specific purpose of this practice. Out of the total respondents, 16% reported burning plastic for at least one purpose, 10% reported using it for two purposes, and 5% for three different purposes.

Nearly half (48%) reported witnessing others burn plastic waste as a cooking fuel, while 14% responded that they had done so themselves. Another 13% indicated they had heard about the practice but had not seen it firsthand (Fig. 2a). Regarding the burning of plastic waste for heating purposes, 37% had seen others doing it, 12% had done it themselves, and 18% had only heard about it being done (Fig. 2b). A smaller proportion of respondents were aware of plastic being burned to prepare cattle feed: 12% had witnessed it, 11% had heard about it, and 4% had engaged in the practice (Fig. 2c). The lower awareness of the latter likely reflects the relatively limited cattle ownership in the urban areas that were the focus of our survey.

Fuel stacking, the use of multiple fuel types to meet household energy needs, is a well-documented practice in low-income settings[37]. However, this behavior can contribute to increased toxic emissions, especially when polluting fuels such as plastic are mixed with other materials[38]. To explore this further, the survey examined the extent to which plastic is combined with other fuels in household fires. Among those aware of plastic burning, 22% reported burning plastic with different fuels, 46% had witnessed this practice, and 14% had heard about it (Fig. 2d). Integrating plastic waste into household fuel use for multiple purposes appears to be relatively common among respondents familiar with plastic combustion.

The survey also investigated whether burning plastic waste is employed to deter pests and insects, as smoke emissions from polluting energy sources are sometimes considered effective in doing so[39]. While only 6% of respondents reported burning plastic waste for this purpose, 17% had witnessed it, and 19% had heard about it (Fig. 2e). The survey also investigated whether plastic waste is used for lighting fires. The survey found that 38% of respondents had used plastic as a fire starter, 40% had witnessed this use, and 13% had only heard about it (Fig. 2f).

The extent to which plastic waste is used as a household fuel varies by country, with patterns that correlate with regional and national income levels. Figure 3 show the proportion of respondents who agreed that plastic waste is used as a fuel substitute, acknowledged plastic burning to be a common practice, and reported awareness of plastic waste combustion for energy purposes according to country income (Fig. 3a, c) and by region (Fig. 3b, d). The measures were converted from a Likert scale – previously discussed in Fig. 1—to a binary variable indicating some or strong agreement. Plastic waste combustion is more prevalent in low-income countries, except for heating purposes (Fig. 3b), which likely reflects differences in climate. Regional differences are also notable, with respondents in Sub-Saharan Africa reporting a higher prevalence of these practices compared to those in other regions, for all purposes (Fig. 3d). Additionally, the disaggregated data suggest that fuel substitution with plastic (the first measure) may be somewhat over-reported in Latin America and the Caribbean (LAC) and Southeast Asia (SEA). This is indicated by higher

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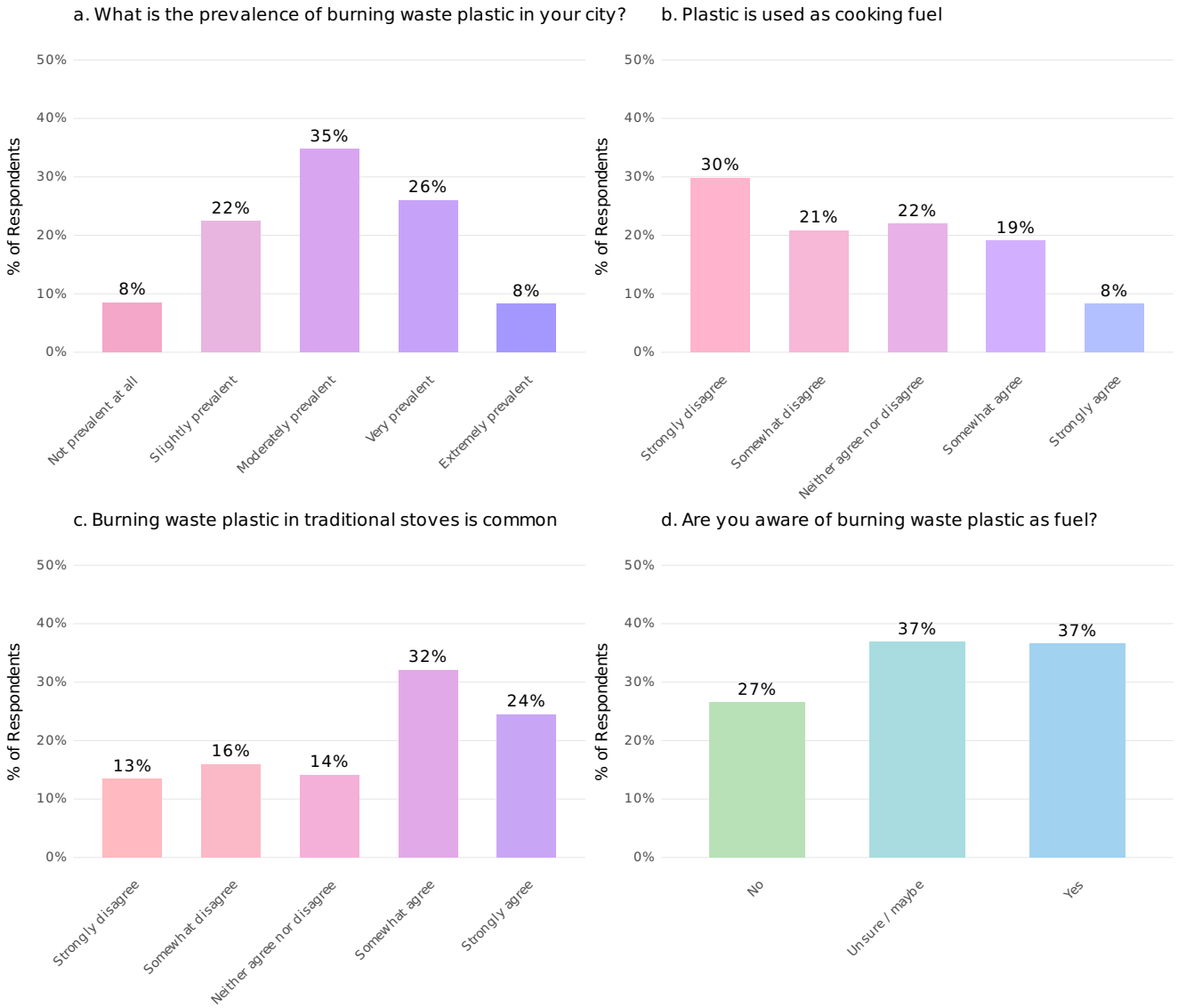

Fig. 1 | Perceptions of burning plastic as a household fuel. a Reported prevalence of burning plastic waste; **b** Agreement that plastic waste is used as a cooking fuel; **c** Agreement that plastic waste is commonly burned in traditional stoves; and **d** Awareness of burning plastic waste as a fuel. The numbers above the bars indicate the percentages for each response. Totals may not equal 100% due to rounding.

rates of agreement (represented by the orange bars) compared to direct awareness of plastic waste combustion for energy needs (green bars).

Respondents who reported awareness of burning plastic waste as a household fuel ($N = 366$) were asked additional questions about the specific types of plastic materials being burned, the product(s) they originated from, and the stoves used for their combustion. Polyethylene terephthalate (PET or PETE) is the most frequently reported type of burned plastic waste, followed by low-density Polyethylene (LDPE). PET and LDPE are common single-use plastics found in beverage bottles (e.g., water and juice bottles) and bags (Fig. 4a). They are the most common plastic materials found in household waste and accumulating in the oceans bordering Sub-Saharan Africa and South Asia[40–42]. The third most frequently reported plastic being burned is high-density polyethylene (HDPE), a material frequently used for chemical containers. The fifth most frequently used plastic material is polyvinyl chloride (PVC), which is mostly used in plastic plumbing pipes, and is a major cause of dioxin emissions[43].

In terms of product origin, nearly two-thirds of respondents reported burning food wrappers, followed by chemical packaging materials such as fertilizers, pesticides, and cleaning liquid containers (Fig. 4b). Food wrappers, made from polypropylene (PP), account for the largest share of waste generation by polymer type[14,44,45], and are reported as the most frequently burned plastic product. Other commonly burned plastic items included non-food household plastics like buckets and plastic bags (35%), construction materials such as pipes (32%), and components from tyres and white goods, i.e., household electrical appliances (26%). Traditional cooking stoves such as those using 3-stone and charcoal are among the most widely used stoves for burning plastic waste (Fig. 4c).

Energy consumption is influenced by household socio-demographic characteristics. To better understand the socio-demographic factors associated with burning plastic waste as a fuel, respondents were presented with a set of factors and asked to rate the likelihood that individuals with these characteristics could burn plastic waste as fuel, on a scale from −10 (not likely) to +10 (most likely).

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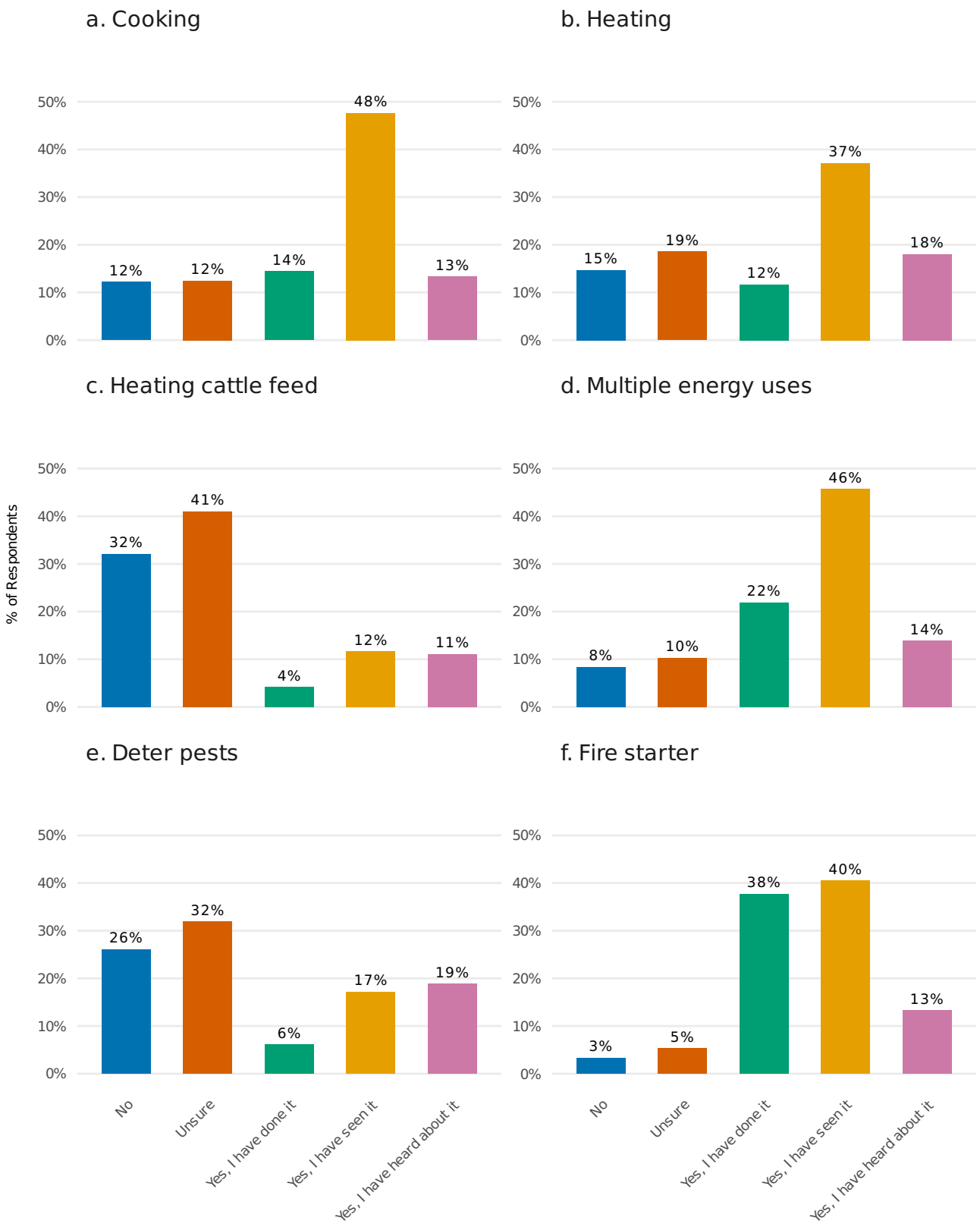

Fig. 2 | Awareness of various uses of plastic waste burning as household fuel. Percentage of respondents aware of plastic waste being burnt and used as (**a**) cooking fuel, (**b**) heating, (**c**) heating cattle feed, (**d**) by mixing with other fuels like firewood, (**e**) deter pests, (**f**) fire starter. This is a follow-up question asked only to respondents who indicated they were aware of burning plastic (Fig. 1d) waste as fuel ($N = 365$). The numbers above the bars indicate the percentages for each response. Totals may not equal 100% due to rounding.

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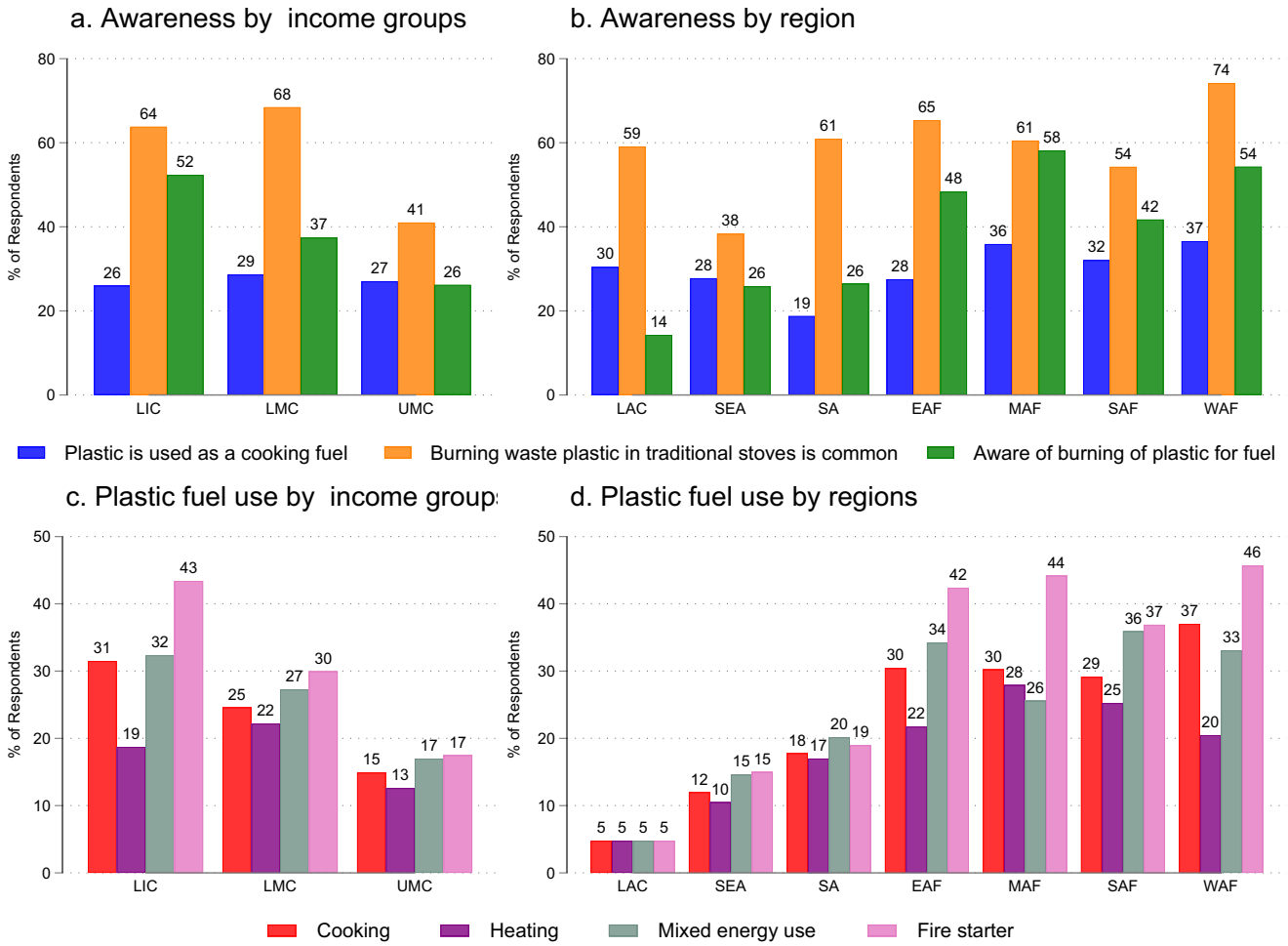

Fig. 3 | Plastic waste burning as a household fuel, according to the World Bank country income category and region. a Proportion of respondents who somewhat or strongly agree that plastic is burnt as a fuel (blue bar); somewhat or strongly agree that it is common practice to burn plastic waste in traditional stoves (orange bar); and report being aware of burning of plastic as a household fuel (green bar) across LIC = low-income country; LMC = lower-middle-income country; and UMC = upper-middle-income country categories. **b** Same variables as panel a, by region LAC = Latin America and the Caribbean; SEA = South Asia SA = South Asia; SAF = Southern Africa; WAF = Western Africa; EAF = Eastern Africa; MAF = Middle Africa. The MAF and LAC numbers are based on responses from a single country in each region, the Democratic Republic of the Congo and Peru, respectively. **c** Proportion of respondents reporting having seen or burnt plastic themselves for various purposes, among those aware of plastic waste burning (the green bars in Panels (**a**, **b**)), by country income category and (**d**) region.

Households that include people with disabilities—with the term 'disabilities' left undefined in the survey question—were seen as less likely to burn plastic waste, possibly due to their limitations in collecting plastic waste (Fig. 5a). By contrast, respondents indicated that households in areas excluded from waste management services could be most likely to burn plastic waste, followed by those experiencing poverty and those living in informal settlements. Additionally, households with members working at waste sites, such as waste pickers, were perceived to be more likely to burn plastic waste as fuel. The regionally disaggregated results highlight variations in the perceptions of these socio-demographic correlates with the burning of plastic waste as fuel.

In compact neighborhoods lacking waste management services, some residents may be concerned about the open burning of plastic waste. In such instances, households may choose to burn plastic waste in their traditional indoor stoves to avoid drawing concern. Respondents were asked to indicate why households might burn plastic waste as a household fuel, based on their levels of agreement with the question "Below are some reasons why households might burn plastic waste for household fuel. Please rate the extent to which you agree with these statements". Respondents indicated strong agreement that a lack of awareness of the health impacts of burning plastic was a reason for burning plastic waste, a finding that is also consistent across regions (Fig. 5b). The second highest level of agreement was for two other reasons: to "manage waste" and cope with "expensive clean fuel". Respondents expressed lower agreement on the role of low availability of traditional fuels as a reason for burning plastic. They generally disagreed that plastic is a versatile fuel or that the burning of plastic waste as a fuel is socially acceptable. In the regionally disaggregated results, respondents from Latin America and the Caribbean tended to highlight a lack of waste management and a lack of awareness as the main reasons for burning plastic. In contrast, respondents from Asia, Southern Africa, and West Africa also tended to emphasize the role played by the low availability of traditional fuels.

Awareness of these risks was assessed, for four different types of risks, based on agreement with the statement "What do you believe are the major risks of burning plastic for households?" (the level of agreement was recorded on a Likert scale ranging from extremely unlikely (1) to extremely likely (5)). Respondents strongly agreed on the risks and impacts of toxic emissions inhalation, fire hazards, and food contamination, with results also consistent across regions (Supplementary Fig. 1, Supplementary Table 2). While a detailed understanding of the risks from burning plastic waste to the environment and human health is limited, there was a high degree of awareness that

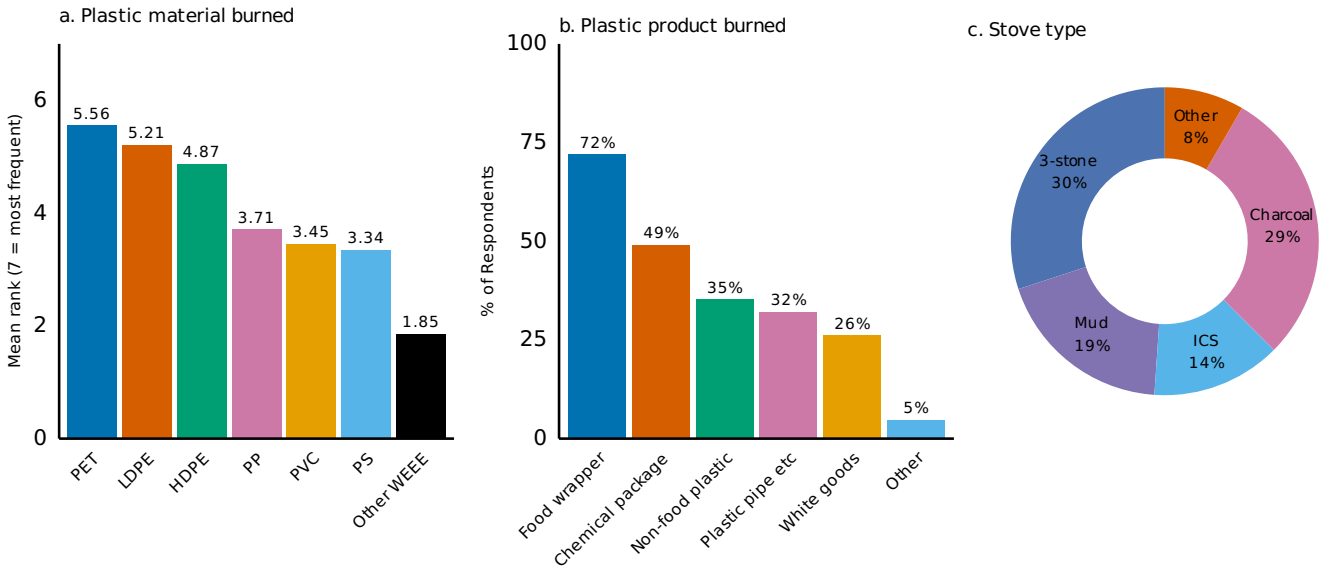

Fig. 4 | Type of plastic material burnt as fuel and stove type used for burning. **a** Mean of the rank value of plastic materials. The y-axis indicates the mean rank value, where 7 is the most frequently burned and 1 is the least frequently burned plastic material (the rank value flipped from the original scale), as reported by those aware of plastic burning for fuel ($N = 306$). **b** Relative frequency of plastic products burned for fuel among those aware of plastic burning ($N = 318$). **c** Percentage of responses by stove type most commonly used by households to burn plastic ($N = 323$). A 3-Stone (Three-Stone) stove is a primitive traditional stove where three stones are arranged to support a pot; a mud stove is an enclosed stove built from mud; an improved cooking stove (ICS) is a more efficient, safer and less polluting stove; and a charcoal stove is designed to use charcoal as fuel.

these impacts could be harmful, with both direct and indirect consequences.

More specifically, out of 936 respondents, 40% indicated that they thought burning plastic was extremely likely to contribute to fire hazards, and 40% stated this was somewhat likely. Regarding the risk of toxic emissions and air pollution from burning plastic, 62% indicated that this was extremely likely, and 26% indicated that it was somewhat likely. Roughly 6 in 10 respondents thought it was extremely likely that toxic chemicals from burning plastic waste could contaminate food and water, while 29% indicated it was somewhat likely.

Given the higher exposure rates for household members who spend more time indoors, respondents were also asked to indicate the likelihood of greater risks of exposure for females, children, people living with disabilities, and senior citizens. Forty-six percent of respondents reported that increased risk of exposure was extremely likely, and 34% reported that it was somewhat likely (See Supplementary Fig. 1).

Energy use, including the burning of plastic waste, is contextual, and addressing energy poverty requires localized solutions that are appropriate to their specific context[46,47]. Respondents were asked to rank what they believed was the most important solution to the issue of burning plastic waste as household fuel in their city. As shown in Fig. 6, the average rankings (where lower values indicate higher effectiveness) suggest that improved and expanded solid waste management services for informal settlements (waste management) are seen as the most effective solution to the problem, followed by increased access to clean energy technologies and raising awareness about the negative effects of burning plastics for fuel. Bans on the use of plastic were also ranked as having high importance, whereas the supply of traditional fuels and the conversion of plastic to a safe fuel were among the lower-ranked solutions. There are regional variations in perceptions of these solutions. Respondents from South Asia and Southern Africa ranked a ban on plastic use as the most effective solution, possibly due to plastic ban policies. Respondents in Latin America and the Caribbean considered waste management and clean cooking to be more important than awareness. In East and Central Africa, access to clean energy was ranked as the most important solution among low-income households. While these results are subjective and may be subject to differing interpretations of this question, the result underscores the need for contextual strategies.

Correlational insights into plastic burning practices

Individuals active in socially engaged professions, e.g., community-based organization personnel, community workers, or teachers, were significantly more likely to agree that plastic waste burning occurs in their communities ($p = 0.003$). However, they did not report direct awareness of others or themselves engaging in it (Fig. 7, Supplementary Table 4). Respondents who perceived municipal solid waste management fees as unaffordable ($p < 0.007$, Column 1; $p < 0.019$, Column 2) were also more likely to report that plastic burning occurs and that they engage in it. A perception of clean fuels as expensive was also positively correlated with these outcomes ($p < 0.000$, Column 1; $p < 0.000$, Column 2; $p < 0.004$, Column 3). Meanwhile, city-level factors such as quantities of plastic waste ($p < 0.023$, Column 2; $p < 0.008$, Column 3), and population without waste collection services ($p < 0.000$, Column 2; $p < 0.000$, Column 3) were positively correlated with direct awareness of others' or individuals' own plastic waste burning for energy purposes. The insignificant correlations between the volume of mismanaged plastic waste in the city and the population without waste collection, on one hand, and respondents' general agreement that plastic is burned for energy purposes, on the other, may be related to overreporting of general awareness compared to direct awareness.

Fuel supply factors (availability and accessibility to clean fuels), urban waste management (linked to economic development), and demand drivers (e.g., higher development and income levels reducing reliance on polluting fuels) all influence plastic burning practices. Interpreted together, they highlight the link between inadequate waste management systems, expensive clean cooking fuel, and reliance on plastic waste as a household fuel. A perception that waste management services and clean fuels are expensive highlights and reiterates the vital importance of affordability. Reliance on traditional fuels and stoves also contributes to household vulnerability, which in turn facilitates the domestic burning of plastic as a fuel. While open burning of plastic

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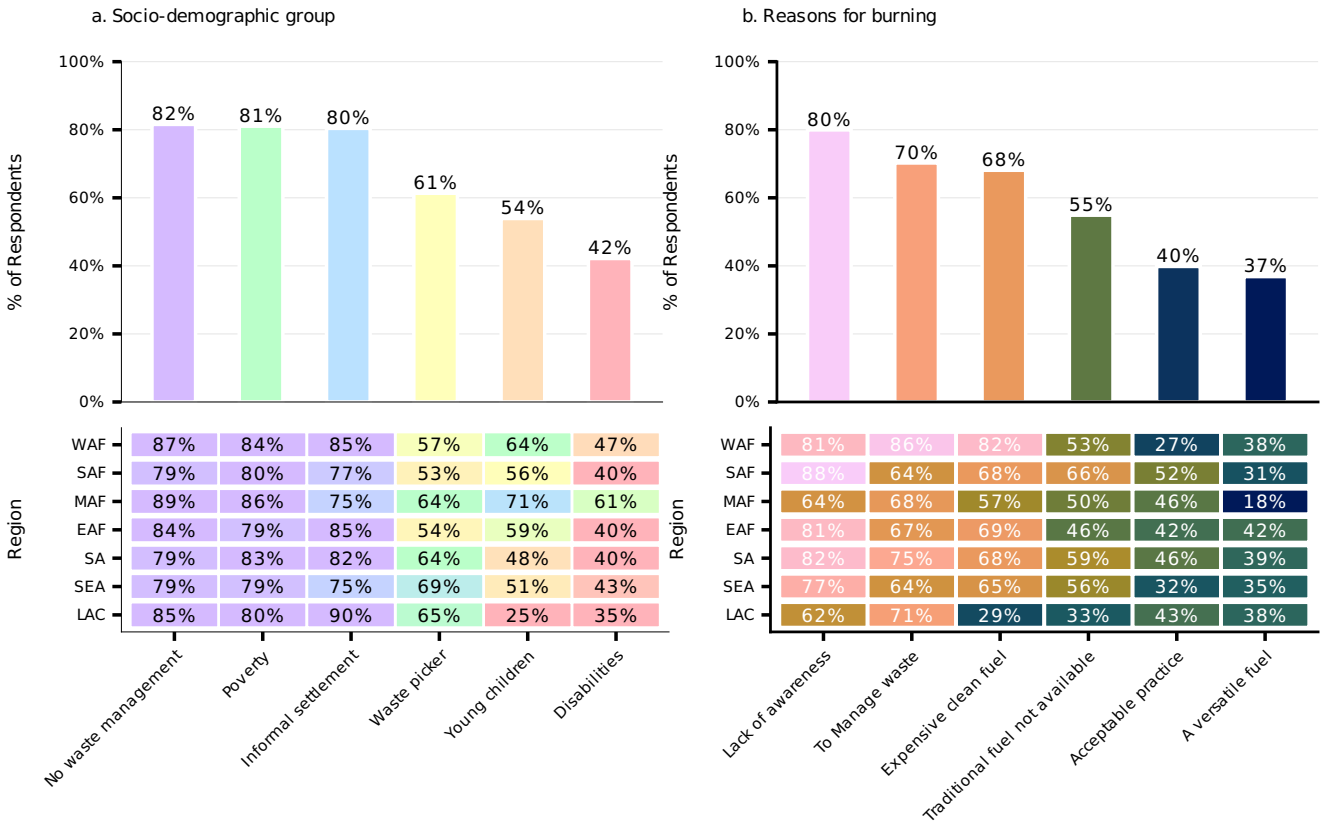

Fig. 5 | Socio-demographic factors associated with, and reasons for, burning plastic waste as a fuel. Overall (bar graph) and disaggregated by region (heatmap). **a** Percentage of respondents who believe burning plastic waste is positively associated with various socio-demographic groups. Responses were measured using a scale ranging from −10 to +10 (where −10 indicates a strong and negative association, i.e., low likelihood of burning plastic waste as household fuel; and +10 indicates a strong and positive association, i.e., high likelihood of burning plastic waste), converted binary variable that takes value of 1 for respondents with positive response (1 to 10) otherwise zero. **b** Percentage of respondents who somewhat agree or strongly agree about the reasons for burning plastic waste overall (bar graph) and disaggregated by region (heatmap). Responses measured using a scale from 1 = strongly disagree to 5 = strongly agree rescaled as a binary that takes the value of 1 for respondents who select somewhat agree or strongly agree, otherwise 0. LAC = Latin America and the Caribbean; SEA = South Asia SA = South Asia; SAF = Southern Africa; WAF = Western Africa; EAF = Eastern Africa; MAF = Middle Africa. The MAF and LAC numbers are based on responses from a single country in each region, the Democratic Republic of the Congo and Peru, respectively.

waste is a well-known and common waste management strategy in many cities in the Global South, the widespread prevalence and correlates of domestic burning of these materials have not previously been documented. These results reinforce the importance of cross-cutting programs to improve waste management systems (SDG11.6) and expand access to affordable, clean cooking solutions to low-income households (SDG7).

Discussion

The energy sources used by households are determined by the context in which they live, as well as the availability and affordability of alternative options. Given the combustible nature of plastic, the increasing volumes of this material in waste, and the reality that many households in the Global South must self-manage their waste, the use of plastic as a domestic fuel may be on the rise. However, a systematic and comprehensive understanding of the scale and distribution of plastic waste burning has heretofore been missing, impeding efforts to plan and develop effective strategies to mitigate the problem.

The results of this study lend stronger credence to this conjecture; a survey of key informants from 26 countries in the Global South reveals that plastic waste has been integrated into household energy practices in numerous and diverse ways in many urban communities. Four key insights emerge from this study. First, the use of plastic as a household fuel is prevalent in cities of the Global South. Though the study statistics should not be interpreted to be representative at the population level in the survey locations, owing to the purposive sampling strategy that was utilized to select knowledgeable community informants as respondents, 16% of respondents reported burning plastic as a fuel in their own households, and awareness of such practices was much higher. Importantly, key community informants are likely to have a higher local socioeconomic status, and their reported rate of burning plastic as fuel be lower than less advantaged groups. Nonetheless, the reported prevalence of this practice is comparable to that found in the World Bank's Multitier Framework Survey conducted in Northwest Nigeria, where 13% of surveyed households reported burning waste, including plastic, as a household fuel, or in smaller-scale surveys in Eswatini and Guatemala[15,19].

Second, the reported burning of plastic waste was found to be prevalent in many countries and cities in this study, suggesting that this practice does not result solely from energy poverty, but also represents a vital informal solution in many settings to cope with systemic municipal service gaps and a high rate of mismanaged plastic. Low-income households living in precarious urban conditions are often forced to self-manage waste[21], and frequently rely on low-cost and easily accessible methods for disposal of accumulating and non-biodegradable waste. The risk that more households will resort to burning plastic waste as fuel could increase unless these service gaps are addressed. Third, combustion of waste, including plastic, can help households living in extreme poverty to satisfy their energy needs in the face of growing scarcity of other traditional low-cost fuel sources.

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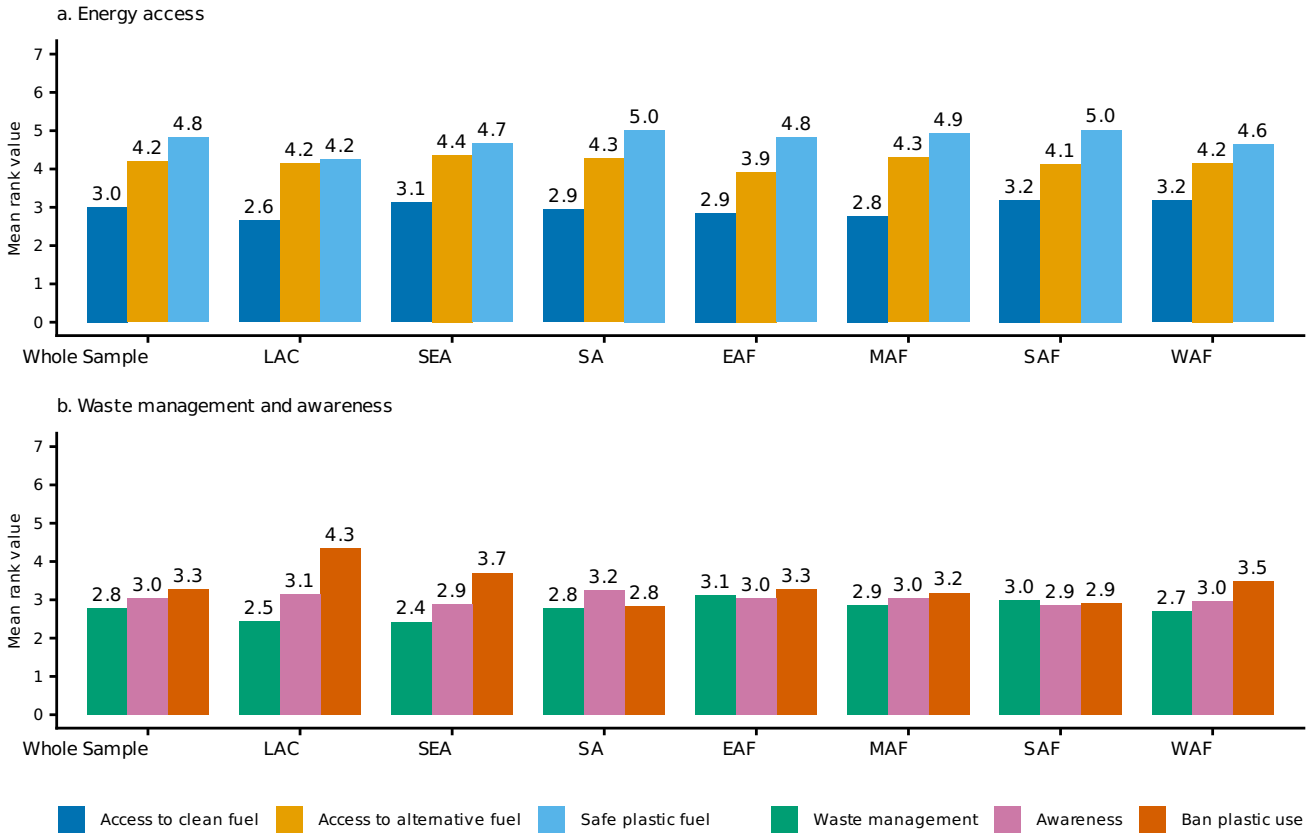

Fig. 6 | Possible solutions to the problem of burning plastic waste as household fuel. Mean value for the ranked relative importance of possible solutions. **a** Energy access-related solutions for the whole sample, and by region. **b** Waste management and awareness-related solutions for the whole sample, and by region. Responses were ranked in order of importance (1 = the most effective solution and 7 = the least effective solution) ($N = 832$). LAC = Latin America and the Caribbean; SEA = South Asia SA = South Asia; SAF = Southern Africa; WAF = Western Africa; EAF = Eastern Africa; MAF = Middle Africa. The MAF and LAC numbers are based on responses from a single country, the Democratic Republic of the Congo and Peru, respectively.

The survey results help illustrate how burning plastic waste emerges as such a zero- or low-cost option and the challenges in deciding between cooking a meal for the family and exposure to potentially hazardous emissions. Poverty, deep inequality and unmanaged urbanization within cities, reduced availability of traditional fuels, and increasing plastic pollution could intensify such practices.

Fourth, our analysis serves to underscore the synergistic relationship between United Nations Sustainable Development Goals (SDGs): making cities more sustainable (SDG11) and access to clean energy (SDG7). Efforts to achieve SDG11, through the provision of adequate housing and improved and inclusive waste management in other cities, will weaken the supply driver of highly available plastic waste and the need for self-management of that waste. SDG11.6 specifically targets increased waste collection services, management of waste in controlled facilities, and reduction of fine particulate matter concentrations in cities. Reducing the burning of waste plastic as fuel is thus a potential channel and area of action to lower emissions through improved waste management. Meanwhile, on the demand side, willingness to burn plastic waste as a fuel or use a traditional stove to manage it is limited if viable and affordable alternatives are present. At the core of this practice is the necessity to satisfy energy demands and to eliminate plastic pollution, at low or zero financial cost. Therefore, progress towards achieving SDG7, which has been greater in urban than in rural settings[48–50] but has largely overlooked the persistent deprivation of low-income neighborhoods in cities in low- and middle-income countries, will weaken the demand element of this practice.

The design of practical solutions to tackle this complex problem requires a deep and contextual understanding of the interlinked problems of household energy poverty and inadequate waste management services, coupled with a willingness to test programs or policies that address those problems. For example, improved solid waste management, specifically waste collection, could decrease the need for burning of plastic as a waste management strategy, but effectively delivering such services in crowded, low-income areas, where collecting waste management fees is difficult and trust in formal government institutions is low, remains a challenge. Similarly, addressing energy insecurity requires new, low-cost clean energy innovations or well-targeted financial support that renders existing solutions more affordable. Moreover, tackling each of these problems in isolation—or incompletely—risks failure. Restrictions on open burning alone, for instance, could push households to burn even more plastic waste inside their homes.

This study took an initial step toward filling critical knowledge gaps in this domain; however, three main limitations should be addressed in future work to enhance understanding and inform decision-making. First, as noted above, the study used a purposive sampling strategy to select knowledgeable community informants as respondents and thus does not provide a population-representative understanding of the scale and distribution of plastic waste burning to meet households' waste management and energy needs. Such respondents may have a biased view of practices in their communities. To build on and validate this work, further investigation is recommended using representative household samples from across the Global South, including plastic waste hotspots and notspots, underserved communities, and informal settlements. This investigation should incorporate plastic as a fuel category and consider local waste

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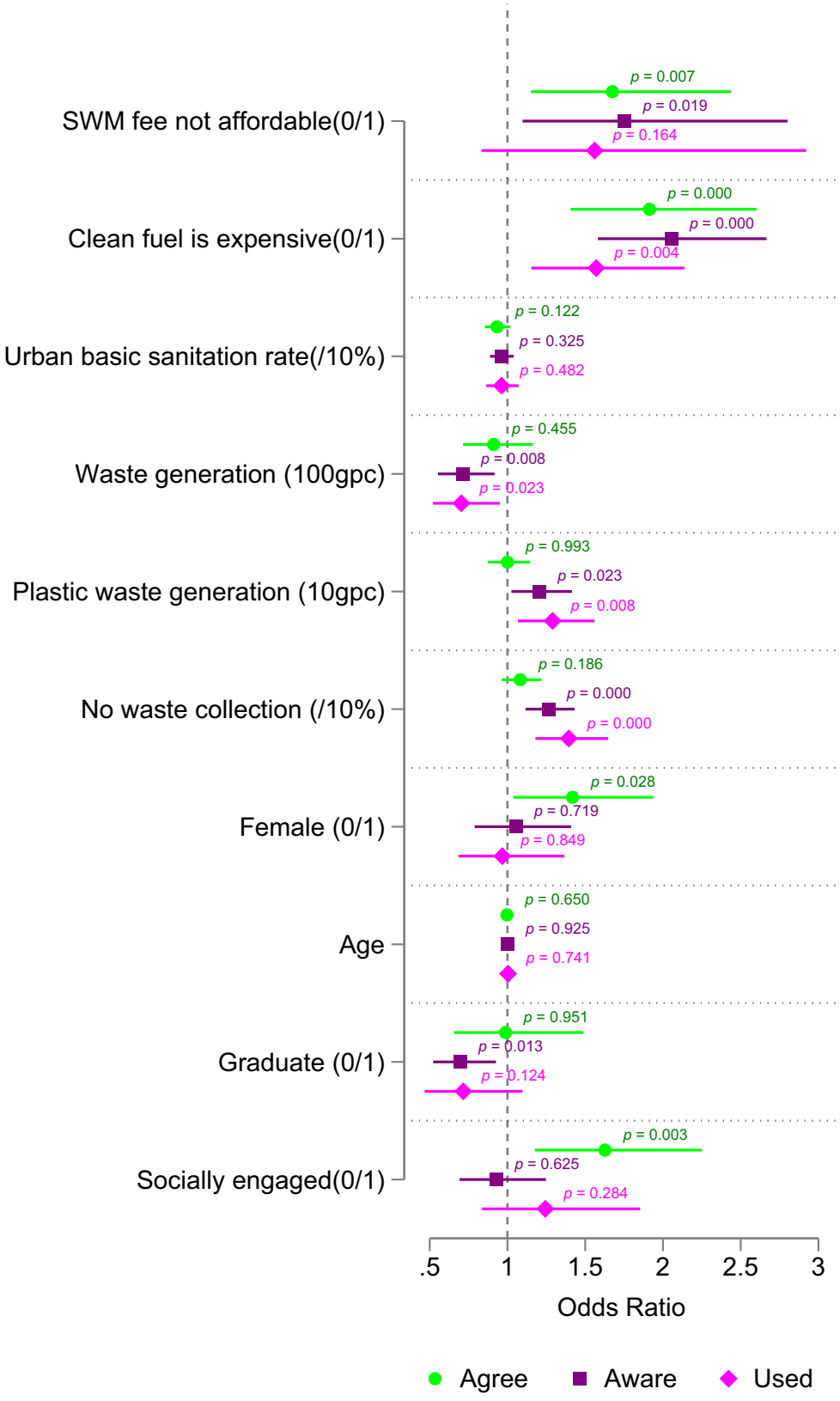

management and settlement contexts. Such work could also investigate these practices in rural areas, which our study did not consider. Second, and relatedly, this study employed a relatively short, internet-based survey due to resource and logistical constraints, which limits the extent to which we could more fully investigate the nature and drivers of this practice. Third, the study does not identify the impacts of these practices on household health and well-being, as well as environmental quality, nor is it suitable for identifying practical strategies to mitigate harmful effects. Work on the former requires attention to research designs that allow valid inferences on the specific impacts of plastic waste burning, which typically co-exists with many other harms, on individuals' and overall social welfare[20,51]. The latter,

Fig. 7 | Plot showing the odds ratio for different factors associated with burning waste plastic as fuel with a 95% confidence interval. Agree (green) shows the odds ratios from the logistic regression for respondents' agreement on the use of plastic as fuel. The dependent variable is binary, converted to indicate if respondents somewhat or strongly agreed with the statements "It is common practice to burn plastic waste (like polythene bags) in the fire of traditional stoves," as 1, and otherwise 0. Aware (purple) presents the odds ratios for the dependent variable for awareness of plastic waste burning based on the third question in Fig. 1, which takes the value of 1 if respondents answered 'yes' to the question: "Are you aware of households burning plastic waste as fuel to meet their household energy needs (e.g., fire starters and for cooking and heating)?", otherwise 0. Used (lavender) shows the odds ratio of respondents' own burning plastic waste for various purposes, where the dependent variable takes a value of 1 if respondents reported burning plastic themselves (yes, I have done it) for cooking, heating, mixed energy use, preparing cattle feed, deterring pests, or starting fires. To improve the readability of coefficient estimates and odds ratios in the coefficient plot, variables measured in percentages (no waste collection and basic sanitation services) and grams (total waste and plastic waste generation) were rescaled (robust 95% confidence interval in bar). Errors are clustered at the city level. See Supplementary Table 3 for summary statistics of variables and Supplementary Table 4 for full results).

meanwhile, requires careful impact evaluations of pilot and scaled-up efforts—combining improved energy access and waste management elements—to reduce the prevalence of this practice. Such studies must devote attention to measuring emissions, food contamination risks, and health and welfare endpoints, to provide deeper insights into the behavioral, economic, and systemic drivers compelling households to use plastic waste for fuel.

Indeed, key factors identified in this study—such as inadequate waste management, energy poverty, limited accessibility and affordability of clean and alternative fuels, cultural norms, and systemic deficiencies in waste management, inclusive urban governance, sustainable human settlement and energy infrastructure—warrant closer examination. A thorough understanding of the prevalence and behavioral aspects of this issue can inform the development of targeted, context-specific programs. These may include educational campaigns highlighting the health and environmental hazards of burning plastic, improving access to clean and affordable energy alternatives, strengthening waste management systems, introducing cost-effective technologies for cleaner plastic combustion, and other viable strategies. As rapid urbanization continues to outpace the expansion of essential services in many regions, the urgency of implementing these measures will only intensify.

Methods

The analysis presented in this paper draws on survey data collected from key informants purposively recruited by the research team, which included researchers based in each of the 26 study countries. These informants provided diverse perspectives on plastic waste burning practices in urban areas across 11 countries in Asia, 1 in Latin America, and 14 in Africa. In each country, efforts were made to survey expert individuals from seven groups that included: a) researchers affiliated with universities or research institutes; b) local government officials or civil service personnel; c) socially engaged professionals, such as doctors and lawyers; d) community leaders (e.g., ward leaders or traditional leaders); e) personnel from NGOs or community-based organization (e.g., cooperatives); f) private sector representatives, such as waste collection managers; and g) other knowledgeable individuals who, while not belonging to the above groups, possess valuable insights into urban realities. The sample is not nationally representative; however, the perspectives of these knowledgeable and community-engaged informants capture a broad range of practices across surveyed countries. (Refer to Supplementary Table 1 for a full list of study countries).

The survey process

The survey was conducted between July and November 2024. Country collaborators distributed the survey via email or by sharing flyers containing links and QR codes to an online Qualtrics form. These flyers were circulated through personal connections and during seminars, conferences, and community meetings to target respondents with relevant knowledge of local urban realities and the survey topics. A survey guideline provided potential respondents with an overview of the study and instructions for completing the questionnaire. Respondents also had the option to request in-person support from a local collaborator for completing survey questions if needed, e.g., for language interpretation or if they were unable to read the questions in the instrument. In such cases, a collaborator or trained enumerator conducted the survey in person or via phone and recorded the responses using the online survey platform.

The survey was implemented in two languages: French and English. The French version was used in Togo and the Democratic Republic of Congo, while the English version was used in all other participating countries. The study was approved by the Curtin University Human Research Ethics Committee (HREC) (approval number HRE2024-0177). Where required, a reciprocal ethics application was used by a country collaborator.

The survey instrument

The questionnaire was structured into multiple sections covering waste and plastic pollution management, cooking fuel use, and the practice of burning plastic (Supplementary Data 1). It included questions on respondents' awareness of direct observations of plastic burning in their communities for household energy needs. Additionally, respondents were asked to rank potential solutions to address plastic burning. The final section gathered information on respondent characteristics and socio-demographic details. The full survey instrument is provided in the Supplementary Information.

Respondents were asked to respond to *"*In your opinion, how prevalent do you think burning waste plastic is in your city?*"* on a Likert scale (Not prevalent at all (1) to extremely prevalent (5)) (Q8.1) to understand the general prevalence of burning plastic waste in their local community.

There were three questions in different sections of the survey about the burning of waste plastic by households for fuel, which were designed to triangulate on perceptions of this practice within each study location.

The first question asked respondents to indicate their level of agreement, on a Likert scale (1 to 5), with the statement "Plastic is used for cooking fuel as a replacement for other fuels." (Q3.1.6). This question sought to assess whether respondents believed that some households in their city burn plastic, at least partially, to meet cooking fuel needs beyond simple ignition.

Second, participants were asked to indicate their level of agreement, using a Likert scale (Strongly disagree (1) to Strongly agree (5)), with the statement: "It is common practice to burn plastic waste (like polythene bags) in the fire of traditional stoves" (Q3.3.2). This question aimed to evaluate the prevalence of burning plastic waste in household stoves, in a way that might also capture burning for purposes of igniting the fire or simply to eliminate plastic waste.

The third question, "Are you aware of households burning waste plastic as fuel to meet their household energy needs (e.g. fire starters and for cooking and heating)?" (Q5.1), with responses of no, unsure/maybe and yes, was aimed to understand respondent awareness about the practice of burning waste plastic as fuel in their locality.

A follow-up question was asked to the respondents who selected yes to the third question to capture more directly their source of

awareness on various purposes of burning waste plastic as fuel. The follow-up question asked "Please indicate whether you are aware of the following scenarios occurring" (Q5.2) where respondents selected among several options—'No'; 'Unsure'; 'Yes; I have done it; 'Yes, I have seen it'; and 'Yes, I have heard about it'—for a) Plastic waste being burnt and used as a fuel for cooking / preparing food (Cooking); b) Plastic waste being burnt and used as a fuel for heating (Heating); c) Plastic waste being burnt and used as a fuel for cattle feed preparation (Cattle feed); d) Plastic waste is burnt alongside other fuels like firewood (Mix fuel); e) Plastic waste being burnt and used to produce smoke that will deter pests e.g. mosquitos (Deter pest); and f) Plastic waste being burnt and used as a fire starter (Fire starter).

Respondents were also asked about the type of waste plastic burned (Q5.5 and Q5.6), the type of stove used for burning (Q5.7), the reason for burning waste plastic as fuel (Q6.1), perceptions of likelihood of burning by different socio-demographic characteristics (Q7.1), and associated risks (Q7.2) and solutions (Q8.2).

Data

A total of 1188 respondents started the survey, but 170 (14% of the sample) responses were not usable (Supplementary Fig. 2). Among these unusable responses, 26 were from individuals who did not consent to participate, 26 came from non-sample countries (likely provided through email referrals), and the remaining responses were from individuals who initially agreed to participate but abandoned the survey after answering only a few questions. This drop-off may have been caused by challenges encountered while completing the survey on some types of mobile devices. After data cleaning, 1018 responses were finally retained for analysis (86% of total responses), though some of these responses contained missing data for specific questions. The lowest number of responses came from South Africa (15 responses), while the largest number was from Indonesia (132 responses). The median number of responses in each country is 34, with a mean of 39 responses.

Of the 904 respondents with fully complete survey data, 35.5% were researchers at universities or research institutes, 20.8% were affiliated with local government or civil service, 6.8% were socially engaged professionals (e.g., teacher, health care provider), 1.9% were community leaders, 9.4% worked for NGOs or CBOs, and 11.6% were employed by private operators and companies (Table 1, Supplementary Table 6 and Supplementary Data 2). The remaining 14% were from other categories such as consultants, politicians, contractors and animal scientists.

The coverage of respondents' work organizations included: 18% in multinational organizations, 45% in national organizations, 20% at municipal or city-level structures, and 17% working at the sub-municipal or community level. Slightly less than half (43%) of the survey respondents were female, and the mean respondent age was 33 years (s.d. = 10.4 years). Most respondents (85%) held a bachelor's degree, while 13% had attained a Doctoral or equivalent degree, and 33% held a Master's or equivalent degree. In terms of primary domains of expertise, 16% of respondents reported specializations in the natural sciences, 25% in engineering, 10% in agricultural sciences, and 8% in medical/health sciences. Finally, regarding experience, 43% of respondents reported having more than five years' experience in their field.

Regression analysis

We employed logistic regression for all models reported in Fig. 7, Supplementary Table 4. The first model reported as green points with horizontal confidence interval bars in Fig. 7, Supplementary Table 4 (Column 1) examines the correlation between respondents' perceptions of burning plastic waste in general and for energy purposes and various demographic, institutional, and city- and country-level variables. Odds ratios were estimated for agreement and awareness regarding the use of plastic waste as household fuel. The first variable focuses on respondents' subjective agreement, where the dependent variable reflects respondents' agreement that plastic waste is burned in household fires, based on Fig. 1b. Specifically, the dependent variable is assigned a value of 1 if the respondent somewhat or strongly agreed with the statement "It is common practice to burn plastic waste (like polythene bags) in the fire of traditional stoves."

The purple points with horizontal confidence interval bars in Fig. 7 examine the correlation between respondents' awareness regarding the burning of plastic waste as fuel and various demographic, institutional, and city- and country-level variables. Specifically, the dependent variable is assigned a value of 1 if the respondent selected yes to the question "Are you aware of households burning waste plastic as fuel to meet their household energy needs (e.g., fire starters and for cooking and heating)?".

The dependent variable in lavender points with horizontal confidence interval bars in Fig. 7 takes the value 1 if the respondent selected 'Yes, I have done it' for any of the six different purposes of burning plastic waste as fuel and otherwise is 0. In our dataset, 16% of respondents reported their own burning of plastic waste as fuel.

All models use the same set of independent variables. The independent variables include respondent demographics and respondent subjective perceptions of the cost of clean fuel and solid waste management. City-level independent variables include the waste generated per capita, plastic waste generation and percentage of population without waste collection services[28]. Country-level data includes basic access to sanitation services (% of urban population)[52]. These variables represent both supply- and demand-side factors that may influence the prevalence of plastic waste burning while controlling for respondent characteristics. For variables with missing data, we imputed a country median where applicable and controlled for missing data in the regression model. Standard errors in all regression models are clustered at the city level.

We note that the survey is not representative of the population in the study locations, and that all responses should be interpreted as being based on respondents' subjective views of the practice and implications of burning plastic waste as a fuel in their cities. Though these respondents are knowledgeable about the contexts they live in, they may nonetheless have a biased view of practices in their communities. The core objective of the study—understanding the prevalence of burning plastic waste as fuel at the Global South scale—should be kept in mind when interpreting the results presented in this research.

Inclusion & ethics statement

This collaborative study consists of local researchers from survey countries, multidisciplinary experts and early career researchers. All members of the research team – representing the various included study countries (see authorship list)—met during a series of collaborative planning meetings to discuss the survey objective and agree on the framework for the survey design and flow to ensure that the questions asked and answered were locally relevant. A core subset of those researchers contributed directly to drafting the survey questions, designing the survey guidelines, translating study materials, analysing the data, and writing the draft manuscript. All co-authors were given the opportunity to comment on the questionnaire, the survey guidelines, and the draft manuscript.

More specifically, the draft survey was circulated for comments and improvement and revised before formatting in Qualtrics. In response to collaborator feedback, the survey was translated into the French language, and a survey implementation guideline was prepared to facilitate the process. The survey question was then piloted, and we discussed the implementation plan several times to ensure it was easy and smooth for both researchers to disseminate and for respondents to answer.

Local researchers were responsible for local distribution of the survey and were given discretion in deciding whether to implement the survey or not, and where to focus the data collection in each of their countries to ensure the survey does not involve risk to health, safety, security or other risks to researchers and also the research is locally relevant. Contributors from different countries also helped distribute the survey link where relevant. In several countries, for example, Benin and Mongolia, the local researchers could not implement the survey due to a number of reasons, such as difficulty in translation of questions and time constraints.

We collected responses using an online format designed in Qualtrics. Each researcher was provided with an email template, flyer and QR code for respondents to use in accessing the survey. Risks to respondents were negligible. First, it focused on subjective perceptions of respondents regarding plastic pollution and the burning of plastic waste as household fuel, which are not particularly sensitive topics. Second, the survey did not involve animals or pose a bio-risk. Third, the survey did not ask for personal identifiers: name, phone number, email or postal address. Respondents were only asked to write their city name and select the name of their country. Thus, the survey was fully anonymised; we could not track who responded. Fourth, respondents were free to ignore the request to respond to the survey, could decline participation on the consent form, or could halt the survey at their will. Finally, the survey did not collect any biological materials, cultural artifacts or associated traditional knowledge.

We obtained overall ethics approval for the study from the Curtin University Human Research Ethics Committee (approval number HRE2024-0177), with all team contributors included as co-PIs. All local researchers were requested to consult their institutions and comply with local regulations before starting the survey. Where appropriate, an ethics application was filed by the in-country collaborators to ensure local compliance, but in many cases, the anonymous nature of the survey and the approval from Curtin University meant that additional approvals were not required. This was true for the researchers affiliated with partner institutions in Indonesia, Malaysia, Maldives, Nepal, India, Lao PDR, Thailand, DR Congo, Eswatini, Rwanda, Botswana, Vietnam, Uganda, the Gambia and India. Other partner institutions do not have an ethics committee and instead defer to the judgment of ethics review teams at the PI institution (e.g., at Curtin University). In such cases, the local researcher obtained permission from their institution before implementing the survey without carrying out a full review by a formal ethics board. Local researchers, such as in Nigeria, South Africa and Ghana, applied for and received full ethics approval, whereas a researcher from Sri Lanka applied for ethics approval at their institution and received an exemption. Note that the surveys were undertaken at different times, as some of the collaborators had to go through the ethics approval process, while others did not.

After the collection of data, we analysed the results and presented them to the research team members. All contributors were included as contributors of the paper and have access to the dataset. Results are disaggregated at the regional level to ensure that they are not stigmatizing or pose a risk to the researchers or participants. The manuscript has used localized evidence and has taken local research relevance into account to build its arguments.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

The survey data, code, and computational environment used in this study have been deposited in two Code Ocean replication capsules, available at https://doi.org/10.24433/CO.6019618.v1 and https://doi.org/10.24433/CO.8594566.v1.

Code availability

The replication code used in this study is available in two Code Ocean capsules: https://doi.org/10.24433/CO.6019618.v1 (Stata) and https://doi.org/10.24433/CO.8594566.v1 (R).

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Author contributions

B.B. conceived the study in discussion with M.J., P.A., I.G., C.O.O., S.M.P., P.D., J.B., T.G., and Y.M. B.B, T.G, S.R., E.A., S.M.P., C.O.O, M.B., P.D., A.S., G.E.D., A.L.A., D.M.A., S.M., P.K.A., M.B., W.D., T.K., J.B., C.A., B.K.V., D.S.W., N.N., A.K., R.K.R., B.C., V.N.E., S.A., K.P., H.N., D.G., E.I., G.M.M, R.M., F.E.H., M.M.G., U.D., H.V., Y.M., M.J., I.G., and P.A. contributed on survey design and the data collection. B.B. analysed the data with support from M.J., I.G., and P.A. B.B., T.G., and M.B. prepared replication data and codes. B.B., M.J., I.G., A.A., T.G., J.B., P.A., P.D., and H.V. wrote the initial draft of the paper and revised the paper, with input from all co-authors. All co-authors read and reviewed the manuscript and agreed with the decision to submit the paper for publication.

Competing interests

The authors declare no competing interests.

Additional information

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