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Inclusive policy development from the ground up: Insights from the household water-energy-food nexus*

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ABSTRACT

Despite substantial contemporary research and a growing trend in exploring the water-energy-food (WEF) nexus, most research efforts have been invested in macro-level supply-side infrastructure and policies. However, prioritizing demand-side management policies can provide new opportunities and untapped potential for addressing interconnected resource challenges. Demand management inherently encompasses users' consumption patterns, behaviors, socio-economic conditions, and choices, thereby necessitating active engagement and participation. Understanding household-level demands is fundamental to assess the demand for and consumption of water, energy, and food, as well as to inform policy decisions. In this context, our study investigated household consumption patterns within the interconnected WEF nexus, including daily practices such as cooking and washing, conservation measures, household governance, and their cross-cutting relationships with climate change. As a case study, we conducted our research in the Jabal Al Natheef neighborhood of Amman City, Jordan. Our findings reveal that households can propose and enact climate-friendly decisions. Significant gender-related differences were also observed in decisions made across WEF household practices. Additionally, households' perspectives highlighted governance issues and revealed gaps in policy implementation along with the need for more inclusive decision-making processes. Our results underscore the importance of understanding household-level WEF nexus dynamics and daily practices in informing environmental policies, particularly those related to climate action. Such policies are best developed from the bottom-up by incorporating household insights, rather than relying solely on top-down, one-size-fits-all solutions.

1. Introduction

The world's natural systems—particularly those that govern water, energy, and food—are under increasing stress due to mounting demand and the worsening impacts of climate change (IPCC, 2023; Lalawmpuii and Rai, 2023; Walker, 2020). These resource systems are deeply interconnected: stress in one domain often spills over into the others (Fujs and Kashiwase, 2023). As such, the Water-Energy-Food (WEF) nexus framework has emerged as a tool to better understand and manage these interdependencies while striving for sustainable, equitable, and climate-resilient development outcomes (FAO, 2014). However, these interconnections are compounded by other structural drivers

* The article aligns well with the journal's aims and scope, which likely focus on interdisciplinary research related to environmental sustainability and policy. It highlights the importance of gender perspectives in shaping household-level environmental decisions. It underscores the need for policy-makers to consider WEF dynamics when formulating effective environmental policies. It supports the idea that policies derived from local knowledge and practices are more likely to be effective and sustainable in addressing environmental challenges compared to centralized, uniform policies. Overall, the article provides valuable insights into how household-level decisions and dynamics can inform and enhance environmental policies, aligning well with the interdisciplinary focus of journals that aim to advance sustainable development and environmental governance.

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such as rapid urbanization, changing consumption patterns, weak governance, and global trade dynamics (Kousar et al., 2021). These pressures intensify both demand and vulnerability across systems, especially in climate- and resource-stressed regions.

In response to these interlinked pressures, there has been a paradigm shift in policy thinking: moving beyond supply-side interventions—such as expanding infrastructure or boosting production—toward demand-side management (DSM) approaches that regulate consumption and promote efficiency (Lin and Jia, 2020). DSM emphasizes the importance of changing user behavior, fostering local participation, and recognizing the role of households as agents of sustainable change. It prioritizes solutions such as water-saving practices, energy efficiency, and food waste reduction. This shift acknowledges that future sustainability will depend not just on expanding supply, but also on managing demand—especially in rapidly urbanizing and climate-vulnerable areas.

Yet, despite the growing interest in DSM, WEF nexus policies have remained largely top-down and technocratic, often overlooking the everyday experiences and practices of households, where much of the actual resource use and decision-making occurs (Holmatov et al., 2023; Ahmed, 2024). Much of the nexus literature remains focused at macro scales—national, sectoral, or regional—thereby missing the realities of communities and individuals who are the first to feel the effects of resource insecurity (Foden et al., 2019; Musetsho et al., 2021; Ningi et al., 2021). This misalignment has major implications for equity: while a country may appear resource secure at the national level, deep pockets of insecurity often persist at the household level, particularly in marginalized urban areas (Hussien et al., 2018).

Recent studies have begun to address this disconnect by exploring the behavioral and social dimensions of the nexus—specifically, how households make decisions, what shapes their consumption patterns, and what conservation strategies they employ in response to scarcity (Shukla et al., 2021). This "downscaling" of the nexus reveals the adaptive practices people already use—such as water reuse, informal food sharing, or off-grid energy solutions—and provides critical insights into how demand-side policies can be grounded in lived realities. Understanding these practices is not only essential for policy relevance and effectiveness, but also for ensuring inclusive, just, and participatory urban governance.

However, the turn toward demand-side approaches must be pursued with attention to equity and social justice. In marginalized urban neighborhoods—where residents often experience chronic resource insecurity—demand-reduction measures can unintentionally shift the burden of sustainability onto those least responsible for resource overuse (Brugmann et al., 2014). These communities may already be practicing frugal and environmentally sound behaviors out of necessity. Framing DSM as a universal responsibility, without considering differentiated capacities, can deepen existing inequalities. Effective policies must therefore be tailored not only to achieve environmental outcomes, but also to improve the livelihoods and resilience of low-income and vulnerable groups.

Urban centers, especially in low- and middle-income countries, are central to the WEF nexus: they consume vast resources, emit substantial greenhouse gases, and are highly vulnerable to climate impacts (Biggs et al., 2015; Dodman et al., 2022; IPCC, 2023). By 2050, the majority of the global population will reside in urban areas, making cities the frontline for resource governance and sustainability interventions. Urban households thus play a vital role in both shaping and responding to WEF challenges. Local governments are in a strategic position to implement localized DSM policies that reflect real household behaviors and constraints. These include incentive programs, decentralized infrastructure, and participatory planning mechanisms that scale up household insights into city-wide solutions.

This paper contributes to this evolving conversation by examining the household WEF nexus in Jabal Al Natheef, one of Amman's most resource-constrained and densely populated neighborhoods. Drawing on household-level data, the study explores how residents perceive the links between water, energy, food, and climate, what conservation practices they adopt, and the motivations behind their behaviors. While many of these practices are driven primarily by economic necessity rather than environmental awareness, they reveal key entry points for inclusive demand-side policy development. By identifying these patterns and preferences, the research demonstrates how ground-level evidence can inform the design and scaling of DSM policies, ensuring they are equitable, context-sensitive, and rooted in the everyday experiences of urban residents.

In doing so, this study aims to bridge the gap between theory and practice in WEF governance—advancing a model of inclusive policy development from the ground up, where household perspectives are not merely observed but actively shape the future of sustainable urban resource management.

2. Method

In this study, researchers employed a case study approach by integrating mixed methods for data collection. This approach aimed to enhance the traditional methods of assessing the WEF nexus by offering a comprehensive means to guide the implementation of effective practices. The study collected and analyzed qualitative and quantitative datasets, including commonly used methods such as interviews along with less common approaches like focus group discussions and field observations. Newer methodologies such as ethnography, which have not been fully explored in the WEF nexus literature, were also deployed.

2.1. Case study description

Jabal Al Natheef is an urban poor neighborhood with 45,263 inhabitants (Department of Statistics, 2020), the majority of whom are Palestinians who immigrated (refugees) during the Nakba in 1948 (UNDP, 2004). The neighborhood is located in the district of Ras Al-Ain, in the eastern part of Amman city in Jordan. Jabal Al Natheef is one of Amman's oldest and most crowded neighborhoods, located on 82,254 m^2 of land with private home ownership (Abed et al., 2015) (Fig. 1). In addition, it is the poorest of Ras Al-Ain's four neighborhoods (Abed et al., 2015; Shnaigat et al., 2014).

The neighborhood is characterized by high building density, overcrowding, high population density, narrow streets, a conservative social structure and views held by the community, lack of security, and domestic violence (Shnaigat et al., 2014). The residents of Jabal Al Natheef suffer from urban poverty, and most men work in construction, taxi driving, street vending, and tailoring. The women are largely employed in hairdressing, secretarial work, sewing, and embroidery. Women report that economic pressures are making it necessary for them to work (Arini, 2014). Jabal Al Natheef has struggled to get recognition from the Greater Amman Municipality. It is a highly marginalized neighborhood and has received few of the services normally provided by the municipality. The inhabitants of Jabal Al Natheef have poor access to basic needs: water (water pipes constructed at random by the residents) and sanitation services (old and insufficient sewage networks that overflow, soiling the streets and paths), electricity (few electrical power lines adjacent to the houses), and poor street lighting (Arini, 2014). The people lack secured tenure associated with limited access to decent housing units, poor investment in services at the architectural- and planning-level, poor drainage that causes floods (especially in the winter season), narrow streets that negatively affect waste collection, and a paucity of public or green spaces for people to interact in. Jabal Al Natheef was not a planned neighborhood; over time, its built environment has greatly deteriorated (Abed et al., 2015; Arini, 2014). Fig. 2 show some snapshots of the community infrastructure.

2.2. Data collection

A mixed-methods approach was adopted for this case study to ensure

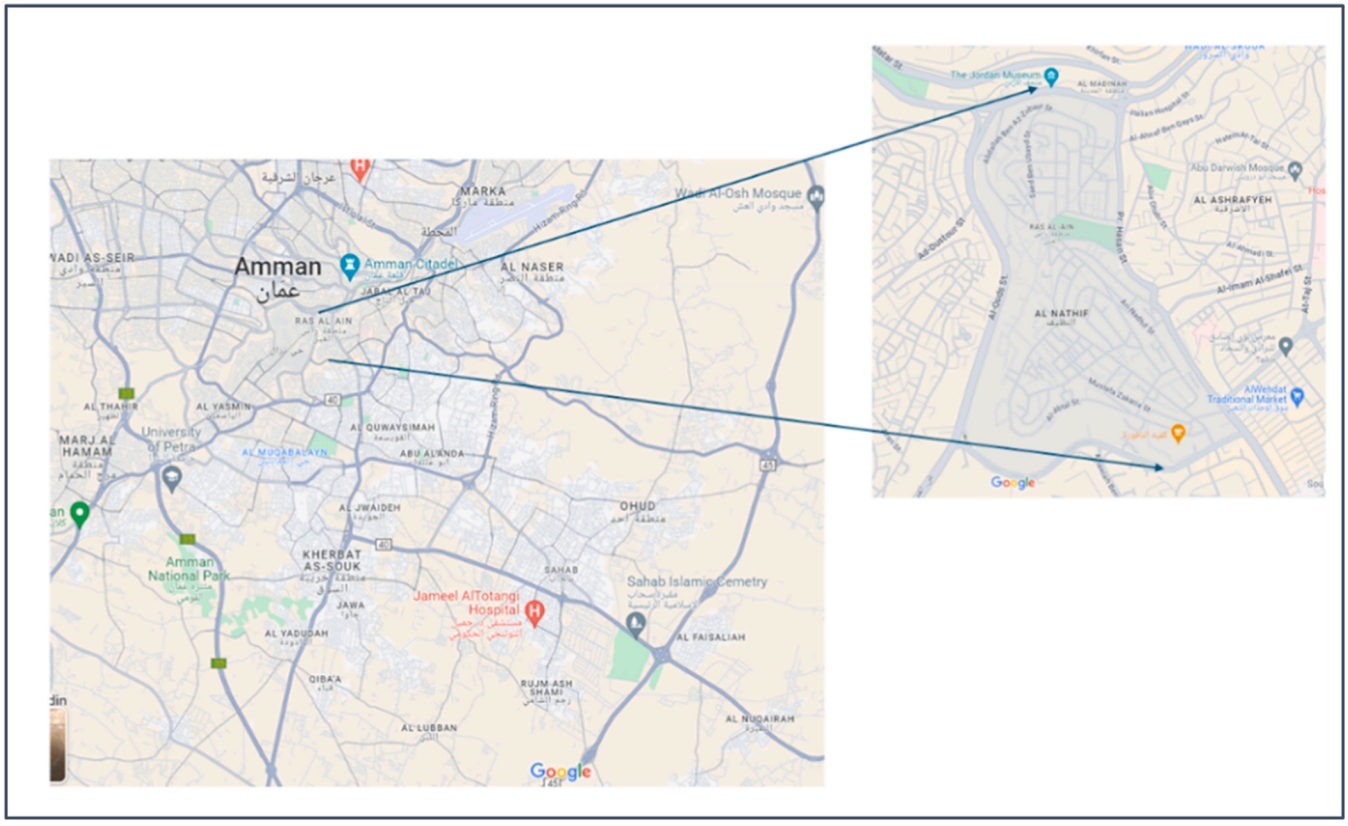

Fig. 1. Jabal Al Natheef Map (Source: Google Maps).

Fig. 2. (A) Narrow stairways typical of Jabal Al Natheef's urban layout (Photo: Hadeel Ayed Mohammad); (B) Densely packed residential units in the neighborhood (Photo: Khalid Ali).

triangulation and a comprehensive understanding of the Jabal Al Natheef context. Data collection was conducted between January and April 2024, using four interrelated methods: policy document review, ethnographic observations, semi-structured interviews, and focus group discussions.

The **policy document review** included both governmental and non-governmental sources, such as strategies, plans, and reports relevant to the Jabal Al Natheef community. These documents provided information on demographics, socio-economic conditions, environmental factors, and resource demands, with a focus on water, energy, and food, and household governance. Though literature directly addressing the WEF nexus at the household level was limited, studies on public policy promoting environmentally friendly household practices were reviewed. The best international practices and policy documents on water, energy,

and food rationing, as well as climate change adaptation and mitigation strategies, were also integrated into the analysis. This review improved understanding of the local governance landscape and identified relationships among key organizations and agencies addressing these issues. Insights from the document review guided the design of subsequent interviews and focus group discussions, aligning them with local and international policy frameworks. Key policy documents, including Jordan's National Water Strategy and the National Climate Change Adaptation Strategy, provided critical resources for adapting policy recommendations and drawing on successful global case studies.

Ethnographic fieldwork offered researchers to gather data within authentic settings, where individuals behave naturally, allowing for an exploration of both verbal and nonverbal behaviors (Reeves et al., 2013). This approach enables the study of marginalized groups and provides insights that can complement other research methods. It yields deep, insightful data and offers insiders' perspectives of reality, enriching the understanding of the subject matter. Additionally, ethnography provides a rich, detailed database for further investigation and research. It serves as a valuable tool to address the limitations of relying solely on interview data by incorporating observations of actions, behaviors, interactions, and beliefs, along with interviews and documentary data (Reeves et al., 2013).

Field observations: Community Observations: This method entails the collection of information through the investigator's observation without interviewing the respondents. The information obtained relates to the behaviors and activities of individuals at the research site. It records what is currently happening and is not complicated by either the past behavior or future intentions or attitudes of respondents. However, it is an expensive, time-consuming method, and the information it provides is also very limited (Kothari, 2004). In this specific research, the field notes were collected first by observing as an outsider and then moving into the setting and observing as an insider. For example, the researchers spent 6 hours (over 2 days) walking through the Jabal Al Natheef neighborhood to understand its various dimensions (streets, transportation means, shops, schools, walk-in clinics, housing styles, environment conditions, air quality, etc.). Subsequently, during the focus group discussions, the researchers observed participants' behaviors and attitudes, how they talked to each other, and how they responded to comments and questions. This provided valuable insight into the community's power dynamics, perspectives, and social interactions, enriching the researchers' understanding of the local context.

Housewives' Daily Practices and Grocery Shopping Observations: The researchers visited 5 houses and spent 3–4 hours (9:00 A.M. to 1:00 P.M.) in each house to observe householders' practices and behaviors in cleaning (using water to wash dishes; washing clothes), cooking (usage of water and energy), and conserving energy, water, and food. The researchers were keen to see if the housewives practice rooftop water harvesting or urban agriculture activities or if they own any energy-efficient appliances. Further, the researchers joined 4 householders while grocery shopping and spent 4 hours observing their behaviors and what factors affect their choices. Photographs were taken to document the observations. The researchers could complement the data derived from the policy document review and the key informants' interviews and gain greater insight into the WEF context and nexus at the household-level. The researchers were able to take notes during these events and engage in casual conversations with participants, which later helped to verify and elaborate on information derived from the other case study data sources.

Complementing these observations were **semi-structured interviews** with six key informant from the neighborhood, comprising the owner of a grocery shop, a taxi driver, a staff member from the Greater Amman Municipality, a nurse from a local health clinic, a member of a community-based organization (CBO), and an NGO representative. The selection of these representatives was guided by a purposive sampling approach. This involved identifying individuals with substantial knowledge, experience, or involvement in the Jabal Al Natheef community that was relevant to the research objectives. Selection criteria included their roles within the community, expertise in pertinent areas, and their capacity to offer diverse perspectives on the issues under investigation.

These interviews delved into various aspects such as socio-economic and environmental challenges, availability, accessibility, and affordability of WEF resources, governmental interventions at the local-level, and existing vertical and horizontal communication channels. They yielded the richest and most detailed information on the Jabal Al Natheef neighborhood, enabling the researchers to gain in-depth and contextual insights.

Finally, **focus group discussions** served to explore community attitudes and collective experiences, examining how knowledge and, more importantly, ideas develop and operate within a given cultural context (Creswell, 2003). Five sessions were held during January–April 2024, attended by 100 participants. Each session lasted about 90 minutes. The targeted participants were residents of the Jabal Al Natheef neighborhood involved in daily activities and practices related to water, energy, and food at home. Accordingly, all participants were women homemakers who were mostly engaged in household activities related to the three resources. In a typical household, activities such as showering, laundry, and dishwashing contribute to water consumption, while cooking, refrigeration, and heating account for energy usage, and food-related activities like meal preparation, waste management, grocery shopping, and storage impact food resources. It was not possible to conduct mixed (men and women) focus group discussions because Jabal Al Natheef is a conservative neighborhood; in this community, men are responsible for household income. However, having separate focus groups was also challenging because of the women's working hours and time limitations. A systematic sampling method was used to select the participants from the Jabal Al Natheef neighborhood. The researchers used the telephone directory of Ruwwad (an active NGO located in the neighborhood since 2005), which lists more than 1000 families (the first participant was selected randomly; then every fifth name was chosen from the telephone directory).

The researchers devised guiding questions to initiate discussions among participants, delving into their perspectives, encounters, and insights regarding the connections between water, energy, food, and climate change awareness within households. These inquiries aim to furnish researchers with valuable insights into the challenges faced by households along with avenues for cultivating more sustainable resource management practices and tackling climate change. Data was collected using flip charts, audio recorders, photographs, and personal observations. The most informative group discussion included several representative quotes describing different dimensions of various themes.

2.3. Study limitations and sampling

This study employed purposive and systematic sampling to capture the socio-economic diversity of low-income neighborhoods in East Amman, specifically in areas like Jabal Al Natheef. While the sample is not statistically representative of all Amman or Jordan, it reflects trends observed in 20–30 % of urban informal settlements. The sample consisted solely of women homemakers, all of whom shared similar income levels, education, and WEF-related behaviors. While this limits variability, it aligns with local norms where women typically manage household-level WEF decisions.

A 35 % rejection rate in the household survey—due to time constraints, privacy concerns, or discomfort with home visits—may have introduced non-response bias, potentially favoring more engaged households. This was mitigated through gender-sensitive approaches, trust-building, and the involvement of local facilitators to ensure a respectful and culturally appropriate process. However, this limitation may have led to the exclusion of perspectives from households who are less willing or able to participate.

Interviews with six experts provided additional insights, though the

choice of a limited number of experts may not have fully captured all relevant interest groups. The selected experts included professionals in resource governance, climate policy, urban planning, and community development. While these groups are central to the research objectives, there may have been perspectives from other interest groups—such as local government officials, industry representatives, or community leaders—that were not adequately represented due to time and logistical constraints.

Despite these limitations, the sample provides a foundational understanding of household-level WEF dynamics in Amman, and the methodology offers a basis for broader application in other Jordanian communities. This research contributes to ongoing discussions about resource governance, public participation, and policy integration in low-income urban settings.

2.4. Inductive data analysis

The literature review, focus group discussions, semi-structured interviews, observations, and expert group input aided the researchers in organizing the collected data into six categories:

1. Socio-economic context of the respondents
2. Climate change awareness
3. Knowledge of WEF resources challenges
4. Household WEF nexus and prioritization
5. Household governance
6. Daily WEF practices

2.5. Validity procedures

To enhance the accuracy and credibility of the findings, two key qualitative validation strategies were employed:

2.5.1. Triangulation

Triangulation strengthens qualitative research by cross-verifying data from multiple sources and methods (Creswell and Miller, 2000; Koch, 1994; Morse et al., 2002; Shenton, 2004). This study integrated qualitative and quantitative data to examine WEF-climate interlinkages in Jabal Al Natheef. Ethnographic findings (observations, focus groups, interviews) were compared with insights from policy and theoretical literature, enabling richer contextual understanding and reducing bias.

2.5.2. Member checking

Accuracy and trustworthiness were reinforced through six member checking techniques: (1) real-time clarification during interviews; (2) summarizing focus group insights for participant validation; (3) presenting observational results to participants for confirmation; (4) re-interviewing or re-contacting participants to assess consistency; (5) verifying consent for quoted material; and (6) validating findings through one-on-one discussions with national experts. These steps ensured alignment between participants' perspectives and the study's interpretations, supporting reliable and context-sensitive recommendations.

3. Results

3.1. Socio-economic context of the respondents

All focus group discussion participants (100 participants) were housewives between 18 and 65 years of age. Of those, 44 participants were illiterate; 41 had finished school, 9 had a college degree, and 6 had a university degree. Of the total participants, 47 % were non-Jordanian, specifically registered refugees. Out of the total participants, 44 % were unemployed (housewives), 30 % were part-time employees, and 20 % were undertaking home-based food production-related jobs — producing goods from their kitchens and selling locally or online (e.g., baking, preserving, or making specialty items like jams or sauces), and 6 % worked full-time (Table 1).

The participants' monthly income ranged between US$150–550, with 31 % of participants earning between US$150–250, 19 % earning between US$250–350, 44 % earning between US$350–450 %, and 6 % earning between US$450–550.

Participants' household sizes were as follows: 66 % of the focus group participants have 8–10 members living in the household, 23 % have 5–7 members, 7 % have 3–4 members, and 4 % have 2 members. Of the participants, 37 % come from women-led households.

Of the total, 77 % participants were tenants renting apartments (1–2 rooms with a small kitchen and one toilet), while 23 % owned their residences (1–3 small rooms with a small kitchen and 1–2 toilets).

Due to the high cost of installing separate water and electricity meters, many low-income households in Jabal Al Natheef rely on shared utility meters: 54 % of focus group participants shared water meters with neighbors, 14 % shared electricity meters, and 32 % shared both. These arrangements were most common in tenant-landlord relationships, where a small tenant family shares a meter with a larger landlord household. In most cases, the tenant pays a fixed monthly fee for utilities, regardless of actual usage.

This setup reduces tenants' motivation to conserve resources since they do not directly see the financial benefits of reduced consumption. On the other hand, landlords have little incentive to invest in conservation technologies or efficiency upgrades, as costs are partially passed to tenants. This often leads to tensions and disputes, especially when utility bills spike or one party is perceived to be overconsuming.

These dynamics underscore the need for targeted policy interventions. Municipal or national programs could subsidize the installation of individual meters in multi-family housing or regulate utility billing practices in rental agreements. Additionally, tenant rights policies could include provisions that encourage equitable access to conservation incentives—such as rebates for efficient appliances or low-flow fixtures—to ensure both landlords and tenants are accountable for, and benefit from, sustainable resource use.

Table 1
Socio-economic context of the participants.

Socio-economic context of the Participants		Number of Participants
Age groups (years)	18–30	12
	31–45	20
	46–65	68
Educational level	Illiterate	44
	Primary	41
	College	9
	University	6
Nationality	Jordanian	53
	Non-Jordanian	47
Occupied Jobs	Full-time	6
	Part-time	30
	Home-based	20
	Unemployed	44
Monthly Income (US$)	150–250	31
	251–350	19
	351–450	44
	451–550	6
Household size (members)	2	4
	3–4	7
	5–7	23
	8–10	66
Family head	Woman	37
	Man	63
Home ownership	Owner	23
	Tenant	77
Shared Utilities	Share water meters	54
	Share electricity meter	14
	Share water and electricity meters	32

3.2. Climate change awareness

Understanding household-level awareness of climate change is critical, as many decisions affecting vulnerability and resilience are made at this scale, with wider implications for socio-economic and policy systems (Elrick-Bar et al., 2014; Bellon and Massetti, 2022; Castro and Sen 2022; Kebir et al., 2023). Table 2 summarizes participants' awareness and perceptions.

Awareness and Sources of Information. Most participants (77 %) had heard of "climate change," mainly via social media (e.g., Facebook, WhatsApp), with others citing community gatherings (8 %), friends/relatives (5 %), television (4 %), radio (3 %), workplaces (2 %), and workshops (1 %). While participants broadly understood it as changes in weather or temperature patterns, detailed understanding was low. Many expressed anxieties, and one participant said, "I am worried about what's happening to the climate. It feels different now." (Participant 4)

3.2.1. Perceived causes

Participants expressed varied understandings of climate change causes—55 % believed it was a divine act, 20 % blamed air pollution, 15 % did not know, and 10 % were unsure. As one put it, *"I believe this is a punishment from God; we became bad humans"* (Participant 1).

3.2.2. Perceived impacts

There was stronger awareness of climate impacts, especially following recent extreme weather events. Participants cited hotter, longer summers, shorter colder winters, floods, dust storms, and irregular crop seasons. One shared, *"Thirty years ago, we had four equal seasons. Now, winters are short, summers long"* (Participant 3). Others noted health effects: *"We go more often to the clinic, mainly for flu—maybe because of post-COVID and the changing weather"* (Participant 2).

Table 2
Climate change awareness among the participants.

Factors		Number of Participants
Means of climate change awareness	Community Gathering	8
	Television	4
	Radio	3
	Work	2
	Friends and relatives	5
	Meeting/ workshops	1
	Social media	77
Causes of climate change	Act of God	55
	Air Pollution	20
	Not sure	10
	Don't know	15
Impact of climate change	High temperature	25
	Low temperature	2
	More precipitation	5
	Less precipitation	15
	Dust storms	20
	Don't know	33
Most vulnerable groups	Children	12
	Disabled people	8
	Sick people	15
	Elderly people	11
	Refugees	10
	Don't know	44
Level of awareness of government actions to cope with climate change impact	Aware	6
	Not aware	70
	Not sure	24
Relation between daily practices and climate change conservation measures	Relation	10
	No relation	66
	Not sure	24

3.2.3. Identification of vulnerable groups

While 44 % of participants could not identify vulnerable groups, others cited the sick (20 %), elderly (16 %), children (12 %), and people with disabilities (8 %). A participant explained, *"My husband has lung disease…when there are dust storms, he can't breathe, and we have to take him to the hospital"* (Participant 7).

3.2.4. Knowledge of government responses

Awareness of climate-related government action was low—70 % were unaware of any municipal or national efforts, especially refugees; 24 % were unsure, and only 6 % reported any knowledge. Participants viewed the government as disengaged, mainly concerned with raising taxes and prices.

3.2.5. Perceived solutions and action

Participants generally felt powerless to act on climate change: *"All you can be responsible for is what you do, and what we can do is very little"* (Participant 1). Although they expected authorities to take stronger measures, none demonstrated knowledge of actionable responses or systemic solutions.

3.2.6. Connection to daily practices

While many felt affected by climate change, 66 % did not recognize any connection between it and their household behaviors, such as recycling or energy saving. These were seen as money-saving measures rather than climate actions. Only 10 % reported any link; 24 % were unsure. Nonetheless, participants expressed curiosity and willingness to learn more.

3.3. Knowledge of WEF resources challenges

Most focus group participants lacked clarity about their water and energy sources, though they were more familiar with food origins. While 84.5 % acknowledged Jordan's water scarcity—mainly through media—knowledge of food and energy security was low, with 90 % unaware of food insecurity and 72 % unfamiliar with energy issues. As one participant said, "*We receive water once every two weeks*" (Participant 9), reflecting personal experience more than systemic understanding.

Improving public awareness of how resources are sourced and managed is critical. It enables informed choices, supports conservation, and fosters engagement in local planning. But knowledge alone isn't enough. Participants voiced concern over rising costs and a lack of tangible support: "*Energy prices are high; it's difficult to afford in winter*" (Participant 8), and "*TV talks about water scarcity, but not how to get conservation devices cheaply*" (Participant 5).

To bridge this gap, the government could combine awareness campaigns with targeted subsidies—for example, for water-saving devices, solar heaters, or energy-efficient appliances—helping households adapt while reinforcing trust and resilience.

3.4. Household WEF prioritization and nexus

When focus group participants were asked to rank water, energy, and food (WEF) resources, 95 % prioritized water due to its irreplaceability in daily life — for drinking, cooking, sanitation, health, and religious practices. As one participant noted, *"If there is no water, we cannot survive. However, we can manage to secure food and energy*" (Participant 10). Food was ranked second by 88.5 % of participants, who emphasized the availability of alternatives (e.g., vegetables, rice, meat) and survival strategies such as reducing intake or using traditional preservation techniques. Many participants shared that they could adapt by storing food or fasting, with one stating, "*We can manage to store food, fast, consume less. But nothing can compensate for water*" (Participant 7). Energy was ranked third by 77.5 %, with alternatives such as candles,

sunlight, gas, or wood for cooking and heating. Another participant described the relative unavailability of substitutes for water, saying, *"Sun gives us energy and life. However, nothing substitutes for water"* (Participant 5).

Initially, participants struggled to recognize the interconnections between WEF resources. However, when prompted with examples like cooking, they began to see interdependence. From these discussions, a household-level WEF nexus conceptual framework (Fig. 3) was developed to illustrate the connections between priorities, practices, and resource challenges.

Participants identified three key WEF interlinkages:

1. **Water–Food Nexus:** Water was deemed essential for food-related practices like cooking and washing. Concerns about affordability, accessibility, and quality were common.
2. **Energy–Food Nexus:** Participants were concerned about rising energy prices, particularly for cooking gas, electricity, gasoline, diesel, and kerosene, all of which impacted food preparation and transportation costs.
3. **Energy–Water Nexus:** Electricity or gas was necessary for heating and cooling appliances, adding further strain on resource management.

After the WEF nexus framework presentation, **90 %** of participants recognized the interlinkages between water, energy, and food. They acknowledged that reducing water use (e.g., smaller quantities for cooking) led to energy savings and vice versa.

3.4.1. Water-centric practices impacting WEF resource interconnections at the household-level

Participants were asked to indicate one or more of the (water, energy, or food) conservation measures implemented in their homes. Of the 100 participants, 95 had implemented at least one or more water conservation measures: reduced water consumption (washing clothes by hand, using washing machines once every 7–10 days, fewer showers, less water used during food preparation, wiping floor instead of using hose, low-water dishwashing strategies, etc.), water reuse (using kitchen water for watering plants, toilet flushing, mopping floor), water-saving devices (taps, showerhead), use of rain barrels, etc. Fig. 4 illustrates the participants' top three water conservation measures implemented for households: (1) reuse water (26 %), (2) reduce numbers of showers (26 %), and (3) water conservation measures (18 %). According to the participants, these practices were driven by reducing the water used and disposed of in two ways. The water is received every 2 weeks. It is a precious resource to save; the participants realize its scarcity and must save money.

3.4.2. Energy-centric practices impacting WEF resource interconnections at the household-level

For energy (Fig. 4), 47 % of the participants indicate deploying energy conservation measures at homes, using various energy efficiency tips to reduce their electricity bills (e.g., switching off extra lights, turning off electronics and computers daily, and ceiling fans, not using heaters during sunny winter days, washing clothes by hand, washing full loads of clothes, and drying clothes using sunlight). Also, 19 % of participants mentioned using solar water heaters, 18 % indicated using energy-efficient light bulbs, 14 % indicated purchasing energy-efficient appliances — mainly washing machines and refrigerators — and 2 % indicated that they had installed renewable energy (PV system). When asked about the major factor affecting their energy conservation decisions, participants indicated the key reason to be minimizing the increase in electricity spending.

3.4.3. Food-centric practices impacting WEF resource interconnections at the household-level

As illustrated in Fig. 4, 36 % of the participants reported adopting various strategies to manage expenses (e.g., shopping with a list, planning weekly menus, buying in bulk during sales, and shopping after 5:00 pm when prices drop). One participant explained, *"I go shopping after 5:00 pm; vendors are about to close, and I can have good deals since they do not want to keep old veggies and fruits for the next day" (Participant 12)*. Another noted, *"I don't care about the quality of veggies or fruits, as long as it is cheap" (Participant 13)*.

Additionally, 23 % described changing consumption behavior,

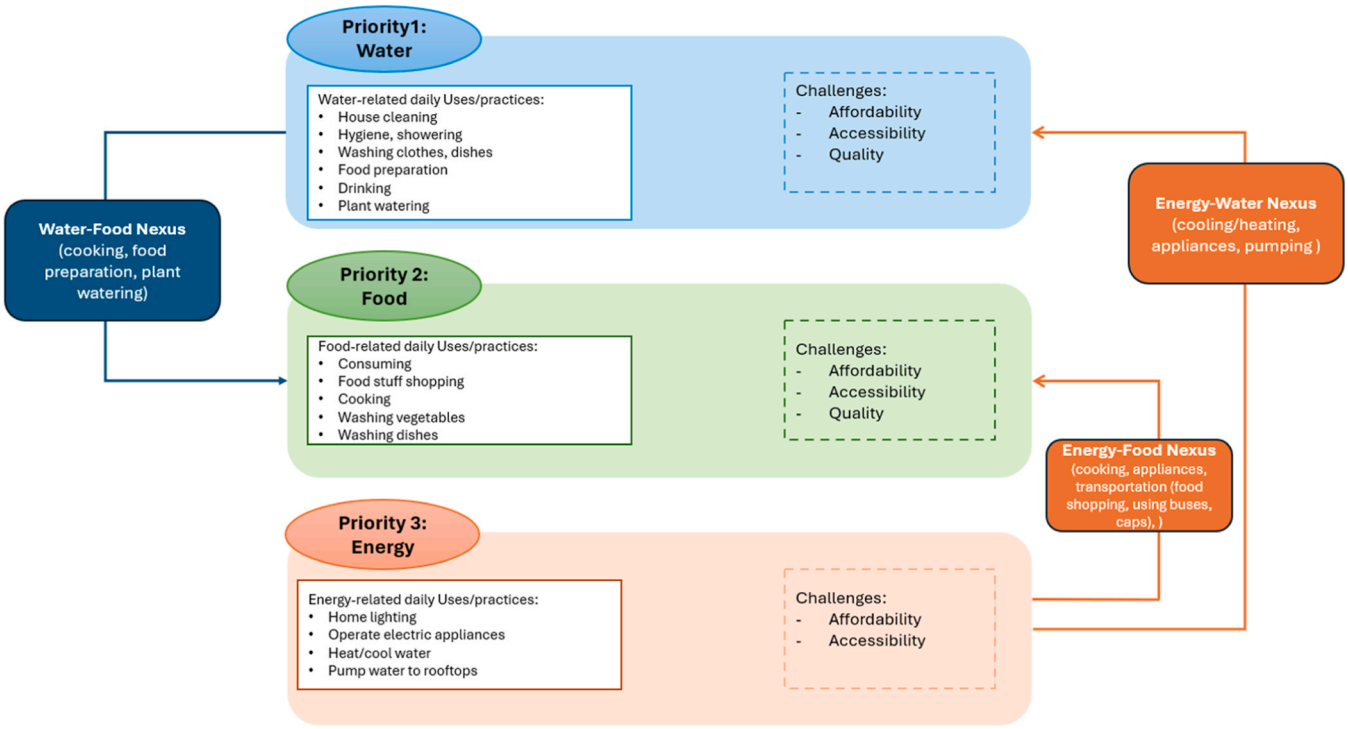

Fig. 3. Household water–energy–food nexus conceptual framework.

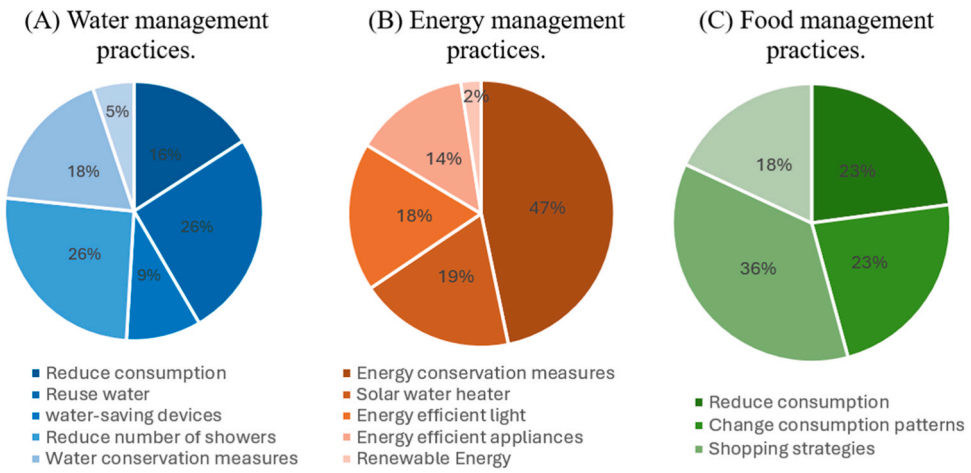

Fig. 4. Water, energy, and food management practice at household level.

including reducing meat intake, freezing vegetables, and minimizing restaurant visits. *"Meat is expensive; we have vegetarian meals several times" (Participant 6),* shared one participant, while another added, "*We eat from a restaurant once or twice a year, for special occasions" (Participant 1). Another* 23 % of the participants reduced their food intake, reporting only one or two meals per day or cooking just twice a week, as one noted: *"I cook twice per week, and I have to manage not to consume more"* (Participant 3). Meanwhile, 18 % relied on food donations. These narratives highlight how financial constraints are reshaping food practices in low-income households, underscoring the importance of targeted support measures.

3.5. Household governance

Exploring "household governance" is key to understanding how families manage water, energy, and food (WEF). It involves make-or-buy decisions, task assignments, constraints, and informal arrangements. Our study found varied governance models: 63 % followed a traditional structure with a male breadwinner and a woman handling household duties, while 37 % were women-headed households managing both income and domestic responsibilities. This highlight shifting gender roles and their impact on decision-making and resource use.

Although couples shared similar financial coping strategies, their "allocation rules" for household tasks differed. Gender roles influenced how work, planning, and WEF decisions were approached. Limited financial means challenged participants to meet both daily needs and long-term goals, with priorities including reducing water, energy, and food costs without sacrificing quality.

Participants reported prioritizing fixed expenses—water, energy, gas, rent—when budgeting. Food spending came afterward, affecting both quantity and quality. While exact figures were known for utility bills, food budgets varied monthly.

When asked who makes decisions on appliances, conservation practices, bill payments, maintenance, and food shopping, responses showed gendered patterns in household roles (Fig. 5).

Studying Jabal Al Natheef households sheds light on daily decisions—from diet to transport and appliance purchases. Choices were influenced by job type, income, cost, brand, social norms, values, and awareness of climate change. Other factors included financing options, subsidies, trust in products, and access to alternatives. Thus, household-level adaptations can ripple through broader socio-economic systems.

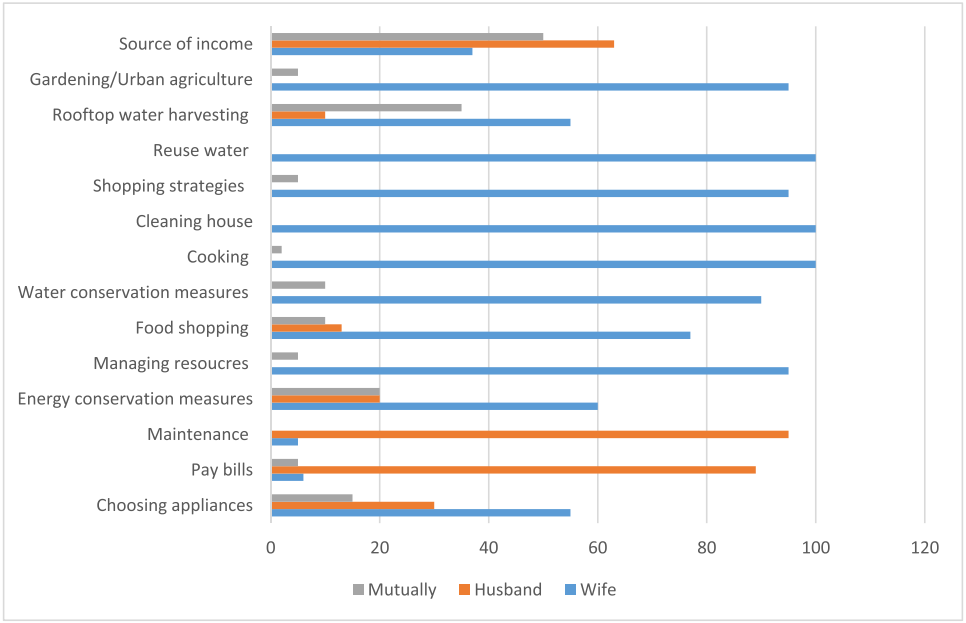

Fig. 5. Women's perception of wife and husband roles and practices in the water-energy-food nexus.

3.6. WEF-related daily practices and grocery shopping observations

Four in-depth household observations were conducted in February 2024, each lasting approximately five hours. While the households varied in size and gender of the head, they shared similar characteristics: poor housing conditions, low and variable monthly incomes, lack of energy-efficient appliances, and reliance on public transportation. Table 3 summarizes their socio-economic profiles.

Despite individual differences, daily water, energy, and food (WEF) practices across the households revealed strong commonalities shaped by economic constraints, cultural values, and structural water scarcity. These practices, though informal and unrecognized by residents as environmentally conscious, demonstrate an inherent integration of the WEF nexus in everyday life.

3.6.1. Water practices

All households employed basic water-saving techniques, including capturing greywater for reuse in flushing toilets or watering plants. Showers and dishwashing routines were adjusted to minimize waste, with motivation driven more by cost and scarcity than environmental awareness.

3.6.2. Laundry and energy practices

Handwashing was common for small loads, and greywater was reused for cleaning. Electricity use was limited lights were off during the day, and appliances like irons or refrigerators were used sparingly. One household created an "electricity fund" to incentivize children to reduce power consumption.

3.6.3. Food and cooking practices

Households in Jabal Al Natheef adopted resourceful food practices shaped by both necessity and sustainability. Cooking in bulk, using pressure cookers, and relying on seasonal ingredients helped conserve energy and reduce waste. Refrigerators were essential for food preservation, reducing spoilage and trips to markets. However, it's important to distinguish scalable practices from those driven by poverty. Limited consumption of meat and dairy, and creative reuse of ingredients like lemon peels, reflect both environmental and economic motives. In contrast, skipping meals or fasting due to lack of food signals vulnerability, not a model to replicate. Sustainable strategies must build on practices that promote affordability and resilience while addressing underlying food insecurity.

Table 3
Observed households' characteristics.

Household characteristics	Household 1	Household 2	Household 3	Household 4
Visit date	3 February 2024	10 February 2024	17 February 2024	24 February 2024
Head of household	Man	Man	Woman	Woman
Family size	5 persons	8 persons	13 persons	3 persons
Job type	Construction	Taxi driver	Tailor	Secretary
Monthly income (JD/month)	190–225 (US $271–321)	257–350 (US $367–500)	190–270 (US $271–385)	150 (US$214)
Water quarterly bill (JD/month)	25 (US$36)	24 (US$34)	34 (US$49)	15 (US$21)
Electricity monthly bill (JD/month)	15 (US$21)	17 (US$24)	25 (US$36)	9 (US$13)
Cooking gas (cylinder/month)	1 (US$14)	1 (US$14)	2 (US$28)	1 (US$14)
Food consumption (JD/month)	~120 (US$171)	~ 60 (US$229)	~185 (US$264)	~90 (US$129)
Rental (JD/month)	55 (US$77)	65 (US$93)	60 (US$86)	45 (US$64)
No. of bedrooms	2	2	2	1
Energy efficient (EE) appliances, light bulbs	None	None	2 EE light bulbs	None

3.6.4. Grocery shopping

Three housewives were observed shopping at Al-Wehdat Market. They walked in groups for companionship and safety, often choosing to shop late on Fridays for discounted produce. Purchases were highly strategic guided by price, quality, and quantity needed to last several weeks. Bargaining was common, and decisions reflected both economic prudence and food planning strategies.

These practices illustrate how low-income households, while navigating scarcity, informally enact resource-efficient behaviors that align with WEF nexus thinking. Their lived experiences offer insights into how bottom-up practices can inform sustainable urban policy interventions, particularly those aimed at integrating WEF considerations into social welfare and climate resilience programs.

4. Discussion

This section critically analyzes and synthesizes the findings presented earlier, drawing on insights from both respondents and researchers. The results are interpreted in light of relevant theoretical and policy literature, aiming to illuminate the complex interplay between household practices, governance structures, and broader sustainability goals in the context of the Water-Energy-Food (WEF) nexus.

The study reinforces that WEF practices are deeply interlinked in daily life, especially among low-income urban households. However, it reveals significant disconnects between grassroots needs and the priorities of national and municipal governance. This underscores the importance of tailoring policy responses to community-specific realities, integrating gender-sensitive and equity-based approaches to ensure both relevance and effectiveness.

4.1. Mismatch between household priorities and policymaker agendas

The research highlights stark differences in how WEF challenges are perceived across governance levels. National policymakers focus primarily on supply-side strategies to secure water and energy for national stability, framing these resources within a security and economic lens (Al-Zu'bi, 2016; Al-Zu'bi 2017; El-Sharif and Muasher, 2024). Food security has only recently gained traction—particularly post-COVID—-while climate policy remains largely mitigation-oriented. At the municipal level, institutions like the Greater Amman Municipality (GAM) operate primarily as service providers with limited authority over WEF or climate policy. Consequently, integrated approaches to urban adaptation and resource governance remain underdeveloped. In contrast, residents of Jabal Al Natheef prioritize survival-level needs: income, food, water, energy, and rent. For them, WEF issues are not abstract policy themes but immediate concerns linked to affordability, infrastructure, and household wellbeing. Climate change is rarely recognized as a distinct issue, though participants report experiencing its effects through erratic water access, rising energy costs, and food insecurity. This misalignment reflects a failure to bridge top-down policy agendas with bottom-up lived realities—weakening governance and stalling inclusive climate action.

4.2. Household insights expose governance and participation gaps

Several critical governance gaps emerged from the perspectives of householders:

4.2.1. Transparency deficits

Respondents reported unclear and inconsistent government

communication regarding energy pricing, fueling skepticism and perceived inequity. Many cited unexplained increases in fuel prices that exacerbate food and energy insecurity—concerns echoed in national assessments (USAID, 2015).

4.2.2. Limited climate and resource awareness

While water scarcity was widely acknowledged, awareness of energy and food system vulnerabilities was low. Many participants lacked understanding of resource origins, climate risks, and available adaptation strategies. Notably, only 10 % of participants associated climate change with their own daily practices. This gap underscores the urgent need for locally relevant, accessible education and outreach.

4.2.3. Ineffective participation channels

Distrust in government institutions was common. Residents described formal complaint channels as inactive or biased and relied instead on informal actors—NGOs, community leaders, and MPs—for problem-solving. This reflects broader civic engagement challenges in Jordan, where civil society remains fragmented and often disconnected from official policymaking processes.

hese findings suggest that participatory platforms must go beyond token consultations. Mechanisms for two-way communication and co-design of policy solutions are essential for building trust, legitimacy, and ownership in WEF governance.

4.2.4. Gender as a crucial lens in WEF decision-making

The study confirms that gender roles significantly shape household-level WEF decisions. Women—particularly housewives—are the primary managers of water and energy consumption, food preparation, and household rationing. These daily practices reflect climate-conscious behaviors, even if not explicitly framed as such.

Men, by contrast, typically manage household finances and utility bills, often controlling decisions about technology purchases (e.g., energy-efficient appliances). This gendered division of responsibility limits women's influence over long-term conservation investments, despite their frontline role in daily resource use (Hamza et al., 2023; UN Women, 2018; Cronkleton et al., 2021).

Recognizing and addressing these asymmetries is vital. Inclusive policies must target both women and men, supporting gender-equitable access to information, financing, and decision-making tools. Failure to do so risks undermining the effectiveness and sustainability of WEF interventions.

4.3. Individual actions matter—but scaling remains a challenge

Household-level WEF conservation practices—such as reducing water use, cooking at home, or turning off lights—were widespread among participants. These actions were primarily motivated by cost savings but carry broader implications:

1. **Environmental Impact**: Resource-efficient behaviors reduce GHG emissions associated with water pumping, energy use, and food transport, supporting climate mitigation efforts.
2. **Resource Security**: Conservation reduces dependency on imports and bolsters resilience to supply shocks—critical for a resource-scarce country like Jordan.
3. **Innovation and Policy**: Supportive policies and incentives (e.g., subsidies for efficient appliances, microfinance schemes) could accelerate behavioral change and technological adoption.

However, these positive practices remain fragmented and difficult to scale. Structural barriers—such as poverty, limited awareness, and lack of access to efficient technologies—must be addressed through integrated, multisectoral interventions.

4.4. Education, equity, and localized communication are key

The findings indicate a troubling gap in public understanding of critical resources. While participants could distinguish between local and imported food, few knew the sources of their water or energy. This limits their ability to make informed decisions and weakens support for long-term sustainability policies.

Moreover, the disconnect between personal behavior and climate outcomes suggests a need for more relatable, narrative-driven climate communication. Messaging should emphasize how simple actions (e.g., reducing food waste, conserving electricity) contribute to household resilience and national sustainability goals. Embedding such education into neighborhood programs and linking it to tangible benefits—like lower bills or community recognition—could be a powerful driver of change.

4.5. Socioeconomic pressures constrain agency—but reveal resilience

The socioeconomic profile of the study population—primarily women homemakers in large, low-income households—exposes the deep-rooted challenges facing marginalized urban communities. Many participants engage in home-based food production to supplement income, displaying a strong sense of resilience and entrepreneurial spirit. However, the economic stress of managing households with 8–10 members on limited incomes exacerbates resource insecurity and restricts adaptive capacity. These findings call for:

- **Education and Skill Development**: Targeted programs to improve literacy and vocational opportunities for women.
- **Utility and Housing Reforms**: Support for separate utility meters to reduce conflict and promote equitable access.
- **Microfinance and Business Support**: Tools to strengthen home-based enterprises and boost household economic stability.

5. Conclusions and policy implications

This study exposes critical limitations in the current implementation of the Water-Energy-Food (WEF) nexus by examining it through the lens of household dynamics—where resource use, climate vulnerability, and adaptation behaviors converge most tangibly. Focusing on the urban poor in Jabal Al Natheef, Jordan, the research surfaces how climate impacts are experienced and negotiated in everyday practices, offering a much-needed demand-side perspective for reimagining the WEF nexus as a vehicle for climate-resilient urban development.

The analysis reveals a clear disconnect between household-level experiences and national or municipal governance approaches. These misalignments stem from differences in priorities, awareness, and capacities, but also point to deeper structural issues—such as fragmented policy environments, weak cross-sectoral coordination, and limited citizen engagement. As a result, the potential of the WEF nexus to function as an integrated governance tool for sustainable development and climate adaptation remains largely unrealized.

A central insight from the study is the often-overlooked yet vital role of gender in shaping adaptation strategies. Although women are key actors in managing water, energy, and food at the household level, their perspectives and needs are frequently excluded from both local and national policy processes. The case of Jabal Al Natheef reinforces the urgency of embedding gender-sensitive approaches into WEF policies—not as a secondary consideration, but as a foundational principle for equitable and effective governance.

Another significant finding is that economic considerations—not environmental awareness—are the primary motivators for household-level behavioral change. This underscores the importance of aligning climate goals with socio-economic incentives to increase the political and practical viability of resource-efficient interventions. Policies that integrate cost savings and livelihood benefits alongside environmental

objectives are more likely to gain traction among vulnerable urban populations.

At a broader scale, this micro-level inquiry offers valuable insights for translating global sustainability goals into context-specific, locally actionable strategies. As cities in the Global South confront escalating challenges of urbanization, climate stress, and social inequality, the lived experiences of households can inform more adaptive, inclusive, and grounded policy solutions. Local governments, in particular, play a crucial bridging role—translating national strategies into community-level action while feeding local knowledge back into higher-level planning.

Ultimately, the research calls for a more polycentric and participatory governance model—one that recognizes the interconnected roles of households, municipalities, and national actors. Mainstreaming household-level evidence into WEF policy design can enhance policy responsiveness, improve social equity, and increase resilience to climate risks.

In conclusion, households are not passive recipients of policy but active sites of innovation, knowledge, and resilience within the WEF nexus. Recognizing and empowering them through inclusive governance frameworks is essential for advancing sustainable, gender-equitable, and climate-resilient urban futures.

CRediT authorship contribution statement

Youssef Brouziyne: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Bassel Daher:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Tafadzwanashe Mabhaudhi:** Writing – review & editing, Formal analysis, Conceptualization. **Maha Al-Zu'bi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

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

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Data availability

The data that has been used is confidential.

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