

Review

# Becoming FEW Conscious: A Conceptual Typology of Household Behavior Change Interventions Targeting the Food-Energy-Water (FEW) Nexus

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**Abstract:** The food-energy-water (FEW) nexus presents an opportunity to rethink predominant approaches to household behavior change science. We linked emerging FEW nexus research with existing literature examining household consumption and pro-environmental behaviors. While a large body of work examines the environmental impacts of household life and explores pathways to behavior change for sustainability, the literature lacks studies that test interventions in multiple FEW resource categories, leaving researchers unable to identify tensions and tradeoffs in the household system. To guide this developing field and accumulate findings on household behavior across disciplines, we proposed a conceptual typology that synthesizes interdisciplinary analytic traditions to classify behavioral interventions targeting the household FEW nexus. The typology synthesizes behavioral interventions as active, passive, or structural, and household-specific or non-specific, illustrating six distinct categories: information, tailored information, action, gamification, policy/price change, and material/technology provision. A review of 40 studies that guided the typology identifies four significant lessons for future intervention research: household non-specific information and tailored information work better together, feedback is more effective when it is persistent, price-based interventions (information or incentives) are often ineffective, and material/technology provision is very effective but utilized in few household studies. To push forward household resource consumption science, we advocated for a holistic nexus focus that is rooted in interdisciplinarity, coalition building with stakeholders, and data reporting that facilitates knowledge accumulation.

**Keywords:** climate change mitigation; household consumption; food-energy-water nexus; pro-environmental behavior

## 1. Introduction and Background

A rapidly expanding area of study in sustainability sciences, the food-energy-water (FEW) nexus challenges previous understandings of household resource consumption. Creating questions about feedback systems, tradeoffs, and actual environmental impacts, the FEW nexus adds further complexity to our understanding of human-environment relationships. The human necessities of housing, sustenance, and transportation require growing supplies of FEW resources. Consuming these resources at our current rate results in air, land, water, and greenhouse gas (GHG) impacts [1,2]. These routine activities are also deeply personal, cultural, and create meaning in our lives. Despite increased attention to the interconnected nature of food, energy, and water consumption, it remains unclear how many household consumption intervention studies utilize the FEW nexus framework.

A large body of literature examines the environmental impacts of household life and explores pathways to behavior change for sustainability in the face of climate change. In 2016, Ivanova et al.

modeled the environmental impact of household consumption globally, finding that it contributes to greater than 60% of GHG emissions and 81% of total freshwater resource worldwide [3]. In 2009, Dietz et al. identified the “behavioral wedge”, arguing that household behavioral changes could reduce 7% of US emissions [4]. More recently, Dubois et al. (2019) pointed to the three major components of household footprints in developed countries: car and plane travel, meat and dairy consumption, and heating, drawing increased attention to the relevance of a FEW focus [5].

Initial studies, on household conservation, focused mainly on energy. Emerging in the 1970s, programs sought to help homeowners reduce their energy use during the energy crisis and were institutionalized in various demand-side management programs for energy [6]. Likewise, areas experiencing drought have sought to understand these dynamics to encourage household water conservation [7]. More recently, two developments have brought the idea of household conservation at the nexus of food, energy, and water to the forefront. Buzby, Wells, and Hyman (2014) found high levels of food waste, approximately 30%, at the retail and consumer level [8]. Additionally, novel research focused on the food, energy, and water nexus highlights the GHG emissions and water consumption that result from food production and preparation [9,10]. The FEW nexus research domain requires considering connections and interdependencies between systems in efforts to solve complex global problems [11]. Albrecht, Crootof, and Scott (2018) explain, “The nexus approach aims to identify tradeoffs and synergies of water energy, and food systems, internalize social and environmental impacts, and guide development of cross-sectoral policies” [12] (p. 1). These studies encourage researchers to think more critically about the interconnections between food, energy, and water resource systems at the household level. Thus, interventions have grown more complex and sophisticated, evolving to target the consumption of multiple resource categories simultaneously and draw attention to the ways that they connect within the household system. This paper seeks to link emerging FEW nexus research with existing literature examining household consumption and pro-environmental behaviors.

To guide this developing field, we proposed a conceptual typology that synthesizes interdisciplinary analytic traditions to classify behavioral interventions targeting the household food, energy, and water (FEW) nexus. The development of a typology enables research on household consumption in the FEW nexus to accumulate findings across disciplines. A limited number of household behavioral intervention studies target consumption in all three resource categories, and to our knowledge, there are no reviews that highlight household consumption behavior at the FEW nexus. Emerging research on food, energy, and water systems has primarily focused on changing production systems rather than consumption. Given this, it is unclear what intervention strategies generally work across all three resource domains, or even how to effectively track food, energy, and water use in a single study. No one household functions precisely like another—household practices both shape and are shaped by the intricacies of individual and family life. Through this lens, our typology is structured to consider the position and function of the individual and household within the intervention. In the analysis that follows, characterizing interventions through these roles provides an alternative way of linking intervention technique to theoretical behavioral determinants. This paper advances past typologies and reviews by emphasizing the significance of the food, energy, and water nexus to household sustainability. Our objective is to look across interventions in the FEW resource domains and identify commonalities between intervention strategies and underlying frameworks as we move forward to address household resource consumption in an interconnected way. Specifically, we asked: What intervention studies exist within the literature that study food, energy, and water resources, both individually and through a nexus approach? What common strategies exist for targeting food, energy, and water conservation in household interventions? What tools might facilitate the development of more comprehensive household FEW nexus studies? We argued that more careful attention to FEW interconnections will advance household consumption research initiatives. Additionally, our understanding moves past individual consumer decision-making to consider structural constraints to behavior change, while drawing attention to how researchers are incorporating these barriers into existing intervention science.

### 1.1. Determinants of Household Consumption Behavior

Steg and Vlek (2009) provided a comprehensive review of pro-environmental behavior (PEB) determinants and argued for a systematic approach to future studies [13]. The review approached PEB through an environmental psychology framework and identified five factors that account for these behaviors: perceived costs and benefits, moral and normative concerns, affect, contextual factors, and habits. Within this framework, the consumer operates as a result of either individual motivation or habit. This structure helps link theory to behavioral determinants targeted in intervention studies.

Understandings of how perceived costs and benefits lead to action stem mainly from the Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB) [14,15]. Kollmuss and Agyeman (2002) comprehensively reviewed theories on pro-environmental behavior, identifying TRA and TPB as the earliest theories to dispute that there is a direct link between knowledge or attitude and behavior, identifying intention as a mediator: “intentions are not only influenced by attitudes but also by social (‘normative’) pressures” [16] (p. 242). Both theories, however, maintain that the individual makes choices rationally through the weighing of reasoned costs and benefits.

Moral and normative concerns, as outlined by Steg and Vlek (2009), focus on values, the role of environmental concern, and moral obligation to engage in PEB [13]. Value-based theories argue that hedonistic, egoistic, altruistic, and biospheric values contribute to pro-environmental [17]. Environmental concern is most commonly measured by the now widely used New Ecological Paradigm (NEP) scale [18,19]. Steg and Vlek (2009) also referred to Schwartz’s (1977) Norm Activation Model (NAM) and the influence of social norms on behavior [20,21]. Theories, including the value-belief-norm theory (VBN) and value-identity-personal norm theory (VIN), bring together these understandings to explain that values may be mediated by other variables, such as beliefs, identity, and personal norms [22]. The final individual behavioral determinant, affect and symbolic motives, is less represented in the literature, and Steg and Vlek (2009) reported that previous studies often relate these variables to car purchase and use [23,24].

Moving past individual motivation-focused behavioral determinants, Steg and Vlek pointed to the importance of understanding contextual and habitual factors for engaging in PEB. Contextual factors are notably not included within the widely used theories outlined above. Political and economic elements, such as “physical infrastructure, technical facilities, the availability of products, and product characteristics” may either directly affect behavior or contribute to attitudes and motivations [13] (p. 312). Recent trends in FEW intervention studies have increased attention to material and technological factors—for example, Devaney and Davies (2017) provided participants in a food sustainability study with tools, including food growing kits, organic food boxes, and fridge triage boxes, as part of a comprehensive intervention package that holistically addresses sustainable food consumption, storage, preparation, and waste [25].

Finally, understanding habit as a behavioral determinant goes beyond previous understandings that focus heavily on consumer reason and rationality in decision-making. Steg and Vlek described habitual behavior as “guided by automated cognitive processes, rather than being preceded by elaborate reasoning” [13] (p. 312). They pointed to Aarts and Dijksterhuis’ (2000) response-frequency measure of general habit strength as a promising methodological way forward [26]. Social practice theory provides an alternative theoretical framework for understanding household consumption, understanding routine household life as comprised of practices that are socially, habitually, and contextually constituted (such as preparing food, bathing, and doing laundry) [27]. Hargreaves (2011) explained, “social practice theory de-centres individuals from analyses, and turns attention instead towards the social and collective organization of practices — broad cultural entities that shape individuals’ perceptions, interpretations and actions within the world” [28] (p. 79). Similarly, Røpke (2009) argued that practice theory might illuminate otherwise hidden or taken for granted aspects of consumption by understanding the consumer as a “practitioner” [29].

## 1.2. Characterizing and Evaluating Behavioral Interventions

Researchers have dealt with the complexity of implementing and advancing behavioral interventions in the social sciences by defining and characterizing intervention techniques. Our proposed typology is informed by previous work in intervention classification, particularly research efforts aimed at health and energy behaviors. Geller et al. (1990) provided a conceptual framework for health interventions, highlighting a taxonomy of 24 types of defined interventions [30]. This taxonomy provides a starting point for understanding the scope and contents of previously tested behavioral change interventions in the context of injury control. Researchers have since worked to build upon this foundation and apply this framework to other areas of intervention research, including resource consumption and pro-environmental behavior. The taxonomy organizes behavior change techniques into three categories: communication/education, activators, and consequences. Communication and education interventions include passive strategies (lectures and demonstrations) and active strategies (commitments and discussions). Activators include goals, competitions, or incentives targeted at an individual or group, occurring before the target behavior. Consequences occur after the target behavior, including feedback, rewards, or penalties. Each intervention type was evaluated based on seven characteristics: involvement, social support, response information, extrinsic control, immediate effects, intrinsic control, and long-term effects. Despite developing a comprehensive means of evaluating intervention studies, the paper noted that “it is extremely difficult to make comparisons across different behaviors and environmental contexts” (p. 134). More recently in health research, Michie et al. (2013) identified replication, implementation, evidence synthesis, and identifying active components as necessary information to include in health intervention study publications to enable knowledge creation and increased intervention efficacy [31].

Abrahamse, Steg, Vlek, and Rothengatter (2005) reviewed household energy conservation intervention studies to characterize and assess intervention efficacy [32]. Following Geller et al.’s taxonomy, they classified interventions as either employing antecedent or consequence strategies. Antecedent strategies influence behavioral determinants before the behavior is performed in the household, while consequence interventions seek to influence behavior through known positive and negative consequences. The review found that antecedent strategies’ effectiveness differed based on the specific type of intervention employed. Information, for example, tends to influence knowledge or attitude without a concrete link to behavior. By providing examples of targeted behaviors, modeling results in both increased knowledge and energy use reductions. As for consequence strategies, the review found both feedback and rewards to be relatively successful for decreasing household energy consumption, with rewards resulting in notably short-lived behavior change. Additionally, the Steg and Vlek reviewed that outlines PEB determinants divide interventions into informational strategies (information, persuasion, social support and role models, public participation) and structural strategies (availability of products and services, legal regulation, financial strategies) [13]. Our typology synthesizes and builds upon these classifications following recent developments in the field while focusing specifically on food, energy, and water resource consumption.

## 2. Methods

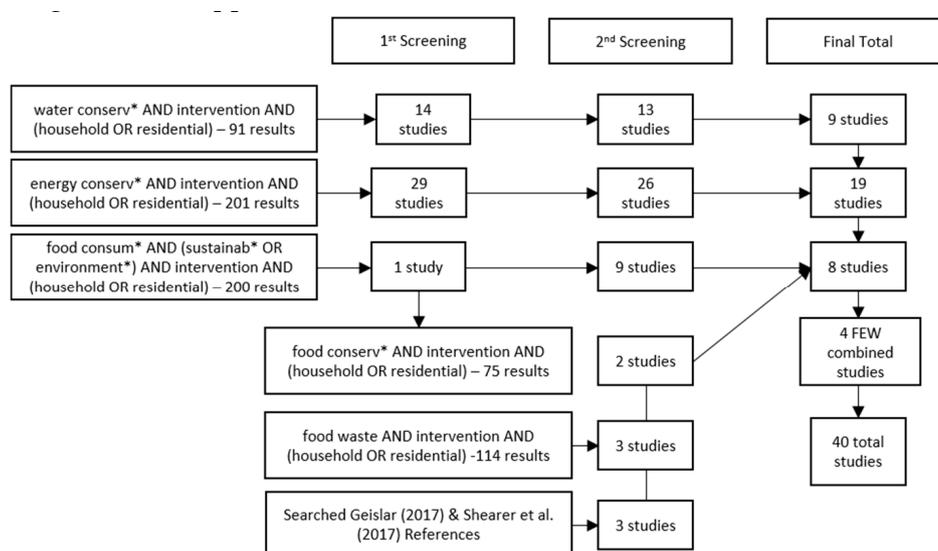
### 2.1. Article Selection Procedure

We selected articles for review to create a typology from the Web of Science database. Search queries used include: water conserv\* AND intervention AND (household OR residential); energy conserv\* AND intervention AND (household OR residential); food consum\* AND (sustainab\* OR environment\*) AND intervention AND (household OR residential); food conserv\* AND intervention AND (household OR residential); food waste AND intervention AND (household OR residential).

For further review, papers had to be full-text and published since 1990 in peer-reviewed journals available in English. We conducted the search in fall 2018. Each article had to focus on a behavioral intervention study with experimental or quasi-experimental design, including a treatment and control

or comparison group. Each intervention had to focus on food, energy, or water consumption, or some combination of the three, and take place in the household. We excluded interventions that focused on other climate mitigation or adaptation behaviors, such as flood preparedness, water quality testing, or agricultural studies. Intervention studies that took place in dormitories, office buildings, or other similar settings were excluded, as motivations for behavior change may differ between settings [33,34]. After papers were determined to meet inclusion criteria based on their abstract, they were read fully and screened again.

We initially located six hundred and eighty-one studies via search and selected forty-nine after the first screening. Out of these studies, we selected forty for review based on the outlined criteria. We identified additional studies for food resources from reference lists of other included papers. The majority of the forty studies focused on energy ( $n = 19$ ), while eight centered on food, nine on water, and four looked at combined food, energy, and water or food and energy consumption. This process is outlined in Figure 1. See Appendix A for the full list of studies.



**Figure 1.** Paper selection methodology for typology review. FEW: food-energy-water.

## 2.2. Generating the Typology

We coded the articles that met the above inclusion criteria for: study design, dependent variable, sample size, target behaviors, intervention duration, study results, self-reported or objective data collection, country/geographical area of intervention study, guiding theories (if identified), mode of intervention delivery, and departments or disciplines of authors. We recorded this information for each paper and created the typology iteratively by analyzing and comparing the study design, intervention techniques, and guiding theories referenced.

Collier, LaPorte, and Seawright’s guidelines for “putting typologies to work” informed our processes. Specifically, we built the typology with attention to the ‘building blocks’ they propose: an overarching concept measured by the typology, row and column variables that articulate multiple dimensions of the main concept, a matrix component to “better organize the typology, tighten its coherence, and think through relations among different components”, and distinct cell types within the matrix [35] (p. 223).

## 3. An Updated Typology for FEW Behavior Interventions

Table 1 illustrates our proposed typology for FEW behavioral interventions. FEW behavioral interventions act as an overarching concept that the typology seeks to organize and synthesize. As described earlier in the paper, this concept advances past typologies and review papers by stressing the significance of the food, energy, and water nexus in household resource consumption

science. The row variables are passive, active, or structural interventions. The distinction between passive and active builds on a characterization proposed by Geller et al. (1990) but applies here to intervention strategies outside of just communication [30]. The added dimension of “structural context” interventions blurs boundaries between active and passive to classify studies that view the household less as a standalone actor and more as a unit within a complex structural system that makes decisions within the context of broader regulatory, political, and social networks. The column variables distinguish between household-specific and non-specific interventions. This added dimension places emphasis on a more recent trend in intervention research that tailors treatments to the individual household. We saw this in information tailored specifically to a household’s resource use, strategies that pinpoint specific actions that members of a household can take to reduce consumption, or material and technology provision that considers what a particular household might need to reduce the resources consumed through routine practices. The arrangement of these row and column variables in a matrix illuminates the relationships between the intervention strategies highlighted within each cell type.

**Table 1.** FEW (food-energy-water) behavioral interventions typology.

		Household Non-Specific	Household Specific
FEW Behavior Interventions	Passive	Information	Tailored Information
	Active	Gamification	Action
	Structural Context	Policy/Price Change	Material/Tech Provision

### 3.1. Justification for a New Typology

The proposed typology builds on the existing behavior change intervention syntheses described above and adds new dimensions based on a review of current intervention studies. While some scholars have regarded typologies as unsophisticated or less rigorous than quantitative analysis, Collier et al. argued that within a defined framework, the typological analysis could be both creative and rigorous. They pointed to the usefulness of typologies for organizing theory and concepts, specifically when there is a need for the synthesis of complex traditions of analysis [35]. The paper also asserted that the concepts typologies seek to organize may change and evolve. Our proposed typology aims to synthesize developments in intervention theory and practice across multiple disciplines.

### 3.2. Information

We described information-based interventions as participant passive and household non-specific. Within information interventions, households often receive generalized information, not specific to their own household or resource use, including information about how to engage in a behavior (instructions, infographics), information about why they should engage in a behavior (behavior-environment link, environmental consequences, costs), or visual prompts or nudges to engage in a desired behavior. This category is distinct from what we deem tailored information, where personalized information is provided based on features of a household or its past behavior. In the information category, providing information is intended to increase knowledge about the environmental impacts of resource overuse, or knowledge about how households can curb usage [36]. Abrahamse et al. pointed out findings by Geller (1981), where information provision generally results in increased knowledge, but not behavioral change or energy savings [37].

The ‘information deficit model’ assumes that imparting knowledge about the consequences unsustainable actions or consumption will alter attitudes, leading to changes in behavior [38]. Testing this model with regards to energy consumption, however, has repeatedly found that while providing information may lead to some changes in attitude, this rarely translates to behavioral change [30,39]. Owens and Driffill pointed to the criticism this model has received in academic work “both on epistemic grounds . . . and for its failure to take account of the social, cultural, and institutional contexts in which attitudes and behaviours are formed” [40] (p. 4413). More recent resource consumption research expresses an awareness of the limitations of this approach, testing additional theoretical

considerations that may better predict behavior change. In a literature review of intervention techniques, Thondhlana and Kua (2016) pointed to the importance of combining non-tailored information with other intervention strategies, including tailored information or feedback about individual energy usage to affect behavior change [41].

### 3.3. Tailored Information

Like information strategies, tailored information is a participant passive approach, but is household-specific in its content and delivery. Tailored information considers the specific household or individual by customizing or tailoring information, often through real-time feedback, individual comparison, or social comparison. Real-time feedback has become increasingly popular, featuring smart technology that continually observes consumption patterns and reports usage.

In contrast to solely providing information to fill a void, researchers often point to the necessity of creating meaningful ways of implementing feedback approaches in the household. Norms have been found to predict other pro-environmental behaviors, including recycling [21,42,43]. Hargreaves et al. (2010) considered the importance of social and cultural norms that affect household energy use: "Rather than being a neutral form of information provision, therefore, feedback on energy use acquires meaning through the discursive, interpretive lens of each household's cultural practices" [39] (p. 6112).

### 3.4. Gamification

From the two forms of information to gamification, there is a shift from passive strategies to active participant interventions. While gamification does not have one standard definition within the literature, in the context of behavior change, it refers to the incorporation of game-based elements into an intervention setting. While gamification aligns with action and experiential learning, its focus on competition and virtual learning distinguishes the category, as well as the fact that it is typically not tailored to an individual household. Gaming in the sphere of resource consumption research is relatively new and rapidly expanding. Before the emergence of video games in energy research, however, reward-based interventions have been found to reduce energy consumption, particularly in the short-term.

Ro et al. (2017) explained that gamification interventions could incorporate the elements of task absorption (or a "state of flow"), competition, normative influence, social diffusion, concrete information, habit formation, and choice [44]. They noted that reward-based interventions might not result in lasting behavior change, as participants focus on an incentive or prize rather than interest in performing a behavior in the long run. The authors recommended, however, only offering relatively small rewards as one solution. Social diffusion refers to how ideas and behaviors are reproduced by example within a community. Social diffusion is essential to the realm of household consumption, as practices performed inside the home are otherwise private.

Despite the more recent popularity of digital gaming, Seaborn and Fels pointed to the historical significance of games, as they "are firmly entrenched in human culture, continuing to influence our social and leisure lives on a scale unprecedented and yet historically anticipated" [45] (p. 14). Seaborn and Fels reviewed gamification as a behavior change tool, understanding it as the incorporation of game elements and mechanics into intervention strategies. The paper pointed to a wide variety of theoretical foundations for game-based interventions, including but not limited to self-determination theory, intrinsic and extrinsic motivation, and situational relevance.

### 3.5. Action

Action-based interventions require an individual or household to take part in an activity designed to teach a behavior, form a habit, reflect on old behaviors, or strategically plan new ones. These interventions are typically participant active and household-specific and stem from work in social psychology and experiential learning. Examples of action interventions include goal setting and

personal pledges, peer support groups, self-monitoring with reflective writing, and rehearsal of target behaviors.

Action interventions like reflective writing and personal pledges have roots in self-affirmation theory. Walter, Demetriades, and Murphy (2017) argued for the use of self-affirmation through reflective writing in environmental behavior interventions, as individuals can assert self-value activities that remind them of their values and how “good they are” [46] (p. 1162). Behavior rehearsal is an intervention technique stemming from social cognitive theory and self-efficacy. Boudet et al. (2016) used action-based interventions, including behavioral reversal, to promote behavior change by increasing participant confidence in their capacity to perform a targeted behavior and yield the intended result [47]. Action interventions can also take place in a group setting, such as peer support groups. Staats, Harland, and Wilke (2004) argued the importance of a supportive social environment to environmental behavior change, citing evidence for the effectiveness of discussion groups and other face-to-face interactions [48]. While interventions in group environments may target norms in a similar way to tailored feedback, the act of discussing pros, cons, or barriers to enacting a behavior may have additional benefits.

### 3.6. Structural Barriers: Price/Policy and Material/Technological Interventions

Abrahamse et al. (2005) explained that interventions might target voluntary behavior change, or instead, towards addressing structural barriers that constrain household decision-makers [32]. We defined structural barriers as those that require a more material change than social context: technological, material, or regulatory changes may be necessary to facilitate behavior change in specific contexts. Within structural interventions, we distinguished between household non-specific strategies that address policy and price and household-specific strategies that target materials and technology.

Based on a review of household energy conservation interventions, Abrahamse et al. pointed to the overwhelming push towards voluntary behavior change as opposed to structural changes within energy consumption research [32]. Over a decade later, while research into changing macro-level resource consumption factors has progressed, most FEW intervention research also focuses on voluntary individual behavior change. As explained by Thondhlana and Kua (2016), “People’s engagement in energy saving behavior may be influenced by their ability. For example, it may be difficult for people to change their behavior if they have to buy expensive energy-saving technology as part of the energy-saving programmes, or if alternative energy-saving options are not available for feasible” [41] (p. 328). Isenhour (2010) found that despite values, attitudes, and beliefs, Swedes faced barriers to sustainable lifestyles that were economic, political, and social [49]. Addressing these structural constraints extends the discussion about consumption past the individual consumer and takes into account the market and social factors to household sustainability transitions. Røpke (2009) pointed to technology as a key motivator or barrier to practices, as “recent development of materials and equipment has reduced the need for traditional skills and enabled new groups of practitioners to perform tasks that were previously too demanding, thus illustrating that the boundary between the elements of material and competence is fluid and subject to change” [29] (p. 2494). Adding a structural dimension makes our typology innovative by linking the concepts of agency and structure within the context of household decision-making.

## 4. Insights from Reviewed FEW Interventions

Out of the 40 studies reviewed, non-tailored information and tailored information were by far the most commonly used intervention techniques in food, energy, and water studies, most studies using both strategies. While researchers applied non-tailored information and tailored information strategies in 83% and 75% of studies, respectively, they utilized action, gamification, and changing contexts in 20%, 5%, and 25% of studies. Gamification is an emerging intervention technique in resource consumption and behavior research; however, only two out of the 40 studies reviewed to generate this typology used the method.

Speaking to the complexity of intervention studies referenced by Geller et al. (1990) and Abrahamse et al. (2005), it is important to note that 75% of studies reviewed used at least two intervention types, with 25% of studies utilizing three or more [30,32]. While a combination of intervention strategies is likely to improve behavior change results, from a research perspective, these combinations contribute to difficulty isolating the specific effects of each approach. Less than half of the studies reviewed provided effect sizes for intervention results, making a meta-analysis unfeasible.

#### 4.1. Food

We identified eight studies that tested interventions for sustainable food consumption or food waste behaviors. Focus on a wide variety of structural constraints throughout the interventions is notable and makes sense as linking food to climate impacts is a more recent development in environmental behavior literature.

Bernstad (2014) measured the effects of interventions on household food waste separation behavior, testing the impacts of providing written information and the installation of food separation equipment [50]. While providing non-tailored information alone (one condition) to study participants did not result in significant changes, installing food sorting equipment in households increased the amount of separately collected food waste and the source-separation ratio. These results illustrate the importance of convenience to changing behavior in the household, as addressing structural constraints, such as the ability to separate food waste, had the greatest success. Results also showed that increasing convenience had long-term effects compared to information provision. Geislar (2017) also found that reducing barriers to recycling food waste by providing curbside carts and collection had significant positive results, but additionally, communicating social norms of food separation led to longer-lasting behavior change [51].

Holistically addressing sustainable food consumption, storage, preparation, and waste, Devaney and Davies (2017) illustrated the success of combining a variety of intervention types in changing householder behaviors [25]. In efforts to support more sustainable eating practices in the home, the study provided participants with structural tools, including food growing kits, organic food boxes, and fridge triage boxes, both tailored and non-tailored informational tools like carbon footprint graphs and portion control guides, and action-based components, including a visit from a chef to inspire meal planning. Results showed that participant food waste overall decreased by 28%, with noted self-reported shifts towards sustainable food purchasing, preparation, and storage. Devaney and Davies concluded, "Findings reinforce calls to connect, combine, and align product, regulatory, informational and motivational supports across the interdependent practices of eating (acquisition, storage and preparation, and waste recovery) to optimize transitions toward sustainability" (p. 823).

The additional five studies used tailored and non-tailored information interventions to target food waste behaviors. A study comparing written and oral non-tailored information provision showed a higher source-separation ratio and a lower ratio of incorrectly sorted material in the group that received oral information, but the effects notably decreased over time [52]. Shearer, Gatersleben, Morse, Smyth, and Hunt (2017) found sticker prompts effective in increasing food waste separation, but it is important to note that infrastructure in the study area (England) was already equipped to collect curbside food waste separately [53]. Schmidt (2016) found that providing tailored recommendations to decrease food waste (for example: avoiding impulsive purchases or immediate discarding of expired but still edible food) improved self-reported behaviors, but the improvement was also observed pre and post-test in the control group [54]. One selected intervention in a paper by Rohm et al. (2017) tested the effects of providing informational brochures and fridge magnets on consumer acceptance of "suboptimal" foods, and did not find any observable effects, but noted that respondents who said they visited an attached website with food waste information self-reported increased effects of both the brochure and magnet [55]. Finally, Nomura, John, and Cotterill (2011) found tailored information in the form of group feedback on recycling behavior to have a positive effect on food waste recycling, with an effect size of 2.8% compared to a control group [56]. The group feedback was presented at

the street level compared to the neighborhood average, and interestingly, the shorter the street was, the more effective the feedback.

In the food intervention studies reviewed, information-based interventions were best suited for participants that already have the structural tools to collect and sort food waste, including designated bins and curbside collection. Only one study sought to impact more than food waste and included sustainable food consumption in targeted behaviors.

#### 4.2. Energy

While tailored information interventions appeared most frequently in the nineteen reviewed studies, research in the energy consumption sphere often utilizes a wide variety of intervention techniques to affect behavior change. Digital home energy monitors were used in five studies (26%) and decreased energy usage in three. Fan, Macgill, and Sproul (2016) found that homes with energy monitors consumed 12.8% less energy than those without, and Grønhøj and Thøgersen (2011) saw an average electricity savings of 8.1% in their treatment group [57,58]. Jessoe and Rapson (2014) used home energy monitors in combination with pricing events, a structural intervention, and found that energy prices became more meaningful when researchers also provided non-price information to participants [59]. Nilsson et al. (2014), however, found no significant effects from the home energy monitors, and van Dam, Bakker, and van Hal (2010) measured the usage of participants who decided to keep their energy monitors after a four-month trial period, finding no sustained energy-saving effects over time [60,61].

Another method of tailored information is social or normative messaging and feedback. Two studies evaluated data from OPOWER Home Energy Report letters that compare homeowner electricity use with that of their neighbors [62,63]. The 2011 paper found an average 2% electricity consumption reduction, with households in the highest deciles of pretreatment consumption averaging more considerable savings. The 2014 report, however, investigated the persistence of effects post-treatment, finding immediate energy savings, relatively quick “backsliding” to pre-treatment levels after the intervention, and increased persistence of intervention effectiveness over long periods. Schultz, Nolan, Cialdini, Goldstein, and Griskevicius (2007) also observed backsliding in response to normative messaging interventions (what they term the ‘boomerang effect’) but found that adding messaging conveying social approval or disapproval neutralized this effect [64]. Harries, Rettie, Studley, Burchell, and Chambers (2013) found that adding social norms information to other forms of electricity feedback increased consumer engagement with the feedback, but ultimately did not reduce energy consumption [65]. Mizobuchi and Takeuchi (2013) found that financial incentives are more successful when combined with normative feedback [66]. Schultz, Estrada, Schmitt, Sokoloski, and Silva-Send (2015) tested a variety of feedback types using in-home electricity displays, finding normative framing to result in greater reductions than simple informational feedback or cost-framed feedback [67].

Testing more than just feedback, Pellerano, Price, Puller, and Sánchez (2017) tested normative messaging along with extrinsic financial incentives on residential electricity consumption, finding that these incentives did not increase the strength of normative messages [68]. In another cost-based intervention, McCoy and Lyons (2017) provided consumers with exposure to time-of-use tariffs, finding that this group of households did reduce overall and peak electricity consumption, but ended up reducing investments in other household energy efficiency measures [69].

Examining a more recent realm of energy research, Ro et al. (2017) tested a game-based intervention [44]. They found reductions in household resource consumption up to six months after the game, with the most considerable reductions in the high-energy consumption group. Sudarshan (2017) also used a competition-based intervention in India, where one group of participants received monetary rewards based on the difference between their electricity consumption and the peer average [70]. In this study, weekly normative feedback was successful at reducing energy consumption but was no longer effective when combined with rewards.

In the realm of energy interventions, feedback is a useful tool for reducing consumption, but the way it is framed and delivered has implications for intervention success. While digital home energy monitors can work to reduce consumption, the type of feedback they provide to consumers must be purposeful and persistent. Games for sustainability behavior show promise, but only one study used this approach and found significant results. While these studies seek to change energy consumption, they are only able to observe energy as electricity consumption, unable to account for the embedded energy in food and water resource use.

#### 4.3. Water

While all water-focused studies included an information provision aspect, two studies also used action-based interventions. Walter et al. (2017) tested the effects of self-affirmation on self-reported water conservation behaviors [46]. Participants receiving the self-affirmation condition completed a reflective writing activity about implementing values in their daily life, while the non-affirmation condition received information about droughts in California, the location of the study. Results showed that those who engaged in self-affirmation had higher self-reported water conservation scores that endured for a month post-treatment. In the second study with an action component, Tijs et al. (2017) aimed to decrease water consumption through changing showering habits [71]. The study had all participants engage with an activity booklet (including action items, such as goal-setting and self-persuasion) over two weeks, but one condition received monetary information appeals, while the other received environmental information appeals. Based on self-reported information about shower length and frequency, the study found those in the environmental appeals group to reduce participant showering frequency, with no change in the monetary appeals group. While this study sheds some light onto the effectiveness of different types of intervention provision, the lack of control group leaves questions about the effectiveness of the action-based intervention components.

The remaining seven studies all included the provision of tailored information, with four out of the seven including a non-tailored information aspect. Glenn, Endter-Wada, Kjelgren, and Neale (2015) sought to reduce landscape water usage at the household level through specifically tailored information: each household received a professional water check, including an evaluation of their sprinkler system and landscape, site-specific irrigation schedules, and tailored recommendations on conservation [72]. While the majority of participants who implemented recommendations made by the water check successfully conserved water, those who did not adopt the recommendations cited “time constraints, cost of implementing recommendations, lack of motivation, personal physical impediments of age or disability, and physical limitations of their sprinkler systems” (p. 87). The study found that while tailored information could be effective in reducing landscape water use, interventions should address contextual factors.

Two studies utilized visual display systems to present tailored information about water usage to participants. Davies, Doolan, van den Honert, and Shi (2014) found in-home displays effective (average reduction of 6.8% during the study period compared to the control group), with effects that endured over time [73]. Stewart, Willis, Panuwatwanich, and Sahin (2013) used a visual display and alarm specific to showering and found a 27% mean reduction in shower volumes initially after display installation, but the effects did not last over time and reverted to pre-study levels after four months [74].

Fielding et al. (2013) implemented three combinations of information provision: non-tailored information alone, non-tailored information with the addition of descriptive norms delivered via postcard, and non-tailored information combined with tailored end-user feedback (via postcard) [75]. Compared to the control group, all three conditions reduced water consumption (with an average reduction of 11.3 Liters per person per day). The effects of all conditions, however, dissipated within one year of implementation. Liu et al. also provided water end-use data via paper report, and while they did not find a statistically significant difference between intervention and control groups, 38% of households in the intervention group self-reported intention to conserve water [76]. Schultz et al. (2016) and Seyranian, Sinatra, and Polikoff (2015) both tested a combination of non-tailored information

provision and varying types of normative feedback, each finding that providing normative information reduced water consumption [77,78]. While Seyranian et al. found that participants who had higher water consumption at baseline responded better to a social norm intervention than general information provision, Schultz et al. found that participants with already strong personal norms surrounding water consumption showed less of a change than those with low personal norms when provided with normative messages.

In the two studies with action components, action interventions, such as reflective self-affirmation writing and goal-setting, were effective for reducing water consumption. Feedback, including visual home displays, was also effective, but the persistence of effects varied across studies. It is important to note that geography played a role in researchers' decisions about where to study water consumption behaviors. Of the four studies conducted in the United States, three took place in California and one in Utah, all areas that are subject to frequent droughts. Of the five studies conducted outside of the US, four were in Australia and one in the Netherlands. Fielding et al. (2013) noted that the study area in Australia had recently experienced their worst documented drought on record [75]. Here, researchers must consider local environmental and policy contexts, crafting interventions specific to the study population.

#### 4.4. Combined Resource Interventions

Four interventions measured consumption in more than one resource category. Abrahamse et al. (2007) sought to affect energy consumption, but unlike many other energy studies, was able to look at indirect energy use embedded in household resource consumption [36]. Tailored information, goal setting, and feedback strategies found savings in the direct energy consumption, but no difference in indirect energy savings compared to a control group. Households in the intervention groups, however, exhibited increased knowledge about resource conservation compared to a control group. Kurz, Donaghue, and Walker (2005) studied water and energy consumption through information provision and social comparative feedback, neither producing significant results for either resource category [79]. This study had unique results, as the only intervention with significant positive effects was appliance labels, which led to a 23% reduction in water consumption.

The following two studies took novel approaches, seeking to create holistic packages of interventions to change resource consumption behavior. Staats et al. (2004) tested the EcoTeam Program intervention package, finding improvements on a wide range of household environmental behaviors that persisted two years post-study [48]. Boudet et al. (2016) tested child-focused interventions targeting household energy and food-and-transport behaviors, finding positive results in both categories [47]. Both studies employed a variety of theory-based intervention techniques ranging across typology categories and targeted a wide range of household environmental behaviors spanning multiple resources.

## 5. Discussion

The review resulted in four key takeaways about interventions utilized in FEW studies. Without effect sizes and additional quantitative data reporting, we could not directly compare intervention strategies but could identify trends in the literature.

First, studies typically used household non-specific (or non-tailored) information in conjunction with household-specific (tailored) information/feedback, and this strategy showed promising results. For example, Bernstad et al. (2013) only used general information in a door-stepping campaign, which was ineffective in changing food waste behaviors [52]. We saw one exception to this trend in Kurz et al. (2005), where tailored information was ineffective, but appliance stickers led to a 23% reduction in water consumption [79]. This result might be because of the persistent, visible nudging offered by the stickers that became a part of water-intensive practices.

Second, feedback is most effective when persistently provided to participants. In the Nomura et al. (2011) study, the first feedback card had no significant effect, and the authors concluded that the cumulative effect of two feedback cards ultimately changed food waste behavior [56]. Studies with

home energy monitors that displayed continuous feedback, including Fan et al. (2015), had promising results [57].

Third, providing pricing information or changing pricing structures through incentives was often ineffective. Pellerano et al. (2017) provided an example that warrants further study: adding economic incentives to normative messaging not only did not increase the efficacy of the messaging but might have reduced it [68]. Sudarshan (2017) offered similar results, as the nudge treatment group no longer reduced consumption with the addition of incentives [70]. Jessoe and Rapson had success with providing price information, but they concluded that it was more meaningful when interventions also provided non-price information to participants [59].

Finally, providing materials or technology that facilitate behavior change worked 100% of the time, but only three studies used this strategy. While providing information was ineffective in Bernstad's (2014) study, installing food waste sorting equipment in households sparked behavior change with long-lasting results [50]. Devany and Davies saw food waste decreased by 28% with their holistic intervention package that included providing items like fridge triage boxes and kitchen caddies to assist with food waste separation [25]. Gieslar (2017) explicitly concluded, "Findings support that residents will begin to separate food waste if provided supportive infrastructure" [51] (p. 577). One additional study (Shearer et al. 2017) pointed to the importance of material infrastructure for resource consumption behavior, as their sticker program led to increased inquiries about food waste recycling caddies in the community [53].

Across the FEW resource domains, household studies used various environmental behavior theories to guide their inquiries and design interventions. While each typology category might be implemented through multiple guiding theories, links were apparent between theory and practice in many intervention studies. Notably, messaging interventions using household-specific information are often guided by value and norm-based theories, including the norm activation model (NAM) and value belief norm (VBN) theory. Interventions that provided materials or technology, like Devany and Davies (2017) [25], cited social practice theory as central to their approach. Future research might further explore how theories of environmental behavior link to each category in our typology of intervention strategies.

### *5.1. Acknowledging the Limits of Household Consumption*

As this review and typology explicitly focused on household-level consumption, it is appropriate to consider the limits of this approach. Lorenzen (2018) pointed out that consumers are often "locked-in" at the technological, organizational, industrial, institutional, and societal levels, leaving only so much room for long-term voluntary behavior change [80]. Other scholars pointed to the many factors at play guiding consumption decisions that extend beyond personal attitudes and values, including political leadership, market forces, and social power structures [49,81]. While aiming to change household behavior can potentially reduce greenhouse gas emissions, researchers must not lose sight of other mitigation tactics that target government actors and transnational corporations.

### *5.2. Bridging Gaps between Disciplines*

Organization of intervention techniques into typologies can ultimately facilitate more cross-disciplinary work, as terminology is explicitly defined. Interventions designed by interdisciplinary teams may be more holistic, comprehensive, and draw from a broader range of theories surrounding resource consumption and environmental behavior, contributing to novel approaches to these complex problems. Boudet et al. (2016) is one example of an intervention study we reviewed in this paper that brought together researchers from a variety of disciplines, including public policy, education, environmental studies, and medicine [47]. The study approached intervention design through social cognitive theory, a framework the researchers describe as notably being used in public health experiments but less utilized in environmental behavior research, contributing a novel approach and advancing our understanding of household consumption behavior.

Scholars in the past two decades have done a great deal of writing on the challenges of interdisciplinary research, including language barriers, publication struggles, and disciplinary expectations [82–84]. In a review of FEW nexus studies, Albrecht, Crootof, and Scott (2018) found, “many nexus methods are confined to disciplinary silos—only about one-quarter combine methods from diverse disciplines and less than one-fifth utilize both quantitative and qualitative approaches” [12] (p. 1). The nexus approach highlights seemingly endless complexities, making household interventions substantially more challenging to design and execute.

### *5.3. Addressing Spillover and Moving towards a Nexus Approach*

In response to our finding that very few studies focus on the multiple components of the FEW nexus, we urge researchers to pursue this novel approach to household resource consumption. As researchers acknowledge interconnections that give rise to the FEW nexus, future intervention research must look across resource domains to gain better understandings of the complex ways that households consume food, energy, and water. In a comprehensive review of FEW nexus studies, Newell et al. (2019) found social science-based studies underrepresented in the literature [85]. Bazilian et al. (2011) pointed to different vocabularies, competing priorities, institutional capabilities, and regulatory regimes between the three systems as drivers of poor communication and ultimately suboptimal decision-making [11]. A persisting problem in changing resource consumption behavior lies in the potential for “spillover” across resource categories [86]. Behavioral spillover occurs when an intervention changes additional behaviors that are not directly targeted [87]. Spillover can be both positive and negative, as Truelove et al. reviewed evidence of pro-environmental behaviors, both increasing and decreasing likelihood of performing an additional pro-environmental behavior [88]. From the perspective of FEW, a study by Tiefenbeck, Staake, Roth, and Sachs (2013) found that weekly feedback decreased household water usage during the intervention, but increased electricity consumption compared to a control group [89]. Monitoring only one resource domain will not capture changes or patterns developed within other domains. Designing interventions that consider the entirety of the FEW nexus can help address this issue while shedding light on the emerging dynamics of consumption spillover. Additionally, interventions that attempt to capture the intersections of food, energy, and water consumption behavior must address how to effectively communicate the indirect and embedded energy use to consumers.

Moving towards a true nexus approach means having the tools and resources to accurately track food, energy, and water use in the household. As researchers can collect and manage larger amounts of data, intervention strategies can grow increasingly specific to the individual household. Sensor technology has revolutionized the ways through which industry and researchers can track household electricity use with fine-grained data [90–93]. With the ability to model household energy use and the availability of big data, providing household-specific tailored information about energy use has become a promising avenue for energy research, but is still often cost-prohibitive and difficult to implement. Technology for water tracking is also advancing, with end-use water meters that can provide data on the frequency and duration of household water use and identify leaks and inefficiencies [94]. Tracking household food consumption presents a much greater challenge, with researchers developing complex and labor-intensive food data collection protocols [95]. Recent life-cycle analysis studies, however, provide promise for integrating food consumption data by estimating the impacts of various food items on greenhouse gas emissions [96].

### *5.4. Knowledge Accumulation*

Ultimately, through a wide variety of behavioral interventions, researchers hope to gain insights into the determinants of resource consumption behavior. Without systematic logging and tracking of study design and results, however, academics and practitioners will continue to face the same challenges of synthesizing the vast amount of existing information. Wynes et al. (2018) provided an example of a better way to understand impacts across studies by quantifying their greenhouse gas

emissions reductions [97]. Providing a weight in kilograms, of reduced carbon dioxide, goes a step further than effect sizes to measure intervention impacts. Wynes et al. found that most behavioral intervention studies they reviewed, however, were not suitable for quantifying emissions reductions. In a similar methodological problem, Albrecht et al. (2018) found that few nexus studies they reviewed (less than one third) used explicitly reproducible methods [12].

Logging the results of behavioral intervention studies on a publicly available database would advance accumulation of knowledge in the field. Studies like Wynes et al. (2018) would have a much larger pool of data to draw from when conducting quantitative analyses. Additionally, tracing unpublished interventions in the database may work to combat publication bias that favors positive results, much like the way clinical trials must be registered before they are completed [98].

### 5.5. *Crafting Purposeful Interventions*

Through the studies described above in the realm of food, energy, and water resource consumption, researchers often cite content and framing of intervention techniques as a primary factor responsible for the success or failure of an intervention. Nuanced intervention design must take context into account—researchers must continue to think critically about geography and sample, specific factors when designing household interventions. It is notable that water resource studies more frequently took place in locations that have previously experienced drought, presenting both a geographical need and potential participant motivation for increased conservation behaviors. Further, we cannot ignore economic and environmental inequalities: most interventions reviewed in this paper took place in economically developed countries. Researchers must use alternative considerations when studying developing economies and economies in transition, which is worth exploring in future research. We must also direct attention toward resource disparities by gender, race, and class within the context of any country under study. Ellegård and Palm (2015) further warned of confusing the individual with the household as a unit of analysis: “Individually tailored information is often discussed, but equally important are information and policy instruments targeting households’ and household members’ combined energy consumption patterns as they are derived from the activity sequences written in the individuals’ time-diaries” [99] (p. 7633).

To move intervention science forward with evolving theory, researchers should think through embedding interventions across typology categories within existing household practices. Beyond seeing immediate or even post-study behavior change results, we must address the policy implications and practicality of proposed interventions. Social practice theory provides one possible framework through which to consider embedding interventions within daily household practices. While providing information can provide initial learning experiences and begin to change social contexts through normative messaging, current research design often continues to lack structural and contextual focus. Action interventions can help to establish household practices, form habits, and create environmental identity. Practices that were previously difficult, or constrained, can change through structural interventions that affect local policy initiatives, like food waste collection or renewable energy assistance programs. Gamification can provide additional behavioral nudges that supplement information provision and provide a hands-on learning experience for participants in specific contexts. Within the proposed typology, the potential impacts of each intervention category are essential to consider in different geographical and political contexts.

## 6. Conclusions

To further advance the science of household resource consumption as a climate change mitigation strategy, interdisciplinary research that highlights the FEW nexus provides a promising approach. In this paper, we linked emerging FEW nexus research with household consumption and pro-environmental behavior literature through an innovative typology that accounts for both behavioral and structural intervention research.

In addition to the generation of a typology and key findings outlined in the discussion, our review highlighted the lack of studies that 1) address multiple FEW domains and 2) report effect sizes that allow comparison of intervention impacts across studies. Across the FEW domains, we saw different types of interventions used and varying results.

More food studies addressed structural constraints than another resource category. Here, information provision was more effective when households already had structural tools to collect and sort food waste. Household food studies more often targeted food waste than food purchasing and other consumer behaviors.

Energy studies showed that feedback was generally effective for reducing household energy use, but the way it was framed has implications for success. Digital home energy monitors were popular and effective, but the feedback they provided must be purposeful and persistent. Within these studies, the energy was typically observed as electricity use and did not consider embedded energy in another resource use.

Within water studies, action interventions were successful but were only present in two studies. Feedback was effective, but persistence varied across studies (many did not include follow-ups). Researchers considered the effects of structural barriers when interventions were not effective. We also noted that geography was framed as important for context (e.g., drought frequency).

Multi-resource studies used intervention “packages” that used multiple strategies and targeted multiple behaviors. These comprehensive intervention packages seem to be effective and warrant further study.

Eventually, the focus must shift to policy: how can effective interventions be successfully implemented and imitated in policy contexts? In the spirit of interdisciplinarity, FEW nexus researchers must connect with broader policy audiences to engage in coalition-building and the development of science-backed policies on local and national levels. Coordinating complex and holistic interventions outside of research settings will take coordination between and buy-in from a wide variety of stakeholders, including local governments, utility companies, and consumers. As the food, energy, and water systems interconnect across the globe, international cooperation and partnerships will also be essential to large-scale conservation efforts. The literature on the co-production of scientific knowledge and participatory research may help us overcome these hurdles [100,101]. With a focus on building and strengthening relationships across sectors, we might create conditions in which policy changes are possible.

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## Appendix A

Table A1 alphabetically lists the studies included in the typology by the first author. F/E/W refers to food, energy, and water studies. The fourth column lists if interventions were effective or not, without providing information about magnitude. If there was a positive treatment effect, the study was marked ‘yes’. If there was no treatment effect or a negative effect, studies were marked ‘no’. The fifth column lists notes that provide some context and help understand the characteristics of the results.

**Table A1.** Studies reviewed for the generation of FEW behavior intervention typologies.

Author/Year	F/E/W	Typology Category	Intervention Effective?	Notes
Abrahamse et al. 2007 [36]	E (FW indirect)	Info, T Info, Action	yes (all treatment conditions)	
Allcott and Rodgers 2014 [63]	E	Info, T Info	yes	Effects initially steep but level off over time
Allcott 2011 [62]	E	Info, T Info	yes	
Bernstad 2014 [50]	F	Info, Material	no (info), yes (material)	
Bernstad et al. 2013 [52]	F	Info	no	
Boudet et al. 2016 [47]	E/F	Info, T Info, Action	yes (for energy, no for food component)	More effective for children than parents
Davies et al. 2014 [73]	W	T Info	yes	Effects maintained over time
Devany and Davies 2017 [25]	F	Info, T Info, Action, Material	yes	Participant households reduced food waste by 28%, with additional behaviors: sustainable purchasing, storage, preparation, and waste recovery practices
Fan et al. 2015 [57]	E	T Info	yes	
Fielding et al. 2013 [75]	W	Info, T Info	yes	In all treatment groups, water use reduction, leveled-off, returning to baseline levels after approx. 12 months. Information provision alone was just as effective as other conditions
Gieslar 2017 [51]	F	Info, T Info, Material	yes	"Findings support that residents will begin to separate food waste if provided supportive infrastructure"
Glenn et al. 2015 [72]	W	T Info	yes	"Our finding suggests that water check programs can be effective in promoting water conservation when the information provided is tailored to meet participants' knowledge and skill levels"
Goodhew et al. 2015 [102]	E	Info, T Info	yes	
Grønhøj and Thøgersen 2011 [58]	E	T Info, Action	yes	
Harries et al. 2013 [65]	E	Info, T Info	no	
Iwafune et al. 2017 [103]	E	T Info	yes	
Jessoe and Rapson 2014 [59]	E	Info, T Info, Price	yes	Price info more meaningful when non-price information is provided
Kua and Wong 2012 [104]	E	Info, T Info, Action	yes	Face-to-face interaction had the highest correlation with action scores
Kurz et al. 2005 [79]	E/W	Info, T Info	yes (appliance labels for water); no (T info/energy)	Appliance labels led to 23% reduction in water consumption

Table A1. Cont.

Author/Year	F/E/W	Typology Category	Intervention Effective?	Notes
Liu et al. 2016 [76]	W	Info, T Info	no	While 38% of households reported changing their behavior, there were no measurable effects
McCoy and Lyons 2017 [69]	E	Info, T Info, Price	yes	Relative to control, treatment groups reduced energy use by 2.5% but were less likely to adopt energy-saving measures during the trial
Mizobuchi and Takeuchi 2013 [66]	E	Info, Price	yes	Households with high NEP (New Ecological Paradigm) score more likely to respond to the reward program and save electricity than those who do not
Nilsson et al. 2014 [60]	E	Info, T Info	no	
Nomura et al. 2011 [56]	F	Info, T Info	yes	The first card had no significant effect, and it was the cumulative effect of two feedback cards that had a significant impact on household participation in recycling food waste
Pellerano et al. 2017 [68]	E	Info, T Info, Price	yes (info, T info), no (price)	Addition of financial incentives did not significantly enhance conservation; Adding economic incentives to normative messages not only did not strengthen the effect of the latter but may reduce it
Ro et al. 2017 [44]	E	Game, Price	yes	
Rohm et al. 2017 [55]	F	Info	no	Brochures and magnets did not affect consumer attitudes; Respondents who had rec'd the magnet and brochure said the brochure influenced their actions
Schmidt 2016 [54]	F	T Info	yes	Specific behaviors: results indicated improvements regarding avoiding impulsive purchases/buying more food than currently necessary, avoiding discarding of excess food, and immediate discarding of expired (but possibly still edible) food
Schultz et al. 2007 [64]	E	T Info	yes	A descriptive normative message detailing avg. neighborhood usage produced either desirable energy savings or the undesirable boomerang effect, depending on whether households were already consuming at a high or low rate. Adding an injunctive message (conveying social approval or disapproval) eliminated the boomerang effect
Schultz et al. 2015 [67]	E	Info, T Info, Price	yes (normative message), no (simple feedback, info, price)	
Schultz et al. 2016 [77]	W	Info, T Info	yes	Residents with strong personal norms about reduced water consumption were less affected by the normative messages than were residents with low personal norms

Table A1. Cont.

Author/Year	F/E/W	Typology Category	Intervention Effective?	Notes
Seyranian et al. 2015 [78]	W	Info, T Info	yes	Higher water consumers at baseline who were exposed to social norms intervention used less water in the short term and long term compared to information only condition; three interventions were equal in magnitude
Shearer et al. 2017 [53]	F	Info	yes	There was a significant increase (20.74%) in the treatment group, and this change in behavior persisted in the longer term. Sticker prompts, therefore, appeared to have a significant and sustained impact on food waste recycling rates; sticker distribution sparked increase inquiries about recycling caddy
Staats et al. 2004 [48]	FEW	Info, T Info, Action	yes	Whole intervention package effective for 19/28 behaviors, maintained 2 years post-study
Stewart et al. 2013 [74]	W	T Info	yes	Water levels back to baseline in 4 months
Sudarshan 2017 [70]	E	Info, T Info, Game, Price	yes (nudge); no (price)	Nudge group reduced by 7%; when incentives were added, households no longer reduced consumption
Thondhlana and Kua 2016 [41]	E	Info, T Info	yes	Households who rec'd a combination of the treatment measures (Full Treatment group) recorded greater energy-savings than those who did not
Tijs et al. 2017 [71]	W	Info, Action	yes	Environmental appeal, but not the monetary appeal, effective in reducing showering frequency
Van dam et al. 2010 [61]	E	Info, T Info	no	
Walter et al. 2017 [46]	W	Info, Action	yes	

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