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RESEARCH ARTICLE

Public attitudes and preferences for green rooftop technologies in the US: a choice experiment

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Abstract

Green rooftops, also known as vegetated roofs, will play a critical role in enhancing the resilience of urban areas in the face of climate change and other contemporary environmental and social challenges. To ensure the optimal design and implementation of these green technologies, it is vital to understand the public's preferences, values, and attitudes toward the government support for green rooftops. This study employs contingent valuation methods, specifically utilizing a payment card and a choice experiment, to investigate these topics that have received inadequate exploration within the current body of literature. Our findings indicate that 45% of the public is aware of green rooftops, and the most desired features on an extensive green rooftop, ranked by importance, are: flowers, grass, trees, and walking paths. The majority (79%) of the public supports a federally proposed legislation currently under review (the Public School Green Rooftop Program) and has a mean willingness to pay of approximately $176 per household as a one-time payment. Additionally, the results show that individuals place a higher value on green rooftops that incorporate solar energy technology compared to those without. Furthermore, there is a perceived, loss of value when access to a green rooftop is limited, as opposed to having open access.

Keywords: choice experiment; green rooftops; public preferences; rooftop farm; stated preferences; urban sustainability

JEL Classification: Q1; Q4; Q5

Introduction

Redesigning urban areas and cities to be more sustainable will be a key change necessary to address the current climate crisis. Green rooftops (GRs)[1] can play a significant role in increasing the sustainability of urban areas. A GR, also known as a vegetated or living roof,

[1]From this point forward, we will refer to a green rooftop in the singular form as GR and in the plural form as GRs

is a layer of vegetation, such as grasses, herbs, and other plants, planted on top of a waterproof system on a flat roof. GRs fall into three main categories: *extensive, intensive,* and *semi-intensive.* These categories differ in the depth of the soil layer and the type and variety of plants that can be grown on them. Extensive GRs are characterized by a shallow soil layer (commonly six inches or less in depth) and are designed for a low-water use and low-maintenance, and feature hardy, drought-tolerant plants like grasses, succulents, and herbs. Additionally, extensive GRs are lighter in weight and hence require less structural support than other types, making them suitable for buildings with weight restrictions. In contrast, intensive GRs have a thicker growing medium (commonly 12 inches or more in depth) allowing for a wider variety of vegetation such as flowers, shrubs, trees, fruits, and vegetables. Intensive GRs require more water usage and labor intensity, and their heavier weight demands greater structural support. These intensive GRs are regularly used as recreational or green spaces for human use. Semi-intensive GRs serve as a combination of the extensive and intensive GRs in terms of soil layer thickness and variety of plants used (Raji et al. 2015).

GRs have a number of well-studied environmental benefits (Wong et al. 2003; Banting et al. 2005; Currie and Bass 2008; Yang et al. 2008; Bianchini and Hewage 2012; Raji et al. 2015; Kim et al. 2018) and community benefits (Bratman et al. 2012; Whittinghill and Rowe 2012; Lee et al. 2015) that make them essential tools in addressing highly complex environmental and social issues like climate change and food security. One of the more commonly cited benefits of GRs is the reduction in the amount of energy used to heat or cool a building. This energy reduction results in collective- and individual-level benefits, such as reduced air emissions and cost savings, respectively. From a collective benefits perspective, GRs provide additional insulation that decreases the amount of energy required to maintain a comfortable indoor temperature and lowers the associated emissions (Wong et al. 2003; Banting et al. 2005; Bianchini and Hewage 2012; Raji et al. 2015). At an individual level, if less energy is required to operate a building with a GR compared to a conventional black roof, then cost savings can be obtained by building owners (Wong et al. 2003; Banting et al. 2005; Bianchini and Hewage 2012; Raji et al. 2015). Another cost-saving opportunity at a building owner level stems from the ability of GRs to protect the roof membrane from ultraviolet radiation and extreme temperature fluctuations, extending the life of the roof by 100%, compared to conventional white[2] (Sproul et al. 2014) and black roofs (Harris 2009; Jelínková et al. 2016).

Second, GRs increase the total amount of vegetation in an area, therefore improving air quality by bolstering the absorption of pollutants through the photosynthesis process (Banting et al. 2005; Currie and Bass 2008; Yang et al. 2008; Bianchini and Hewage 2012; Li and Yeung 2014). The photosynthesis process sequesters carbon dioxide allowing GRs to serve as local carbon sinks (Banting et al. 2005; Getter et al. 2009; Bianchini and Hewage 2012). Furthermore, GRs help enhance the biodiversity in urban areas through habitat creation for a variety of insects, bird species, (Wang et al. 2022; Williams et al. 2014; Wooster et al. 2022), and pollinators. Habitat creation comes directly via the flowering plants that attract bees, butterflies, and other pollinators (Wang et al. 2022; Wooster et al. 2022), and indirectly through microclimate moderation, which is the regulation of temperature and humidity that helps create a more hospitable habitat for urban biodiversity (Mayrand and Philippe 2018). Additionally, GRs are well-known as an effective technology for alleviating the burden on stormwater management systems, reducing urban flooding and the associated damage to infrastructure from stormwater

[2]*A white roof utilizes white solar reflective paint to reflect radiation back into space, white roofs* stay cool and help promote cooler building interiors and reduce heat building up in cities.

runoff (Banting et al. 2005; Mentens et al. 2006; Stovin 2010; Li and Yeung 2014; Lee et al. 2015). GRs have the capacity to absorb 25% to 86% of the rainwater (Mentens, Raes, and Hermy 2006). Another benefit from increased vegetation on rooftops is the mitigation of the urban heat island effect, which is the phenomenon of higher temperatures in urban areas compared to surrounding rural areas (Banting et al. 2005; Bianchini and Hewage 2012; Kim et al. 2018). Vegetated roofs can cool the surrounding environment by providing shade, evapotranspiration, and reflection of solar radiation (Wong et al. 2003; Rosenzweig et al. 2006; Susca et al. 2011). Reducing the heat island effect mitigates the damaging impacts of heatwaves on human health (Laaidi et al. 2012; Marvuglia et al. 2020).

Another important aspect of GRs is that they have the potential to contribute to food security in urban areas by providing space for production of food. Urban agriculture, including growing of vegetables, herbs, and other food crops on GRs, can help to increase the availability of fresh, locally grown produce and reduce the dependence on food imports (Whittinghill and Rowe 2012; Ackerman et al. 2014; Specht et al. 2014; Specht et al. 2017). Martellozzo et al. (2014) indicates that less than one-third of the global urban area is required to produce the amount of vegetables consumed by city dwellers. Furthermore, GRs can be a vital tool in reducing food waste by shortening the supply chain, as approximately two-thirds of all food waste occurs in the supply chain during harvest, storage, and transportation (Zhong et al. 2017). Alternative agriculture methods are needed to overcome the challenges of food security driven by climate change (De Zeeuw et al. 2011; Sagnik 2021). GRs can help mitigate climate-related impacts from conventional agriculture such as dwindling water supply (Malhi et al. 2021) and farmable soil (Baul and McDonald 2015), as urban compared to conventional agriculture requires less water consumption (Briceño 2018) and reduces land degradation and soil loss (IPCC 2019: Climate Change and Land).

In addition, GRs provide other direct and indirect benefits to the surrounding communities. One noteworthy benefit is the increased access to green space. This aligns with the American Public Health Association's recommendation for the integration of nature into towns and cities to help contribute to better public health and overall, more sustainable societies (American Public Health Association 2013). Viewing greenery has been shown to have several positive effects, including the ability to decrease stress, improve mental health, increase attention capacity, and increase job satisfaction levels (Largo-Wight et al. 2011; Bratman et al. 2012; Jimenez et al. 2021). More specifically, GRs versus conventional rooftops have been found to increase attention, promote relaxation, and overall improve workers' performance (Lee et al. 2015).

For all their benefits, one major drawback of GRs is their high upfront costs. These costs have been a major barrier to entry for the GRs industry (Bianchini and Hewage 2012; Li and Yeung 2014; Kim et al. 2018) as they range from \$10 to \$40 more per square foot than that of a conventional roof. In efforts to decrease the upfront financial burden of GRs, a wide array of policies across the United States (U.S.) have offered monetary incentives to building owners (Appendix A) (*Static1.Squarespace.com)*. Currently, federal representative Nydia M Velazquez of New York has proposed a bill (H.R. 7693) called the Public-School Green Rooftop Program (*GR Program*). This is a grant program designed to fund the installation of GR systems on public school buildings. This bill, along with other policies and programs, is aimed at catalyzing the growth of the GR industry given their well-studied benefits.

In contrast to their well-documented environmental, economic, and community benefits, there have been limited research efforts to investigate public awareness, preferences, and values for GRs, as well as the public's attitudes toward government support of these green technologies. This information is crucial in helping policy makers draft and implement GR policies that will be effective and accepted by the communities.

This study is one of the very few stated preference surveys to explore public awareness, preferences, and support of government programs for GR technology in the U.S.. We are focusing our research on the recently proposed bill (*GR Program)*, since it provides a unique opportunity for us to lend realism to our investigation of community members' support and value of government programs for GR technologies. In this paper, we conducted a survey of the U.S. public using an online platform and aim to address three research questions: (1) What is the level of support and willingness to pay (WTP) for the current federally proposed *GR Program*? (2) What are the public's usage, preferences, and WTP for extensive commercial GRs? and (3) What is the level of support and preferences for rooftop farms?

The primary contribution of our research is to provide evidence on public support of government programs for GR technologies. Further, we sought to expand our understanding by exploring the public awareness, usage, and preferences for GRs. We incorporate a choice experiment to gauge more general preferences and value for a GR that is being installed on a commercial building with monetary aid being provided through a hypothetical state-sponsored GR bill. Gauging the public's preferences and WTP for different characteristics of GRs is key in designing effective policies and strategies that align with the needs of the impacted communities. The evidence we provide in this study can be an important aid in the efficient allocation of government funding and community acceptance of GRs and GR policy. Finally, as GRs have the potential to have a meaningful impact on food security issues in urban settings, understanding the public's preferences for a rooftop produce farm will be beneficial when designing GRs policies that aim to promote food security.

Our paper has the following structure: in the "Literature review" section we provide a brief overview of the relevant literature, followed by the "Methods" section, where we outline the methods employed in our study. The subsequent section, "Results" presents our findings, and in the "Discussion" section we provide a comprehensive analysis and interpretation of our results. We conclude our paper in the "Conclusion and recommendations" section by offering recommendations for policy makers and suggestions of future work for researchers.

Literature review

Few studies have explored the public's awareness, preferences, and values for GRs, as well as the attitudes toward the government support of GRs. Public awareness of GRs seems to be high as Netusil et al. (2022) reported 58% of their online survey sample from Portland, Oregon was familiar with GRs. Additionally, Jungels et al. (2013) found that 73% of their sample from the Northeast portion of the U.S. were aware of GRs as a concept, and slightly less (65%) of these respondents who were aware had also seen one prior to their on-site survey. In Belgium, Vancstockem et al. (2018) reported the majority (80%) of respondents indicated having a good understanding of the concept of GRs, while Sarwar and Alsaggaf (2020) reported awareness levels of 59% of their sample of Pakistani respondents.

Regarding preferences and perceptions of GRs, high levels of support have been documented in Sawar and Alsaggaf (2020), who report that 78% of their sample strongly agrees or agrees to the willingness to adopt GRs. In South Korea, Kim et al. (2018) found that 80% of their respondents expressed the necessity for GRs in urban areas and indicated that providing a rest area, reducing the urban heat island effect, and improving urban landscape are three key benefits of GRs. In the United Kingdom, White and Gaterslebel (2011) found that houses with vegetation were significantly preferred to those without. Similarly, Lee et al. (2015) reported office workers in Australia preferred all living roofs to concrete roofs, with the most desirable living roofs having tall, green, grassy, and flowering vegetation. A similar finding was reported in Spain by Fernandez-Cañero et al. (2013) as GRs with more variety of colors were preferred over alternatives, while the Jungles et al. (2013) study also found respondents preferred either sedum[3] or flowering roofs over grass dominated roofs.

The literature on GRs just recently started to focus on the public values and attitudes toward government support of GRs. The existing literature has found positive and significant WTP values for GRs and high level of agreement toward the government support of GRs. Most recently, Netusil et al. (2022) used a choice experiment to reveal that households, depending on the program characteristics and benefits derived, are WTP between $202 and $442 in a one-time payment for a government-sponsored GR program that runs for a year. A study by Teotónio et al. (2020) in Portugal found that individuals were more likely to pay a higher proportion of their rent or mortgage for the installation of GRs that they can access as opposed to those that are not accessible. The study found that 10% and 32% of the sample refused to invest and that 33% and 11.3% were willing to pay greater than 5% but less than 10% of their rent or mortgage for the installations of accesibale and inaccessible GRs respectfully. The researchers concluded that the accessibility of GRs and knowledge of its benefits play a key role in determining individuals' WTP for the installation of GRs. In Pakistan, Sarwar and Alsaggaf (2020) found that 92% of citizens strongly agree or agree with government support of GRs. In South Korea Ji, Lee and Huh (2022) utilized a dichotomous choice to gauge residents' WTP for GRs and found respondents were WTP 3.77 USD per year to build GRs in their respective cities.

This body of research suggests that there is some groundwork on public awareness, attitudes, and preferences of GRs. However, aside from vegetation options, little is known about the publics' preferences for amenities on GRs and the incorporation of other green technologies such as solar energy. Similarly, there is a lack of evidence about the support and preferences for rooftop farms. Finally, research is needed on community values and attitudes toward government support of GRs. Our study contributes to this nascent literature by filling some of these gaps.

Methods

Survey design and implementation

An online survey was designed using a professional platform (Qualtrics) and was distributed across the U.S. in the Spring of 2021 and again in the Spring of 2022[4]. This paper will focus on the second data collection round from the Spring of 2022. Prior to the survey distribution, two focus groups ($n = 13$) were conducted to gather instrumental feedback on the survey design. The focus groups lasted 75 minutes, and subjects were compensated $15 for their participation. Subjects were recruited through the University of Rhode Island's nine colleges and had participants from the student, staff, and faculty body (with ages ranging from 20 to 70 years old), representing six different states.

The survey was distributed via Amazon Mechanical Turk (MTurk), a widely used survey recruitment tool that has been found to be fairly representative of the general population (Berinsky et al. 2012; Goodman and Paolacci 2017; McCredie and Morey 2019) Although MTurk respondents have been found, on average, to be younger, more educated, and

[3]Sedum is a type of flowering succulent plant that is tough and hardy.

[4]We decided to run a second data collection once most COVID-19 pandemic-induced restrictions were lifted in the United States to avoid any potential effects these restrictions and the novelty of the pandemic may have had on the public's attitudes, usage, and preferences towards GR.

employed less compared to the general population (Paolacci and Chandler 2014), it is still proven to generate a subject pool that is no worse than convenience samples (Berinsky et al. 2012). To mitigate any potential data quality concerns, only workers having high "approval rates" (HITs > 97%)[5] were allowed to participate in this study (Paolacci and Chandler 2014; Peer et al. 2014). Workers' tasks were clearly stated, including description of the survey, realistic completion time, time constraints, and clear compensation rules (Harms and DeSimone 2015; Lovett et al. 2018). In the Qualtrics survey, a CAPTCHA Verification question was utilized as well as screening questions to ensure participants belonged in the target population and are humans (Smith et al. 2015; Sharpe et al. 2017). After the data were collected, the IP addresses were checked for duplicates and location verification (Hauser et al. 2018). The mean completion time[6] (13 minutes) of the survey was checked, and speeders (those completing the survey in under 6 minutes) were removed (Sharpe et al. 2017). Finally, attention check questions were utilized, as well as a short answer questions designed to flag bots[7].

The first section of the survey, the introduction, opens with a CAPTCHA Verification question, followed by presenting participants with an opening page which showed the University of Rhode Island's logo and a short message thanking the respondents for their participation and a recommendation to take the survey on a screen larger than 7 inches. Following the opening page, a consent form was presented. The researchers obtained Institutional Review Board approval for the survey and all survey-related materials (e.g. focus group, recruitment material, and consent forms). After the consent form, screening questions were asked to ensure that respondents are eligible, with an eligible respondent being a resident of the U.S. and 18 years of age or older.

The second section of the survey collected data on awareness and usage of GRs. The first question asked respondents about their awareness of GRs, with possible responses as *"Yes (please explain), No, or Unsure."* Only the respondents that reported being aware of GRs received the five follow-up questions about their knowledge and usage of GRs. The first follow-up question asked respondents to indicate how much they agree or disagree on a 5-point Likert scale (*1 = strongly agree to 5 = strongly disagree*) with the following statement: "*I am an expert on green rooftops.*" Following this question, respondents were asked "*Are you aware of any green rooftop installations currently operating in your city or town?*" with choice options including *"Yes"* or *"No."* Next, respondents were asked *"Have you seen a green rooftop in person?"* with choice options *"Yes" or "No."* Only respondent answering yes to seeing a GR continued to the following set of questions inquiring about spending time on GRs. First respondent answered the question *"You mentioned that you have seen a green rooftop. Have you ever spent time on a green rooftop?"* with choice options including *"Yes"* or *"No."* Respondents that answered yes to spending time on GRs were then asked about the frequency of spending time on GRs, by being presented with the question, *"How often do you spend time on green rooftop(s)?"* with choice options including *"weekly, bi-weekly, once a month, every few months, once a year, only once."*

[5]The Hit Approval Rate represents the proportion of completed tasks that are approved by Requesters. Depending on the type of task (surveys for example), you may want to set the HIT Approval Rate above 98% to enforce even higher quality.

[6]The mean completion time was calculated by removing the speeders, less than 6 minutes and the upper bound greater than 30 minutes. People spending greater than 30 minutes presumably stopped and restarted.

[7]A short answer question was utilized to flag bots, the question asked for a list of produce items respondents would want on a GR farm, answers were requested to be in lowercase letters with a comma between each produce item. Responses that provide definitions of GRs, listed their benefits, or did not make sense/did not answer the question were flagged and removed from the analysis.

The third section of the survey aimed to determine respondents' support and value for the *GR Program,* the federally proposed GR bill. The section opened with a short statement describing the *GR Program* (Appendix B) and continued by asking respondents how they would want their government representatives to vote on the proposed program with options including *"for, against, and unsure."* Respondents who selected *against* or *unsure* were asked a follow-up multiple-choice question that aimed to clarify the motivation behind their choices. A WTP question was asked for the *GR Program* in the form of payment card[8] (Appendix C). The question used a sliding scale that allowed respondents to choose from a wide range of amounts (from \$0 to \$500[9]). Respondents that reported a WTP of zero were asked a follow-up question about the motivation behind their choices. Next, respondents were presented with some information on GRs (found in the relevant literature), including information on the definition of GRs and their benefits and costs (Appendix D). Once the respondents were familiarized with GRs, the researchers asked the respondents once more about their vote and WTP for the *GR Program*. Again, respondents that selected the option to reject the program or reported a WTP of zero dollars were asked follow-up questions about the motivation behind their choices.

The fourth section in the survey aimed to determine what features respondents would want on a GR installation on a commercial building they frequently visit and how frequently they would visit this particular GR. First, to identify the commercial building respondents most frequently visit, the sample was asked to select from a list of 14 buildings the one they most frequently visited *(Building options included: school, hospital, library, coffee shop, grocery store, restaurant, bar, gym or workout facility, sport stadium, airport, museum, zoo, parking garage, residential complex/apartment, other*). Follow-up questions were asked about why the respondent visited the commercial building they selected with options including *work, volunteer, recreational, errands, appointments/meetings, other (please specify).* Additionally, respondents were asked to report how often they visited the building. To identify the most desired features a respondent wanted on a GR, respondents were informed that the commercial building the respondent previously selected will be installing a GR and that they will have access to this site. Then, a multiple-choice question asked the respondents to choose the features they would want to be included on the GR from a list of 15 randomized options (*grass, shrubs/bushes, trees, flowers, walking paths, benches, area to work out, tables and chairs, lounge chairs, shaded area, garden/farm (producing fruits/vegetables, small ponds, bee hives, bird baths, solar panels*), as well as options to indicate that they do not want a GR installed, have other preferences, and an attention check. A follow-up question was asked to all respondents that did not select the option *"I do not want a GR installed"* ($n = 513$) about how frequently the respondents would visit the hypothetical GR, if it had the desired features previously selected with choice options including *"weekly, bi-weekly, once a month, every few months, once a year, and never."*

The fifth section included a choice experiment to determine respondents' WTP for a GR installation on the commercial building the respondent selected in the previous section. This section of the survey is described in detail in "Choice Experiment Design."

The sixth section aimed to gauge respondents' support and preferences for a GR that hosts a produce farm on the commercial building chosen by the respondent in the previous section. The first question inquired about general support for a rooftop farm installed on

[8]A payment card style contingent valuation question presents respondents with a numerical range of monetary options (including a zero value) to choose from, in either a sliding scale, in bins, or in set values formats.

[9]More information about the choice of this range is provided in the GR Program *WTP Elicitation Method* section below.

the commercial building they frequently visited, with a 5-point Likert scale from "*Very supportive to Not at all supportive.*" Next, respondents had to indicate what types of fruits and vegetables they prefer to be grown on the rooftop farm. The short answers were processed with a free online word cloud generator to identify the most frequently reported produce items. Respondents were also asked how frequently they would purchase produce from the rooftop farm, with six choice options (*daily, multiple times a week, once a week, monthly, less than once a month, and never*), and their preferred venue to purchase the produce, with four different options: *weekly farmers' market, weekly community supported agriculture, daily store, or online delivery*. Lastly, respondents received a matrix style question with a 5-point Likert scale from "*Very important to Not at all important,*" about the importance of the produce grown on the rooftop farm being "*organic, sustainably grown, non-GMO, grown by local farmers, fresh, and pesticide free.*"

The seventh and final section of the survey collected data on other factors that may affect the respondents' decisions, such as social and demographic characteristics and attitudes toward environmental protection. To measure the respondents' environmental attitudes, the researchers used the well-known New Ecological Paradigm scale (Dunlap et al. 2000). The survey concluded thanking the participants for their time and providing a space for feedback or comments.

GR Program *WTP elicitation method*

For the valuation of the *GR Program*, we used a payment card method, which can be in the form of a sliding scale from zero to a predetermined upper value, or a table of values that includes zero. There are several benefits to using a payment card method to elicit WTP values. One benefit is that it helps to avoid the starting point or anchoring bias, which is a cognitive bias that occurs when people are influenced by the first value or piece of information they receive (the "anchor") and adjust their estimates or judgments based on that anchor (Mitchell and Carson 1989; Bateman et al. 2002). Another benefit of the payment card is that respondents are more certain about the values they provide, and hence the estimate of WTP obtained using this method is more reliable or accurate than that obtained using a dichotomous choice method (Ready et al. 2001). A choice experiment was less desirable in this situation as the researchers were not interested in different characteristics of the *GR Program* but solely concerned with determining community's support and WTP for the current proposed legislation.

However, the payment card method is prone to range and centering bias (Mitchell and Carson 1989), which can undermine the validity of the results. These shortcomings have been studied in the literature, and research suggests that they can be addressed by using a wide range of WTP values that covers the entire possible spectrum, rather than truncating it. This can help to mitigate range and centering bias (Mitchell and Carson 1989; Rowe et al. 1996; Covey et al. 2007). The range for the payment card ($0 to $500) was carefully chosen based on information obtained from surveying the relevant literature (Netusil et al. 2022; Wieczerak et al. 2022), feedback from focus groups, and the total amount of appropriations: $2.2 billion over five years (H.R.1863 – Public School Green Rooftop Program 117th) being requested to implement the *GR Program*. Some of our focus group participants stated they would be willing to pay more than $300 dollars for GR installations on public schools. These participants felt that the benefits to the education system and reduction in cost to the school district resulting from GR installations would outweigh a one-time increase in their federal income taxes. The range we chose for our study aligns with the most recent findings in the literature that show households in Portland, Oregon, have a WTP between $202 and $442 for a one-year-long GR program, depending on the characteristics of the program (Netusil et al. 2022). Following existing guidelines in relevant literature (Rowe et al. 1996; Covey et al. 2007), to mitigate centering and range bias, the upper bound for the payment card was chosen to be $500.

Contingent valuation surveys are subject to pitfalls such as information effects (Bergstrom et al. 1989), orderings effects (Halvorsen 1996), and hypothetical bias (Johnston 2006) among others. Minimizing the impact of these biases can be achieved by careful study design and implementation. To avoid any information or ordering effects[10] when assessing public support and WTP for the *GR Program*, the researchers decided to ask about support and WTP for the *GR Program* at the beginning of the survey. Since the *GR Program* is a proposed piece of legislation that already exists, it took precedence over the choice experiment, which was a hypothetical situation. Therefore, the section on the *GR Program* came before the choice experiment. The researchers were also concerned that a misunderstanding of GRs could bias the results of the survey. Previous focus group discussions had found that about 25% of participants had an incorrect or alternate definitions or ideas of a GR. Further, most recent literature using a contingent valuation survey found that 84% of the respondents visited the GR under study but only 40% were aware it was a GR (Nguyen et al. 2022). To address the issue of participants potentially having a misunderstanding of what a GR is, we considered it important to provide information on GRs to ensure that respondents had a consistent understanding of them. This would allow us to see if the information provided had any impact on respondents' WTP for the *GR Program*. We believed that this would not significantly burden the respondents and would provide useful information for policy makers. It would also give us an indication of how the information provided might influence the results of the choice experiment.

Choice experiment design

A choice experiment was utilized to assess the respondents' preferences and estimate their WTP for different attributes of GRs. The experiment involves presenting respondents with hypothetical scenarios or choice sets that vary in terms of specific attributes related to GRs. Respondents are then asked to choose their preferred option from each set. The design of the choice experiment can greatly impact results; therefore, close attention was paid in developing a realistic market and choice sets. Before starting the choice experiment respondents were provided with clear and concise information about the experiment and information about the hypothetical GR bill[2] and the maintenance process for the GR (Appendix E). This information was provided to help create a scenario that was as realistic as possible before entering the choice experiment.

One major concern with using choice experiments is that respondents' decisions may not accurately reflect what they would do in real life, as no money or goods are being exchanged. This is known as hypothetical bias. To mitigate the concern of hypothetical bias, we followed an ex-ante and ex-post approach as suggested by [11]Özdemir et al. (2009) and Tonsor and Shupp (2011). Prior to the choice experiment, the researchers provided "cheap talk" information, which explained to the respondents that their responses were

[10]The researchers were unable to collect enough responses to conduct a split sample analysis, which would have allowed them to understand the influence of the order in which the payment card and choice experiment were presented (i.e. whether presenting the payment card first or the choice experiment first had an effect on the results). This was due to budget constraints.

[11]The hypothetical bill mimics other past and current state programs and policies, which are listed in Appendix A

Table 1. Choice experiment attributes and levels

Attributes	Levels
Type of Vegetation	Grass
	Flower gardens
	Shrubs/Bushes
	Produce gardens
Type of Amenities	Benches/Sitting areas
	Shaded area
	Walking paths
	Small ponds
Percent of Solar Panels	None
	10% to 19% of total rooftop has solar
	20% to 40% of total rooftop has solar
	Please note there will be no access to the solar panel area.
Community Access	**Limited:** Only building users can access the green rooftop
	Open: Both community members and building users can access the green rooftop at any time
	Mixed: Both community members and building users can access the green rooftop during limited times/hours
Payment	One time increase in 2022 state income taxes ($10, $20, $40, $80)

being used in important research that could influence current policy. We also asked the respondents to answer the questions as if the GR installation would actually be built and paid for through an increase in their state income taxes. After the choice experiment, a follow-up consequentially question was asked, to gauge how strongly respondents agree or disagree that the results of the survey will aid in decision-making process around future GR policy.

Our choice experiment includes five attributes: vegetation, amenities, community access, solar, and the payment vehicle, each with varying levels (Table 1). The attributes and their respective levels were carefully selected by conducting focus groups, surveying the relevant literature (Fernandez-Cañero et al. 2013; Lee et al. 2015; Kim et al. 2018; Vanstockem et al. 2018), and reviewing current GRs installed across the U.S. These attributes and levels closely mirror existing characteristics and features implemented on existing GRs installations on commercial buildings. Focus group discussions helped eliminate attribute levels that were of less importance such as workout areas and food services and highlighted important attributes such as community access and solar.

The payment vehicle, which represents the method of collecting payment from respondents in a choice experiment, was chosen to be a one-time increase in the respondents' state income taxes for the year 2022. This method was selected in part because the GR bill being evaluated was a hypothetical state-funded grant program, and state governments typically receive a significant portion of their funding for public services through taxes. A tax was also chosen because it has been widely used in the literature to

Scenario 1: Please select your preferred proposal among the options given below

Attributes	Proposal A	Proposal B	Proposal C
Vegetation	Shrubs/Bushes	Grass	Flower gardens
Amenities	Benches/Sitting areas	Walking paths	Small ponds
Solar Panels	10 to 19%	None	20 to 40%
Community Access	Mixed (all public, limited hours)	Limited (building users only)	Open (all public, 24/7)
Payment	$20	$80	$10

- ○ Proposal A
- ○ Proposal B
- ○ Proposal C
- ○ None of the above

Figure 1. Choice experiment set example.

elicit WTP for ecosystem services via a choice experiment (Rambonilaza and Dachary-Bernard 2007; Wattage et al. 2011; Jacobsen et al. 2012; Ndunda and Mungatana 2013). The payment vehicle levels ($10, $20, $40, $80) were informed by the focus groups, the first data collection, and surveying the relevant literature. Most of the focus group participants believed that a reasonable amount to pay for a state bill would be between $10 and $100 per year. This was a lower range than what was previously reported for the federal *GR Program*. Focus group participants mentioned that the primary reason for the lower range of WTP values for the state-sponsored bill in the choice experiment was because private building owners would be the primary beneficiaries, rather than public schools. The first data collection, which took place in Spring 2021, found that the resulting mean WTP values were consistent with those found in other studies that have explored WTP for GRs and green infrastructure (Netusil et al. 2022; Wieczerak et al. 2022).

The choice experiment was designed in Stata (a statistical software) using the command *dcreate,* which creates efficient designs for discrete choice experiments using the modified Fedorov algorithm. The algorithm maximizes the D-efficiency of the design based on the covariance matrix of the logit model (Hole 2015). The design generated eight choice sets. Each choice set included three alternatives, named Proposal A, Proposal B, and Proposal C, with a fourth option that allowed respondents to reject the rooftop proposal (Holmes et al. 2017) (Figure 1). Each respondent was randomly assigned four of the eight available choice sets.

Econometric model

Choice experiments have a simplistic model that allows valuation of multiple attributes. They can provide a close estimate to respondents' actual behaviors. Specifically, choice modeling is based on consumer theory and random utility theory. Based on Lancastrian consumer theory (Lancaster 1966), choice modeling theory states that goods provide utility to consumers based on their attributes and can be broken down into separate utilities to reflect this. Therefore, this assumption can be applied to uncover prices consumers are WTP for each attribute. Random utility theory assumes consumers are rational decision makers that make choices to achieve the highest level of utility from the available options

(McFadden 1974). Subsequently, the likelihood of an individual selecting a given alternative will be higher if the utility provided by the alternative is the highest among the different options.

The utility U_{ijt} that an individual (i) can gain when choosing the alternative (j) ϵ $\{1, \ldots, J\}$ from choice set (t) ϵ $\{1, \ldots, T\}$ depends on observable and unobservable components. The observable components (V_{ijt}) are the linear additive combination of the explanatory variables, the GR attributes, and individual characteristics. The individual's utility can be expressed in a linear equation in the form:

$$U_{ijt} = \beta_i' V_{ijt} + \varepsilon_{ijt} \tag{1}$$

which includes β'_{i}, a vector of unknown marginal utilities that are to be estimated for the GRs attributes and control variables. The unobservable random component, ϵ_{ijt}, is assumed to be identically and independently distributed (iid) and follows the extreme value type 1 distribution (Hensher and Greene 2003).

The respondent will maximize their utility by choosing an alternative that will return the highest utility. The probability (P_{ijt}) from an individual (i) choosing alternative (j) from a choice set (t) that yields the highest U_{ijt} is given by:

$$P_{ijt} = \int \frac{e^{\beta'_{\mathrm{i}} V_{ijt}}}{\sum_{\mathrm{j}} \beta'_{\mathrm{i}} V_{ijt}} f(\beta|\theta) d\beta \tag{2}$$

where $f(\beta|\theta)$ is the density function of β. The theory states that the difference in the utility of products drives product choices. The choice probabilities of an individual (i) selecting the j^{th} alternative can be estimated using a random parameters mixed logit model:

$$P\left(Y_{it} = j\right) = \frac{\exp\left(v_{ijt} b'\right)}{\sum_{\mathrm{j}=1}^{\mathrm{J}} \exp\left(v_{ijt} b'\right)} \tag{3}$$

where Y_{it} represents the option in which individual (i) has chosen in choice set (t). A random parameters mixed logit model was chosen as the model of choice so both characteristics of the GR and the individual can be included (Hoffman and Duncan 1988.). A random parameters mixed logit model addresses the three limitations associated with standard logit models by allowing for random taste variation, unrestricted substitution patterns, and correlations in unobserved factors over time.

The random parameters mix logit model includes controls for the choice experiment attributes (price, vegetation, amenities, solar, and accessibility). Except for price, which is specified as a continuous variable, all other attribute controls are specified as dichotomous variables with shrubs/bushes, shaded area, no solar, and open access being the reference categories. Further, the alternate specific constant for no GRs installations is included. Each parameter is assumed to be normally distributed with the exception of the price coefficient which is specified to be log-normal.

To calculate the WTP_{ijt} for each respondent, the ratio between the estimated marginal utility for the GRs attribute is divided by the exponent of the estimated marginal utility for the monetary attribute (price), as seen below. It is necessary to take the exponent of the price parameter since it was specified to be log-normal distribution.

$$WTP_{ijt} = \frac{\beta_t}{\exp\left(\beta_{price}\right)} \tag{4}$$

Table 2. Demographics

Variables Race %	Survey	U.S.	Variables Political Views %	Survey	U.S.
White	90.7	72.0	*Republican*	26.4	N/A
Black or African American	7.1	12.8	*Democrat*	62.7	N/A
American Indian	1.2	.9	*Independent*	10.5	N/A
Asian	2.2	5.7	*Prefer not to Answer*	0.2	N/A
Pacific Islander	0.2	.2	**Marital Status %**		
Two or more races	2	3.4	*Single*	12.7	33.9
Hispanic or Latino	20	18.4	*Married*	85	47.6
Female %	54.4	49.2	*Widowed*	0.4	5.7
Age (Mean)	38.3	38.5	*Divorce*	1.98	10.9
Education %			*Separated*	0	1.8
Less than HS	0	11.4	**Regions**		
HS or Equivalent	1.97	26.9	North East	11.9	17.2
Some College or Associates	6.7	28.6	South	48.5	38.3
Bachelors	64	20.3	West	24.5	23.7
Graduate or professional	27.2	12.8	Midwest	15.1	20.7
Mean Household Income $	60,423	92,324			

Notes: $N = 530$. United States demographics were taken from the 2019 ACS Data.

Results

Summary statistics

The descriptive statistics of the survey sample ($n = 530$) can be seen in Table 2, along with the American Community Survey (ACS) data from 2019. It should be noted that the sample over-represents more educated individuals, as a majority of the sample holds a bachelor's degree. The sample has a lower mean income of $31,604 than that reported by the ACS data. The difference between our sample's education level and income is a typical result of recruitment through MTurk (Paolacci and Chandler 2014). Further, the sample over-represents white and married households. Most of the sample (71%) have children with more than half (63%) having children under 18 years of age and only about 16% having children older than 18 years of age. More than a third of respondents (41%) have been living in their current place of residency for more than 10 years, most respondents (63%) live in a home they own, and most live in an urban area (67%). The three most represented states are California (15%), Texas (14%), and Florida (7%), which are also the most populous states in the U.S. The sample does not include representation from eight states: Idaho, Iowa, Nevada, North Dakota, Rhode Island, South Dakota, Vermont, and Wyoming. This does not represent a point of concern as the sample distribution between U.S. regions (Northeast, Midwest, South, and West) properly reflects the 2019 ACS population distributions across the four regions. Regarding access to green space, most of

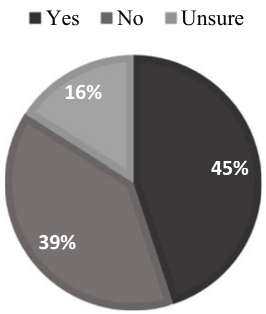

Figure 2. Awareness of GR ($n = 530$).
Notes: The figure displays respondents' awareness level of GRs ($n = 530$).

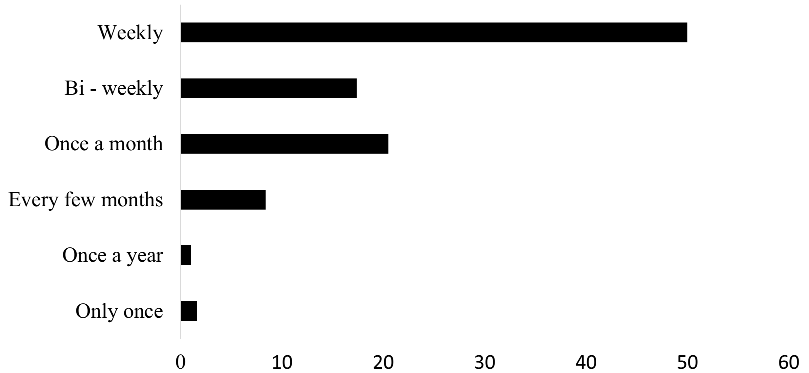

Figure 3. Frequency of visiting GR (%).
Notes: The figure displays the frequency of visiting GR from the portion of the sample ($n = 190$) that reported visiting a GR.

the sample (88%) reported they have green space, open space, or a park within 20 minutes of their residency. Of the 88% who have access to green space, more than half (62%) visit this space weekly and 21% visit this space every other week.

Awareness and usages of GR

Almost half (45%) of our respondents are aware of GRs (Figure 2), and, of those, 75% agree or strongly agree that they consider themselves experts on green rooftops with only 23% disagreeing or strongly disagreeing with the statement posed in the question.

Of those aware of GRs, the majority (87%) had also seen a GR. From the sub-sample that had seen a GR ($n = 204$), almost all (93%) have been on or visited a GR. Half of those respondents who reported visiting a GR ($n = 190$) did so on a weekly basis (Figure 3).

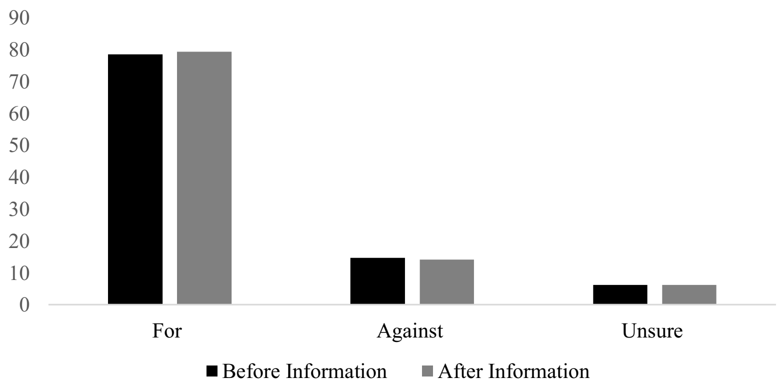

Figure 4. Vote on bill for *GR Program* (%).
Notes: This figure displays how respondents would want their government representatives to vote for the *GR Program*. $N = 530$.

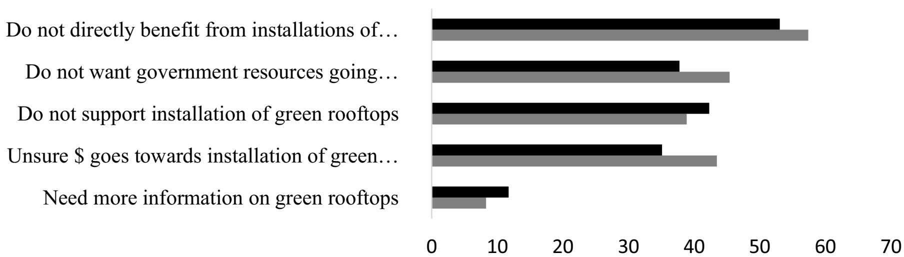

Figure 5. Reasons for voting against/unsure *GR Program* (%).
Notes: The figure displays the reported reasons why respondents (Round 1: $n = 111$ and Round 2: $n = 108$) did not want their government representatives to support the *GR Program*.

Government support for GR program

Most respondents (79%) expressed support for the *GR Program* by indicating that they would want their government representatives to vote in favor of the bill (Figure 4). Of the 111 respondents who did not support the *GR Program*, 57% cited the fact that GRs do not directly benefit them, and 45% stated that they did not want government resources allocated toward the bill (Figure 5). After being provided with information about GRs benefits and costs, there was no statistical difference in the way the sample responded to how they would want their government representatives to vote for the *GR Program* (*t*-test *p* value = 0.53), as 84% of sample did not change their responses. After information was provided, the participants who did not support the *GR Program* reported increased levels for all the reasons they did not support the bill, with two exceptions: not supporting the installation of GRs and wanting more information about them (Figure 5). Follow-up t-tests reveal no significant differences in the reasons why respondents do not support the bill.

The payment card question for the *GR Program* revealed that the mean WTP (MWTP) was $176 dollars and less than 2% of the sample reported zero value toward the *GR Program*. After providing information to respondents about the GRs' benefits and costs, there was a significant difference in how much extra money the sample would be WTP in

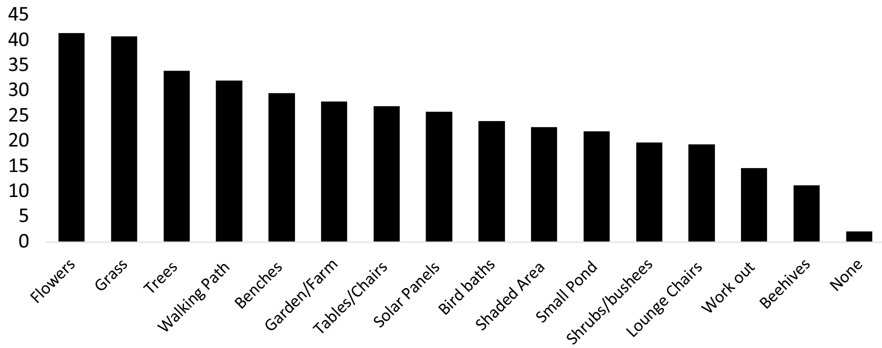

Figure 6. Desired features on hypothetical GR (%).
Notes: This figure displays the % of respondents that reported wanting a particular feature on a GR. $N = 521$.

their 2022 federal income taxes toward the *GR Program* (t-test p value $= 0.002$). The MWTP increased by \$9. About 15% of the sample responded with the same WTP value before and after information was provided. Almost 35% of respondents decreased their WTP (with decreases ranging from \$1 to \$274), while 54% increased their WTP (with increases ranging from \$1 to \$394).

Desired features on hypothetical GR

The commercial buildings most visited by respondents were schools (19%), restaurants (16%), and residential/apartment complex (12%). The primary activities performed at the building they most frequently visited were work (36%), volunteering (26%), or recreational (13%). The largest portion of the sample (33%) visited their selected commercial building four to six days a week followed closely by a frequency of one to three days per week (31%). When asked what features the respondent would want on a GR installed on their chosen commercial building, our results revealed that the most desired elements were flowers (42%), grass (41%), and trees (34%). The next two most desired features include amenities, such as walking paths (32%) and benches (30%) (Figure 6). Respondents that indicated they do not want a GR ($n = 11$) were excluded from the follow-up questions. When asked about visitation frequency if the desired features were included in the installation, the sub-sample ($n = 513$) reported they would visit the hypothetical GR weekly (44%) and bi-weekly (17%).

Support and preferences for rooftop farm

Most of the sample (84%) reported being very supportive or supportive of a GR farm. The types of fruits and vegetables respondents prefer to be grown on the rooftop farm were lettuce, flowers, kale, tomatoes, and arugula. Slightly more than half of the sample (54%) reported they would purchase produce daily or multiple times a week. The two most popular venues to purchase the produce grown on the rooftop farm were from farmers' markets (58%) and by online delivery systems (45%). Respondents placed high importance on all options for how the produce was grown on a rooftop, with fresh (73%) and grown by local farmers (67%) ranking the highest for combined responses of *very important* and *important* (Figure 7).

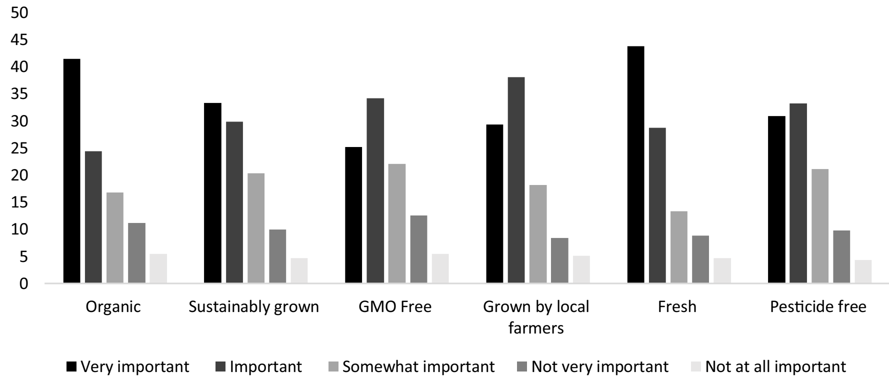

Figure 7. Preference for characteristics of produce grown on GR farm.
Notes: This figure displays the reported importance of produce items being grown on a rooftop farm to have these characteristics. $N = 512$.

Choice experiment results

All respondents ($n = 530$) participated in the choice experiment, and with four choice tasks per respondent, the survey yielded 2,120 choice tasks, totaling 8,472 observations. Within the choice experiment, there was low refusal to GRs installations, with only 1% of the respondents choosing no GR proposal over the three proposals presented.

Based on the random parameters mixed logit results (Table 3), the researchers observe a significant negative price coefficient which is consistent with economic theory. All choice experiment attributes are dichotomous variables with the reference group in parentheses. Our regression results reveal that most of the rooftop attributes provide utility to the public. We observe a positive and significant coefficient for grass and flowers under the vegetation attribute. Additionally, there is a negative but not significant coefficient for produce gardens. Therefore, compared to shrubs and bushes, flowers and grass provide the public with utility. For amenities, we observe a positive and significant coefficient for benches and walking paths, while ponds have a negative but insignificant price coefficient. Therefore, compared to shaded area benches and walking paths provide the public utility, with benches providing a greater level of utility as the coefficient is larger. For the solar energy attribute, solar installations covering 10% to 19% (Solar 10) and ones covering 20% to 40% (Solar 20) of the rooftop have significant and positive coefficients. Hence, having solar on the GRs compared to having none brings the public utility. Lastly, for accessibility to the GRs, we report a negative and significant coefficient on limited accessibility and a negative but insignificant coefficient on mixed accessibility. Compared to open access, limited accessibility brings disutility to the public.

We found that respondents are WTP the most for benches ($320), solar installation cover of 20% to 40% of the rooftop ($276), flower gardens ($269), and grass ($262). The alternate specific constant, No GR, was negative and significant; therefore, the public has a loss of utility when no GR is installed.

Several robustness checks were conducted to ensure consistency in model specification and to control for heterogeneity differences amongst demographic characteristics and other factors that may impact choices (Appendix F, Tables 1–6). To test for consistency in

Table 3. Mean willingness to pay for GR attributes

Variables	Coeff.	S.E.	Mean WTP $
No GR	−7.82**	1.41	−5283.69
Price (log)	−6.59***	0.48	
Vegetation (Shrubs/Bushes)			
Grass	0.36***	0.09	262.00
Produce gardens	−.1	0.09	−72.78
Flower gardens	0.37***	0.08	269.28
Amenities (Shaded Area)			
Benches	0.44**	0.11	320.22
Walking Paths	0.23***	0.07	167.39
Ponds	−.004	0.08	−2.91
Solar (None)			
Solar 10	.13*	0.08	94.61
Solar 20	0.38***	0.08	276.56
Community Access (Open)			
Mix	−0.07	0.06	−50.94
Limited	−0.25**	0.09	−181.95

Notes: All parameters are modeled as random parameters. All parameters are normally distributed except the price is log-normally distributed. Attributes in the parenthesis are the reference category. All variables are dummy (0/1) except the price is continuous. ***, **, * denote significance at 1%, 5%, and 10% level. Log-likelihood = −2323.8 chi-squared = 89.76 $N = 8{,}472$. $WTP_{ijt} = \frac{\beta_t}{\exp(\beta_{price})}$.

results, we used different model specifications, including changing the reference group for the vegetation and amenities[12] attributes (Appendix F, Tables 1–3) and changing the model choice from a mixed logit to a generalized multinomial logit model (GMNL) (Appendix F, Table 4). Results remained consistent with varying model specification and the inclusion of control variables for different demographics groups, for more information please see Appendix F.

Since our sample over-represents white, educated, homeowners, and married individuals, we explored[13] the potential impacts on our results through additional logistical and linear regressions (Appendix F Tables 7–12). The logistic regression revealed that marital status, homeownership, and population density area delineation (urban/rural) had varied significantly with awareness of GRs. Being married is associated with a 52% decrease in awareness of GRs. Being an urban resident compared to rural/suburban resident is associated with 99% increase in the likelihood of being aware of GRs. Homeowners compared to non-homeowners were associated with 73% increased likelihood of being aware of GRs (Appendix F, Table 7). GR visitation frequency varied significantly with political affiliation, population density area delineation, and green space

[12]Reference groups were not altered for solar and accessibility as they had a natural/logical ordering, and using the lowest level as the reference group is the obvious reference group

[13]We thank our anonymous reviewer for this suggestion.

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visitation frequency (Appendix F, Table 8). Urban residents were found to have a 342% increased likelihood of being a frequent visitor to GRs compared to rural and suburban residents. Additionally, there was significant positive difference (238%) for individuals that regularly visited green space (weekly) to be more frequent visitors to GRs compared to individuals that did not visit green space as frequently (less than once a week). How respondents voted on the *GR Program* before information on GRs was provided, varied significantly by the frequency of green space visitation of individuals, with frequent visitors being 206% more likely to vote "for" the *GR Program (*Appendix F, Table 11). After information was received about GRs, there were significant differences between race groups (white versus non-white population) and the U.S. regions (northeast versus the south). The white group versus non-white population is 88% less likely to vote for the *GR Program* and the northeast versus the south is 67% less likely to vote for the *GR Program* (Appendix F, Table 12).

Linear regression results revealed WTP values for the *GR Program* prior to information being received varied significantly and negatively for whites compared to non-whites and for females compared to males with values being $43 and $28 less, respectively (Appendix F, Table 9), while WTP values varied significantly and positively, regionally, and at the education level. Individuals living in the west and the northeast compared to the south were WTP $27 and $43 more, respectively. Individuals holding a bachelor's degree were WTP $69 more compared to individuals having a high school or associates degree. After information on GR was received, WTP values for gender, education, and the northeast remain fairly constant with only changes in magnitude (Appendix F, Table 10). Political difference arose to be significant, with both democrats ($40) and republicans ($50) WTP more for the *GR Program* compared to independents. Urban homes compared to rural and suburban homes had a significantly higher WTP ($28) for the *GR Program* after information was received on GRs.

Discussion

In this study, we aimed to investigate public awareness, preferences, attitudes, and WTP toward GR technologies and gauge support for a government-proposed program related to them. Results from our survey showed that approximately half of the respondents were aware of GRs, and around 40% of those respondents had also seen one. This is lower than what has been reported in previous research. For example, a study conducted in Portland, Oregon reported that 57.8% of the respondents had seen or visited a GR, and another study in the Northeastern U.S. found that 73% of respondents were aware of GRs and 65% had seen one before their survey (Jungels et al, 2013; Netusil et al. 2022). We believe that differences in data collection methods and location may be the reasons for the discrepancy. The Northeastern study employed an intercept survey at seven GR locations, which may have led to an increase in selection bias in the sample collected, while the Portland respondents' awareness may have been influenced by the ongoing government's efforts to increase installations of GRs within the city (Ecoroof Incentive; Grey to Green Accomplishments). International studies in Pakistan, Belgium, and Portugal also found that the majority of survey respondents are aware of GRs (Vanstockem et al. 2018; Sarwar and Alsaggaf 2020; Teotónio et al. 2020). The variation in the level of knowledge about GRs across different countries or regions may be influenced by cultural factors, the prevalence of GRs in those areas, and government policies and incentives related to them (Ismail et al. 2012).

For the attributes tested in our choice experiment, our findings indicate that the majority of the public preferred vegetative coverings for extensive commercial GRs to consist of grass and flowers. While the multiple-choice question revealed the highest preference of features on GR included vegetation such as flowers, grass, and trees, as these were selected most frequently among the fifteen options presented. Research suggests that people generally favor GRs that mimic natural ecosystems and include a diverse range of plants, including native species, grasses, flowers, and shrubs. Several studies found that the public prefer sedum[14], grassy, flowering, or herbaceous vegetation, and a variety of color (Fernandez-Cañero et al. 2013; Jungels et al. 2013; Lee et al. 2015; Vanstockem et al. 2018).

Although some groundwork research exists about GRs awareness and types of vegetation preferred on GRs, there is little known in the literature about preferences and WTP for amenities on GRs. Our survey found that walking paths and benches were selected as the top two most desired amenities. Additionally, the choice experiment revealed that the highest WTP was for benches ($320). This is an intuitively appealing result, as walking paths and benches have the potential to enhance the experience of the GRs by allowing individuals to walk around and get close to certain GRs features, as well as rest and enjoy the scenery. Our results also showed that incorporating solar panels into the GR was preferred to having no solar power feature. This result may indicate that the integration of solar technology on GRs is positively perceived by the public, as it provides both aesthetic and environmental benefits. To the best of our knowledge, our study is the first to highlight the public preferences for this specific amenity. This novel finding could greatly benefit both policy makers and building owners as solar panels placed on GRs provide higher profits from the additional energy generated by the solar panels (Ramshani et al. 2020) due to the increased efficiency of the panels (Fleck et al. 2022). Another intuitive finding in our paper is the one about the public preferring open access to GRs over limited access, as the choice experiment showed a negative and significant coefficient on limited availability. If the public can directly enjoy the green space provided by the GRs, then they are more likely to support these programs. A similar result was found by Teotónio et al. (2020) who reported that accessibility had a significant impact on the WTP toward GRs.

Regarding produce farms on GRs, our results showed that they were selected less frequently than other vegetation options, and there was no statistical significance of this feature in the choice experiment, suggesting that, perhaps, they were not as popular among other GR options. This aligns with the findings of a study by Kim et al. (2018) which reported that most of the respondents (79%) preferred roof gardens (flowers) over farms (produce). However, our survey also found that a majority of the sample (84%) expressed strong support or support for a rooftop farm. This information was obtained in a section of the survey focused solely on support and preferences for rooftop farms. The difference in preferences might be due to the survey design and simply respondents preferring a rooftop farm over a conventional rooftop. When presented with other vegetation options, respondents favored grass and flowers over produce farms on a GR. However when presented with a rooftop farm option compared to a conventional rooftop, they strongly prefer the rooftop farm. So, while the rooftop farm may not be the public's first choice or most preferred attribute, it is still preferred to the no GR option. This is an important insight from a policy perspective as it points to the capability of GRs in addressing food insecurity (Whittinghill and Rowe 2012; Ackerman et al. 2014; Specht et al. 2014; Specht et al., 2017) and combating climate-related impacts from conventional agriculture (Baul and McDonald 2015; Malhi et al. 2021).

In addition to preferences for attributes of GRs, our study revealed that the public is very supportive of these green technologies overall and government support of GRs. The

[14]Sedum is a type of flowering succulent plant that is tough and hardy.

vast majority of respondents want their government representatives to vote in favor of the *GR Program* and reported a MWTP of about $176 to $185 in their 2022 federal income taxes to support this bill. This high level of support for government policy involving GRs has also been documented in previous research, such as a study by Sarwar and Alsaggaf (2020) which found that 92% of citizens strongly agree or agree to government support of GRs. Additionally, research by Netusil et al. (2022) found that households were WTP between $202 to $442 per year for a government-supported program to help facilitate the installation of GRs in Portland, Oregon.

Our survey also indicates that majority of the sample (54%) increased their WTP for the *GR Program* after information was provided on GRs benefits, costs, and drawbacks. This novel finding suggests that providing the public with more information about GRs could increase the WTP for government-sponsored programs. Similarly, previous research has also found that knowledge of the benefits of GRs has a significant impact on the WTP for them, as reported by Teotónio et al. (2020) and Jungels et al. (2013). Our results also point out that, after information on GRs was provided, respondents that cited a particular reason for not supporting the *GR Program* increased; however, these differences were not significant. We hypothesize that once respondents were provided with information, some of their doubts or uncertainties have resolved or their concerns became clearer, as the number of respondents reporting they needed more information about GRs decreased. Overall, our study provides empirical evidence of the public's willingness to accept a one-time increase in income taxes to provide funds to the government to support programs aimed at aiding the installations of accessible GRs.

Finally, based on our analysis of social and demographic variables' impact on awareness and visitation of GRs, we suggest that policy makers employ programs that are designed to increase public awareness and education of GRs technologies prior to or simultaneously with any GR support policy. One noteworthy result of this covariate analysis, though intuitive, is that urban populations - in contrast to rural ones - are more likely to be aware of GRs and visit them more frequenty. Moreover, frequent visitors of GRs show a higher WTP for the *GR Program*. This may be due to the fact that urban residents have limited access to open or green spaces; thus, they seek and highly value GRs as they offer access to naturalistic landscapes. Secondly, GRs are more often installed in urban areas than non-urban areas so increased exposure may lead to higher usage and value for GRs. While other social and demographic variables' significantly impacted the likelihood of GR awareness and usage along with the support and WTP for *GR Program,* there was no clear trend amongst these groups, aside from the urban-rural differences discussed above.

Given the importance of GRs in addressing the climate crisis, contributing to food security in urban areas, and creating overall healthier cities, it is crucial to understand public preferences and attitudes toward government support for these technologies. To the best of our knowledge, there are few studies that focus on providing a holistic view of the public's reaction to not only the technology itself but also the propensity to support programs that promote it. This investigation filled this gap by providing timely information, as the first federal bill to allocate resources to the installation of GRs on primary and secondary schools (the *GR Program*) is currently being proposed.

Conclusion and recommendations

GRs can play a crucial role in addressing the impacts of climate change, enhancing food security, and delivering a range of benefits to both the public and individuals. Previous research has extensively examined the environmental and community benefits of GRs, but less attention has been given to understanding public attitudes and preferences toward them. This study aimed to fill this gap by providing empirical evidence on public preferences for attributes of GRs and support for government-sponsored GR programs.

Our findings suggest that there is an overwhelming level of support for the installation of GRs on commercial buildings, government-sponsored GRs programs, and WTP to promote GRs technology in the community. Our results show that the most preferred vegetations on GRs are grass, flowers, and trees, with preferred amenities being benches and walking paths. Respondents also expressed a preference for GRs that incorporate solar installations, have rooftop farming, and are accessible to the public. This study offers insights that can assist policy makers and city planners in developing government programs related to GR technologies. We recommend that GRs feature grass, flowers, walking paths, solar panels, and unrestricted public access. Additionally, we suggest that policy makers incentivize building owners to provide open access to GRs and to grow produce on the rooftops. The study also provides empirical support for the federal government to pass the *GR Program*, as the majority of the public support the bill and are willing to accept a one-time increase in their federal income taxes to fund the program. Our monetary estimates for the public's WTP to support the *GR Program* may be used by decision makers and other stakeholders in cost-benefit analyses of GRs.

Further studies are needed and should consider utilizing imagery in their research design, similar to Fernandez-Cañero et al. (2013) and Nagase and Koyama (2020) or virtual reality, as utilized in Bateman et al. (2009) since the GRs' visual aesthetics may greatly impact preferences and WTP. Another venue of research could be the exploration of barriers to entry, willingness to adopt, publics' preferences on the integration of solar panels and GRs, and preferences of the building owners about GRs technology, as these topics will all be vital in catalyzing the GRs industry and creating more efficient policies. More information is needed on how preferences vary by demographic groups and location. Lastly, it will be essential for researchers to determine who is receiving the government funding and what groups are being impacted by the funding to mitigate disparities across races and income groups.

Supplementary material. For supplementary material accompanying this paper visit https://doi.org/10.1017/age.2023.17

Data availability statement. The data and code that support the findings of this study are available from the corresponding author, NM, upon reasonable request.

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Competing interests. The Authors have no competing interests.

Ethical standards. Informed consent was obtained from all individual participants involved in the study.

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