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Perceptions on barriers and opportunities for integrating urban agri-green roofs: A European Mediterranean compact city case

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ABSTRACT

The main objective of this study is to analyze the perceived barriers and opportunities with regard to the implementation of urban agri-green roofs (UAGR) in cities. The case study was conducted in Barcelona, a Mediterranean compact city. The World Café method was used in this work. Five categories of barriers and opportunities were discussed (social, environmental, legal/administrative, technological/architectural, and economic) by interdisciplinary stakeholders.

A total of 129 barriers and opportunities were identified. The main barriers identified were as follows: the lack of information and social cohesion regarding UAGR projects; the Mediterranean climate; the lack of specific regulations and protocols; the initial investment; and the pre-condition of the roof and its load bearing capacity. The main opportunities were social cohesion; improved life quality; new specific regulations; the profits derived from UAGR projects; and aesthetic improvement.

The UAGR's scale of impact results showed a homogeneous distribution between "building" and "city", while the "global" scale remains residual. Regarding the stage of the UAGR life cycle at which barriers and opportunities emerge, the results highlight how most opportunities appear during the "use" stage of the roof, whereas barriers do so during the "project" stage.

1. Introduction

The global population has increased rapidly since 1950. According to the projections, 68% of the world's population will live in cities by 2050 (United Nations, 2018).

Urban areas have increased the pressure and exploitation levels imposed on the ecosystems both at local and global scale as they are responsible directly or indirectly for approximately 75% of global energy consumption and 80% of greenhouse gas (GHG) emissions (Ash et al., 2008), exerting high impacts on levels of atmospheric pollution and the rising demand for natural resources (Cerón-Palma et al., 2012). In addition, the built urban environment contributes to the urban heat island (UHI) effect; specifically, temperatures in urban areas can be up to 5–12 °C warmer compared to surrounding rural areas (Lee et al., 2014), contributing to climate change.

Apart from the above-mentioned problems, cities with high population density, the so-called compact cities, also experience important issues related to a lack of space and more specifically green spaces. In this sense, real estate speculation, increased population density, spatial limitations, and the high competition in relation to land in urban areas have implicitly led to a decrease in the available green space surface per capita, demonstrating the need for new strategies to compensate for that deficit (Tappert et al., 2018). Given the multiple benefits at the social, economic, and environmental levels provided by green spaces and the

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growing concern with regard to the creation of sustainable cities towards an improved quality of life, there is significant interest and need to enhance such spaces (Taylor & Hochuli, 2017); however, the spatial limitations and high competition in cities for space make opportunities for greening increasing difficult. In this sense, rooftops are relevant to the transformation from underused spaces to green and productive spaces (Toboso-Chavero et al., 2018).

1.1. Rooftop urban agriculture functionalities and experiences in cities

Rooftop urban agriculture (RUA) in cities with high population densities has multiple functionalities: it generates new agricultural spaces, represents an alternative to the current value chains about meeting the demand for food in urban areas, and serves as an ideal tool to cover cities' food needs by improving a city's self-sufficiency, reducing its dependence on foods that must be shipped in from a distance and the derived costs and contribute to a more circular urban food production system and developing a fundamental role in other areas of city life (Nadal, Cerón-Palma, et al., 2018; Sanyé-Mengual et al., 2016). Further, its benefits can be extended to addressing issues of psychological and physical health, social cohesion, economic development, urban and landscape planning, and sustainability (Azunre et al., 2019; Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht & Sanyé-Mengual, 2017). It also has a relevant impact in terms of increasing biodiversity and habitats that are more suited to the life of flora and fauna in cities, creating green spaces and serving as an ideal tool for education and environmental awareness. Furthermore, increasing green spaces in cities by implementing RUA has been demonstrated to be one of the key approaches for mitigating UHI effects (Alexandri & Jones, 2008; Lee et al., 2014; Susca et al., 2011). In addition, RUA decreases energy consumption due thermal properties and insulating effects, creating energy savings for both cooling and heating buildings (Muñoz-Liesa et al., 2020; Nadal, Oriol, et al., 2018; Susca et al., 2011).

1.2. City policies: green and urban agriculture roofs

Due to the multiple benefits from green roofs (GR), urban policies have been implemented in a global context, and the most representative incentive policies correspond to subsidy (53%) and adopting bylaws (15%). Most of these policies are presented in European cities (79% subsidy and 23% bylaw) and North American and Asian cities (12% and 9% subsidy and 32% bylaw) (Liberalesso et al., 2020).

Regarding North Europe, in 1996, the city of Basel (Switzerland) started to promote green roofs via subsidy programs (Climate adapt, 2015). In the Netherlands, several municipalities support the construction of green roofs requiring minimum criteria to be able to apply for subsidies (Almelo, 2020; Amstelveen, 2019; Amsterdam, 2020; Den Bosch, 2020; Groningen, 2020; Hengelo, 2020; Leeuwarden, 2020; Leiden, 2020). In Germany, at least 48 cities provide financial support (Technical and Environment Administration Copenhagen, 2016) that primarily covers 50% to 60% of the green roof cost (Berardi et al., 2014; Grant, 2018).

In the United States (USA), many cities (Austin, Baltimore, Milwaukee, Minneapolis, Philadelphia, New York City (NYC), Portland, Seattle, and Washington) offered financial support (Berardi et al., 2014). For example, Chicago supports up to 50% of the cost if the green roof covers greater than 50% of the net roof area (Adaptation Clearinghouse, 2015; Berardi et al., 2014).

Singapore encourages the installation of green roofs by subsidizing up to 50% of the cost for both residential and commercial buildings; green roofs must be maintained for at least five years after construction (Singapore Government, 2020).

Some cities in North Europe have approved changes in building, construction (e.g., Basel, Berlin, Stuttgart, and Copenhagen) and land-use planning codes (for example in London) to require bylaw green roofs. At the country level, France integrated a national law to require green roofs or solar panels in all new buildings located in commercial zones (The Guardian, 2015).

Other cities around the world also have adopted bylaws on the construction of green roofs on new buildings, Toronto (Canada) was the first city in North America to integrate these bylaws (City of Toronto, 2009). In Asia, the city of Tokyo requires green roofs on both private and public buildings (C40 Cities, 2015). More recently, in South America, the cities of Guarulhos and Recife in Brazil and Cordoba in Argentina also required green roofs (Grant & Gedge, 2019; Law No *7031*, 2012; Liberalesso et al., 2020).

Regarding policies for integrating RUA, New York City, Washington DC, Chicago, Toronto, Singapore, and Paris initiated pioneer programs related to food production on building rooftops. The NYC council included the use of rooftops for food production in local plans (The New York City Council, 2010). Chicago reformed city laws regarding UA, allowing urban farms on rooftops (City of Chicago, 2020; Urban sustainability exchange, 2011). In Singapore, urban planners included rooftop farms in the definition of urban green spaces and diversified the classification of agriculture land use, allowing this activity in urban areas (Diehl et al., 2020). Through the Parisculteurs program, Paris supports rooftop urban agriculture projects, and more than 48 projects have been developed on both public and private buildings since the first call in 2016 (Ville de Paris, 2019). The Barcelona city Council promoted The First Green Roof Contest in 2017. Winning projects received a subsidy up to 75% of the construction cost. The requirements stipulated that a minimum of 50% of the roof area or 200 m^2 had to be green, especially (but not only) on residential roofs. Subsidies were not restricted to the integration of ornamental plants, and projects could also integrate food production, rainwater harvesting, and renewable energy systems (Barcelona City Council, 2017).

As we can observe, cities worldwide are adopting green roof policies, especially North Europe, North America, and some Asian cities. In the case of South Europe, information in the literature regarding policies to support RUA projects are lacking. In Barcelona, recent subsidies have been emerged to encourage the implementation of these types of projects. However, the lack of promotion, specific laws, legal procedures, and urban codes can act as barriers to integrate these policies in cities that recently started to adopt support.

1.3. Approach for identifying green roofs and rooftop urban agriculture barriers and opportunities

As observed in the last section, legal barriers, such laws, and administrative procedures, are an important issue regarding RUA implementation. In addition to legal barriers, others barriers and opportunities, such as social, environmental, economic, aesthetical, and technological barriers, have been identified (Cerón-Palma et al., 2012; Heath, 2009; Hendricks & Calkins, 2006; Sanyé-Mengual et al., 2016; Sarwar & Alsaggaf, 2020; Specht & Sanyé-Mengual, 2017; Specht, Siebert, & Thomaier, 2016; Zhang et al., 2012). Table 1 presents some studies conducted to identify barriers and opportunities for implementing GR and RUA from the point of view of stakeholders or citizens.

The system studied included rooftop greenhouses (RTGs), rooftop open-air farming and urban rooftop farming (URF), all possible types of urban agriculture in and on buildings (ZFarming), and urban agriculture (UA*), including rooftop agriculture and green roofs (GR). Data collection was performed using interviews (I), seminar of discussions (S), and questionnaires (Q). Participants from studies included stakeholders already actively involved in green roofs or rooftop agriculture projects (AS), stakeholders not actively involved but considered important due to their knowledge (NAS), and citizen or residents (C).

As reflected in Table 1, the most frequent methods used for data collection included interviews and questionnaires; most of these studies included different and multidisciplinary participants specialized in diverse fields, including city planning, construction, public administration, research centers, agronomy, food distribution, sales, associations,

Table 1
Studies of barriers and opportunities from stakeholders' perceptions.

City	System	Data collection			Participant			Key approach	Reference
		I	S	Q	AS	NAS	C		
Barcelona (Spain)	RTGs		●		●			Barriers and opportunities	(Cerón-Palma et al., 2012)
Barcelona (Spain)	URF	●			●	●		Barriers and opportunities	(Sanyé-Mengual et al., 2016)
Berlin (Germany)	ZFarming	●			●	●		Benefits and risks	(Specht, Siebert, & Thomaier, 2016)
Berlin (Germany) and Barcelona (Spain)	URF	●			●	●		Risks	(Specht & Sanyé-Mengual, 2017)
Bologna (Italy)	UA*			●			●	Social acceptance	(Sanyé-Mengual, Specht, et al., 2018)
Chicago and Indianapolis (USA)	GR			●	●	●		Cost, benefits, barriers, and incentives	(Hendricks & Calkins, 2006)
Hong Kong (China)	GR	●		●	●	●		Barriers	(Zhang et al., 2012)
Lahore (Pakistan)	GR			●			●	Motivation to adopt GR	(Sarwar & Alsaggaf, 2020)
Texas (USA)	GR	●			●			Barriers and facilitators	(Heath, 2009)

and activist institutions from both private and public institutions (Heath, 2009; Sarwar & Alsaggaf, 2020; Specht & Sanyé-Mengual, 2017; Specht, Siebert, & Thomaier, 2016). In contrast, other works focused on developers, city officials, and architects (Heath, 2009; Zhang et al., 2012). Citizen and residents perceptions also have been the center of studies (Hendricks & Calkins, 2006; Sanyé-Mengual, Specht, et al., 2018; Sarwar & Alsaggaf, 2020). Perspectives focused on building owners and architects (Hendricks & Calkins, 2006) are minimally reported.

Studies that consider data collection methods where stakeholders interact and share their knowledge and experiences (e.g., focus groups, Knowledge network, or World Café) to address barriers and opportunities regarding the implementation of GR and RUA projects are lacking.

1.4. World Café method

World Café is based in a constructive conversation related to critical questions and collaborative learning. It assumes that the knowledge that we are searching is already present (Fouché & Light, 2011). This participatory method is particularly powerful due the informal environment, and its structured dialogue focuses on questions relevant to the participants and promotes rounds of information exchanges between the stakeholders that results in a cross-pollination of ideas (Estacio & Karic, 2015; Fouché & Light, 2011; Prewitt, 2011). This method has been used in a variety of settings to identify and analyze barriers and opportunities and other research aspects. For example, in London, the method was used as one part of "Well London", a five-year program to promote the health and well-being of their residents (Bertotti et al., 2012). In addition, the method has been used in deprived urban neighborhoods to analyze how residents view 'community' and the barriers to community cohesion (Bertotti et al., 2012). The method has been used in higher education to encourage reflection on internationalization (Estacio & Karic, 2015). In Ireland and the USA, the method was used for prioritization of marginalized communities (MacFarlane et al., 2017). In Genova, it was used to identify potential areas of research for measuring sustainability performance (Silva & Guenther, 2018). World Café was employed in secondary school classrooms to identify barriers and opportunities to implement an educative program (Cosby et al., 2019). The method was also used in Ireland to explore barriers and opportunities to enhance research among pharmacists (Kavanagh et al., 2020).

In this study, the World Café technique was chosen to elicit barriers and opportunities from the stakeholders because this method allows participants to share their thoughts and opinions in an open, welcoming, and social environment. Participants feel comfortable in this setting, so this method provides an opportunity for mutual insight and innovative thinking and creates possibilities for action (Estacio & Karic, 2015; Fouché & Light, 2011).

Additionally, World Café has been used effectively in analyzing barriers and opportunities (Bertotti et al., 2012; Cosby et al., 2019; Kavanagh et al., 2020). This method exhibited a significantly higher positive effect compared with traditional strategy workshops (Chang & Chen, 2015).

Worldwide, GR and RUA are increasingly used in cities, primarily as a part of air quality, climate resilience, and biodiversity strategies. Various policies and regulations in promoting green roofs and rooftop agriculture have been developed and introduced in North Europe (particularly Germany and the Netherlands) and North America. These contexts represent cases with cold winters and fewer sun hours compared with other regions, such as the South of Europe where climate conditions are more favorable for rooftop agriculture production (Sanyé-Mengual et al., 2016).

On the other hand, regarding case studies, the literature indicates a high potential of roofs (2608 ha) suitable for GR and RUA implementation in Barcelona city (Urban Ecology Agency Barcelona, 2010). Even with this potential, currently only the 0.36% of Barcelona's roofs are GR and RUA (Urban Ecology Agency Barcelona, 2010).

Previous works show a lack of policies and incentives to encourage GR and RUA projects in Barcelona; however, the recent Climate Plan 2018–2030 considers GR and RUA implementation to mitigate and adapt to climate change and improve the quality of life (Barcelona City Council, 2018). In this sense, the municipality of Barcelona recently started to encourage these types of facilities through the first contest called The First Green Roofs Contest. In this sense, the incentives for these projects appear to be very recent compared with other geographic regions.

Few studies have examined barriers and opportunities of GR and RUA projects in Barcelona, and these works were performed before the first subsidy initiative was launched. Furthermore, data collection was performed by interviews, and discussions were held in seminars. These methods have some limitations for generating insights from participants about their knowledge and experiences. Other methods, such as the World Café, can be used as a platform to gather collective knowledge to address these types of subjects.

For this work, the term urban agri-green roofs (UAGR) will be used to refer both green roofs without and with horticulture activities considering open-air as a production system.

The study makes relevant contributions with respect to previous research in this field. First and contrary to most barriers-opportunities studies and policies developed in North Europe and North America, this research focuses on Southern European, where incentives to support UAGR have recently emerged. For this reason, the contributed findings are important to provide a solid basis for the policies that aid in the development of sustainability in cities moving towards the implementation of these policies, such as Barcelona. Second, the use of World Café is an effective method for collecting data on perceptions of barriers and opportunities, but it has not been used on previous research in Barcelona. Third, this study assessed the personal experience of the stakeholders with The First Green Roof Contest and their real experience in the different stages of the project- construction-use process. Based on the above perspectives, this is a new approach in this field of study.

Finally, the work explores new perspectives regarding not only the identification of barriers and opportunities but also the stage of the life cycle (project-construction-use) of UAGR and the scale where barriers and opportunities are presented, representing an original and integrated approach to the topic to be investigated.

In this regard, the aim of this research is to identify the perceptions of barriers and opportunities for implementing UAGR projects in a Mediterranean compact city. In this sense, the specific objectives are as follows:

(1) To identify potential social, environmental, legal/administrative, technological/architectural, and economic barriers and opportunities for integrating UAGR.
(2) To determine the scale, including building, city, or global aspects, of potential barriers and opportunities are presented.
(3) To classify the perceptions of potential barriers and opportunities within a UAGR project's life cycle stages: project-construction-use.

2. Methods

Five stages were considered to address the work: (1) case study, (2) participants' definitions, (3) identification of barriers and opportunities, (4) data collection, and (5) data analysis. These stages are described in detail in the following subsections. Fig. 1 presents the workflow of this research.

2.1. Case study

The city of Barcelona (Spain) was chosen as a case study based on the following criteria:

(1) *Mediterranean compact city*. According to macro definitions, countries of Southern Europe share some geopolitical and socio-economic characteristics (Leontidou, 1990) and advanced socio-economic and political realities distinguish by similar urban issues compared with North African and Middle Eastern Mediterranean cities (Pace, 2002). Regarding micro definitions, the typical elements of many Mediterranean cities were defined as follows: recognizability of urban spaces, the subdivision of neighborhoods, and the continuous mix of architectural typologies. Mediterranean cities have been affected by similar problems, such as intensive housing; lack of green areas, infrastructures, and services; and intensive exploitation of soil (Leontidou, 1990; Pace, 2002). These sharing characteristics make Mediterranean cities from Europe countries comparable (Leontidou, 1990).

Barcelona is considered worldwide as an example of a compact city (Parés et al., 2013; Rueda, 2007) with 1.6 million inhabitants in 101.3 km^2 (15,747 inhabitants/km^2), representing one of the most dense cities in Europe (Barcelona City Council, 2018).

(2) *Lack of green spaces and competition of land*. Approximately 20% of the city's surface is occupied by densely built houses, and the city has 17.6 m^2 of green surface including Collserola Natural Park per inhabitant. Excluding this zone, the green space per inhabitant is only approximately 7 m^2 (Barcelona City Council, 2018).
(3) *Suitable weather*. Barcelona has predominant sunny weather during most of the year with average temperatures between 12 and 18 °C during the winter and 20–26 °C during the summer (Barcelona City Council, 2018). These climate conditions represent a good environment for agricultural production.

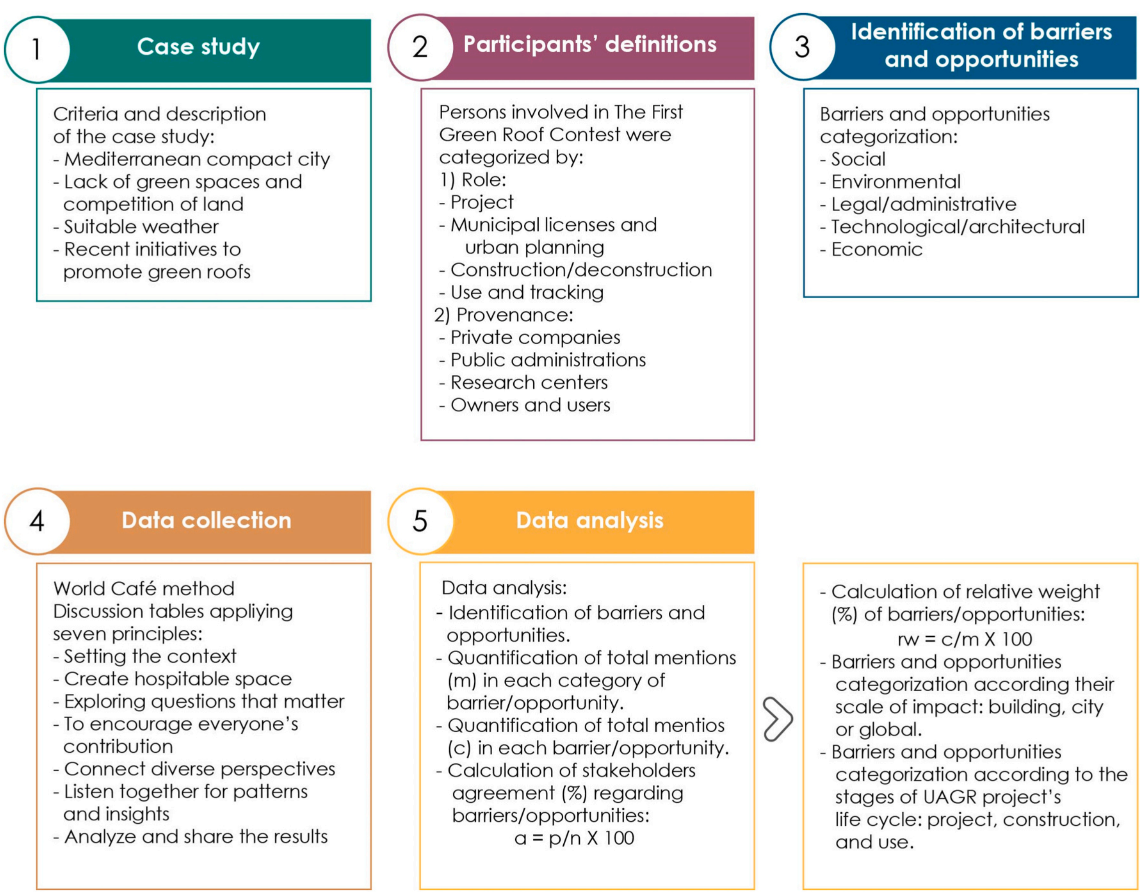

Fig. 1. Workflow to identify potential barriers and opportunities regarding UAGR implementation. Percentage of agreement (a) where p represents the number of stakeholders who identified the same barrier or opportunity and n is the total number of participants in the sessions. Relative weight (rw) expressed in percentage where c is the total times that each barrier or opportunity was mentioned and m the total mentions in each barrier/opportunity category.

(4) *Recent initiatives to promote green roofs*. Barcelona's Climate Plan 2018–2030 set the following objective: to reach 34,100 m^2 of green roofs, walls, and facades by 2030. Some of the short-term actions include to drawing up a bylaw to promote productive roofs and consolidating the annual green roof contest.

Within this background, a call of projects for The First Green Roof Contest was made in 2017. Projects could integrate UAGR, rainwater harvesting, and renewable energy systems. However, this study focuses on UAGR issues. The boundaries of the study area comprise Barcelona municipality districts, where the UAGR project winners of The First Green Roof Contest were located: L'Exaimple, Ciutat Vella, Sants Montjuic, Sarria-Sant Gervasi, Gracia, Horta-Gunardó, and Sant Andreu. In this context, this work considers public and private buildings with diverse building uses according to the participant projects, including housing, educational, offices, health, and industrial uses.

2.2. Participants definition

Participants were persons involved in Barcelona's First Green Roof Contest. In this sense, participants had recent and updated knowledge of the process of implementation of UAGR (from project to use stages). Stakeholders were categorized according to two main criteria: 1) the specific role that they play in the stages of the project's life cycle regarding the implementation of UAGR, (a) project, (b) municipal licenses and urban planning, (c) construction/deconstruction, and (d) use and tracking; and 2) their provenance, including (a) private companies (PC), (b) public administrations (PA), (c) research centers (RC), and (d) owners and users (OU). Fig. 2 shows categorization of participants.

2.3. Identification of barriers and opportunities

Five categories of barriers and opportunities were identified based on the previous literature related to rooftop urban agriculture perceptions (Cerón-Palma et al., 2012; Nadal, Oriol, et al., 2018; Sanyé-Mengual et al., 2016; Specht & Sanyé-Mengual, 2017): (1) social, (2) environmental, (3) legal/administrative, (4) technological/architectural, and (5) economic.

2.4. Data collection

The data collection was performed using the World Café method (The World Café Community Foundation, 2015) by applying the seven principles of the method.

As a first step, the session began with registration. Each participant was supplied with a label with name and a code according to their stakeholder category. After registration, a welcome presentation was made followed by an explanation of the purpose of the conversation and how the workshop would proceed.

The workshop comprised two sessions (performed in one day) and five rounds (in each discussion table) by session. The first session focused on the barriers, and the second session focused on the opportunities related with UAGR. A break occurred between each session.

The room was set up with five discussion tables; each one focused on one specific barriers/opportunities category. Participants were organized into five groups (participants chose the table where they wanted to start) composed of between 4 and 5 people and one host.

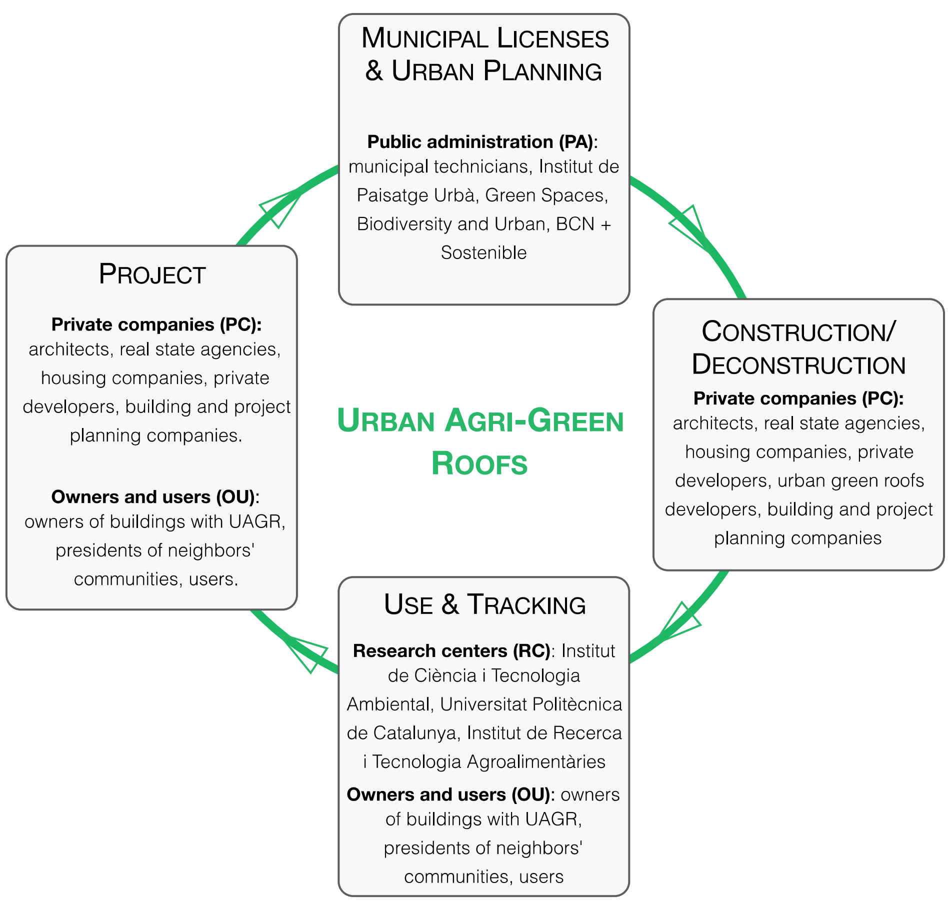

Fig. 2. Stakeholders involved in the stages of a UAGR.

2.4.1. Applying the World Café method principles

1. Setting the context. The topics were set by the barriers/opportunities in the five categories previously identified: social, environmental, legal/administrative, technological/architectural, and economic. The workshop was designed to facilitate the sharing knowledge and recent experiences regarding their participation in the contest through multi-directional knowledge exchange by contributing, connecting, and listening to each other.
2. Create hospitable space. An informal environment with a relaxed atmosphere was the aim, which was addressed through two main aspects: (1) comfortable space and furniture and (2) appropriate facilitators. The room for the workshop was big enough to allow five groups to work comfortably and simultaneously (an events hall of Barcelona's municipality building). The room was set up in a café style with chairs and tables; the room had a patio with natural light. Coffee and catering services were offered free of charge during all workshop sessions.

Facilitators were previously trained on the goals and practice of the World Café method. Table hosts came from diverse fields related to green roof projects (one architect, one agronomist, two environmental scientists and one green roof entrepreneur). Most of the hosts had academic and research backgrounds and practiced in their specific professional field.

A welcome to the table discussion and introduction were made by hosts in each round of discussion.

3. Exploring questions that matter. Discussions started with an open question that would identify key barriers and opportunities related to UAGR projects. The same question was discussed in the five tables, but each table focused on a different topic. This setup allowed stakeholders to explore the related areas around a question. The following question was discussed:

What are the barriers or opportunities (according to the session) related to UAGR projects?

Each round of discussion lasted 15 min. Once the designated time expired, the participants in each table were asked to rotate and form new groups to discuss other topic; stakeholders participated in all discussion tables with different groups. If during the discussions, no contributions were made, a list of barriers and/or opportunities and based on the literature was prepared in advance and was offered to those attending to boost the discussion (see supplemental information).

4. Encourage everyone's contribution. The principal aim of the table host was to facilitate dialogue, welcome each new group of participants, introduce them to the topic being discussed, and ensure that everybody's voice and ideas are heard. No limit in the number of interventions discussed by a participant was set.
5. Connect diverse perspectives. This principle was developed to provide a continuity of ideas from the table hosts who remained in the same table and used the provided notes of the previous group(s) to provide them with input into previously discussed topics.
6. Listen together for patterns and insights. The host encouraged participants to listen and pay attention to others' opinions. At the conclusion of the question, participants shared their insights and thoughts about collective patterns of knowledge.

The method used aims to capture the participants' views and insights. In this sense, the goal was to be as non-disruptive as possible while simultaneously helping to maintain the informality and café-like atmosphere in the room. The host at each table recorded the responses and added notes of the narratives provided by the participants.

7. Analyze and share the results. Findings from the discussion tables were visible for everyone to view and thematically displayed on tables. Hosts and stakeholders were encouraged to view the collection of experiences and knowledge. In addition, after data analysis, a plenary session with participants was held, and results were presented in this session.

2.5. Data analysis

Data generated from the discussion tables were thematically organized and analyzed in Microsoft Excel ®. This process made it possible to preserve the essence and nuances of each contribution while synthesizing the ideas under the same barrier or opportunity category. The process of data representation involved the following steps:

1. Identification of barriers/opportunities: social, environmental, legal/administrative, technological/architectural, and economic.
2. Quantification of the total mentions (m) in each barrier/opportunity category: social, environmental, legal/administrative, technological/architectural, and economic.
3. Quantification of total mentions (c) in each barrier/opportunity identified.
4. Percentage of agreement. Eq. (1) was used to obtain stakeholder agreement regarding barriers/opportunities. Where a is the agreement (%), p represents the number of stakeholders that identified the same barrier or opportunity and n is the total number of participants in the sessions.

$$a = p/n \times 100 \tag{1}$$

5. Relative weight. Eq. (2) was used to calculate the percentage of relative weight (rw) of the barrier/opportunity. Where c is the total mentions in each barrier/opportunity, and m corresponds to the total mentions in each category of barrier/opportunity.

$$rw = c/m \times 100 \tag{2}$$

6. Categorization of the scale of impact. This step refers to the specific area where each barrier or opportunity is presented. For this criterion, three main scales were distinguished: building (B), city (C), and global (G). A scale was assigned to each barrier and opportunity.
7. Categorization of the stages of UAGR project's life cycle. This step refers to the specific stage of the complete implementation of the UAGR process at which each barrier and opportunity appears. For this criterion, three main stages were distinguished: project (P) if the barrier or opportunity appears during the design; construction/deconstruction (C) if the barrier or opportunity appears during the process of mounting or disassembling the UAGR; and use (U) if the barrier or opportunity appears once the UAGR has been built and has a relationship with its operation.

3. Results and discussion

3.1. Identification of barriers and opportunities

The seminar was attended by 70% of the invited actors (24 out of 34). As mentioned above (Section 2.2), the segments of the participation were divided according to the role played by the stakeholders in the UAGR projects: 11 belonged to private companies (PC), 5 were involved in public administration (PA), 4 were members of research centers (RC), and 4 attended as building owners and users (OU). However, during the session, some participants left discussion tables about the economic barriers for personal reasons. Thus, the number of participants in this category were as follows: $n = 22$ (barriers) and $n = 18$ (opportunities).

During data collection, it was not necessary to use the *barriers and opportunities support list for the World Café by categories* (see the list on supplementary information) prepared to boost the discussion. A total of 59 barriers (z) were identified: 13 social, 12 environmental, 15 legal/administrative, 6 economic, 13 and technological/architectural. A total of 70 opportunities (z) were detected: 22 social, 13 environmental, 11 legal/administrative, 11 economic, and 13 technological/architectural. Fig. 3 presents a summary of most mentioned barriers and opportunities in each category and their relative weight. The total number of mentions (t) was 317 for barriers and 297 for opportunities considering all barriers and opportunities categories. For full data see the table *complete barriers and opportunities data extracted from the UAGR seminar* from the supplementary information.

The total mentions in each barriers category (m) were as follow: 110 social, 74 legal/administrative, 64 technological/architectural, 44 environmental, and 25 economic. The total mentions in each category of opportunities were as follows: 117 social, 55 environmental, 48 legal/administrative, 40 technological/architectural, and 37 economic. Result showed that not all barriers/opportunities categories have the same number of mentions. The category that generated more mentions was the social category with a total of 227 considering both barriers and opportunities, whereas the economic category generated the least comments with a total of 62.

Tables 2 and 3 present the most mentioned barriers and opportunities based on their relative weight, stakeholders' agreement, scale, and stage of UAGR life cycle.

3.1.1. Social barriers and opportunities

The notable social barriers perceived by the stakeholders with consensus among all the actors were (1) the need of information and scope of UAGR projects, such as prejudices, skepticism, lack of running examples and sensibility, little or no support by the municipality or the feeling that agri-green roofs will bring more problems than benefits, and (2) the lack of social cohesion, including low involvement of the community members in the implementation of these types of projects. Both barriers represent 44% of the total contributions in this area.

The lack of information about the real scope of UAGR projects includes the fact that fears and prejudices against such a project can influence more than the potential benefits, such as performing major work, water, and humidity or the influence of pollution on agricultural products. The absence of spirit and social cohesion affects the "project" stage insofar as the lack of predisposition by users and owners of buildings makes it difficult to implement UAGR projects. According to the registered opinions, such lack of spirit is not considered to be due to skepticism but rather various concepts, such as "social good" or "citizen awareness". Specifically, these concepts suggest that the priority of the collective interest against the individual is not well-integrated in city communities.

Another barrier is the doubt about whether these spaces will be used (75% of agreement). This issue is not unanimously perceived by any type of actor; however, in each category, someone identifies this barrier. Future maintenance problems (46% of agreement) are also an important

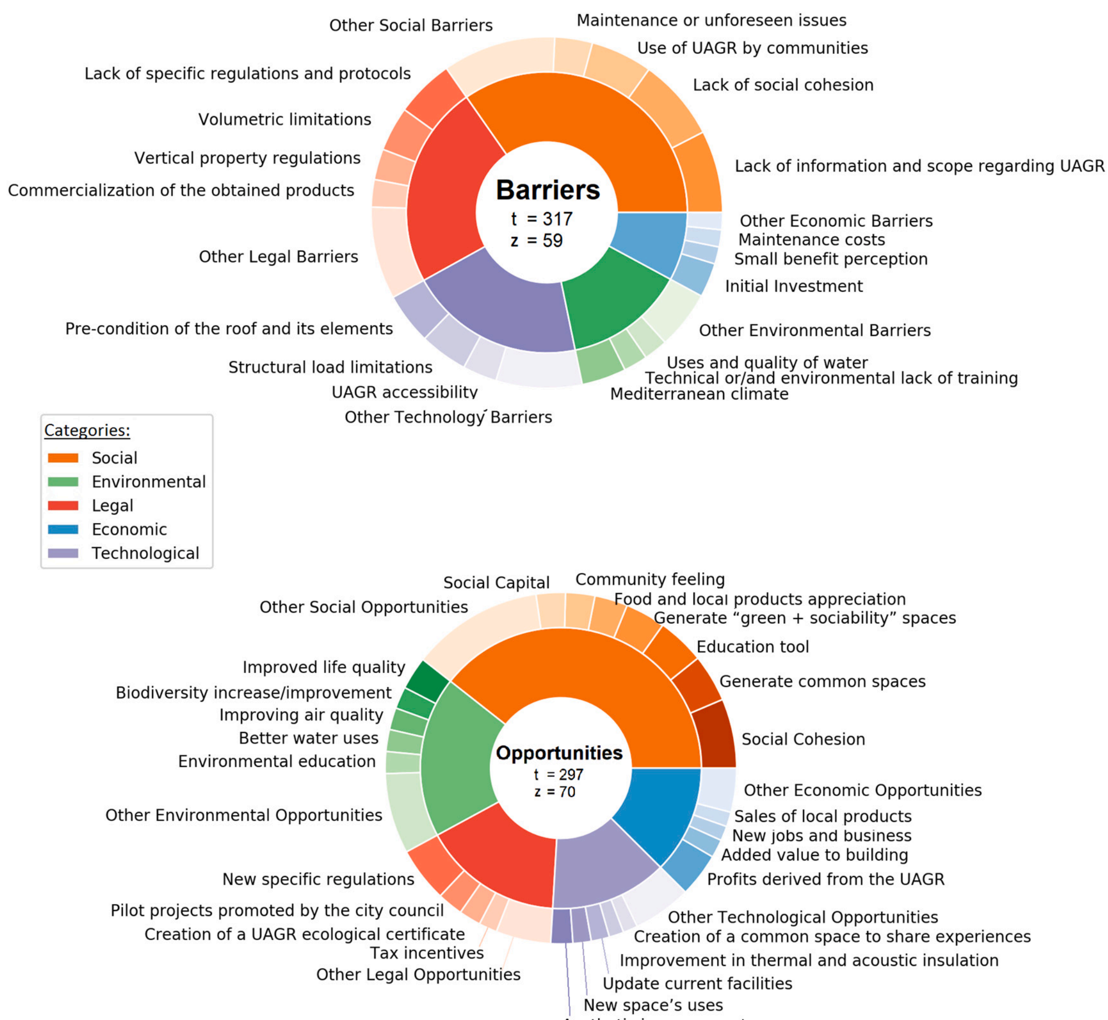

Fig. 3. Summary of most mentioned barriers and opportunities regarding the UAGR Barcelona case study. Here, *t* represents the total number of mentions considering all barriers/opportunities categories, and *z* represents the total barriers/opportunities identified.

Table 2
Barriers regarding UAGR implementation in the city of Barcelona. If a barrier was unanimously identified among all the stakeholders of the same type, it is represented in dark grey. If the barrier was identified by some stakeholders but not all, it is noted in light grey. If the barrier was not identified by stakeholders, it appears blank. Stakeholders were public administration (PA), private companies (PC), research centers (RC), and owners and users (OU). Scale includes city (C), building (B), and global (G). Stage of UAGR life cycle comprises project (P), construction (C), and use (U).

Category	Barrier	Relative weight (%)	Stakeholders agreement (%)	Public administration (PA)	Private companies (PC)	Research centers (RC)	Owners and users (OU)	Scale	Stage of UAGR life cycle
Social	Lack of information and scope regarding UAGR	22	100					C	P
	Lack of social cohesion	22	100					B	P
	Use of UAGR by communities	16	75,0					B	U
	Maintenance or unforeseen issues	10	46					B	U
Environmental	Mediterranean climate	30	54					G	U
	Technical or/and environmental lack of training	16	29					B	P
	Uses and quality of water	16	29					C	U
Legal	Lack of specific regulations and protocols	23	71					C	P
	Volumetric limitations	18	54					B	P
	Vertical property regulations	12	38					B	P
	Commercialization of the obtained products	11	33					C	P
Economic	Initial investment	40	46					B	P
	Small benefit perception	20	23					B	P
	Maintenance costs	20	23					B	U
Technological	Pre-condition of the roof and its elements	23	63					B	P
	Structural load limitations	22	58					B	P
	UAGR accessibility	16	42					B	P

concern.

Consumers' lack of trust in the quality and health risks of producing food on rooftops represents the principal social barrier reported in some cities, including Bologna (Sanyé-Mengual, Orsini, & Gianquinto, 2018) and Berlin (Specht, Siebert, & Thomaier, 2016; Specht, Weith, et al., 2016), as it is a new model of food production and there is an absence of information about how it performs in relation to air pollution in urban areas. This perception is related to prejudices and skepticism, which is one of the principals (lack of information and scope regarding UAGR) social barriers identified in this study. A recent study related to air pollution in rooftop crops shows that heavy metal concentrations in lettuce are less than the EU-legislated level even when the lettuce crops grown using open-air growing systems were located in high-traffic areas of Barcelona (Ercilla-Montserrat et al., 2018).

The previous studies identify low acceptance and concerns related to rooftop food production using soil-less growing systems, which is perceived as "artificial, unnatural, and not real" (Sanyé-Mengual et al., 2016; Specht & Sanyé-Mengual, 2017). However, this barrier was not mentioned in the results of the seminar. A positive perception was reported in a previous study in Barcelona (Ercilla-Montserrat et al., 2019). In this sense, it is important that Municipalities develop programs to disseminate appropriate information about UAGR crop systems and the quality of the products to the stakeholders, which could be reflected in the gradual decrease of this shared social barrier in various European cities.

In Berlin, a social perception was identified, namely that this type of project is exclusive and acts as a driver for gentrification (Specht, Siebert, & Thomaier, 2016). In NYC, noteworthy discrepancies in obtaining assets in the UA framework were noted, this generate inequality for UA projects (Cohen & Reynolds, 2015). Gentrification is also a concern and a paradox of urban greening (Cole et al., 2017; Specht & Sanyé-Mengual, 2017; Wolch et al., 2014). These perceptions were not mentioned in the World Café conducted in Barcelona. However, this study revealed a new concern about the lack of social cohesion; this social barrier was not found in previous studies where the social cohesion was perceived only as an opportunity.

Regarding social opportunities, several proposals were observed as well as numerous nuances when discussing the perceptions described under one opportunity topic. The only social opportunity that generates an absolute consensus in its perception among all the stakeholders was "social cohesion"; however, the relative weight of the responses was lower than that noted for barriers (16% of the total opinions versus 22%). In this sense, under the umbrella of the opportunity mentioned, the actors perceive that UAGR could offer the possibility to generate new rules and attitudes as well as the possibility of benefiting specific groups of users and offering new spaces for citizen participation at all levels (for example, geriatrics, schools, individuals, or families).

Another widely perceived opportunity (68% of stakeholders) corresponds to the possibility of creating community garden spaces, which was accepted by all participants related to the fields of research (RC) and private companies (PC). Educational opportunity emerges with the same percentage of perception although with a slight variation in the distribution among stakeholders. In this category, the richness and variety of references that we could classify as the same barrier were remarkable. It should also be noted that social cohesion was also perceived as a barrier (as lacking) and as an opportunity (as UAGR can offer new spaces and methods to generate it). Another important detail corresponds to the fact that many of the mentioned social barriers and opportunities are not "purely" social but are very interrelated among other categories (socio-economic, legal, administrative, and environmental).

Regarding social opportunities, this study and previous studies from Barcelona, Bologna and Berlin identified social cohesion and education as major benefits of the integration of UAGR projects (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht, Siebert, & Thomaier, 2016). In this sense, UAGR emerged as a catalyst for community improvement and social interaction. In addition, UAGR the strengthened social ties and served as an educational tool and a major means of appreciating local products (Cerón-Palma et al., 2012). In discussing

Table 3
Opportunities regarding UAGR implementation in the city of Barcelona. If an opportunity was unanimously identified among all the stakeholders of the same type, it is represented in dark grey. If the barrier was identified by some stakeholders but not all, it is noted in light grey. If the barrier was not identified by stakeholders, it appears blank. Stakeholders were public administration (PA), private companies (PC), research centers (RC), and owners and users (OU). Scale includes city (C), building (B), and global (G). Stage of UAGR life cycle comprises project (P), construction (C), and use (U).

Category	Opportunity	Relative weight (%)	Stakeholders agreement (%)	Public administration (PA)	Private companies (PC)	Research cente.s (RC)	Owners and users (OU)	Scale	Stage of UAGR life cycle
Social	Social cohesion	16	100	dark grey	dark grey	dark grey	dark grey	B	U
	Generate common spaces	11	68	light grey	light grey	dark grey	dark grey	B	U
	Education tool	11	68	light grey	light grey	dark grey	light grey	C	U
	Generate "green + sociability" spaces	9	58	light grey	light grey	dark grey	light grey	B	U
	Food and local products appreciation	8	47	light grey	light grey	dark grey	light grey	G	U
	Community feeling	7	42	light grey	light grey	dark grey	light grey	B	U
	Social capital	7	42	light grey	light grey		light grey	G	U
Environmental	Improved life quality	16	47	light grey	light grey		light grey	B	U
	Biodiversity increase/improvement	11	32	light grey	light grey		light grey	C	U
	Improved air quality	11	32	light grey	light grey		light grey	C	U
	Better water uses	11	32	light grey	light grey		light grey	B	U
	Environmental education	11	32	light grey	light grey			C	U
Legal	New specific regulations	31	79	dark grey	light grey		light grey	C	P
	Pilot projects promoted by the city council	15	37	light grey	light grey		light grey	C	P
	Creation of a UAGR ecological certificate	13	32		light grey		light grey	C	P
	Tax incentives	10	26	light grey	light grey		light grey	C	P
Economic	Profits derived from the UAGR	32	67	light grey	light grey	dark grey	light grey	B	U
	Added value to building	15	28		light grey		light grey	B	U
	New jobs and business	11	22	light grey	light grey	dark grey		C	U
	Sales of local products	11	22	light grey	light grey			C	U
Technological	Aesthetic improvement	15	32	light grey	light grey			B	U
	New space's uses	13	26	light grey	light grey		light grey	B	U
	Update current facilities	13	26	light grey	light grey		light grey	B	U
	Improvement in thermal and acoustic insulation	10	21	light grey	light grey	dark grey		B	U
	Creation of a common space to share experiences related with UAGR	10	21	light grey			light grey	C	U

barriers and limitations, we found connections with the possibility of low user acceptance and social indifference; however, the lack of qualified personnel to take advantage of the educational potential, the incompatibility of UAGR with city activities, and the loss of rural jobs or social disparities about the accessibility to the production systems were not perceived as barriers in the seminar. Otherwise, the lack of information and scope of UAGR, which appear as the most important barriers in this study, are not reported in previous works.

3.1.2. Environmental barriers and opportunities

In the environmental field, less concordance is found among stakeholders compared with the social field. Thus, only one barrier, the Mediterranean climate, exhibits greater than 50% agreement among shareholder categories, and only two (Mediterranean climate and the uses and quality of water) generated consensus among all stakeholder categories.

Mediterranean climate obtains the specific weight of 30% with respect to total responses in this category, and it is identified by all stakeholders' categories. However, none of them identified it unanimously. Mediterranean climate is identified as a barrier regarding the form and frequency of precipitation, which occurs in sporadic but intense events (storms) with sun effects and wind. The uses and quality of water were also perceived as a barrier for all stakeholders although with less agreement and relative weight (29% and 16%). The barrier of lack of technical or/and environmental training exhibits the same percentage as the uses and quality of water. This limitation refers to the lack of knowledge by the stakeholders involved in UAGR projects in various relevant topics, including bird migration and the selection of vegetation or species that should be introduced to preserve ecosystem equilibrium. However, this barrier was not identified by any of the actors corresponding to the owners and users (OU) category.

The major environmental barrier identified in the seminar was Barcelona's climate conditions. This result had no relationship between the environmental barriers reported in the previous works (e.g., Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht et al., 2014), which could be attributed the participants in this study who interpreted the environmental concept in relation to the climate and natural resource conditions for growing food rather than environmental impacts. The major environmental concerns in the previous research were related to the environmental impact of construction materials (Sanyé-Mengual et al., 2016; Specht & Sanyé-Mengual, 2017; Specht, Siebert, & Thomaier, 2016). Health risks due to air pollution, low expected quality products (Specht, Siebert, & Thomaier, 2016), and problems regarding organic waste management (Cerón-Palma et al., 2012) were not mentioned in the seminar.

With respect to opportunities, the heterogeneous tendency remains, and no clear opportunity was perceived in four of five categories by participants. The category with the greatest percentage of acceptance (improved life quality) does not reach 50%, and it has a relative weight of 16%. The next highest category of acceptance has a relative weight of 11% and 32% agreement. "Environmental education" was only perceived by stakeholders from public administration and private companies.

It should be noted that opportunities regarding climate change mitigation, reduction of UHI effect, energy savings, and improvements in thermal and acoustic insulation were very residual (none exceeds 7% relative weight).

In addition, carbon footprint reduction and reduction impacts associated with transport (Cerón-Palma et al., 2012) were identified under the improved air quality opportunity, as does biodiversity improvement (Williams et al., 2010). This is in keeping with the general perception that there is a clear lack of information about the scope and effects of UAGR within the population.

Regarding water management, policies from North Europe, required water retention capacity at list from 15 l/m^2 to 30 l/m^2 depending on the municipality to obtain a subsidy (Almelo, 2020; Amstelveen, 2019; Amsterdam, 2020; Den Bosch, 2020; Groningen, 2020; Hengelo, 2020; Leeuwarden, 2020; Leiden, 2020).

3.1.3. Legal/administrative barriers and opportunities

In terms of legal and administrative barriers and opportunities, more consensus was found among the stakeholders compared with the environmental field. Within the barriers, the lack of specific regulations and protocols regarding UAGR was remarkable with 71% of agreement among actors, 23% relative weight and unanimous identification by the four types of stakeholders. However, this barrier was only identified by all the individuals in the public administration group. Some interventions recorded during the seminar referred to criteria disparity, differences in legislation interpretation or lack of stability; these findings coincided with those reported by Specht, Siebert, and Thomaier (2016) where stakeholders from Berlin perceived numerous uncertainties and regulatory gaps.

Another barrier that stands out is building volume limitation in the implementation of UAGR (54% agreement and 17% relative weight) as specific legislation is limiting in terms of structural reinforcement, shadow, or greenhouses facilities. Rooftop greenhouses encounter a barrier to development as some buildings are at or exceed their floor-to-area ratio (FAR) allowance, preventing an addition to the building. Policy changes to facilitate their development have been implemented in NYC where the Departments of Buildings and City Planning developed a waiver program for greenhouses seeking space on buildings that have met or exceeded their FAR (The New York City Council, 2010), and similar policy changes were recently implemented in Paris (Paris Local Urban Plan, 2018).

It is also important to mention two more barriers as they are also identified by all types of stakeholders although at a reduced percentage. First is the percentage of acceptance of the owners when implementing a UAGR in a community of owners. This is an important limiting factor given that approval by at least 80% of owners is required for a UAGR to prosper. However, for other modifications (such as the installation of an elevator, for example), 50% is sufficient. The second barrier refers to the difficulties of the legal commercialization of agricultural products grown on roofs or regarding urban agriculture. There is a clear identification of regulatory barriers for UAGR projects that is shared with other cities.

In the case of Barcelona, its General Metropolitan Plan does not allow agriculture activities inside the city, which makes the commercialization of food produced in the city unlawful. There are also height and volume limitations regarding the installation of RTGs due to the Spanish Technical Building Code.

Regarding opportunities, the feedback dynamics that are present in the previous categories are repeated. Specifically, barriers and opportunities were simultaneously identified. This does not mean that the barriers and opportunities coincide but rather that the actions to be taken to overcome them are focused on the same field as well as the opportunities that they present. In this sense, the possibility of developing specific regulations for UAGR (79% of agreement and 31% of specific weight) emerges as the most widely identified opportunity. Therefore, UAGR projects open the door to a deep analysis to elaborate upon their own regulations, unify the administration criteria and facilitate changes in the normative and legal procedures. It must be emphasized that all the stakeholders in the public administration group identified this opportunity, whereas no one in the research centers did.

As we have shown, regulatory barriers are potential opportunities to create laws and programs to promote and increase UAGR projects. The experience of cities that have changed policies concerning the integration of UAGR projects show the potential that Barcelona now must change the law towards regulations that are more *friendly* to UAGR projects. Thus, some legal initiatives have emerged in Barcelona. Beginning in 1999, the Ordinance of Urban Landscape of Barcelona authorized planters and pots on rooftops as long as they are mobile. Later, in 2013, the Barcelona Green Infrastructure and Biodiversity Plan advocated for the promotion of urban green zones on rooftops. In 2017, the Stimulus Programme for the City's Urban Green Infrastructures proposed an increase of 1 m^2 of urban green areas per inhabitant by 2030, taking rooftops into account. In 2018, within the framework of the Climate Plan 2018–2030 for Barcelona (the research of this paper is in fact part of this green infrastructure promotion plan by the city council), several proposals were introduced, such as laws to promote productive rooftops, boost the energy generation on rooftops and promote water collection and use in buildings. There is a need to assess the regulatory barriers of UAGR projects to encourage food production on rooftops within each city and explore the use of incentives to encourage these projects, providing advantages in the local economy and social benefits and mitigating environmental impacts.

3.1.4. Economic barriers and opportunities

The discussions of economic barriers are one of the sections in which there was less participation. Only 25 answers were registered (for 117 in social barriers or 74 in legal barriers), and no barrier reached 50% agreement among stakeholders (Table 2).

Taking this lack of engagement into account, the most widely perceived barrier corresponds to the initial capital investment with 46% agreement among stakeholders but a relative weight of 40%. This barrier was identified by all the typologies of participants. This barrier refers to the installation and facilities costs, work, and materials, as well as economic disproportion between the necessary structural reinforcement and the cost of the UAGR elements. In addition, the rehabilitation of a roof under a UAGR project can be much more expensive than conventional rehabilitation. Stakeholders from this and other worldwide (Barcelona, Berlin, Chicago, Illinois, and Hong Kong) studies expressed their concerns about the financial issues of UAGR perceiving higher investments (Hendricks & Calkins, 2006; Sanyé-Mengual et al., 2016; Specht, Siebert, & Thomaier, 2016; Zhang et al., 2012).

Other significant barriers include maintenance costs (not identified by owners and users) and the low perception of UAGR's benefits and advantages given that these factors are perceived as "extra expenses", and there is minimal interest in investing in it. These findings coincide with other studies where maintenance costs have been ranked by housing project managers as the third most significant barrier in Hong Kong, the third decision priority by owners and architects from Chicago and Indianapolis, and one of the most significant barriers identified by Chicago's architects (Hendricks & Calkins, 2006; Zhang et al., 2012). Weak structural loading for integrating UAGR systems as well as increases in design and construction cost were also reported by Zhang et al. (2012).

Regarding this fact, the relationships between this barrier and the social barrier of a lack of information and prejudices regarding UAGR emerged since users are not aware of the potential benefits that the implementation of such a project can bring, including economic benefits in the form of savings, for example, in energy bills or the development of activities and services on the roofs.

The difficulty of commercializing the products obtained from UAGR appeared in a residual manner during the seminar (4% relative weight).

Previous studies from Barcelona, Berlin and Bologna (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Sanyé-Mengual, Orsini, & Gianquinto, 2018; Specht & Sanyé-Mengual, 2017) also identified minimal or no perceived economic benefits as a strong barrier together with the fact that it is difficult to develop a rooftop business (connected with legal issues), which some authors (Palmer et al., 2016; Specht &

Sanyé-Mengual, 2017) have also identified as a prominent economic barrier together with the competition of UAGR with other rooftop uses.

In terms of opportunities, the profits derived from the new uses of the roofs clearly stands out to profit economically from a space that was previously not associated with any pecuniary use. This opportunity stands out above the others with 67% agreement among stakeholders, 32% relative weight and identification by all types of actors. Within a "direct profit" perspective, a multitude of business opportunities is found for the community and/or construction companies that incorporate UAGR with possibilities, such as renting the space, guided tours or holding events, potential food and rainwater harvesting, renewable energy production/self-consumption and the production and possible sale of resources. The reduction of costs related to food production, consumption, and distribution; savings in energy bills; and the switch of the production chain to a more local scale represent indirect opportunities identified in the seminar.

Other highlighted opportunities in terms of the percentage of agreement and relative weight include the added value for the building (revaluation), the possibility of creation of new companies and jobs or the commercialization of local products and/or services. However, for all these opportunities, the perception among the stakeholders is very heterogeneous. Participants in the field of public administration (PA) and private companies (PC) are very receptive, whereas those involved in research centers (RC) or owners and users (OU) are less receptive.

When discussing economic opportunities, it is important to note the double-stranded character presented by the participants. In this sense, employment opportunities cannot imply a significant number of livable wage jobs, and they even require additional expertise. Furthermore, the increased value added to the buildings can lead to the displacement of low-income residents.

Short-term business opportunities may imply unproven profitability in the long-term along with indispensable financial and political support, which is not always assured (Palmer et al., 2016). The economic feasibility of these projects must be assessed on a case-by-case basis (Freisinger et al., 2015).

3.1.5. Technological and architectural barriers and opportunities

Two architectural and technological barriers stand out. First, the previous situation of the elements on the roof was identified as a barrier with 62% agreement among stakeholders and 23% relative weight. This barrier refers to the current uses and pre-existing elements in the roof that constrain adaptation for new UAGR uses, such as air conditioning facilities, TV aerials, photovoltaic panels, or gardening elements. The second barrier, which is interrelated with the legal field, is the building's load limitation with 58% agreement and 22% relative weight. Both barriers were identified by all the typologies of the stakeholders but not unanimously.

The complexity of incorporating food, rainwater harvesting, and renewable energy system flows in buildings; the transportation of inputs and outputs of UAGR systems; complications in terms of rehabilitating existing roofs or the use of polluting construction materials are rarely mentioned in the seminar. Collectively, these barriers have less than 10% relative weight.

The third perceived barrier (UAGR accessibility) is not often reported in the literature but issues associated with this barrier are extensively studied in the literature (Cerón-Palma et al., 2012; Nadal, Cerón-Palma, et al., 2018; Sanyé-Mengual et al., 2016). Along with these issues, the risks associated with urban integration, which include conflicts (Specht & Sanyé-Mengual, 2017; Specht, Siebert, & Thomaier, 2016) with the "urbanity" and "agriculture" concepts, animal production, noise and/or smell problems or visual/aesthetic image conflicts, were not mentioned in the seminar; however, the possibility of aesthetic city improvement was perceived as an opportunity. Load resistance was identified in this and previous studies from Barcelona (Cerón-Palma et al., 2012). Although the previous literature has referred to large barriers and opportunities for social, economic, and environmental issues, the clear identification of architectural barriers and opportunities is lacking. In this sense, this study may make an important contribution to this specific issue.

Regarding opportunities, it is remarkable that none are identified by all types of stakeholders. This notion is reflected in the low percentages of agreement among actors. Thus, no opportunity reaches 50% agreement, and the highest percentage is 31%. Thus, the most perceived opportunity (with 32% agreement and 15% relative weight) corresponds to the possibilities of aesthetic improvement offered by UAGR project implementation, including the development of architects' creativity, developing new "beauty" and "urbanity" concepts within the city or the possibility of "hiding" pre-existing facilities/machinery on the roofs. However, this opportunity was only identified by the actors belonging to public administration and private companies.

New space uses and the possibility to update current installations were perceived with similar agreement and relative weight (26% and 12%, respectively). In addition, although the numbers are lower than those noted in the first mentioned opportunity, their acceptance among the types of actors is extensive given that only stakeholders belonging to research centers do not identify them. The new uses of space include the possibility of creating quality and comfortable areas, the use of underutilized spaces or responding to new spatial needs. Further, the possibility of updating current installations includes the detection and amendment of hidden deficiencies as well as improvement in the current state of the roofs.

The relationship between architectural/technological and environmental opportunities is also noteworthy as many proposals in the architectural field have a direct impact on the environment. In this sense, for example, the opportunities to cities and buildings that are more sustainable, such as improvements to thermal and energy insulation or the possibility of creating green corridors, were identified in both categories. Special mention should be given to the "construction" stage, which only presents four technological/architectural barriers and one barrier regarding legal/administrative issues, and no opportunities of any type were identified.

3.2. Barriers and opportunities scale: building, city or global

Fig. 4 illustrates the results related to scale. The overall results showed that the barriers and opportunities identified by stakeholders during the seminar were mainly distributed between "city" (47%) and "building" (44%), whereas "global" remains at 9%. Regarding barriers, the data from the seminar reflect that 45% belong to "city", 46% to "building" and 9% to "global".

In terms of categories, "city" is the predominant scale in the legal and administrative barriers (approximately 70% of relative weight), whereas the "building" scale (75% of relative weight) is emphasized in the architectural and technological barriers. The remaining present a more homogenous distribution with percentages of approximately 50% between "city" and "building". The "global" scale has minimal impact on the barriers, reaching only 8% relative weight.

With regard to opportunities, the "building" scale is still outstanding (close to 70% of relative weight) in the technological and architectural field, whereas the "city" scale stands out with 63% relative weight in the legal and administration area. In the economic field, the distribution is homogenous with approximately 45% of opportunities pertaining to the "city" scale and 36% to the "building" scale. In the environmental field, the opportunities are distributed homogenously between the "building" and "city" scales (with relative weights of 46%, respectively).

Finally, in the social sphere, more opportunities appear is the "city" scale at approximately 55% followed by the "building" (35%) and "global" (10%) scales. However, the "global" scale minimally represents 10% of the total perceived opportunities. Additionally, the "city" scale encompasses 49% of opportunities, whereas the "building" scale occupies the remaining 41%.

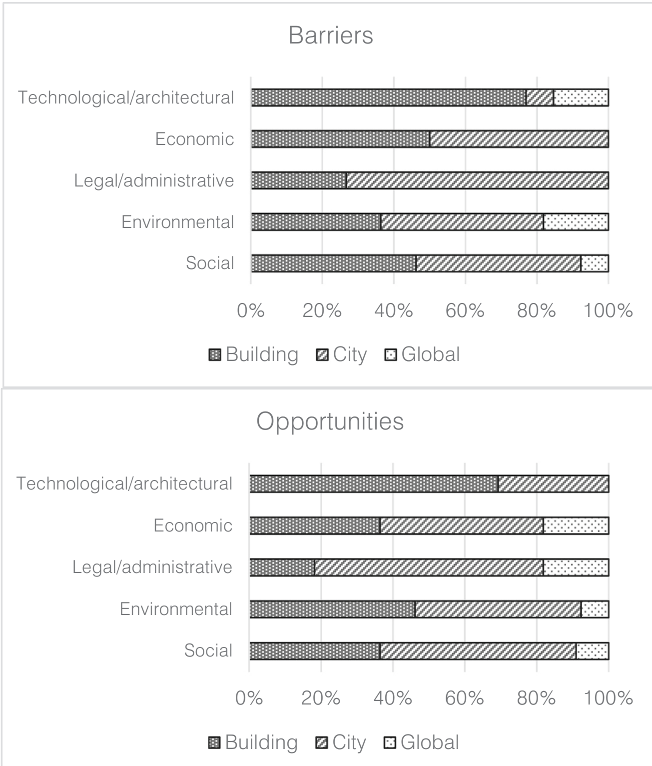

Fig. 4. Scale of impact of potential barriers and opportunities regarding UAGRs in the city of Barcelona.

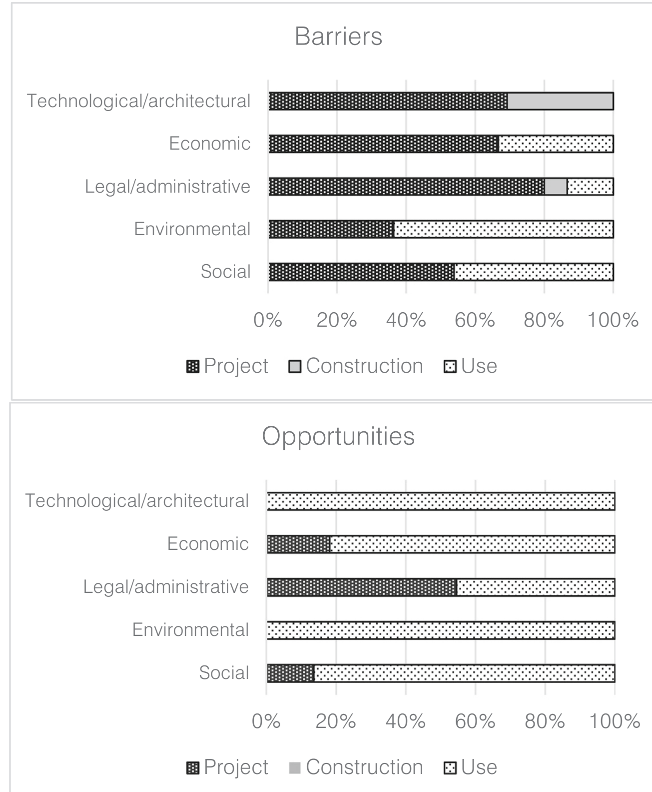

Fig. 5. Stage of UAGR life cycle where potential barriers and opportunities emerge regarding UAGRs in the city of Barcelona.

3.3. Barriers and opportunities within UAGR projects life cycle stages

Regarding the stages of a UAGR life cycle, it is essential to highlight the clear division between barriers and opportunities (Fig. 5). Referring to the barriers, the "project" stage stands out compared with the remaining stages (62% relative weight). Next, we find the "use" stage (29%) followed by the "construction" stage (9%). Thus, only the environmental category presents a predominance of the "use" stage in the discussions of the barriers, whereas barriers in the other categories (technological/architectural, legal, economic, and social) are clearly project based.

Within the opportunities, the distribution changes radically, and a clear predominance of the "use" stage emerges with 84% relative weight of the total of opportunities. The "project" stage presents 16% relative weight, whereas no opportunity is identified at the "construction" stage.

Thus, until UAGRs are in operation, most opportunities are not perceived (or they simply do not appear until the UAGR is completely operational). This finding leads us to consider why it is difficult to perceive UAGRs' benefits given that without any or fewer UAGR projects in operation, the population will never be aware of its implications and advantages.

4. Takeaway for practice

Policies for integrating UAGR projects should be an interlinked system of laws on national, regional, and local levels and connected with legal regulations regarding construction, resource management, commercial, and urban planning. Based on the results of this work, some practice and policy recommendation are described:

(1) Planning authorities must consider UAGR projects in their national and local plans to encourage UAGR on new buildings and achieve UAGR projects through new policies and modifications in urban and building codes by considering the particularities of local development plans.

(2) For existing buildings, it is generally more difficult to integrate UAGR according to buildings preconditions. In this case, the integration of incentives should be flexible, and several options must be developed, for example tax reduction subsidies or call for projects with financial support. An example of such incentive is determining the subsidy amount per each constructed square meter or a percentage of the total construction costs. It is important to create a simple structure of the offered incentives and clearly establishing what the project should encompass and the minimum requirements to be eligible to apply.

(3) For the practice of food production on rooftops, the following legal issues must be addressed:

- A flexible land-use that allow agricultural activities in cities must be considered by urban planners.
- Trade of products must be allowed with accurate production and distribution regulations.
- In the case of RTGs, it is necessary to develop a more comprehensive law to allow this type of infrastructure. Regarding the volume and floor area permitted in building codes and restrictions for building heights regulations should be flexible to support rather than act as a barrier.

(4) Financial incentives should not be assigned exclusively to the stage of UAGR construction. The stage of use is extremely important. However, it requires maintenance works, and a subsidy plans for maintenance costs should be considered.

(5) Policies also can encourage other environmental goals through UAGR projects. A minimum requirement and a type of score ranking can be developed to offer more subsidies or incentives

according to the solutions integrated in the projects regarding goals in specific locations or circumstances, for example:

- Stormwater runoff mitigation by water retention capacity.
- Rainwater use by collecting rainwater from rooftops.
- Integration of renewable energy by including photovoltaics, solar thermal panels, or wind turbines.
- Social cohesion by including spaces designed to create community activities.

(6) To improve education and awareness of UARG functions and benefits, the following practice are recommended:

- Education programs to disseminate appropriate information to residents, investors, and city policy makers should be integrated in a municipal campaign in collaboration with academics, research centers, or specialized companies involved in UAGR projects.
- Those who are interested in learning more about the technology should have access to UARG demonstration projects.
- A database of UAGR projects in cities and scientific evidence regarding benefits of UAGR projects should be generated.

(7) Regarding the development of technology and training programs, it is important to create policies to encourage the development of technologies regarding sustainable criteria, such as materials and processes for integrating UAGR projects. Also, it is necessary to support training policies for professionals specialized in sustainability regarding UAGR design and construction.
(8) The development of UAGR projects could cause gentrification. In this sense, it is important that government integrates regulations to avoid it.

5. Conclusions

This study has allowed for the attainment of a highly instructive picture of the perception of UAGR projects in the city of Barcelona, and this information can aid in the characterization of other cities with similar features.

Because most barriers are perceived in the project stage and opportunities are not perceived until the use phase, an effort by the government is needed to implement UAGR projects such that the population can perceive the benefits generated in all areas of society in an accurate manner.

This study highlighted the need for awareness and information activities, and these barriers can be solved with targeted information, education, and research dissemination of knowledge regarding UAGRS projects benefits among different actors but especially owners and users to promote a better understanding of their potential benefits. To elaborate a clear specific regulation regarding UAGR, generating more social consensus and cohesion along with economic support for those projects will be critical in facilitating its implementation. Moreover, despite the extensive list of barriers and opportunities, their relative weights are concentrated, exhibiting minimal dispersion. These features would facilitate a policy approach in Barcelona. Results can be a reference to others Mediterranean and compact cities aiming to boost agri-green roofs since they share similar characteristics such as urban forms and buildings, and similar issues such as lack of information and specific regulations and protocols, social cohesion, and initial investments in this type of facilities, among other factors. Therefore, this research is an asset towards helping such type of cities to predict and overcome plausible limitations and promoting the opportunities yielded by these projects.

Considering the focus for future research, it would be appropriate to investigate the development of indicators to monitor the impact of UAGR to verify how they match the stakeholders' perception. A constraint for our study was not having enough data to perform a comprehensive sustainability assessment since agri-green roofs are recent infrastructures and the most critical point was to identify all possible limitations and opportunities regarding agri-green roofs in Barcelona, intending to transform these projects in long-term successes and help other cities in possible drawbacks they can find to implement them in their cities. For these reasons, for future studies, we recommend carrying out a sustainability assessment regarding agri-green roofs.

It would also be appropriate to generate more consensus and social cohesion. One essential means of contributing to this purpose would be to expand dissemination studies on UAGR opportunities and to respond to the main prejudices of potential users. Research to quantify the economic, environmental, and performance benefits of UAGR will ultimately generate interest in potential adopters on the value of this project. The key points that should be evaluated in future work include the following: methods to introduce UAGR within current legal frameworks and expand on the interest in the impact and sustainability of the used materials and the disequilibrium that can be generated in local ecosystems.

Policies regarding development of technology and construction for more sustainable buildings as well as educational programs to train professionals in the field of sustainable constructions are important to address.

Several of the identified barriers have close links to government policy insufficiency; thus, there is urgency for policy instruments. Support policies should include various financial opportunities as well as bylaw requirements, and municipalities should provide technological information and support for UAGR systems in the construction phase and consider incentives for the use stage.

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CRediT authorship contribution statement

Perla Zambrano-Prado: methodology design; investigation; data collection; writing original draft, review and editing; and visualizations.
David Pons-Gumí: methodology design; data collection; formal analysis; writing original draft.
Susana Toboso-Chavero: methodology design; data collection; writing original draft review and editing; and visualizations.
Felipe Parada: data collection; formal analysis; and visualizations.
Alejandro Josa: project administration and funding acquisition.
Xavier Gabarrell: project administration; and funding acquisition.
Joan Rieradevall: conceptualization; supervision; and project administration.

Declaration of conflicting interest

The authors declare no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2021.103196.

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