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Awareness of urban climate adaptation strategies –an international overview

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ABSTRACT

Problems caused by urban climate phenomena such as urban heat island intensification, nuisance winds, or the lack of ventilation, are a growing concern with urban population growth and aging infrastructure. While many possible solutions are known, effective adaptation strategies have been insufficiently implemented to ameliorate urban climate problems. Reasons for this 'implementation gap' such as the *level of awareness* about *implementable solutions* have received little attention in the literature. An important question thus remains unanswered: what do different urban actors (citizens; politicians; urban planners and designers; and urban climate experts) who shape the urban environment and thus its climate, know about urban climate adaptation measures? We conducted a pilot study using semi-structured interviews with specialists in the field of urban sustainability related to urban planning and climate in ten countries worldwide. Interview results indicated that awareness of adaptation measures differs between countries, but even more so between different actor groups. Citizens and politicians are less aware than urban planners or designers and urban climate experts. Awareness raising should involve media campaigns, further education and display of good practice. Politicians should work on better laws and their enforcement and urban climate experts on good knowledge communication.

1. Introduction

The way that a city is designed strongly influences the urban climate. Without careful planning cities can experience problems such as urban heat island intensification (UHII) as well as strong and turbulent winds in some areas and stagnant air in others. These can affect the safety, health, and well-being of urban inhabitants (Blocken and Carmeliet, 2004; Kovats and Hajat, 2008; Smargiassi et al., 2009; McKenzie, 2015). Further, urban growth (Seto et al., 2011) and climate change (Klein et al., 2014) can worsen or amplify urban climate extreme conditions without appropriate design considerations prior to implementation (Grimmond, 2007; Smith and Levermore, 2008). Advanced attention to local urban climate variables (Oke et al., 2017) and strategies in urban planning and design

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can positively influence exposure to these phenomena and help adapt cities to climate change. Such approaches have been widely reported in the literature, with four main strategies identified to positively influence urban climate:

1. The actual *layout of cities*, including the configuration of buildings, other spatial volumes (e.g. trees, earthen artefacts like dikes), and open spaces (see, for example: Bottema, 1993; Bosselmann et al., 1995; Kanda et al., 2007; Jamei et al., 2016; Ren et al., 2018).

2. The *amount and spatial distribution of vegetated areas* such as grasslands, parks, urban forests, and elements such as trees, shrubs, greened roofs, walls, pergolas, etc. (see, for example: Shashua-Bar et al., 2006; Gill et al., 2007; Lobaccaro and Acero, 2015; Brown et al., 2015; Klemm et al., 2017b; Solcerova et al., 2017).

3. The use of different *materials* for buildings, pavements, and other urban surfaces that have an impact on urban climate through their albedo, emissivity, and other thermal/radiative properties (see, for example: Givoni, 1998; Doulos et al., 2004; Synnefa et al., 2007; Karlessi et al., 2009; Kleerekoper et al., 2015).

4. Lowering the level of *anthropogenic heat production* by limiting the production of residual heat of air conditioning, the excess heat production of combustion processes in urban motorized traffic or industry (see, for example: Ichinose et al., 1999; Bohnenstengel et al., 2014; Salamanca et al., 2014).

Several publications have translated this scientific knowledge into lay language accessible by professional planners and designers or by the public (Brown and Gillespie, 1995; Littlefair, 2000; Brown, 2010; Erell et al., 2011; Santamouris, 2013; Lenzholzer, 2015). The literature also indicates that the call for action on improving the urban climate conditions and adapting cities has been present in the urban climate literature for decades, yet insufficient action has been taken to improve urban climate conditions (Scherer et al., 1999; Eliasson, 2000; Mills, 2006; Alcoforado et al., 2009; Hebbert and Mackillop, 2013). Given the abundance of literature on interventions to moderate or improve the urban climate by location or climate type, the question arises as to whether the actors who shape the urban environment are aware of this existing knowledge? Filling this knowledge gap is an important step in the 'awareness-action' framework (Fishbein and Ajzen, 2011) that describes the different steps between knowing about a problem and eventually solving it.

Runhaar et al. (2012) and Boezeman and Kooij (2015) have already indicated that the awareness regarding water-related issues in cities receive ample attention, but that this is not yet the case for urban climate problems. Furthermore, the actors in water-related interventions (states, water board, cities) substantially differ from the actors that are involved in urban climate improvement.

Hence, it is important to understand the awareness levels of different actors who shape the urban environment, or in short: who is aware of what? This question is relevant because the scale and type of urban design and planning interventions can be implemented by specific actors. On a small scale, adaptation can include, for instance, the use of different building and paving materials (Smith and Levermore, 2008; Karlessi et al., 2009; Rosso et al., 2016; Chatzidimitriou and Yannas, 2016), greening walls (Alexandri and Jones, 2008; Köhler, 2008; Djedjig et al., 2013), de-paving yards (Scholz and Grabowiecki, 2007), or the creation of wind-safe buildings and surroundings (Bottema, 1999). Adaptation on this small scale mainly lies in the hands of citizens who own the properties or the architects/ garden designers who shape these spaces. On a larger scale, implementation of urban climate effective interventions take place in public spaces such as parks (Bowler et al., 2010; Geneletti and Zardo, 2016; Klemm et al., 2017b), streets (Ali-Toudert and Mayer, 2006; Klemm et al., 2015b), squares (Lenzholzer, 2012; Cortesão et al., 2016) and needs action at the appropriate spatial scale for use by urban designers, planners and public decision makers (Solís et al., 2017). However, the existing literature has mainly focused on adaptation actions of local authorities (Mees, 2017) and policy makers (Tàbara et al., 2010; Corfee-Morlot et al., 2011; Biesbroek et al., 2013; Lee and Hughes, 2017). The literature rarely accounts for the roles of other actors who also are part of the implementation of urban climate interventions, including citizens, urban designers/ planners, and urban climate experts (who often advise other actors on adaptation, also see (Corfee-Morlot et al., 2011; Pardo Martínez et al., 2018).

The literature about climate change perception has reported that variance in different countries might be explained by a range of factors. First, they can be influenced by common or daily experiences of predominant climate situations or weather extremes (Lee et al., 2015; Capstick et al., 2015; Hornsey et al., 2016; Demski et al., 2017; Madsen et al., 2019). Second, variance can be explained by the level of education in a country (Lee et al., 2015; Knight, 2016) that is also closely related to income levels (see Zajenkowski et al., 2013). Based on the insights from this literature, we hypothesized that the experience of climate phenomena and the level of education in a country might explain the level of awareness. Both parameters (climate experience and education level) were therefore studied as potential explanatory factors for awareness levels about design interventions to improve the overall urban climatic conditions.

To summarize: this study was concerned with the levels of awareness about urban climate adaptation, and our main research questions are: How aware are different actors in different countries about urban climate adaptation strategies? How can those awareness levels be explained? If the awareness levels are low, what could be done to raise them for the different groups of actors? Alongside these questions, we first made assumptions about how varying awareness levels in different countries might be explained. We hypothesized that the awareness might be influenced by common or daily experience of predominant and extreme temperatures. We hypothesized that a further explanatory factor for the variance may also include the level of education in a country and these factors were to be studied in relation to the awareness levels.

2. Materials and methods

In line with earlier work based on the dataset from our worldwide study (Lenzholzer et al., 2020), we used a mixed methods approach that combined quantitative and qualitative methods. Our study was conducted in ten countries worldwide that are situated in different climate zones, have different levels of development, and different political cultures. The countries studied are Belgium,

Bulgaria, China, Germany, Indonesia, Kenya, Netherlands, New Zealand, South Korea, and USA. These countries represent the climate zones that are inhabited by the majority of the world's population. They belong to three zones of the Köppen climate classification system (Kottek et al., 2006): zone A equatorial (Indonesia, Kenya), zone C warm temperate (Belgium, Bulgaria, Germany, Netherlands, New Zealand), zone D snow (South Korea). China and the USA include various climate zones, but 90% of the respondents from the two countries came from the zone C. The choice of these countries form—to some extent—a convenience sample because we could only work with students and colleagues who were able to speak the local languages.

The study was conducted from 2015 to 2017 inclusive, and consisted of semi-structured interviews with 102 participants (Belgium: 10, Bulgaria: 10, China: 9, Germany: 11, Indonesia: 10, Kenya: 11, Netherlands: 12, New Zealand: 10, South Korea: 9, USA: 10). The interviewees were specialists in the urban sustainability field, mainly from consultancies, government, academia, and NGOs. They were selected based on their overview about the current urban climate issues in their respective country and their knowledge about the current awareness levels among the different actors deriving from their professional and/or academic work in the field. Most interviews were taken face-to face. About one third were obtained through Skype or telephone and the questions 1 and 3 for the USA interviews were answered via SurveyMonkey.

The interview questions dealt with the awareness about four types of urban climate adaptation strategies:

a) the layout of the city (building volumes and configurations, street widths, etc.) that can influence heat and wind patterns
b) the use of vegetation (grass, trees, green walls, etc.) that can lower urban temperatures
c) the use of materials (building and paving materials, coatings, etc.) to lower urban temperatures
d) minimizing anthropogenic heat sources (such as air conditioner use)

Respondents were asked to estimate the awareness levels for different actors (citizens, politicians, urban planners/designers and urban climate scientists/experts) in their country. They indicated the awareness levels on a 5-point Likert scale between ‘very aware’ and ‘not aware’ and we added the option for a ‘neutral’ answer because we expected that some interviewees would see large differences in awareness among the respective group of actors. Furthermore, the respondents were invited to comment their choices. In a separate second question, interviewees were asked to suggest ways to increase overall population awareness about the urban climate adaptation options.

The data derived from the Likert-scale answers were analysed with descriptive statistics in Excel and the results from the respective countries were compared. As mentioned in the introduction, we assumed that the national climate circumstances (e.g., predominant patterns in wind, cold, heat, precipitation) might have an influence on the awareness about urban climate, as populations may be exposed to its typical phenomena to varying degrees in their country. To compare the interview data with climate data, we collected relevant climate data for all countries: data for the mean and the extreme temperatures. We retrieved the data from the Climate Knowledge Portal of the World Bank (2019) which were collected during the years 1991–2016. We further analysed our interview data in Excel. We first clustered the results by an affirmative answer to the respective question (e.g. ‘very aware’/‘aware’) and the dissenting answers (‘less aware’/ ‘not aware’) and omitted ‘neutral’ and ‘do not know’ as these responses do not provide usable data for statistical comparison. Based on these clustered awareness data, we generated regressions relating climate data to affirmative and dissenting responses. For the regressions, we related higher awareness levels to rising average/extreme temperatures and vice versa.

Furthermore, we assumed that the education levels in different countries might have an influence on the awareness of politicians and citizens (urban planners/ designers and urban climate experts are highly educated by default), as these two groups often represent different education levels. Hence, we ranked the countries according to the education index of the UN (UnitedNations, 2019). Within this index, the countries studied belong to the following groups:

i) countries with highest education levels (first quartile of ranking): Belgium, Germany, Netherlands, New Zealand, South Korea, USA
ii) countries with medium education levels (second quartile of ranking): Bulgaria, China
iii) countries with lower education levels (third quartile of ranking): Indonesia
iv) countries with low education levels (fourth quartile of ranking): Kenya

The data for all countries per education level group were accumulated and averages calculated for the classes ‘very aware’/ ‘aware’ and ‘less aware’ / ‘not aware’. The classes ‘neutral’ and ‘do not know’ were omitted as they do not provide usable data for regressions. We then generated regressions for the education level data and their relationship to the awareness levels.

The data of the comments regarding the choices in the Likert scales in question 1a-d as well as data from the open interview question 2 were analysed through a qualitative content analysis in Atlas.ti. To analyse the wide array of answers, we developed a list of codes that represent similar types of answers. These coded arrays of answers were assigned to each answer and subsequently presented in co-occurrence tables related to the countries in which they were mentioned (see appendix).

3. Results and discussion

In this section the results of the inquiries are reported in the order of the questionnaire presented to our interviewees, separated

Table 1
Overview of regression results for countries' temperature data.

Relations per question	Category of actors	R^2 values high level awareness	R^2 values low level awareness
Awareness about city layout related to:			
Average temperature	Citizens	−0.121	0.249
	Politicians	−0.395	0.312
	Urban pl./ des.	−0.001	0.128
	Urban climate exp.	0.045	−0.113
Extreme temperature	Citizens	−0.526	0.378
	Politicians	−0.247	0.090
	Urban pl./ des.	−0.041	0.004
	Urban climate exp.	0.108	−0.084
Awareness urban vegetation related to:			
Average temperature	Citizens	−0.052	0.441
	Politicians	−0.230	0.243
	Urban pl./ des.	0.001	0.030
	Urban climate exp.	0.174	0.000
Extreme temperature	Citizens	- 0.181	0.125
	Politicians	−0.166	0.092
	Urban pl./ des.	0.076	−0.074
	Urban climate exp.	0.087	0.000
Awareness on use of materials related to:			
Average temperature	Citizens	0.101	- 0.140
	Politicians	0.018	- 0.003
	Urban pl./ des.	- 0.241	0.122
	Urban climate exp.	0.002	- 0.019
Extreme temperature	Citizens	0.000	0.009
	Politicians	- 0.002	- 0.005
	Urban pl./ des.	- 0.036	0.026
	Urban climate exp.	0.034	- 0.015
Awareness of anthrop. heat red. related to:			
Average temperature	Citizens	- 0.005	- 0.022
	Politicians	- 0.076	0.000
	Urban pl./ des.	0.002	- 0.025
	Urban climate exp.	0.001	- 0.023
Extreme temperature	Citizens	0.035	- 0.234
	Politicians	0.002	0.077
	Urban pl./ des.	0.024	0.105
	Urban climate exp.	0.038	- 0.003

according to the four different actor groups that the answers refer to. Answering the questions 1a-d resulted in quantitative information based on the Likert scales, but in some cases, interviewees also provided extra comments about why a certain level of awareness was assigned to a certain group (> 350 comments). Answers to question 2 contained qualitative results from the different answers (> 2500) that were scrutinized in the content analysis. These data reflect an informed estimation by the respondents and the respondents did not speak as representatives of the four actor groups. For example, a consultant may speak towards how politicians might use urban climate formation, yet the interviewee is not a politician themselves. For the sake of lingual simplicity, however, this context will not be mentioned in each sentence when the results are described.

For each cluster of answers the outcomes have been discussed (also in relation to literature, if possible), and related to data on education levels and climate data for the respective countries.

The relationships between the temperature data and awareness were represented in scatterplots (see appendix) and Table 1 provides an overview of the regression data connecting awareness to temperature data. The relationships between awareness levels and education levels have been represented in column diagrams (see appendix) and Table 2 presents regression results connecting awareness to education levels. The presentation of the results for each question has been followed by a conclusion that summarized the results and compared the results between actor groups.

Table 2
Overview of regression results for countries' education levels.

Relations education levels to	Category of actors	R^2 values high level awareness	R^2 values low level awareness
Awareness about city layout			
	Citizens	−0.853	0.360
	Politicians	−0.873	0.691
Awareness urban vegetation			
	Citizens	−0.003	0.297
	Politicians	−0.314	0.640
Awareness on use of materials			
	Citizens	0.343	- 0.188
	Politicians	0.201	- 0.060
Awareness of anthrop.heat reduction			
	Citizens	- 0.030	0.310
	Politicians	- 0.076	0.003

3.1. How aware are the groups of the following four urban climate adaptation measures?

3.1.1. City design/layout

3.1.1.1. Citizens. Citizens generally had a low awareness of how urban design influences the climate in cities (see Fig. 1).

However, in a few countries, such as New Zealand and The Netherlands, the awareness was clearly higher than in most other countries. The interviewee's comments showed that a lower awareness is because urban climate is an invisible abstract phenomenon (New Zealand, The Netherlands), an issue that was also mentioned concerning climate adaptation in general (Corfee-Morlot et al., 2011). Also, urban design and planning are somewhat uncommon to citizens, as *"urban design is not their daily business"* (Belgian interviewee) and *"urban design is too large in scale for citizens to understand it"* (Dutch interviewee). In a similar vein, it was mentioned that people lack the insight into the way city layout creates a distinct urban climate (Belgium, Kenya). A higher awareness evolves through daily experience of urban climate phenomena, as expressed by an interviewee from New Zealand: *"People are aware of solar orientation, particularly with housing"*. The literature indicates that experience of typical microclimate situations—for instance within a specific urban fabric's normal circumstances (Lenzholzer, 2010; Vasilikou and Nikolopoulou, 2020) or in more extreme circumstances such as during heat waves (Franck et al., 2013)—indeed shapes people's awareness.

The levels of education in different countries were related to the levels of awareness of urban layout influencing the urban climate. However, there was no relationship between mean air temperature and citizen awareness, but there was a weak relationship with minimum and maximum temperatures (see Tables 1 and 2).

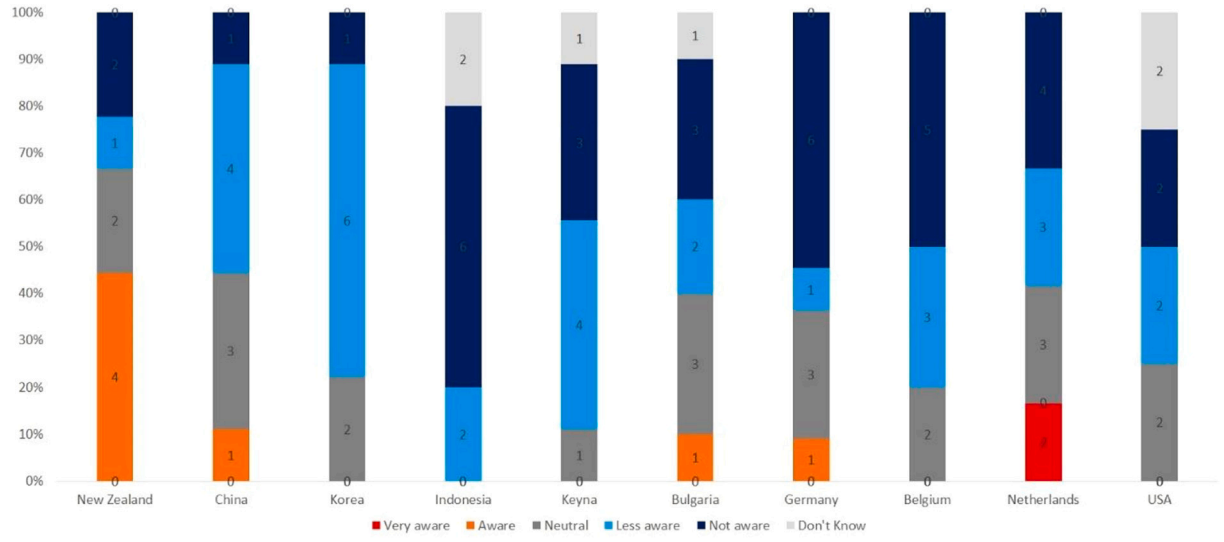

Fig. 1. Awareness levels of citizens regarding city layout influencing urban climate.

3.1.1.2. Politicians. Generally speaking, politicians in most countries were not very aware of the relationship between urban climate and urban layout (see Fig. 2). In a few countries such as New Zealand, Germany, and The Netherlands the awareness was higher than in the other countries. The interviewee's comments focused on the lack of knowledge among politicians. For instance, a Dutch interviewee narrated: *"some interventions are known by politicians but rather because they enhance the livability of an area, but not for the actual urban climate effects"*. As a means to raise awareness a Belgian interviewee thinks that *"politicians are getting aware of the possibilities in urban design through visualizations of the climate responsive designs"*.

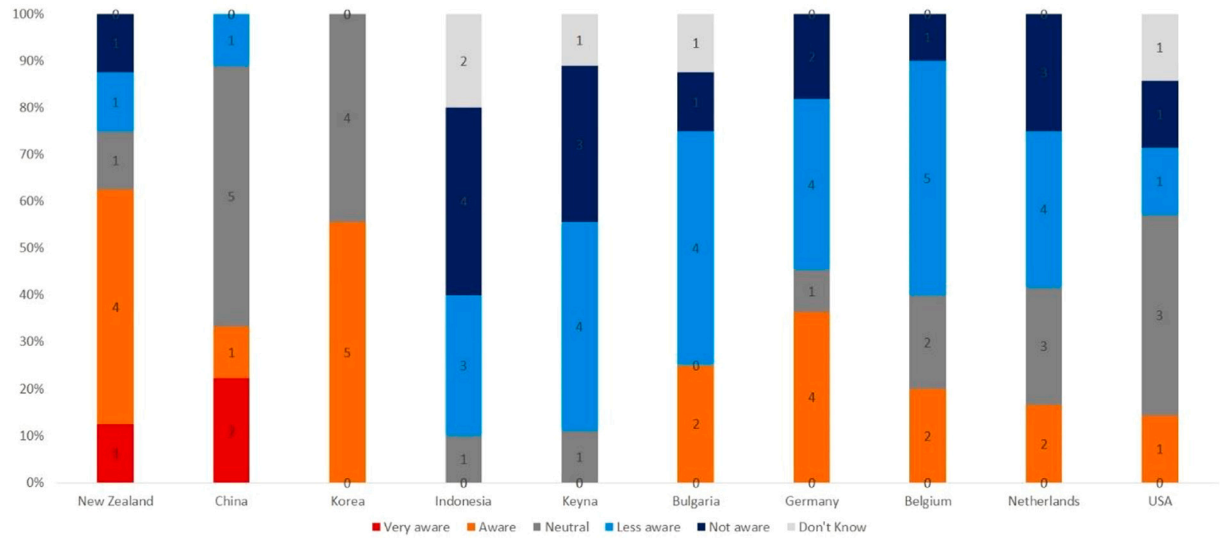

Fig. 2. Awareness levels of politicians regarding city layout influencing urban climate.

Education levels of countries clearly seem to influence the awareness among the politicians, but temperature data (both means and extremes) do not indicate any relationships (see Tables 1 and 2).

3.1.1.3. Urban planners and designers. There was a high level of awareness among urban planners and designers about the effects of urban layouts in all countries (see Fig. 3). The interviewees' comments showed that lower awareness was due to the denial of the issue (climate change and need for adaptation) in general and prioritizing of other issues, so that interventions in city layouts for urban climate improvements get overruled. For instance, aesthetic issues can be a major factor that are prioritized, as a Dutch interviewee reported: *"designers sometimes prefer the 'beautiful form' to climate responsive design"*. According to other comments, higher awareness was attributable to the formal education of students for their future tasks as planners and designers and of professionals during their career in lifelong learning routes.

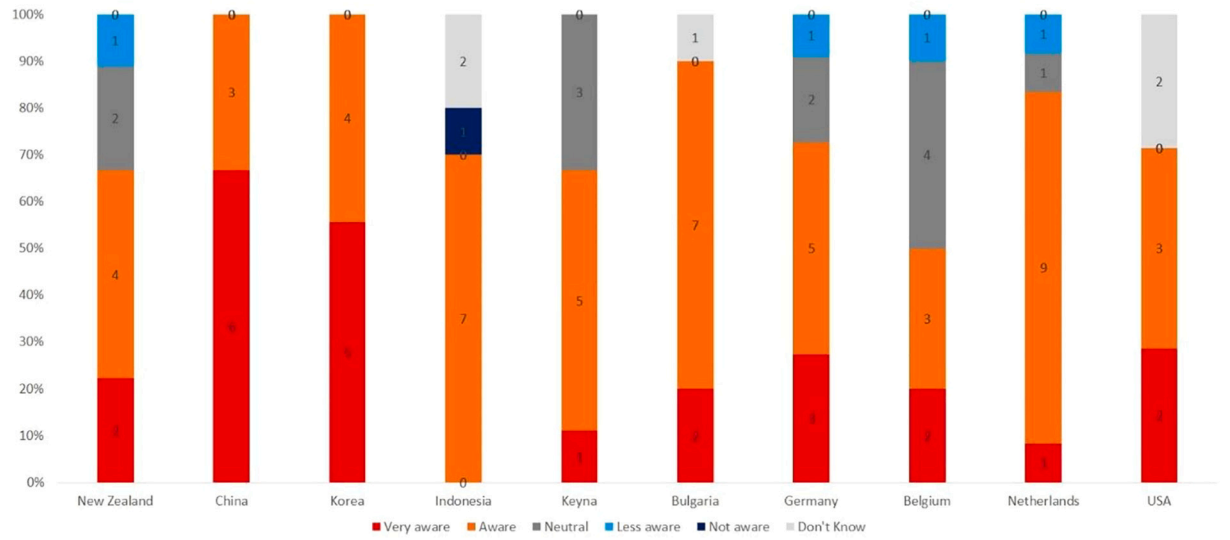

Fig. 3. Awareness levels of urban planners and designers regarding city layout influencing urban climate.

3.1.1.4. Urban climate experts. There was also a high level of awareness among urban climate experts about the effects of city layout on urban climate in all countries (see Fig. 4). Some interviewees' comments indicated that lower awareness occurs when the urban climate experts have too little scientific evidence of the effects of city layouts on urban climate and that in some cases the urban climate experts – mostly being scientists and not design or planning practitioners – were not sufficiently aware of adaptation options through urban planning and design. Two Belgian interviews reported: *"urban climate experts have too little expertise about urban design"* and that *"climate experts are not involved in the design process itself"*. Such a lack of cooperation and communication between urban climate experts and other actors has been addressed in the literature before (Eliasson, 2000; Corburn, 2009; Hebbert and Mackillop, 2013; Webb, 2017).

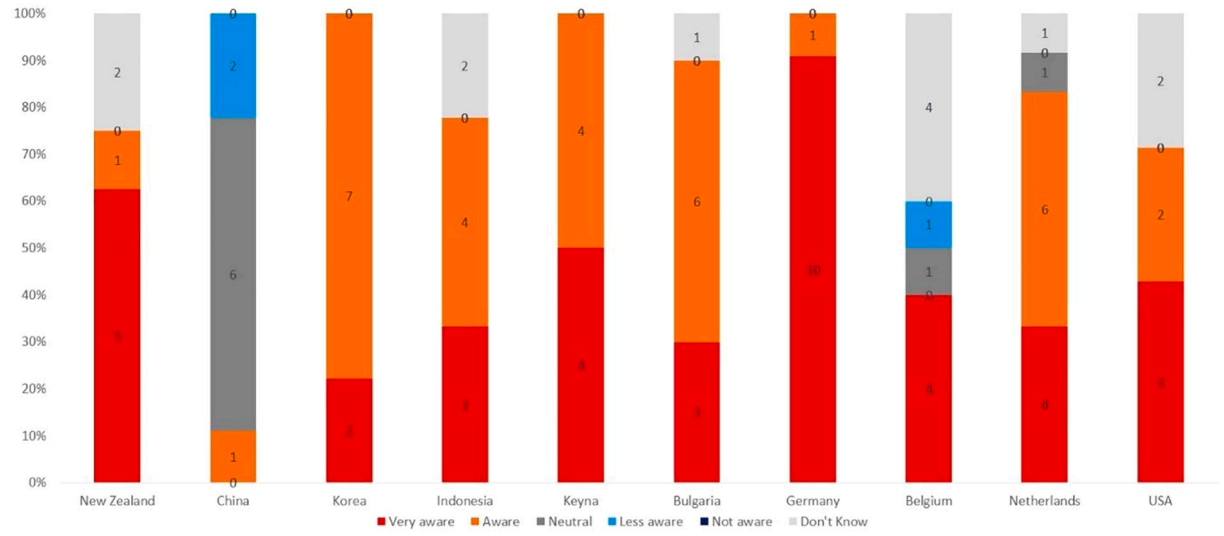

Fig. 4. Awareness levels of urban climate experts regarding city layout influencing urban climate.

3.1.2. Urban vegetation

3.1.2.1. Citizens. Overall, the citizens seemed to be divided in their awareness levels: about one half seemed to be aware of the influence of vegetation on urban climate and the other half was not (see Fig. 5). In some countries such as New Zealand, Belgium China, Kenya, Bulgaria and Germany, citizens tended to have higher awareness, whereas in Indonesia it was comparatively low. The interviewees' comments showed that lower awareness had various causes: urban climate being an abstract, invisible phenomenon (also see (Corfee-Morlot et al., 2011), that citizens did not know how vegetation influences urban climate, as an interviewee from

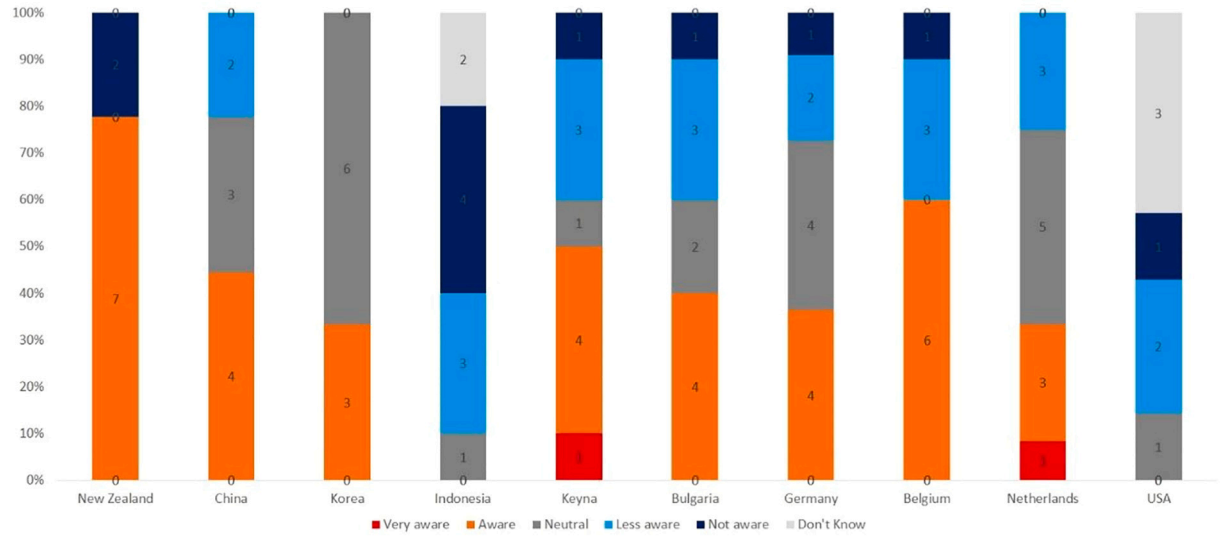

Fig. 5. Awareness levels of citizens regarding vegetation influencing urban climate.

New Zealand reports: *"People don't think of urban vegetation in terms of climate change adaptation, more for biodiversity and visual amenity",* an issue that is also reported by Derkzen et al. (2017). Also, citizens tended to prioritize other factors in shaping their environment. A Kenyan interviewee explained that there is a *"tendency in urban areas to pave green areas for easier maintenance and there is no law against it".*

Higher awareness occurred due to daily experience of the cooling potential of urban green, as has been indicated by Klemm et al. (2015b). This awareness was especially prominent in cities of developing countries with warm climates, as an interviewee from Kenya explained:" *Everyone is aware of urban vegetation and its value. In the built environment more built up space and concrete mean more dust, less water absorption. Most people come from rural backgrounds thus know of the value of nature."* Sometimes awareness could also be higher due to the fact that urban greening can be a spearhead topic in grassroot movements (e.g. in The Netherlands and Kenya).

3.1.2.2. Politicians. It seems that the politicians in most countries were quite aware of the relationships between urban climate and urban greenery (see Fig. 6). In a few countries, such as Kenya, Bulgaria, Netherlands and Indonesia, the awareness among politicians was considered lower than in most other countries.

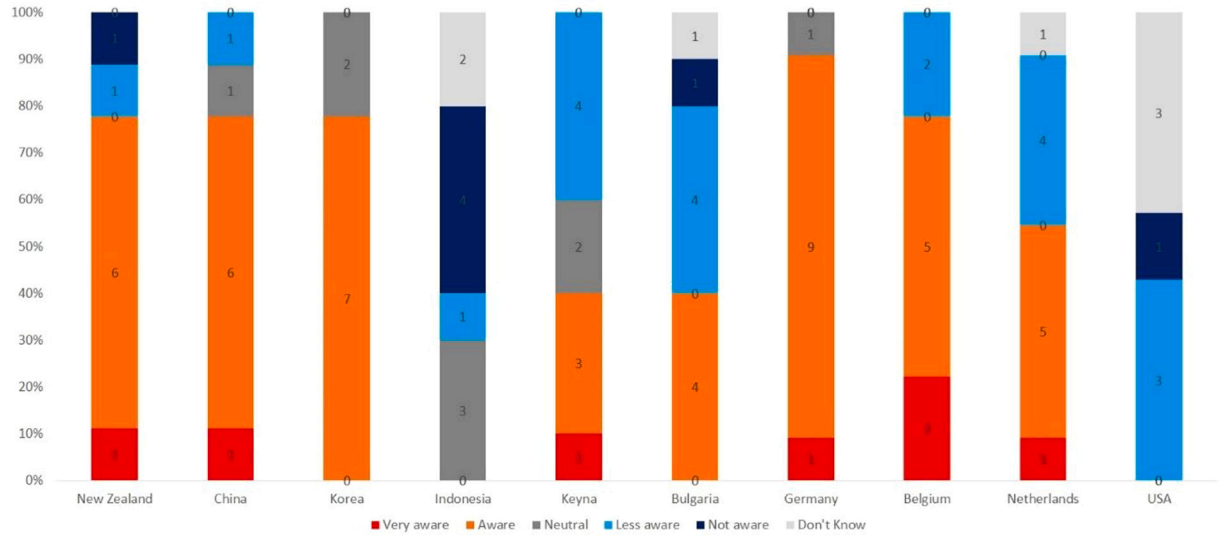

Fig. 6. Awareness levels of politicians regarding vegetation influencing urban climate.

The interviewees' comments showed that lower awareness was due to their insufficient knowledge of vegetation affecting urban climate and higher awareness was due to good examples or demonstration projects. A South Korean interviewee said: *"Urban greenery is the most concrete and common measure in use at present. As you can see in the [undisclosed location] climate adaptation plan document, there is a growing concern in increasing the amount of vegetation and green space."*

The regressions indicate that there are relationships between the typical education levels of countries and awareness levels of politicians (see Tables 1 and 2).

3.1.2.3. Urban planners and designers. Data indicate a rather high level of awareness among urban planners and designers about the effects of green interventions on urban climate in all countries (see Fig. 7). The interviewees' comments did not provide clear reasons for a higher awareness, but other research supports this rather high awareness level about green interventions (Geneletti and Zardo, 2016). In the cases when lower awareness existed, it seemed to be influenced by the predominance of other priorities (e.g. local political agendas and project briefs that have other focus areas).

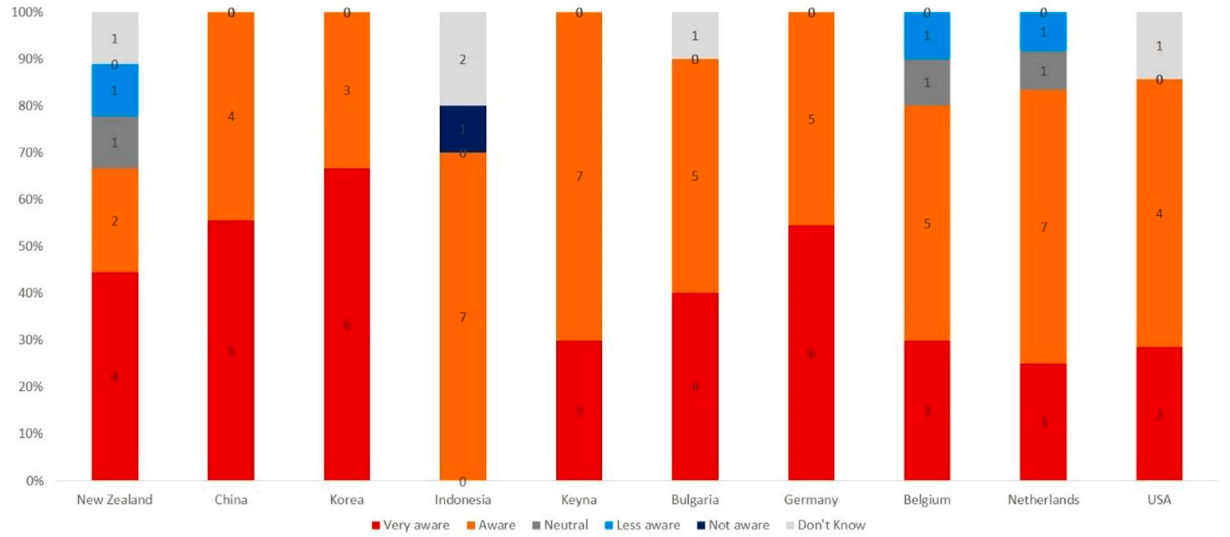

Fig. 7. Awareness levels of urban planners and designers regarding vegetation influencing urban climate.

3.1.2.4. Urban climate experts. The majority of urban climate experts were considered to be 'very aware' of the relations between urban climate and urban greening (see Fig. 8). The interviewees did not provide significant additional comments as the urban climate experts have acquired this knowledge through the scientific literature and first- hand empirical data about the influence of vegetation on urban climate.

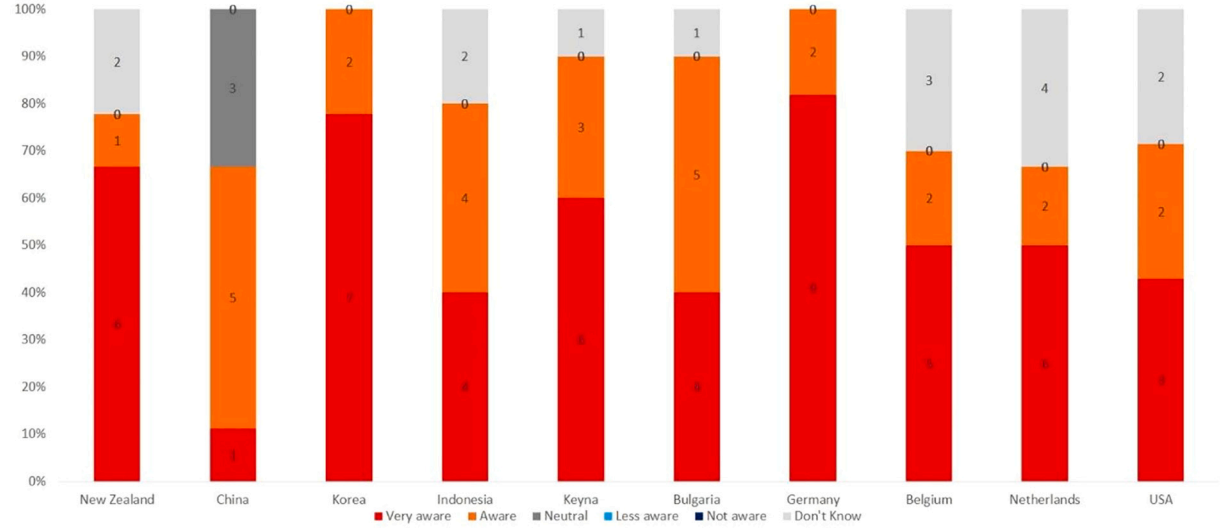

Fig. 8. Awareness levels of urban climate experts regarding vegetation influencing urban climate.

3.1.3. Use of material

3.1.3.1. Citizens. Citizens were not very aware of the options to change urban climate through conscious use of building and pavement materials (see Fig. 9). Some interviewees mentioned that citizens choose materials based on cost aspects or mainly for their aesthetic characteristics, as was summarized by of an interviewee from Kenya: *"materials are used in cities that look beautiful, i.e. the colour, there is no consideration of the property of the materials. … For example, we use materials because we think they make our houses and spaces look expensive, with the goal to look 'posh'"*.

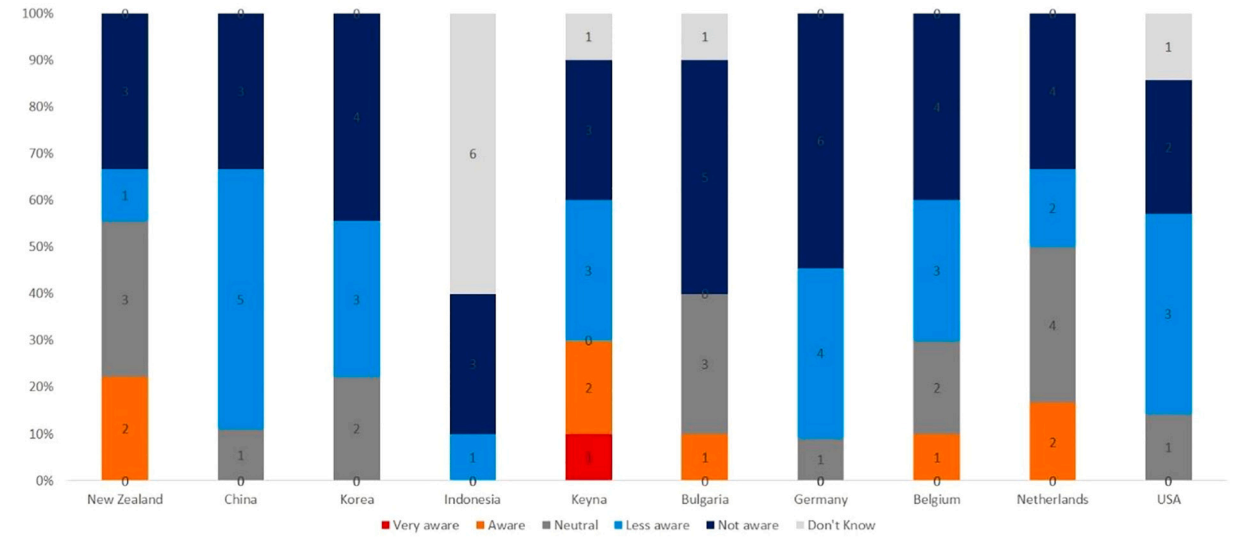

Fig. 9. Awareness levels of citizens regarding material use influencing urban climate.

3.1.3.2. Politicians. The politicians in most countries were not very aware of the relationship between urban climate and surface materials (see Fig. 10). In Kenya, New Zealand, and Belgium, the awareness was somewhat higher than in other countries. In Belgium the interviewees mentioned a new building regulation that prohibits the use of low albedo material, and in a South Korean city the *"government has a growing interest in dealing building materials for cooling urban heat. For example, there is a consideration in developing planning regulations of using light colored materials for buildings and traffic roads."*

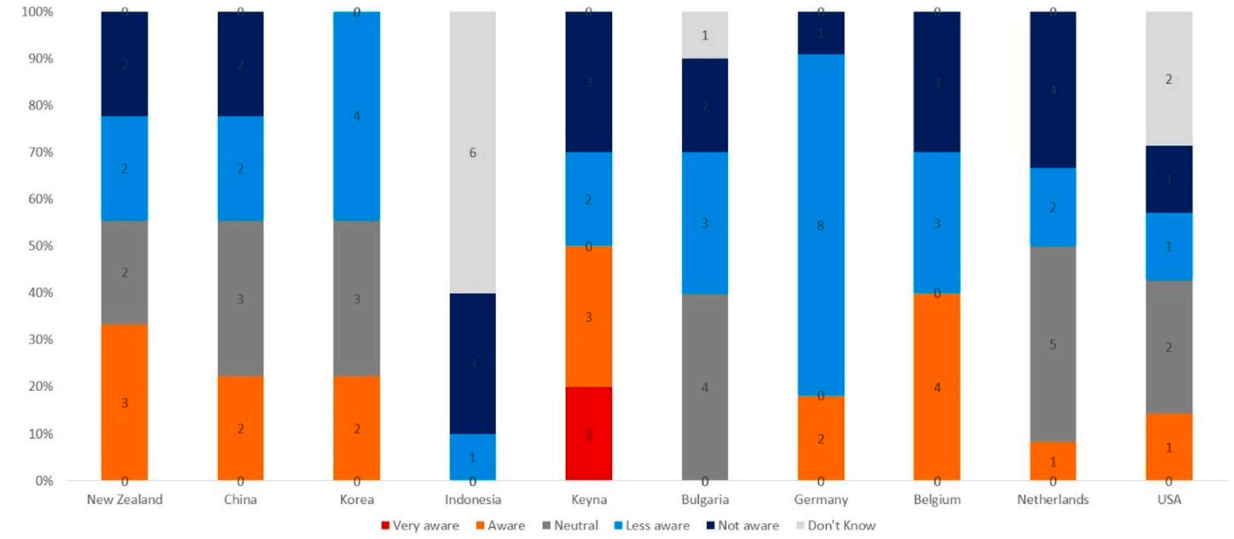

Fig. 10. Awareness levels of politicians regarding material use influencing urban climate.

3.1.3.3. Urban planners and designers. Most urban planners and designers were well-aware of the relationships between materiality of urban surfaces and urban climate (see Fig. 11). The interviewees' comments showed that planners and designers were especially aware of the effect of road surface and the use of light-colored materials on urban climate. However, they also mentioned that planners and designers in some countries are aware but make compromises in their choices of materials due to other priorities.

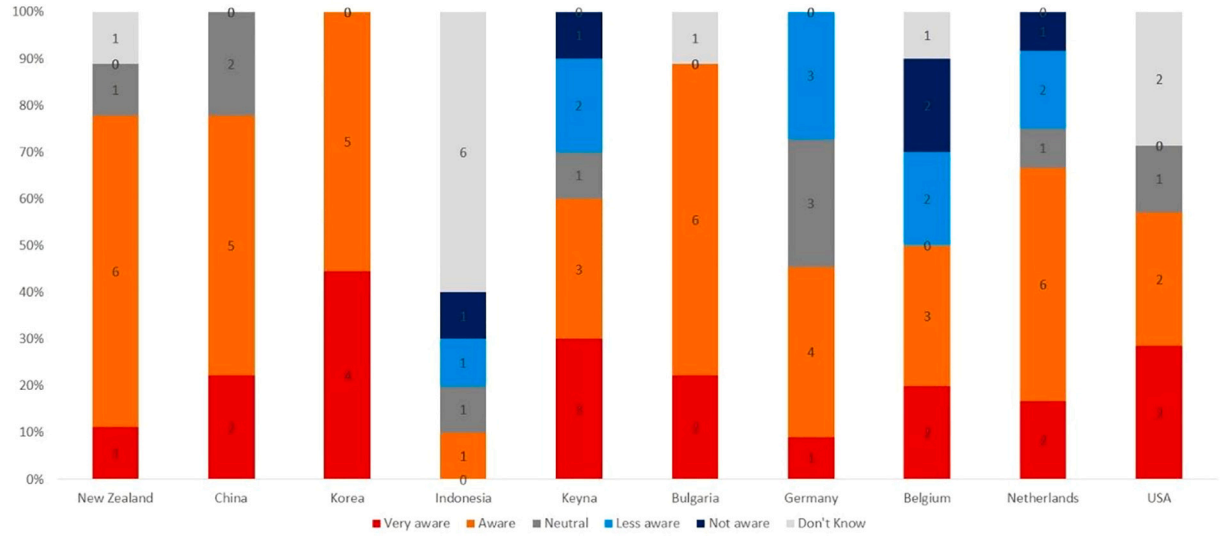

Fig. 11. Awareness levels of urban planners and designers regarding material use influencing urban climate.

3.1.3.4. Urban climate experts. The majority of urban climate experts were aware of the relationship between urban climate and urban materials, but the awareness about building materials was lower in China and Kenya (see Fig. 12). In this context interviewees from Kenya mentioned a general lack of climate experts in the country, which might explain this result. The Chinese interviewees unfortunately did not provide further comments that would explain this finding.

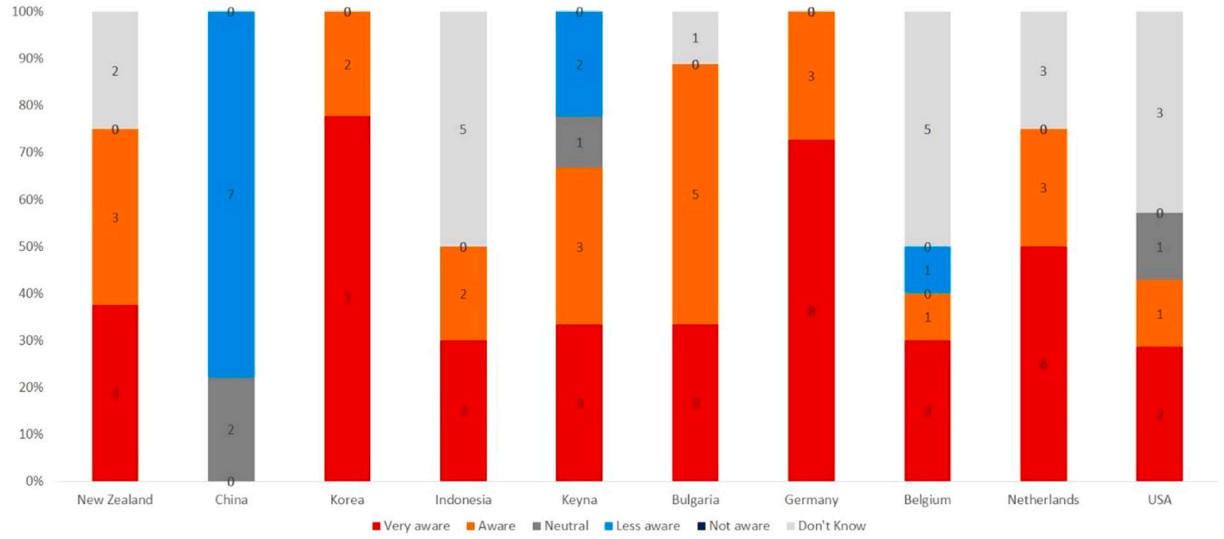

Fig. 12. Awareness levels of urban climate experts regarding material use influencing urban climate.

3.1.4. Anthropogenic heat reduction

3.1.4.1. Citizens. Citizens were rather not aware of the options to change urban climate through controlling anthropogenic heat (see Fig. 13). This was clearly expressed by the interviewee from Kenya who said: *"A lot of people think air-conditioning is a sign of a good building, when ironically it means that the design often did not take ventilation into account"*. Other interviewees' comments showed that citizens tend to link the use of cars and air conditioners to other reasons, such as air pollution or saving fuel costs, rather than reducing urban overheating. These results indicate a lower awareness level about the impact of anthropogenic heat than the study of Ho et al. (2020) conducted in Hongkong. This difference in awareness might occur due to the special circumstances in Hongkong which is very densely built up and where traffic congestion and air conditioning can have a stronger impact than in other cities.

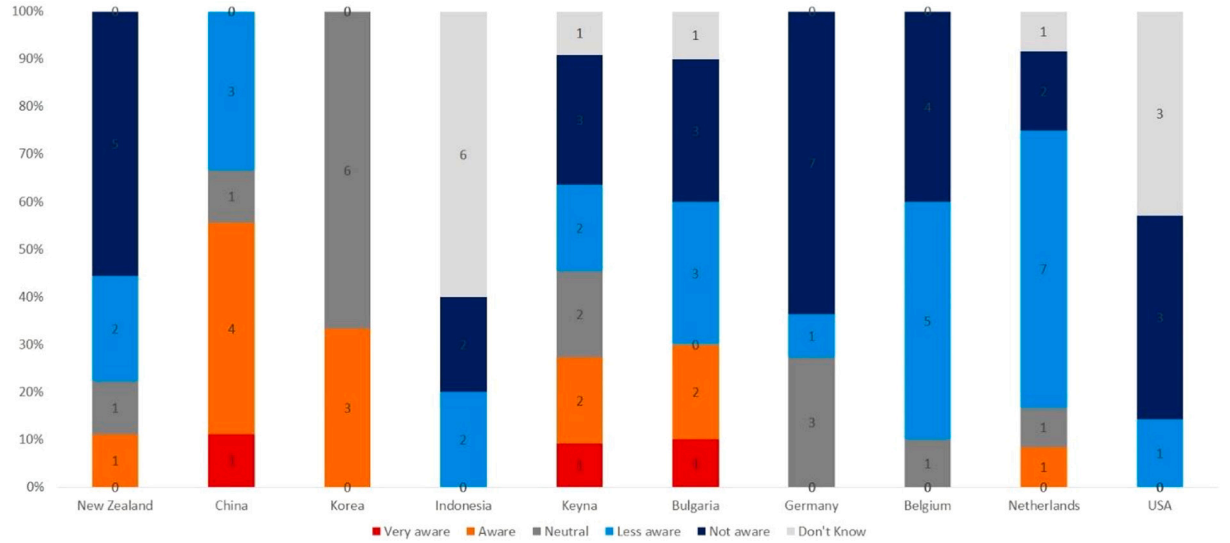

Fig. 13. Awareness levels of citizens regarding anthropogenic heat influencing urban climate.

3.1.4.2. Politicians. The politicians in most countries were not very aware of the relationship between urban climate and controlling excess heat from combustion processes (see Fig. 14). In China and South Korea, awareness among politicians was higher than in other countries, whereas in Belgium, the Netherlands, Bulgaria, USA, and Germany, it was quite low. Additional explanatory comments were not provided by the interviewees.

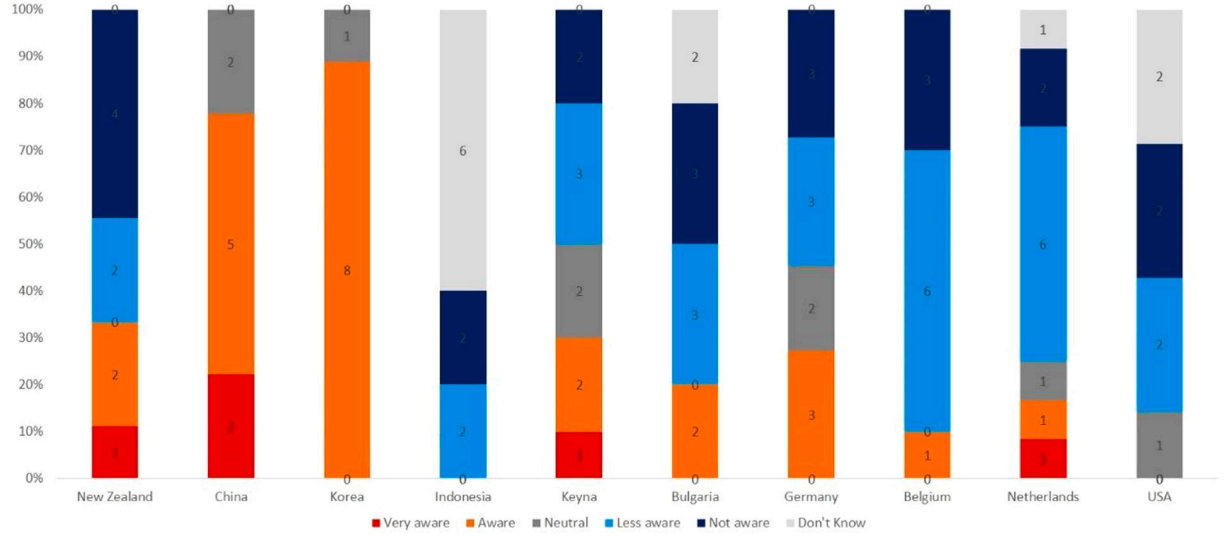

Fig. 14. Awareness levels of politicians regarding anthropogenic heat influencing urban climate.

3.1.4.3. Urban planners and designers. There was quite a high level of awareness among urban planners and designers about the effects of anthropogenic heat on urban climate in general (see Fig. 15). Some interviewees mentioned that this was a result of their training: *"I imagine the majority are aware i.e. featuring in their curriculum when they study"*. Only in Belgium and the Netherlands planners and designers were often considered 'less aware'.

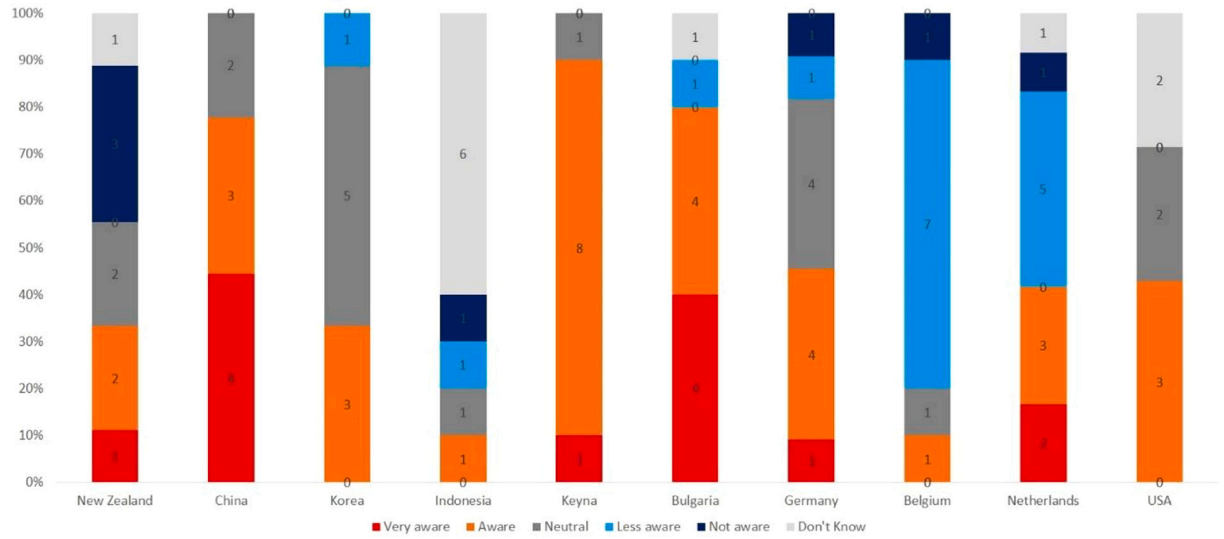

Fig. 15. Awareness levels of urban planners and designers regarding anthropogenic heat influencing urban climate.

3.1.4.4. Urban climate experts. Urban climate experts were generally well aware of the relationship between anthropogenic heat and their effect on urban climate (see Fig. 16). The interviewees did not provide any additional comments, but it was striking that in some cases, urban climate adaptation researchers suggested the use of air conditioners to combat urban heat (Kirshen et al., 2008; Hallegatte, 2009). Suggesting such maladaptation is detrimental to the communication with all the other actors who expect to be able to trust the experts' advice.

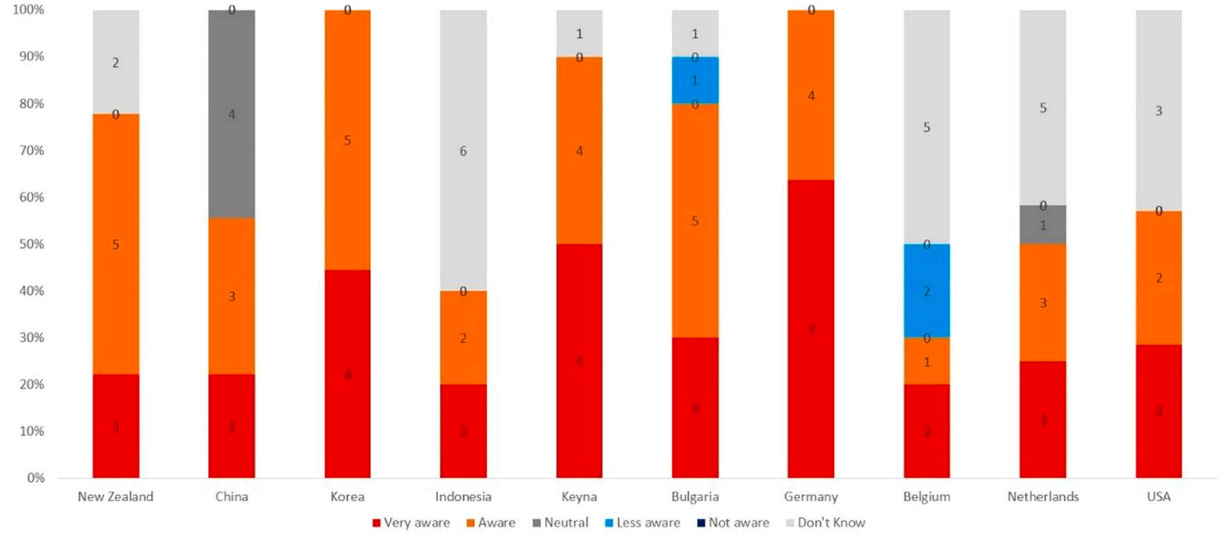

Fig. 16. Awareness levels of urban climate experts regarding anthropogenic heat influencing urban climate.

3.1.4.5. Short summary and comparison between groups

a) City design/ layout

Based on interviewees' responses concerning the four actor groups, they perceived citizens to be generally less aware because both urban design and urban climate processes are quite abstract concepts. Also, politicians had low awareness of urban layout as a measure to influence urban climate, but in some countries they were significantly more aware. The education levels in countries affect the awareness level about these biophysical mechanisms. Urban planners and designers, as well as urban climate experts, in

all countries were perceived to have high awareness, mainly based on knowledge acquired in their formal education.

b) Vegetation
Citizens were perceived to show large differences in awareness levels. It seems that the awareness of urban greening and its urban climate effects can be explained by daily experience of citizens but not by a country's education level. In contrast to citizens, politicians were perceived to be more aware, mainly because of daily experience. As opposed to the first two groups, urban planners/ designers and urban climate experts were well aware of the influence of vegetation through their education.

c) Use of material
Citizens and politicians were perceived by the interviewees to be less aware of this adaptation measure. It might be affected by the level of formal education in this topic, as urban planners/designers were perceived to be quite aware and urban climate experts were very aware of these effects.

d) Anthropogenic heat reduction
Citizens and politicians had little awareness in almost all countries, potentially because anthropogenic heat is a very abstract phenomenon. In contrast, urban planners/designers were quite aware and urban climate experts were very aware of these effects because of their education.

Overall there was no clear influence of temperature experience (neither averages nor extremes) as a driver for awareness about the four types of adaptation solutions. This outcome is in contrast to findings in the literature on climate change which reports that the experience of climate situations clearly influences the awareness (e.g. Demski et al., 2017), especially in more rural communities (Ruiz et al., 2020). This might be attributable to the fact that our research does not focus on the climate change phenomena themselves, but rather on the interventions to influence those phenomena in urban environments. The education levels in a country seem to explain awareness levels among citizens and politicians about urban layouts and vegetation (mostly among politicians) being able to change the urban climate to some extent, but not for the use of materials and anthropogenic heat reduction. The awareness of urban vegetation being able to significantly change urban climate was acknowledged based on people's daily experience (also see: Klemm et al., 2015a; Klemm et al., 2015b; Arnberger et al., 2017).

3.2. In case awareness is low, what is needed to increase the awareness among those groups of the four urban climate adaptation measures mentioned in the questions before?

3.2.1. Citizens

The interviewees suggested a wide variety of measures to raise awareness among citizens about urban climate adaptation measures. The most frequently mentioned measures were media campaigns, demonstration of best practice, and education of citizens. Media campaigns were mentioned by interviewees from eight different countries, especially Bulgaria, China and Indonesia. Demonstration of best practice was also mentioned by interviewees from eight countries, especially in Germany, China and Belgium. Such demonstration of best practice is 'localizing' the abstract ideas of urban climate interventions, which has been identified as crucial by several authors addressing climate adaptation awareness in general (Wirth et al., 2014; Sheppard, 2015; Mees et al., 2018). Education of citizens was mentioned by interviewees of all ten countries, in particular Germany, Indonesia, The Netherlands and New Zealand. Examples of the types of education mentioned by the interviewees were: education or counseling by independent organizations or businesses, such as consumer advice centers and community programmes (Germany, New Zealand), and lessons at primary and secondary schools (Indonesia, The Netherlands, New Zealand). An interviewee in New Zealand referred to the nationwide Enviroschools Programme that supports children to design and implement sustainability actions in their school, neighborhood and country.

The results show that raising awareness about adaptation measures needs a more interactive approach, such as demonstrating best practice and having people partake in interactive events. As was stated by a Belgian interviewee: *"Let people really feel the difference of various urban climate situations so that they understand what design can do"*. In some cases, such strategies have been used, for instance the 'climate awareness walks' conducted in Toulouse (Lemonsu et al., 2020) as well as in London and Rome (Vasilikou and Nikolopoulou, 2020). Such interactive and participatory approaches have also been suggested in the literature about climate adaptation (Collins and Ison, 2009; Carmin et al., 2012; Klein et al., 2014; Olazabal et al., 2018). Three German interviewees expressed the need for good examples of material use in communal built projects, and five suggested good win-win examples of climate adaptation and aesthetics, sojourn quality and energy efficiency such as the implementation of green roofs and facades or 'cool materials' that improve urban climate, lower the indoor energy use and provide attractive places. Another person stated that *"People and businesses in New Zealand seem to respond better to examples of businesses demonstrating solutions, rather than to just educational messages from Central Government"*. This sentiment seems in line with literature that suggest social pressure as a good means to raise awareness and instigate action (Derkzen et al., 2017). Additionally, a Chinese interviewee mentioned that demonstrating best practice can introduce do-it-yourself (DIY) measures to citizens, which then could support bottom-up initiatives. This comment suggests that demonstration of best practice should ideally be a joint effort of public and private partners.

Another frequently mentioned measure was financial stimulation and incentives, by interviewees from six different countries, especially brought forward by German interviewees. They argue that financial mechanisms can raise awareness of citizens and politicians alike, by stimulating and demanding action "*like granting national subsidies to create municipal climate protection concepts or financial aid e.g. for urban restructuring only if an approved climate adaptation concept exists"*. However, financial stimulation itself is not necessarily effective, as experience from Stuttgart showed: *"Even though since decennia the city of Stuttgart grants funding for green roof implementation, and also promotes it in the context of climate adaptation, there is almost no response (especially concerning green facades)*.

This is caused by missing awareness/negation of the effects on the one side and a fear of difficult maintenance on the other". Less mentioned measures were the use of IT tools and enforcement of laws and rules. Other means such as visual communication were rarely mentioned although a Belgian interviewee suggests: *"It's important that you show people things they recognize. Show it to them with 3d images or with a fly-through.",* a strategy that has also been proposed by researchers working general climate change communication (Sheppard, 2005; Moser, 2010, 2016). In this context various researchers also suggest artistic means such as theatre, poetry and narratives as a means to raise awareness and in which eliciting (especially pleasant) emotion can play an important role (Corfee-Morlot et al., 2011; Wirth et al., 2014; Moser, 2016).

3.2.2. Politicians

Interviewees suggested enforcement of laws and rules, and lifelong learning of professionals as being effective tools. Law enforcement was mentioned by interviewees from eight different countries, especially Germany, Kenya and New Zealand. Several German interviewees suggested that climate adaptation should be included in political agendas by discussing regulations in local/regional committees. This was also mentioned by interviewees in Kenya, who stated that politicians tend to interact a lot with experts when legislation is being created, which generates an opportunity for awareness raising. Moreover, a German interviewees mentioned that adaptive measures such as the use of materials, colors and surfaces can be legally determined by federal construction regulations ('Landesbauordnung') separate from the national construction law ('Baugesetzbuch'). This can be further supported by climate labelling of e.g. certain material (such as DGBN gold certificate). Other authors had already emphasized that law and policy enforcement is an effective means to raise awareness about urban climate issues (Corburn, 2009) and urban water management (Mees et al., 2013).

Lifelong learning was mentioned by interviewees from six countries, especially Indonesia and China. They suggested that climate adaptation options be incorporated into training programs for politicians, thus not only confronting politicians with the problems, but also teaching them about the potential solutions. Other measures were mentioned much less, such as demonstration of best practice and financial incentives, interactive events, quality labels (such as LEED or BREAM) and media campaigns (e.g., by USA interviewees). Interestingly, there were hardly any mentions of the potential role which politicians can take in raising awareness or pushing agendas as powerful spokesmen, a potential that was emphasized before (Uittenbroek et al., 2016) and the fact that politicians are expected to be the 'problem owners' who instigate adaptation processes. In practice it seems that the problem ownership especially for heat stress remains unclear (Runhaar et al., 2012).

3.2.3. Urban planners and designers

Lifelong learning of professionals was the most common measure mentioned to raise awareness among urban planners and designers (26 out of 79 measures in total). This was mentioned by interviewees from nine different countries (except Indonesia), especially by interviewees from China, the Netherlands, Belgium and Kenya. Although the education of urban planners and designers on urban climate solutions is considered rather well-developed, the interviewees suggest more professional training of urban planners and designers about urban climate adaptation measures. Other measures such as demonstration of best practice, education of future professionals, interactive events, enforcement of laws and rules, interdisciplinary cooperation and media campaigns, were less frequently mentioned. In this context it is surprising that the means of project demonstrations and visualizations have not been mentioned more frequently because they have been suggested by others as suitable means to raise awareness about climate adaptation in general within the community of planners and designers (Sheppard, 2012; Moser, 2014; Mees et al., 2018).

3.2.4. Climate experts

Climate experts were considered to be very aware of climate adaptation measures. The measures mentioned to raise awareness tended to focus more on issues of communication with non-scientists rather than raising awareness itself. To do so, lifelong learning of professionals was mentioned most often, by interviewees from three different countries, China, the Netherlands and South Korea. The answers emphasized that training should focus on communication skills with other professionals and the general public. Climate experts should be trained more on urban planning and design matters and in offering clear design guidelines, for example as produced by Klemm et al. (2017a) and Cortesão et al. (2019). The interviewees suggested that climate experts should also have a closer cooperation with urban planners and designers as the urban climate experts tend to be too academic, an issue that has also been emphasized by various other authors (Corburn, 2009; Hebbert and Mackillop, 2013; Webb, 2017). Other measures that were mentioned three or more times, by interviewees from the same three countries, were demonstration of best practice, enforcement of laws and policies and interactive events.

3.2.5. Short summary and comparison of results

Raising awareness among citizens should happen through providing information and education, good communication, supported by more interactive approaches. The demonstration of best practices was regarded as useful, especially when combined with do-it-yourself (DIY) measures for citizens. This should incorporate clear communication by both the government and businesses about the effectiveness of measures and issues of maintenance, as well as provision of financial support.

Many of the measures mentioned for raising awareness among citizens were also mentioned as measures to raise awareness among politicians. However, the ones mentioned the most were quite different: politicians need to focus on policy and law enforcement and lifelong learning. Examples for law enforcement are national or federal laws and regulations about the use of materials, and climate or quality labels. It was perceived that in the process of policy making, politicians tend to interact more closely with urban climate experts and other professionals, which creates an opportunity for awareness raising among politicians.

Similar to politicians, lifelong learning was regarded as a key measure for raising awareness in urban planners/designers. Climate experts were considered to be already very aware of climate adaptation options, but a key challenge is their lack of effective communication and their need for training in communicating with other professionals and citizens, as well as offering more useable solutions and design guidelines.

4. Conclusions

To improve urban climates various steps are needed, starting with raising awareness about problems and potential solutions before suitable solutions can eventually be implemented. It is necessary to understand what different actors know about the different types of interventions to improve urban climate conditions and how their awareness level can be raised. Thus, this study specifically asked: what do the different actors—being citizens, politicians, urban planners and designers, and also urban climate experts—who shape the urban environment know about urban climate adaptation measures? Secondly, what is the amount of variation between countries and potential drivers of awareness, such as education levels and typical temperature phenomena.

The results indicated that that there were significant differences between countries in terms of their awareness about urban climate adaptation strategies. These awareness levels were not found to be based on climatic circumstances, but were somewhat dependent on the typical education levels in countries. This implies that strategies to raise awareness have to be tailored to the respective education levels in countries and education levels of the actors involved.

Awareness levels diverged more between different groups of actors than between countries. Data indicated large differences in the perceived awareness levels between citizens and politicians (both lower) on the one hand and urban planners and designers and urban climate experts on the other hand (both higher). The high awareness among the latter were mainly attributable to higher formal education they had received. As the two groups who are less aware – the citizens and politicians – also have a large impact on decision making and providing resources to implement measures for urban climate improvement, their awareness about the measures needs to be raised.

Effective methods for raising awareness could include educating citizens and politicians through media campaigns that offer easily understandable information on the types of interventions to provide the experience of good practical examples of successful projects. Interactive events such as workshops, games or exhibitions are promising strategies for improving awareness about urban climate measures. Such measures can also foster empowerment and self-help for citizens to improve urban climate conditions in their direct living environments.

There is a need for urban climate experts to learn to more effectively communication their scientific knowledge and also to learn to understand the ‘language’ of the groups who plan and build urban environments (such as urban designers and architects). This point is particularly relevant in countries with rather extreme climates and lower standards in building quality.

Such awareness-raising strategies could be optimally combined in projects where different actor groups co-create adaptation projects for mutually enhancing effects. Additionally, applying single strategies to raise awareness will have positive effects and nudge people to take action in solving urban climate problems.

However, more research is necessary as this study only covered a limited range of countries. More studies in the Global South and non-Western countries are necessary. Also larger amounts of interviewees per country would be desirable to prevent potentially biased assertions. Two other actor groups that influence how cities are designed were not included in this study but were identified by some of the respondents: the media, when it comes to communication; and real estate developers when it comes to defining briefs for urban design projects. Furthermore, the results of this study might be somewhat biased because the interviewees might not be sufficiently representative for their respective country (especially in large countries like China and the USA, with many climatic zones and different sub-cultures). To supplement our explorative, comparative research more widespread interviews and more quantitative analysis, e.g. surveys among the respective actor groups themselves, should be conducted in the future.

Although more research is needed, it is imperative to commence with the awareness raising strategies shortly because urban climate problems need to be solved soon, especially in the light of worsening conditions induced by climate change.

Declaration of Competing Interest

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

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Appendix A. Supplementary data

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