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"Megacities: Sustainability & Geopolitics"

Eleni Zi

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Eleni Zi

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Abstract

Recognizing the importance of the existence and role of megacities in contemporary societies, the subject thesis aims to analyze the core aspects of the rapid growth of megacities, including both qualitative and quantitative data, with regard to the concepts of sustainability and geopolitics. In this scope, a descriptive analysis of the most outstanding sustainability metrics and calculation formulas is present in this thesis, accompanied by specific measures and policies undertaken and implemented in different case studies. The thorough analysis of the available bibliography regarding megacities and sustainability is followed by a geopolitical review, with specific reference to the challenges detected within and among megacities, as well as to the advantageous practices adopted by them. Additionally, a questionnaire has been created for the purpose of the present thesis, addressed to a focal group of experts, whose outcomes are demonstrated and discussed, providing a more representable and unambiguous depiction of the correlation between megacities, sustainability and geopolitics. Finally, a series of recommendations and incentives for further research and advancement of the current endeavor are also part of this thesis, constituting a useful ground for further research.

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Chapter 1 – Introduction

1.1 Preface

In contemporary societies, megacities have come to the fore, with more and more attention concentrated in them. Their increasing population number, their achievements, as well as the issues associated with their operation and growth seem to hold a major role in public belief, pushing for examining further their special characteristics, their potential, and the risks their development indicate.

Climate change and the threats it signifies on a global scale, is held high on each country's agenda. Sustainable development, decreasing emissions and supporting green growth constitute practices accepted and enforced by a large number of nations, indicating a change in the consumption model and mentality established within them. In parallel, countries strive to obtain as much geopolitical power and stability as possible. In geopolitical terms, nations have always attempted to enhance their economic, political, and military power, in order to be able to influence the decision-making process worldwide, strengthening their geospatial position and enhancing further their capabilities.

However, how do megacities perform, in this context? How are they associated with sustainability and how could they be defined and described in geopolitical terms? Before diving too deep into addressing the above-mentioned questions, it would be helpful and valuable to provide short definitions of the core terminology employed within this particular thesis, scrutinizing the principles of the current analysis.

According to the Cambridge Business English Dictionary (n.d.), *megacities* are described as cities of considerable size, consisting of a population of more than 10 million citizens. Megacities can also be established by inevitably connecting two or more urban areas, which have grown to a great extent.

Sustainability is a term used to illustrate a development process, which requires a unified approach, and considers both environmental aspects and economic performance and development (Nations, n.d.). In accordance with the Brundtland Commission's report, sustainable development indicates "meeting the needs of the present without compromising the ability of future generations to meet their needs.". The concept of sustainability consists

of three main pillars, namely the economic, the environmental, and the social. *Economic sustainability* relates to the number of natural resources required to provide exhaustible and renewable physical inputs for economic production. *Environmental sustainability* emphasizes on elements essential for the life continuity, like the atmosphere or soil, which need to be preserved for economic production or even for humankind existence. *Social sustainability*, on the other hand, is centered on the human effects of economic systems, including the attempts to eliminate poverty or hunger, as well as to encounter inequality (Mollenkamp, 2021).

Geopolitics, the last of the core terminology the subject thesis is associated with, refer to the examination of the role and influence of factors such as geography, economics, and demography on the politics and particularly on the foreign policy adopted by each nation (Merriam-Webster, n.d.). It provides the basis for analyzing international relations, by combining political and geographic aspects. In this context, location, resources, and accessibility seem to highly contribute towards the determination of power within a country (Castree et al., 2013). In essence, geopolitics provide a structured method for examining and determining foreign policy in order to comprehend, clarify, and forecast a state's political behavior taking into consideration geographical variables, such as spatial studies, climate, topography, and natural resources of the region under evaluation.

In the context briefly described above, the subject thesis under the title *"Megacities: Sustainability and Geopolitics"* seeks to investigate the relations shaped and cultivated concerning the core terms of *megacities*, *sustainability*, and *geopolitics*. It attempts to analyze thoroughly the essential and crucial characteristics and elements of megacities' generation and rapid growth, the risks associated with their operation and expansion, as well as the differences in terms of development and prevailing circumstances between more and less developed regions.

1.2 Goal of thesis

As far as sustainability is concerned, the thesis focuses on presenting the most widely known and used sustainability metrics, as well as different approaches regarding energy systems modeling. To achieve advanced comprehension of the issue, various sustainability dimensions are demonstrated, accompanied by a useful distinction between "growth" and "development". On top of that, highly associated with sustainability, the carbon footprint

connected with megacities is, also, outlined, including its different types and the available calculation formulas utilized by the scientific community.

The geopolitical aspect of the performance and development associated with megacities, encompasses a review of their basic features related to their socio-economic and environmental performance. These characteristics are interpreted with respect to their population size and density, as well as to the urban areas within them. On top of that, the main risks, identified both within megacities, but also among them, are presented, while good practices adopted and implemented by them, as well as further recommendations to enhance their geopolitical power are also introduced in the following chapters.

With the established aim of determining the relations and interactions constructed between the above-mentioned terms, in essence megacities, sustainability and geopolitics, a relative questionnaire has been issued, addressed to a limited number of experts. The questionnaire attempts to cover the major focal points, as derived from the literature review conducted, and to demonstrate the viewpoints of a group of experts on the subject issues. In short, apart from the acknowledgements derived from the focal group, the survey involves a summary of comments and suggestions proposed by a fragment of the sample, leading to valuable recommendations for future versions.

1.3 Structure of thesis

The subject thesis is divided into the following chapters:

- Chapter 2 (Literature Review), which contains a profound examination and analysis of the available bibliography regarding megacities, sustainability, and geopolitics and is subdivided, respectively.
- Chapter 3 (Methodology), in which the tools and sample selection, as well as the structure of the questionnaire are thoroughly presented, justifying the content of the questions, the types of the answers and the objective behind them.
- Chapter 4 (Results), which presents the responses on the above-mentioned questions stemmed from the experts and the recommendations emanated from two of them.
- Chapter 5 (Conclusions), which summarizes the basic conclusions and portrays certain limitations and recommendations for further research, as derived from the subject analysis.

Chapter 2 – Literature review

2.1 Brief introduction

The development of megacities is derived from and associated with urban growth and urbanization. Urban growth results from natural increase of urban population, as a consequence of a rise in births and fall in deaths, from migration, both from rural areas within a country and from abroad, as well as from reclassification, meaning that the geographical area of a city tends to expand and cover regions formerly considered rural (United Nations, Department of Economic and Social Affairs, 2019). Urbanization is associated with the three core components of sustainable development; the social, the economic, and the environmental, while its level is related to the level of income among the different countries and regions. High-income countries seem to have higher levels of urbanization, contrary to lower-income states.

By 2018, 55% of the world population was living in an urban area, with Northern America, Latin America and the Caribbean, Europe and Oceania being the most urbanized regions. Although the rate of urbanization in Asia remains lower than 50%, Tokyo is the largest city worldwide, followed by Delhi, Shanghai, Mexico City, São Paulo, Cairo, Mumbai, Beijing and Dhaka.

Nevertheless, since the 1950's the world's population has faced a rapid urbanization process. While in 1950 70% of people lived in rural areas worldwide, it was in 2007 when the urban population exceeded the rural one and it is expected to continue in this direction in the upcoming years. Latin America and the Caribbean as well as Northern America’s urban population exceeds 80%, Oceania’s is nearly 70% and Europe’s is almost 50%. In contrast, Africa’s urban population is roughly over 40%. Therefore, it is assumed that different rates of urbanization will occur in different regions, with Africa and Asia expected to be characterized by higher rates of urbanization, compared to other regions worldwide.

Regarding all the crucial dimensions of urbanization, careful and efficient management can result in great advances derived from its benefits, while at the same time potential drawbacks can be effectively minimized, thanks to the policies implemented. Urbanization can lead to economic growth and development, as well

as to an important reduction in poverty, since it offers great chances for entrepreneurship, technological innovation, human development, and establishment of economies of scale, all of which can improve the lives of citizens and contribute to a sustainable way of living. Such policies shall take into consideration all the above-mentioned aspects, including features like equal access to energy, social services, education, transportation, working and a generally safe environment.

However, simultaneously, a major challenge for the sustainable future of the rapidly growing cities is to adopt and enforce adequate management and policies, especially in most of the low and middle-low-income regions, which are expected to grow at high rates. In this context, the case study of Lagos State serves as a representative example. In Lagos, both high and low-income neighborhoods deal with disruptions in their electricity supply, therefore they often use alternative sources, like gas stoves, kerosene, diesel generators (which indicate high pollution levels) or solar power to cover their energy needs (Olurode et al., 2018). This is a common phenomenon in developing states alongside corruption, inadequate road network, extreme poverty, and highly constrained provision of social services.

Energy provision varies among less developed countries, with the poorer ones facing serious energy poverty related issues. Especially in the case of Nigeria, only a slight percentage of its population has access to modern types of energy, while at the same time the energy crisis stands at extremely high rates. Fast-paced urbanization has imposed certain burdens on the infrastructure sector in Lagos state related, also, to the existing energy crisis. In order to resolve the power problem, the implementation of Power Sector Reforms is proposed, as well as diversification of power sources, improvement of the network and, consequently, elimination of disruptions. In parallel, the adoption and implementation of Independent Power Plants has helped Nigeria to improve electricity provision, by allowing private entities to participate in the previously purely public power market. Subsequently, electricity supply reliability has been improved, allowing for more citizens to benefit from better services.

2.2 Development of megacities

Megacities have their origin in the West, however they have been widely spread in the East, as well, during the last years. It is commonly accepted, in the West, that careful management of urbanization can bring overall balance in this type of cities, promoting the

sustainable development of megacities, however this fact is less considered in other regions, like Africa and Latin America, where the vast majority of population has to deal with certain economic and social difficulties (The European Committee of the Regions, 2021).

Informal settlements are common in developing countries pushing further towards a more sustainable development and operation of cities in order to enhance quality of life (Abd Alla et al., 2021). Although, from an energy-efficiency point of view, it seems more reasonable to attain this kind of accommodation (less greenhouse gas emissions are created), from a socio-economical point of view it is unacceptable, because not only do those people live under difficult circumstances (they barely have access to energy), but there is also little margin for economic development. Therefore, relocation to proper accommodation indicates the provision of adequate water and energy services, which will improve the general standard of living. In order for authorities to tackle this issue more effectively, implementing the proper measures and sharing of knowledge between cities, both at national, regional and international level, are considered important and determinant.

The current urbanization trend, tracking back to the 1950's, has two specific characteristics; the number and the size of megacities have rapidly and excessively grown, especially in the developing world, while the power obtained by certain megacities, derived from their economic development and, therefore, power, has led to an unequal and uneven development on certain, only, regions. In this context, global cities have emerged, cities with a great concentration of specialized services and interactions internationally (Bourdeau-Lepage & Huriot, 2007).

Thanks to their coordination capabilities, global cities manage to hold a major position in the global economy. Coordination basically refers to megacity’s ability to provide a series of services, which, in turn, result in greater returns for the city. Providing services also requires information availability and usage. Apart from the coordination function, institutions, both formal and informal, are involved in determining economic activity by controlling the available choices of economic agents, as well as the potentials of economic organizations.

Nevertheless, less developed countries, characterized by high degree of corruption, have to deal with numerous difficulties regarding coordination and institutional coherence, affecting their economic growth potential. The generation and development of megacities requires a minimum level of development; therefore, the poorest countries seem incapable of creating such urban hubs. In developing countries, megacities are the result of a growth in population and of migration. Moreover, megacity’s economic performance seems to

determine its global status and function and low development indicates weak performances globally.

City size surely depends on urban diversity; however, it is not related to its global status and performance. Size could matter, only if it led to the creation of sufficient diversity, information externalities and skills, which, in turn, would push towards further coordination. The development of powerful megacities around the globe may generate more inequalities among the countries, as well as more competition for dominance and even geopolitical survival.

Another quite interesting study refers to the transition from traditional cities to nodes, meaning that a polycentric model, including a series of connected mega-regions, is emerging and China seems to move towards that direction (The European Committee of the Regions, 2021). Cities gain more importance in terms of connectivity and their size tends to be a less important aspect, nowadays. Connectivity is highly associated with the term *"smart cities"* and all the benefits they can bring. In association with that, cities seem to attract innovative technologies, which can be used both for productivity increase and to promote a better life quality. In this context, investments in infrastructure for transportation, digitalization, education, cybersecurity, and environmental protection are of the highest importance.

Megacities tend to be concentrated near coastal areas, where the climate and the benefits derived from the commercial usage of the sea-roads offer a large variety of economic and social opportunities. On top of that, they tend to concentrate within them great geopolitical importance, because of the value they bring to the general community and the state. Even though they provide for great economic, political, and social chances, megacities might also be vulnerable to external shocks, regarding fields like that of food, water, energy, and climate change. Even though cities seem to obtain more and more power, both nationally and in their interaction with other global actors, they cannot be considered international players, since they are subject to the national law of their country.

As it has already been mentioned, during the last years, megacities have been evolving, especially in the Asian and Latin American regions. As the city size grows, so does the need for imports and consumption, but so does also the waste production. The way of spatial and economic growth of urban entities is highly associated with their social, economic, and environmental impacts in the whole world, since cities are open systems and value chains allow for that transmission of effects (Gilles et al., 2021). In this context, 3 emissions scopes should be considered regarding inventory building efforts in cities. Scope 1 includes emissions associated directly with production procedures, scope 2 involves emissions

connected to direct purchases of electricity, while scope 3 encompasses indirect emissions, found within the supply chain of a product. The latter one seems to be the most crucial, since indirect emissions underestimation may lead to greater misleading in environmental impacts assessments and, consequently, to the policies implemented.

Considering the correlation between city size and energy consumption, even though Tokyo is the largest megacity in terms of population size, it consumes less energy, compared to New York, where more energy is required for transportation and heating/industrial purposes (Kennedy et al., 2015). Water consumption is also higher in New York, where the majority of it is used in thermoelectric plants, as well as solid waste production. Waste production is a fact for large and megacities, which have to import large quantities of materials and goods to sustain their survival, which, in turn, lead to more waste.

Electricity is highly associated with economic growth and development. In this context, megacities that are characterized by less density, like New York or Los Angeles, providing their population more building floor space, result, inevitably, in greater electricity consumption. While this is a fact for more developed megacities, there still are regions with resources and energy consumption extremely lower than the rates of a standard living. These megacities are mainly located in South Asia and, supposing they are still being developed, they shall increase their consumption level in order to survive and evolve.

Since cities account for 70% of global primary energy use, as well as for the production of 60% of the worldwide greenhouse gas emissions, their growth has been associated with challenges of environmental sustainability (Kennedy et al., 2015). In this context, megacities have been linked to a series of global risks and problems, such as extreme levels of poverty, health issues, due to air pollution within these cities, social-spatial fragmentation and so on. The operation of megacities requires an adequate number and quality of technological development and management, in order to offer the citizens a satisfying way of living. Even though among all those megacities currently present, there are some of the wealthiest cities in the world, some of the poorer megacities have also developed efficient ways to eliminate global environmental burdens and enhance their energy efficiency.

All in all, whether a megacity will develop as a sustainable hub or not, depends on the way they obtain, share, and manage their energy and material resources. It is concluded that some megacities need to increase their consumption level, in order to provide their citizens with adequate services to sustain a qualitative lifestyle, while others need to reduce and control the energy and material flow, associated with their activity, in order to diminish the consequent environmental problems that might be created. Although policies hold a major

role towards that goal, there are other factors, as well, such as urban form, climate and economic activity that greatly influence energy consumption.

2.3 Megacities and sustainability

2.3.1. Different urban sustainability metrics

Sustainability is a term encompassing an enhanced environment, a strong economy, and a more active community (Majd & Tabibian, 2015). When it comes to cities, they are described as participating in a metabolistic procedure and they are characterized as sustainable when their resource inputs (i.e., energy, land, water, materials) and their waste outputs (i.e., solid, liquid and water waste) are diminishing, while their standard of living, which includes health, housing, employment, leisure activities, community etc., is improving.

Sustainable development is outlined by the social, the economic and the ecological dimension. The social dimension encompasses equality and comprehensiveness, which promote equal rights over every dimension of local societies, including economic, natural and physical wealth. The social dimensions of developing sustainably can be indicated, among others, by population growth and density, life expectancy rate, immigration rate, income inequality level and unemployment rate.

The economic dimension employs the ability and strength to support the coordination between native and regional actors to be used for the advantage of community, leaving, simultaneously, the natural reserves nondestructive and non-exhausted. The economic dimensions of sustainable development can be assessed through the GDP growth rate, the unemployment rate, the quality and accessibility of transportation networks, the local economic structure, the nature of infrastructure etc.

The ecological dimension of sustainability is associated with the urban production and the influence of construction on the well-being of citizens and on the reliability of the megacity. They can be examined through air pollution, water and groundwater pollution, waste management circumstances, biodiversity, deforestation, and so on.

Some researchers acknowledge, apart from the above-mentioned sustainability dimensions, the political sustainability, which is defined as the power of authorities to influence the connection and actions of different actors in each of the before-mentioned fields, towards the minimization of climate change consequences. Democratization along

with local public society motivation and contribution can result in better and more sustainable performance within megacities.

Regarding the development of megacities, the environment has been set aside, because economic profit has been considered more important, a high priority. Therefore, numerous environmental resources have been depleted or destroyed, since no sustainable development principles and options were considered, when megacities were being developed. However, new ways and adequate solutions to the above-stated issues shall be found. Better coordination regarding transportation, space planning and land use, promotion of local production and green compact cities, as well as adopting more sustainable measures in infrastructure, have shown to be effective towards sustainable development of megacities.

Sustainable development itself should not be considered as a technical issue, but rather as a problem which requires governmental, economic, and social change in order to be achieved. The difference between "growth", which is associated with only achieving larger amounts of property, and "development", which involves a balance between every aspect of an expansion process, helps towards better defining and understanding sustainable development. The latter consists in balancing the inputs and outputs to obtain higher profit without wasting crucial amounts of capitals.

Urban sustainability can be measured by implementing a long list of different tools and methods, including material flows, input-output analysis, optimization, and multi-criteria decision aid (MCDA), each of them being characterized by numerous advantages and disadvantages, which were precisely referred to (Shmelev, 2016). MCDA has the ability to encompass multidimensional alternatives, different kinds of information and policy priorities, as well as to employ a stronger environmental perspective, resulting in a more accurate and informative output. Multidimensional analysis is required since there are no two identical cities regarding their performance. The ability to examine and understand such a heterogeneity can help towards assessing the policies adopted, make any necessary adjustments, and promote new strategies and innovations, contributing to a more effective problem-solving stance.

Qu et al.'s study uses the energy ecological footprint method (EEFM) to create a list of indicators regarding sustainability assessment of urban residential consumption (Qu et al., 2020). According to recent research, environmental degradation is the result of overpopulation, as well as of pollution and resources overconsumption driven by urban residents. In China alone, household energy consumption constitutes one of the most important factors of energy consumption. Even though sustainable consumption is a concept

known for a lot of years, urban residential consumption sustainability varies largely across different regions and cities, emphasizing the importance of its sustainability assessment to present the most appropriate and effective, targeted policy recommendations.

Resource sustainability can be assessed using the ecological footprint, which derives from the comparison of the amount of required bio-productive land for a given population with the amount of available bio-productive land in that specific territory. The determination of human activities located within the carrying capacity of the area is possible through this practice, however it is a method which is based solely on the "user side", lacking a more complete approach.

Another method for sustainability assessment is a combination of ecological footprint and other methods for problem solving, with the EEF being a representative example. EEF is a tool encompassing quantitative data, used to calculate resource consumption and environmental pollution on to regional capacity. Energy analysis is possible through the quantitative calculation of natural resources and anthropogenic economic activities, by converting all different types of energy into the standardized solar energy value. Thanks to this method, "supply side" is also considered. Nevertheless, inaccurate energy calculations are possible since there is a certain lack of region-specific energy transformation. However, the EEF is widely accepted and used by numerous researchers, since it allows for multiple combinations and offers a more comprehensive content and output.

Urban residential consumption sustainability evaluation should reflect and take into consideration the long series of changes occurring in intensities, energy flows, pathways, and any potential consequences they might indicate. In this context, Ecological Deficit/Surplus (ED/ES) represents a difference between the EEC and the EEF, reflecting the sustainable development and ecological balance on a region-level, regarding the absolute value changes. The Ecological Footprint Intensity Index (EFII) reflects the stress of the socio-economic system to the ecosystem due to the relative value changes, namely the stress level of EEF to EEC. The Ecological Footprint Diversity Index (EFDI) is used to analyze the size and distribution of the components of the EEF from a structure perspective, including the abundance and distribution parts. The former is related to the number of the six land types, while the latter refers to their distribution that compromise the EEF. Finally, Ecological and Economic Coordination Index (EECI) is associated with the examination of the coordination degree between socio-economic and eco-systems.

As it has already been mentioned before, different megacities imply different needs and different priorities. A megacity characterized by a shortage in terms of natural resources

should focus on creating an ecological space system, constructed of multiple levels, functions and networks, while a megacity with rich natural resources could emphasize on enforcing local afforestation projects with complete jurisdiction. It is true that socioeconomic development, especially as an inevitable consequence of the development of megacities, results in a faster ecosystem services consumption than their renewal capabilities (Türe & Türe, 2020). At the same time socioeconomic indices can serve as considerable indicators for sustainable development since they seem to constitute environmentally strong indices. Among others, the Ecological Footprint (EF) is a calculation method of measuring the environmental and ecological results from activities related to socioeconomic aspects, adopted widely by researchers and academics, during recent years. It provides the basis for constructing a sustainable future, which will take into consideration the ecological budget of cities, as well.

In Türe & Türe's paper, the main target is oriented towards creating a model combining the Human Development Index (HDI) with the EF, the so-called HDI-EF mathematical model, which will allow the assessment of sustainable human development on EF from the HDI perspective valued for Istanbul's districts. HDI measures a country's achievements, namely human development, in three basic sectors/dimensions: the Life Expectancy Index (LEI), the Education Index (EI) and the GDP Index (GDPI). On the other hand, EF is a method employed to present the environmental impacts of certain players (e.g., cities, countries, work areas, institutions etc.) by calculating the area of productive biological land needed to cover the needs of the general population or the individuals. Its main components are (i) consumption multiplied by global yield, (ii) biocapacity and (iii) ecological balance. If the EF is higher than the total capacity, certain measures to enhance the regenerative capacity of the present natural capacity are necessary.

Eventually, urban sustainability is characterized by a multidimensional ability to operate effectively in social, environmental, and economic domains, at the same time (Shmelev, 2016). Due to its multidimensional nature, consisting of a system combined of multiple interdisciplinary dimensions, the most appropriate set of tools to examine it might be the Multi-Criteria Decision Aid.

Urban sustainability could also be defined as the interaction of the systemic characteristics of a city combined with city-ecosystem interactions analysis. The Principal Component Analysis (PCA) is used in order to eliminate complexity of multidimensional datasets, since it identifies and emphasizes the major components, which constitute linear combinations of the initial variables. The APIS multicriteria assessment tool provides the

ability to assess different priorities of policy, including the study of different approaches, like Economic dominance over Environmental, Environmental over Economic dominance and Social dominance over Economic, providing a thorough and multifaceted approach and assessment.

2.3.2. Urban energy system modeling

In the forthcoming years, carbon emissions in megacities are expected to grow rapidly and to a great extent in developing countries, while at the same time they are estimated as being stable for more developed regions. In order to tackle this issue, it is crucial to develop an effective and adequate monitoring system, by combining present and future scientific methods and technologies, so that carbon management in urban areas will be further supported and evolved (Duren & Miller, 2012). Urban energy systems modelling, combining procedures for obtaining and using energy to cover the relevant needs of citizens, is crucial in order to allow megacities to meet their sustainability targets (Abd Alla et al., 2021).

TIMES model is a bottom-up technology-rich procedure aiming at identifying the most cost-effective technology mix to address the exogenous energy demand of the whole energy system under consideration. TIMES model helps to investigate the role employed by the authorities related to the energy sector and their uneven and ineffective policies adopted, resulting in certain recommendations.

In most of the cases, cities tend to follow a controversial practice, focusing on eco-efficiency investments, while, simultaneously, serving as social drivers, aiming at providing enhanced lifestyles and adequate consumption levels for their residents (Türe & Türe, 2020). In this context, meaningful and effective indexes are crucial and necessary to provide a representative measurement of the way local resources, ecosystems and biodiversity are dismantled by population growth, economic activities and their consequent environmental impacts and crises taking place at a local level.

2.3.3. Different types of carbon footprint

Global carbon cycle and climate change have been crucially affected by the rapid urbanization and the considerable urban expansion, as basic consequences of the development of megacities (Yang & Meng, 2019). Since such cities are characterized by great power and influence, the adoption and implementation of appropriate national strategic

plans and actions to cope with climate challenges, including low-carbon development transformation policies, will contribute to the achievement of future medium and long-term carbon emissions reduction goals, set by the subject country. The grade to which regional carbon emissions can be reduced is highly linked to GDP. Economic growth can be efficiently combined with environmental improvement by identifying the basic carbon footprint driving factors for each megacity and by determining the specific characteristics of each factor at the different economic development stages. As a result, targeted carbon emission policies can be adopted for different stages.

Carbon footprint is defined as the total amount of greenhouse gas emissions (GHG) caused by a person, a product, a service, an event, or an organization through its whole lifetime period, at every single of its stages (material production, manufacturing, use, end-of-life) (Center for Sustainable Systems, 2021). Apart from direct emissions, indirect sources of emissions are also crucial in determining CF (Moran et al., 2018). Indirect emissions are associated with consumption and life cycle of products or services and are often not included in the CF estimation, resulting in lower outputs rather than realistic. Often enough, the CF of megacities is higher than their direct emissions.

Regarding the estimation and approach of carbon flows inventories, different clusters of urban activities are identified (Chen et al., 2020). The territorial inventories are connected to emissions related to production nationally, however, in order to determine more precisely megacity's carbon footprint, it is reasonable enough that a wider scope shall be chosen, including both urban and exo-urban carbon. On top of that, because of the multiple relations that are maintained between different cities or countries, trans-boundary flows should also be taken into consideration. Within this framework, three basic scopes are identified. The first includes carbon emissions derived from urban industrial processes or combustion fuels. The second is connected to emissions created from electricity, heat, cooling and steam provided to the city. The third encompasses emissions that are the outcome of activities within the city, while they were released outside of it.

Regarding carbon footprint indicators, numerous approaches exist, namely: territorial carbon emission (TCE), consumption-based carbon footprint (CBF), community-wide infrastructure carbon footprint (CIF), wider production carbon footprint (WPCF), as well as full scope carbon footprint (FCP). There should be a careful approach when multiple cities are included in a sample, since activities related to trade (imports and exports) could possibly result in double counting.

In Yang and Meng's study, the carbon footprint model, with its related indicators, is employed in order to determine the industrial production, the energy production, livestock and waste carbon emissions, as well as the specific relationship between carbon footprint and economic development in the Chinese megacity Xi'an (Yang & Meng, 2019). In this context, energy consumption (and, especially the energy related to the per capita residential floor area) was shown to be the major CF contributor, followed by the polluting emission account. Moreover, municipal solid waste was also responsible for the rise in carbon emission. On top of that, the decoupling of economic growth and the carbon footprint indicates that after a certain threshold of economic growth, the carbon footprint's marginal effect is greater than that of economic growth. The faster the CF growth, the less effective the decoupling measure.

2.3.4. Carbon footprint factors in megacities

Carbon Footprint (CF) seems to be associated with numerous aspects and fields. Income level is one of them, since a very small number of high-income cities accounted for 30-45% of emissions on a global scale (Moran et al., 2018). Especially in the UK it is found that socio-economic factors, such as income, education, household size or car ownership, determine its CF, contrary to infrastructure of geographic parameters, which are usually considered as major drivers. Therefore, there is a strong correlation between economic activity and CF.

However, even though rationally higher CF are expected to occur in more developed, high-income countries, it is also a common fact that less developed regions, like Senegal or Egypt, relatively important levels of CF are present, even though total and per capita levels of emissions are considered low, probably due to their rapid population growth. The concentration of emissions is not determined solely by the geographic region or the income level, but by other factors, as well. Industries, especially heavy industry, accounts for a great percentage of emissions related to exports and trade, while certain choices made by consumers are connected to greater amounts of emissions.

Among the main sources of emissions food, which accounts for 10-30% of a household's carbon footprint, household emissions caused by electricity consumption, as well as transportation are included (Center for Sustainable Systems, 2021). It should be noted that electricity produced by nuclear, wind, hydroelectric and solar sources create no emissions at the time of its production, however during their upstream production activities emissions are surely released. In Chen's article, with a sample of 4 megacities examined, it was shown that

their infrastructure carbon footprints were related to emissions associated with electricity, while their consumption-based ones were affected by imports of electricity, as well as other services and products (Chen et al., 2020). The former type of footprints accounts for more than 70% of total carbon emissions in import supply chains.

Regarding energy mix and CF, the amount of carbon dioxide emissions is highly correlated to the share of coal, indicating a great need to transform and decarbonize the energy sector, by changing the energy mix of the city (Shmelev & Shmeleva, 2019). At the same time, carbon dioxide emissions have been correlated to the transportation sector, as well, as the major commute type of a megacity can influence the emissions exhausted. A less significant confirmation of the relationship between the share of creative economy and carbon dioxide emissions was possible through Shmelev & Shmeleva's study, while no trade-off between recycling and carbon dioxide emissions has been confirmed. The contribution of renewable energy towards reducing greenhouse gas emissions has once again been confirmed at an extremely high level of statistical significance, as well as the fact that larger amounts of carbon dioxide emissions are accompanied by more water consumption. Finally, no relationship between the higher education levels and income differentiation, as well as no significant correlation between GDP and income differentiation have been confirmed, as a result of the study under consideration.

As it is expected, buildings are responsible for a great percentage, approximately 40%, of the global energy consumption and carbon dioxide emissions associated with buildings have been rising at 1% rate per year, since 2010 (Huang et al., 2019). In the megacity Shenzhen, two main categories of buildings were identified; general public buildings and energy-saving public buildings, the latter one including newly constructed and renovated public buildings. Huang et al.'s analysis showed that material production created the majority of emissions, reaching up to 72%, with the usage stage (15%), transportation (8%) and construction (5%) sector following. Energy structure affects the total amount of carbon dioxide emissions, indicating that an increase in the usage of clean energy for power production, combined with electricity efficiency, could reduce carbon emissions.

Considering energy demand, it has been shown that, in developed countries, higher standards of living indicate higher energy consumption, together with transportation, the building and housing construction, as well as public health and safety services (Gautam et al., 2019). Almost 50% of final consumer energy is consumed to cover heating at lower temperature, followed by 30% used for transportation and mobility, 15% for electric motors and merely 10% for high-temperature intensive industrial activities.

According to Gilles et al.'s research, Bogota's main carbon footprint indicators derive from imports of goods that are consumed by the citizens, namely computers, vehicles, machinery and electrical equipment (Gilles et al., 2021). Potential shifting of the import sources from China to the US and Latin America are found to provide for important chances for emission reductions, further supporting efforts made by the authorities towards climate change mitigation. The results show that a decrease in emissions would be a fact, in the case of Bogota, if the shift of imports from China to the US or to Latin American countries occurred, since differences in carbon-intensities are present and more opportunities for carbon mitigation are created, thanks to nearshoring. Bogota's main emission hotspots are in China and the US. Potential alternative sourcing countries include Latin American states, since Bogota is located in the same region as the latter and better trading relations with those countries could result in numerous benefits, even creating a more economically integrated and strong region. Nevertheless, it also acknowledged that an adequate substitution for imports derived from China, or the US cannot be found in Latin America, since the latter states are unable to satisfy the large demand. At the same time, source shifting could indicate differences in prices, quality, or variety of products.

Source shifting has been gaining more attention after the COVID-19 pandemic, the economic war between China and the USA, as well as Brexit, all of them constituting aspects of potential risks of global value chain disruptions. Three different source-shifting scenarios have been applied by the researchers related to shifting imports from China and the US to 6 Latin American countries and from China to the US. The outcomes have shown that Bogota is considered an emissions net importer country, indicating that its final demand is barely satisfied internally, and its exports are extremely limited. Its carbon footprint is lower, compared to European, American, Australian, and British megacities, but much closer to Chinese cities. Three sectors are found to be the most carbon-intensive; transportation, construction, and electricity-gas-and-water, followed by coke & petroleum products and trade. Among others, the most important import emissions are derived from electricity, gas and water and transportation, chemicals, coke and petroleum products and non-metal mineral products. Source-shifting from China and the US to Latin American countries has been characterized as less effective since it has the effect of increasing the latter's carbon footprint rather than decreasing the emissions in the former. However, source-shifting strategies in the case of China present a greater emission reduction, compared to imports from the USA. Imports from the USA are less carbon-intensive than those from Latin American countries, as well, due to the technological improvements in the former. All in all, the largest reductions

occur in emissions derived from imports of Chinese products, i.e., machinery, electrical equipment, and textiles.

The major factors of increased carbon footprint in the case of Istanbul are production, consumption, and tourism (Türe & Türe, 2020). Ecological footprint seems to grow mainly as a result of flows of energy, goods, water, information, transport and capital, which are the basic factors for human development. Although they can result in ecological deficits for cities, if they are successfully managed, they can contribute to a more sustainable future.

In this context, carbon emissions measurement needs to take into consideration each aspect of the structure and operation of megacities. It is understood that such big-size cities, apart from carbon emissions, are linked to methane emissions, derived from landfills, natural gas facilities and water waste management techniques, adding up to their total emissions mix (Duren & Miller, 2012). Therefore, multiple and frequent monitoring, combining both top-down and bottom-up observations, is necessary to provide accurate and traceable estimation of emissions on a global scale. On top of that, the implementation of contemporary technologies, such as satellite observatories and surface-based networks, can offer a more accurate and broad illustration of the current situation regarding carbon emissions in megacities.

2.3.5. Carbon footprint calculation formulas

Carbon footprint can be calculated using a long series of different methods and formulas. Its determination approaches might be territorial-based, or consumption-based, however a combination of both seems more useful and precise. Since cities are considered open economic systems with a great variety of interactions with other entities, mitigating emissions would be more effective, through that combination, avoiding the shifting of a carbon-intense activity from a region to another. On top of that, the responsibility of wealthy cities over climate change is better understood and demonstrated (Gilles et al., 2021).

For this purpose, an environmentally extended multiregional input-output model (EEMRIO) can be implemented to calculate carbon footprint, since it provides for a thorough analysis of international supply chains. EEMRIO entails interconnections in international production procedures, estimates their ecological impacts on supply chains globally, identifies the origin and final destination of products/services via international markets and indicates environmental responsibilities, considering both production- and consumption-based approaches.

Of course, when different carbon footprint metrics are applied, different results are derived, which affect the evaluation of carbon mitigation measures and policies implemented, as well as the goals that are set (Chen et al., 2020). From a Total Carbon Emission (TCE) and Community-wide Infrastructure Footprint (CIF) perspective, transportation accounts for a large percentage of emissions production, while service sectors, like information transmission, financial services, computer software and financial services have exceeded some manufacturing sectors. The different types of carbon footprint, as illustrated above, can act as a benchmark for defining the most appropriate targets and complement each other, resulting in ambitious carbon mitigation goals, while at the same time supporting economic development. Consumption reduction, improvement of domestic markets and production efficiencies can all contribute to a certain extent to carbon mitigation and provide for useful policy scenario analysis.

2.4 Megacities and geopolitics

2.4.1. Megacities in numbers

Following the analysis incorporated in section 2.3, where a series of the most widely known and used metrics to determine sustainability are demonstrated, section 2.4 is targeted towards presenting geopolitical features attributed to megacities. In this direction, Table 2.1 below has been designed, encompassing data for thirty-five (35) megacities located in Asia, Africa, Europe, North and South America. The data included in Table 2.1 refer to 2020 records. Columns *"CITY"*, *"COUNTRY"* and *"REGION"* provide for the basic geospatial identity of the megacities under consideration, while *"POPULATION"* column comprises the total of the citizens living within each particular megacity.

"BUILT-UP LAND AREA" is used to determine the area occupied for urban residential usage (i.e., buildings), commercial and industrial purposes (including extractive facilities, landfills, ports etc.), as well as for transportation objectives (roads, parking lots, pavements etc.), that can be found within cities. It is calculated in square kilometers with 2020 being the year of reference.

"GDP per capita" constitutes a representative indicator of economic performance, representing its standard of living, by measuring a country's total output divided by its

population. In this case, it is measured in US dollars with a nationwide coverage, and it comprises a notable metric for comparing wellbeing among different countries.

"CO_2 per capita" represents the average carbon dioxide emissions a citizen produces. It is calculated by dividing a country's total emissions with its population and it consists of the emissions derived from the burning of fossil fuels for energy and cement production without including land use change.

***Table 2.1**. Megacities in numbers*

No	CITY	COUNTRY	REGION	POPULATION	BUILT-UP LAND AREA (in km^2)	GDP per capita (in US$)	CO_2 per capita (in tonnes)	HDI (Human Development Intex)
1	Tokyo	Japan	Asia	37,393,128	8,231.00	40,193.30	8.15	0.92
2	Delhi	India	Asia	30,290,936	2,233.00	1,927.70	1.77	0.65
3	Shanghai	China	Asia	27,058,480	4,069.00	10,434.80	7.41	0.76
4	Sao Paulo	Brazil	South America	22,043,028	3,237.00	6,796.80	2.20	0.77
5	Mexico City	Mexico	South America	21,782,378	2,385.00	8,329.30	2.77	0.78
6	Dhaka	Bangladesh	Asia	21,005,860	456.00	1,961.60	0.56	0.63
7	Cairo	Egypt	Africa	20,900,604	2,010.00	3,569.20	2.09	0.71
8	Beijing	China	Asia	20,462,610	4,172.00	10,434.80	7.41	0.76
9	Mumbai	India	Asia	20,411,274	1,008.00	1,927.70	1.77	0.65
10	Osaka	Japan	Asia	19,165,340	3,020.00	40,193.30	8.15	0.92
11	New York	United States	North America	19,155,700	12,093.00	63,593.40	14.24	0.93
12	Karachi	Pakistan	Asia	16,093,786	1,044.00	1,188.90	1.06	0.56
13	Chongqing	China	Asia	15,872,179	1,536.00	10,434.80	7.41	0.76
14	Istanbul	Turkey	Asia	15,190,336	1,375.00	8,536.40	4.66	0.82
15	Buenos Aires	Argentina	South America	15,153,729	3,222.00	8,579.00	3.47	0.85
16	Kolkata	India	Asia	14,850,066	1,352.00	1,927.70	1.77	0.65
17	Lagos	Nigeria	Africa	14,368,332	1,966.00	2,097.10	0.61	0.54
18	Manila	Philippines	Asia	13,923,452	1,873.00	3,298.80	1.24	0.72
19	Tianjin	China	Asia	13,589,078	2,813.00	10,434.80	7.41	0.76
20	Rio de Janeiro	Brazil	South America	13,458,075	2,020.00	6,796.80	2.20	0.77
21	Guangzhou	China	Asia	13,301,532	4,341.00	10,434.80	7.41	0.76
22	Los Angeles	United States	North America	13,179,700	6,351.00	63,593.40	14.24	0.93
23	Lahore	Pakistan	Asia	12,642,423	852.00	1,188.90	1.06	0.56
24	Moscow	Russian Federation	Europe	12,537,954	5,879.00	10,126.70	10.81	0.82
25	Shenzhen	China	Asia	12,356,820	1,803.00	10,434.80	7.41	0.76
26	Bangalore	India	Asia	12,326,532	1,204.00	1,927.70	1.77	0.65
27	Paris	France	Europe	11,017,230	2,844.00	39,030.40	4.24	0.90
28	Bogota	Colombia	South America	10,978,360	562.00	5,334.60	1.75	0.77
29	Chennai	India	Asia	10,971,108	1,085.00	1,927.70	1.77	0.65
30	Jakarta	Indonesia	Asia	10,770,480	3,541.00	3,869.60	2.16	0.72
31	Lima	Peru	South America	10,719,188	891.00	6,126.90	1.36	0.78
32	Bangkok	Thailand	Asia	10,539,415	3,199.00	7,186.90	3.69	0.78
33	Seoul	South Korea	Asia	9,963,452	2,769.00	31,631.50	11.66	0.92
34	London	United Kingdom	Europe	9,304,016	1,738.00	41,059.20	4.85	0.93
35	Tehran	Iran	Asia	9,134,708	1,704.00	1,927.70	8.87	0.78

Note. Data collected from: 2022 World Population by Country. Worldpopulationreview.com. (2022). Retrieved 10 March 2022, from https://worldpopulationreview.com/, Demographia World Urban Areas. (2021). 17th Annual Edition (202106). Retrieved 16 March 2022, from http://demographia.com/db-worldua.pdf, GDP per capita (current US$) | Data. Data.worldbank.org. (2022). Retrieved 15 March 2022, from https://data.worldbank.org/indicator/NY.GDP.PCAP.CD, Hannah Ritchie, Max Roser (2020). CO_2 and Greenhouse Gas Emissions. Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions, Global economy, world economy | TheGlobalEconomy.com, TheGlobalEconomy.com (2022). Retrieved 17 March 2022, from https://www.theglobaleconomy.com/.

Finally, *"HDI (Human Development Index)"*, as it has been mentioned in the previous section, measures a country's performance in the scope of life expectancy, access to education and the standard of living. These three key dimensions provide for the measurement of human development within a country. HDI is calculated and displayed as a fraction of 1, where higher scores signify improved performance.

As it can be observed in Table 2.1, the population of Tokyo is the biggest one (37,393,128 residents), followed by Delhi (30,290,936 residents) and Shanghai (27,058,480 residents), while Seoul, London and Tehran appear to be placed slightly below the 10,000,000, with 9,963,452, 9,304,016 and 9,134,708 residents, respectively. Nevertheless, most of the megacities under examination seem to fall between 10,000,000 and 20,000,000 citizens. However, even though population serves as a valuable indicator for a city's identity, it should not be inspected separately from other factors, since the relevant results might differ greatly. Population density, for example, a metric that calculates the number of citizens living in a square kilometer of land, indicating how densely an area is inhabited, holds a major role in analyzing geopolitical features of megacities.

Considering the six above-mentioned megacities, namely Tokyo, Delhi, Shanghai, Seoul, London, and Tehran, presented in a descending order, it is attempted to calculate population density for each of them, by dividing their total population with their built-up land area. Under this new prism, it is reckoned that Delhi is the most densely inhabited among these 6 megacities, with about 13,565 people per square kilometer, followed by Shanghai with nearly 6,650 citizens per square kilometer, Tehran with almost 5,361, London with around 5,353, Tokyo with 4,543 and, finally, Seoul with 3,598 citizens per square kilometer. Therefore, even though Tokyo leads the above-mentioned chart in terms of population size, it is not as heavily inhabited as other megacities.

In this context, comparing the 3 megacities with the largest population size with the 3, which have the lowest, as depicted in Table 2.1, it would be interesting and useful enough to examine the Gross Domestic Product (GDP) per country, a factor that provides for a valuable comparison in economic terms.

In Figure 2.1, the total of the megacities included in the subject thesis are placed in descending order, starting with the country characterized with the highest GDP per capita, namely the United States (63,593.40$ for 2020). It is revealed that the United Kingdom, with London being a megacity of a relatively small population size and a rather medium level of

density, stands at the second place with a GDP of 41,059.20$ per capita in 2020. Japan follows, with 40,193.30$ per capita. South Korea is in 5th place with a GDP of 31,631.50$, while China stands at the 6th place with 10,434.80$ (GDP per capita in 2020). India and Iran are detected at the graph's bottom, with 1,927.70$ for each of them, while Pakistan presents the lowest value at 1,188.90$ per capita.

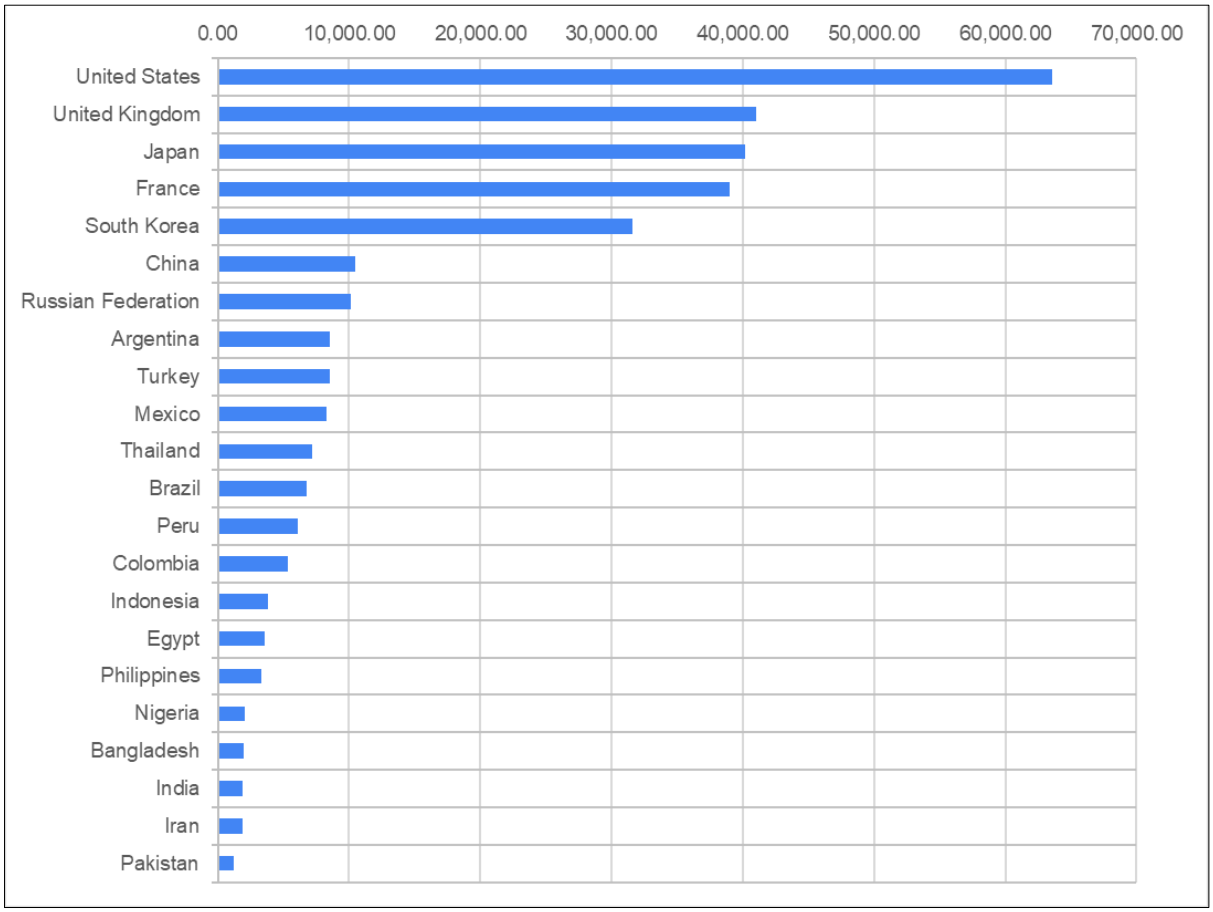

Figure 2.1. *Megacities' GDP (2020) Note: Data collected from: GDP per capita (current US$) | Data. Data.worldbank.org. (2022). Retrieved 15 March 2022, from https://data.worldbank.org/indicator/NY.GDP.PCAP.CD*

At the same time, it would be interesting to review the carbon dioxide emissions amounts produced by each citizen of the subject countries calculated in tonnes for 2020, as well as their Human Development Index (HDI) rates, so that certain conclusions regarding wellbeing within megacities could be derived. Figure 2.2 depicts the rise and fall in the quantities of carbon dioxide emissions generated in each country from the burning of fossil fuels for energy and cement production from 1750 till 2020. In general, it can be observed that the beginning of the production of fossil fuels is dated back to the late 18th and early 19th centuries, during the Industrial Revolution, when the internal combustion engines were invented and further advanced, in countries including the United States of America, Russia,

the United Kingdom and France, which are characterized by rich natural resources and advanced industry capabilities, respectively. The consecutive rise and fall in carbon dioxide emissions reflect the events that took place in the international field. The two World Wars pushed for an increase in the use of fossil fuels in the war zone, consuming huge amounts of oil and gas to feed the fighting industry.

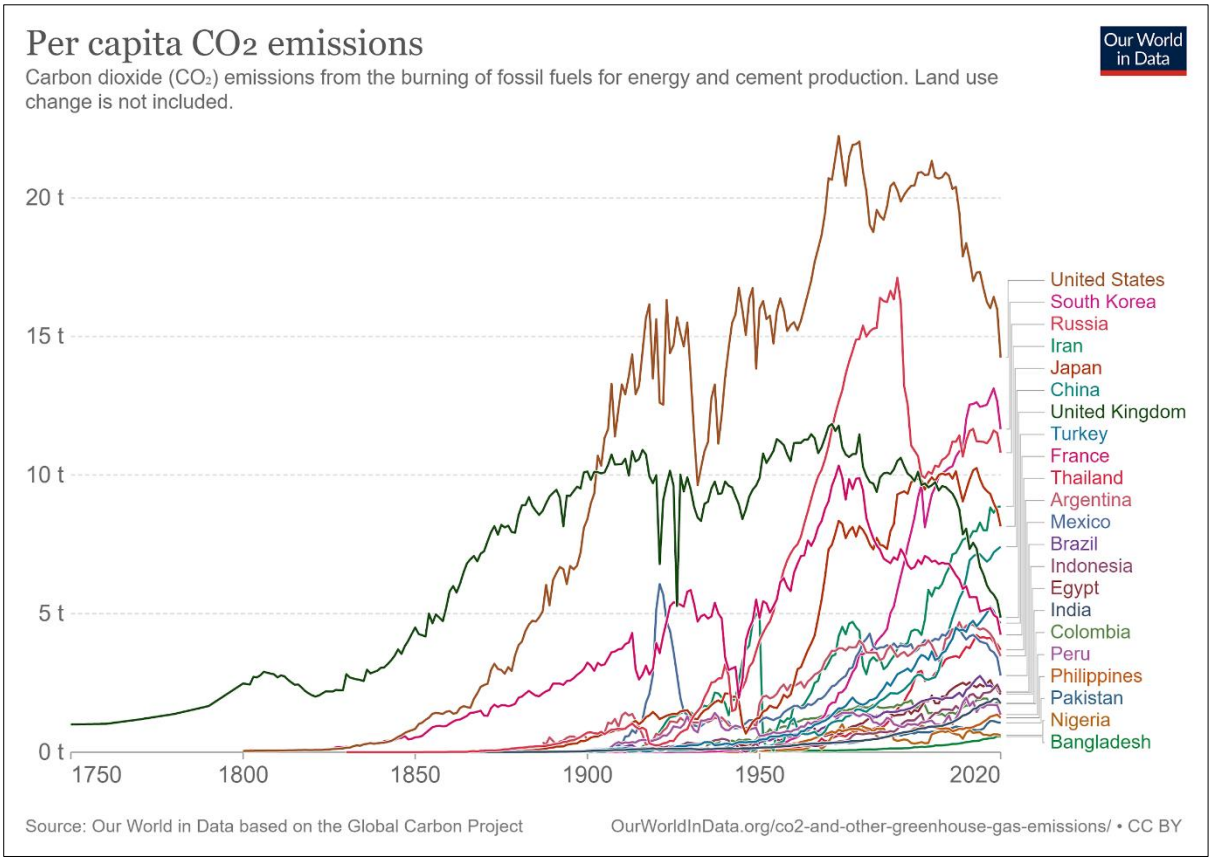

Figure 2.2. *Megacities' CO2 per capita (2020) Note: Figure incorporated from: CO_2 and Greenhouse Gas Emissions. Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions*

The establishment of the Organization of the Petroleum Exporting Countries (OPEC) in 1960, an intergovernmental organization consisting of developing countries that produce and export oil, aiming to coordinate and consolidate their petroleum related policies, seems to have changed the energy scenery leading to a period of great rise in carbon emissions. The oil and energy crises of 1973 and 1979 have been responsible for a slight fall in the consumption of fossil fuels and a relatively modest continuation in the upcoming years until the end of the Cold War in 1991 with the collapse of the Soviet Union. In the 21st century, a general rise in carbon emissions production can be noticed, because of the population growth paired with technological advancements and improvement in terms of lifestyle. Nevertheless, the Russia–Ukraine gas disputes (2005-2006 and 2009) combined with the global financial crisis of 2008

have influenced the energy consumption and therefore the amounts of carbon dioxide emissions by decreasing them, even though they still stand at high levels. Reaching 2020, as it can be observed in the right-hand side of the Figure 2.2, the COVID-19 pandemic has resulted in a subsequent fall in carbon dioxide emissions, although it should be noticed that these amounts remain high enough.

To present a more accurate and numerical approach of the carbon dioxide emissions derived from each country, it should be mentioned that, in 2020, 14.24 tonnes of carbon dioxide were emitted by an average American (USA) citizen, 11.66 tonnes by an average South Korean and 10.81 tonnes by a typical Russian resident. On the other hand, citizens of Bangladesh, Nigeria and Pakistan seem to have produced the lowest amounts of carbon dioxide emissions, namely 0.56, 0.61 and 1.06 tonnes, respectively.

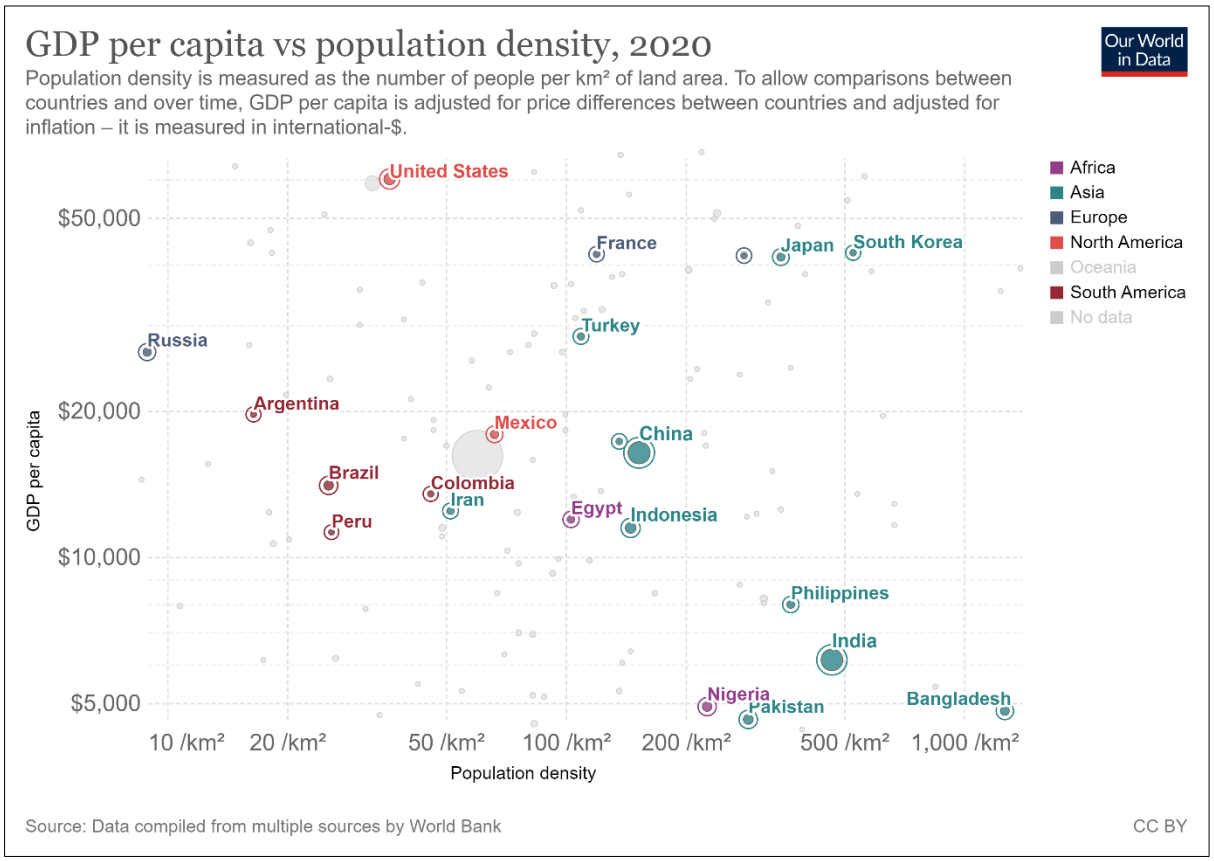

Figure 2.3 *Megacities' GDP vs population density (2020) Note: Figure incorporated from: CO_2 and Greenhouse Gas Emissions. Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions*

Regarding the Human Development Index, as illustrated in Table 2.1, it can be noticed that the United States of America and the United Kingdom are located on the top of the list with 0.93 points each, followed by Japan and South Korea with 0.92 points each, and France

with 0.90 points, while Bangladesh, Pakistan and Nigeria have the lowest ranking at 0.63, 0.56 and 0.54, accordingly.

In the same direction, Figure 2.3 provides for a comparison of different regions regarding the gross domestic product (GDP) per capita and the population density for 2020. The vertical axis indicates the GDP per capita in international dollars and the horizontal axis represents the population density counted in the number of people per square kilometer. The higher a country stands in Figure 2.3, the better its economic performance and the further on the left it is located, the less densely it is inhabited.

From the above-mentioned figure, as well as from the analysis established, multiple outcomes can be derived, which are summarized below:

i. The population of a megacity is not necessarily indicative of its overall performance; other factors and aspects, encompassing population density, GDP per capita, carbon dioxide emissions per capita and Human Development Index (HDI) rates constitute evidence of its activities.
ii. Countries with a higher GDP per capita seem also to rank high on the HDI scale with the sole exception of China, whose rate stands at 0.76.
iii. Neither GDP, nor HDI are tied to carbon dioxide emissions, since there are cases with lower GDP per capita and more emissions, as well as cases with higher HDI rates and fewer emissions. The justification of such differences can be discovered through the careful examination of each megacity's particular characteristics that compound its identity. Whether a nation is an energy importer or exporter, whether it sustains heavy industry or not, are some of the factors that influence the above-mentioned metrics.

2.4.2. Challenges within and among megacities

The development of megacities is associated with a series of challenges, encountered both within them, at a national level, and among them, at a transnational level. In each case, certain attention should be addressed to the particular occasion and the special characteristics of each issue, so that a thorough analysis of the given situation is possible to arise.

Nationally, megacities are, indeed, linked to an increase in environmental challenges regarding housing, infrastructure, and services, therefore they are highly connected to decarbonization issues (Abd Alla et al., 2021). The rapid population growth, combined with higher density and a consequent rapid urban development create further climate change risks.

In this context, unemployment is the biggest challenge megacities have to deal with, in economic terms, air pollution is considered the most crucial threat regarding environmental issues, poor living conditions are the most important among other social challenges and transportation poses the most crucial infrastructure challenge to be handled. The sustainability challenge is a fact for megacities, with the ongoing urbanization model being highly unsustainable. The rise in population pushes for a rise in density, otherwise the costs of building would be higher, the mobility far worse and the agricultural land diminished.

On top of that, megacities, due to their structure and operation might also be subject to transmission of infectious diseases and pandemics, as well as to natural disasters, which result from the degradation of the natural environment and its biodiversity. Residential energy consumption, another aspect associated with the development of megacities, urbanization growth and increasing domestic demand, have been responsible for numerous environmental issues, like biodiversity loss or ecosystem degradation (Qu et al., 2020), while the consumption of transportation fuels is greater in wealthier megacities, where more and more citizens choose to own a car for their daily commute. London and Paris have implemented measures aiming to eliminate traffic conjunction and air pollution. These cases contrast the cases of countries, which have been faced with extremely rapid growth, like Beijing or Shanghai.

Regarding the quality of life provided within megacities, although such types of cities are associated with great consumption, it is true that in many of them, the vast majority of the population lives under difficult circumstances, sometimes not even having access to some basic services, like clean water or sanitation. At the same time, illegal water withdrawals or losses due to the aged and inadequate infrastructure is a fact for many developing megacities. Interestingly enough, London has managed to reduce its electricity consumption, by raising electricity prices, improving overall energy efficiency, increasing public awareness and reducing manufacturing.

Finally, although it is true that green spaces offer a large variety of benefits for everyday life, ranging from providing for mental and physical health to promoting urban biodiversity, population growth results in certain pressure to replace such spaces with residential areas, in order to accommodate the growing number of citizens, posing another important issue to be considered (The European Committee of the Regions, 2021).

On the other hand, as far as the international profile of megacities is concerned, they are thought to be associated with numerous global risks, encompassing geopolitical, environmental, economic, societal, and technological aspects (Kennedy et al., 2015). Many of

them are unable to provide their citizens with basic services, resulting in extreme levels of poverty and severe health problems. In this context, the major driving factors regarding megacity's future are economic instability, security threats, social issues, and environmental degradation (The European Committee of the Regions, 2021). The bigger a city becomes, the more its biodiversity is affected, leading to large-scale changes. In parallel with the natural ecosystem, the social structure of megacities promotes the individualism, a tendency to focus less on the community and more on the individual, while at the same time the cosmopolitan nature of such cities, which also offer more opportunities to their population, leads to the inclusion of many migrants, changing, by this manner, the urban citizenship norms, which could potentially lead to political and social unrest. Moreover, it is true that megacities consume a lot, a fact that might lead to resource competition, an outcome with ambiguous endings.

Undoubtedly, because of the opportunities and the potential they offer, megacities seem to create and reinforce inequalities, both within them, between the rich and the poor, but also among megacities of developed and developing countries, of the West and the East, respectively. Such a polarization could lead to urban conflicts, therefore certain weight should be handed in the reunification of divided cities and regions.

In their study, Kennedy et al. (2015) have demonstrated that even though Tokyo is the largest megacity, in terms of population size, New York consumes much more energy, due to its greater need for transportation and heating/industrial fuels. The population size as well as the size of economies are accountable for the amount of energy consumed, while per capita electricity use in megacities seems to be associated with urbanized area per person. From the analysis conducted (Kennedy et al., 2015), certain hypotheses can be derived:

a) In developing megacities, people tend to climb in the social ladder, their income increases, and they tend to consume more energy

b) Low efficient technologies and appliances in developing megacities result in more energy losses, therefore more energy consumption

c) London and Paris, although megacities of crucial size, are characterized by negative rates regarding the correlation/relationship between electricity consumption growth and population growth (in most megacities, the former exceeds the latter), which could be attributed to the adaptation of new technologies, to the implementation of energy efficiency measures and to the latest economic crisis.

Therefore, it is true that, by definition, megacities are faced with numerous issues in multiple levels, a fact that emphasizes the need for careful assessments and for adopting and implementing the appropriate measures and practices in each particular case.

2.4.3. Good practices adopted and further recommendations

Among the numerous cities worldwide some of the wealthiest and more developed are considered megacities (Kennedy et al., 2015). Nevertheless, both developed and developing megacities have the potential to grow and thrive as innovative centers and sustainable regions, based on the way they obtain, manage, and share their energy and material flows.

It is argued that urbanization, technological improvement, and capital accumulation can enhance economic power. Indeed, many developed megacities, like Tokyo, New York and Los Angeles are associated with high percentages of the global GDP (The European Committee of the Regions, 2021). In the case of African megacities, characterized by lower development rates, their future urbanization is likely to push for the necessary change in terms of development and growth, supporting the advancement of the standard of living.

Regarding the contemporary trends of energy supply and demand, as the world population rapidly grows and more and more megacities arise, the gap between them seems to grow, respectively (Gautam et al., 2019). Available options to cope with it include reduction in energy consumption (as a result of economic constraints) and usage of alternative energy sources and advanced technologies, which can increase energy supply. In this context, since the current energy consumption model is associated with important environmental issues, due to the extended use of primary energy, the technological exploitation of alternative renewable energy sources serves as an adequate driver to a more sustainable future.

In parallel, green growth, a term widely used regarding the sustainable expansion of megacities, describes the combination of economic growth and the perseverance of natural ecosystems. Green growth strategies and the energy sector are linked, through the achievement of environmental and economic objectives, thanks to innovation and research, the combination of productivity growth and the environment survival, the financial burden of purely managed natural resources and the opportunities for development of new markets.

Co-impacts of energy technologies hold a major role, regarding the selection and implementation of different policies. Before such policies are framed, every potential environmental, economic, and social aspects/impacts need to be carefully assessed and

properly accounted for. At the same time, the scope and scale of energy technologies must be adequately determined, using quantitative data, while in the selection procedure a normalized evaluative measure should be set. In this context, several megacities worldwide have adopted certain Waste-To-Energy (WTE) technologies, in order to reduce their solid waste amounts, which are turned into multiple types of energy products (Gautam et al., 2019). WTE technologies indicate many advantages, including greenhouse gas emissions reduction, creation of green jobs, increase of renewable and base load energy, or superior environmental performance. Prevention, recycling, composting and energy from waste is a practice adopted in the USA, while China has emerged as a leader regarding the development, adoption, and implementation of WTE systems, as part of its general waste management strategy, along with Paris and London. Megacities are faced with municipal waste generation challenges and a WTE system choice could help them increase the sustainable and reliable energy necessary for their operation on a daily basis. Electricity and heat can be delivered to all citizens, through this network, leading to maximized efficiency, basically in more population-dense areas.

Simultaneously, in order to transform the above-mentioned green growth goal into policy, certain elements should be considered. Energy innovation should be supported and promoted through the implemented policies, encompassing focusing on new ideas and global entrepreneurship norms combined with the local needs. Energy integration and implementation are, also, important components of policy, encompassing the establishment of carbon tax regimes, price-based markets, green investments, or cancellation of subsidies in fossil fuels. Finally, energy transformation in practice is crucial for the adequacy of any policies adopted and enforced.

Another valuable manner for strengthening sustainable development and enhancing megacity's power is through the creation of the so-called Low-Carbon Cities. These cities are characterized by low carbon production, low carbon technology and low carbon energy use and are frequently developed in many countries, especially in China, aiming to reduce energy consumption and fossil fuel and, therefore, eliminate carbon emissions (Ma et al., 2021). Among others, Chinese megacities Shanghai, Shenzhen and Baoding constitute such representative examples. To construct this type of cities, multiple low carbon policy instruments have been implemented so far, including carbon taxes and clean innovation. Low carbon instruments are divided into hierarchy-based instruments (i.e. forceful policy measures), market-based instruments (such as tax incentives, carbon trade policy, financial subsidies), information-based instruments (including the environmental pollution data

disclosure) and network-based instruments (which support the cooperation between organizations).

Hierarchy-based policy instruments encompass top-down measures adopted by authorities, specified by regulations or laws, which are identified as robust and effective. Nevertheless, they are sometimes inflexible, leading to innovation backfires or economic inefficiency. Market-based instruments implicate the application of economic or financial policies to support clean production methods and reduce pollution. Such instruments have been adopted by the governments of Brazil and South Africa, as well as by many EU state members. Market-based instruments present more flexibility and less administrative costs, however they may become economically inefficient or create opposite environmental circumstances, like energy overconsumption. Information-based instruments are associated with public learning and knowledge transfer. Preferences and actions associated with citizens are influenced by information sharing, which is also considered a coercive and relatively efficient measure. Nonetheless, this instrument encounters the possibility of failing at influencing people's actions and behavior, since this is entirely based on the options and actions of citizens, or the possibility of short-term implementation, or even the possibility of organizations unwilling to disclose information and knowledge, based on privacy and safety motives. Finally, network-based instruments indicate a looser type of governance, supported by both public and private actors, who collaborate in order to reach the goals and targets set. This type of instrument is accompanied by a series of positive effects, like flexibility and cohesion, as well as negative effects, such as issues related to efficiency, accountability, and equity.

In their study, Ma et al. (2021) aim to identify the causal relationship among the four types of low carbon instruments described above and their effectiveness regarding sustainability, in the case of Chinese cities. It has been shown that a combination of market-based and hierarchical instruments without any network-based instruments were more effective towards reducing high pollution or enhancing polluting equipment and it included government compensations to companies that were financially affected by the energy transition process. Hierarchy and information-based networks were highly effective in the above-mentioned environmental efforts, since they involved plans to strictly control pollution, develop new energy sources and close down backward production. The combined selection of hierarchy, market and information-based policies has been adopted by many megacities and it consists of both control measures and economic motivations (like subsidizing electric vehicles) to tackle various environmental problems. Finally, hierarchy

and network-based policy instruments together offer an alternative solution to low carbon city construction and it has been selected by a small number of cities worldwide.

All in all, it has been observed that larger cities tend to consume larger amounts of energy and if they are characterized by good economic conditions, they are capable of investing more in controlling their carbon emissions (Ma et al., 2021). Therefore, in these cities, the adoption of low carbon policy instruments and policy effectiveness are highly influenced by their economic conditions. The industrial structure of cities affects available policies for the government, as well as their effectiveness/performance. At the same time, the government's capacity and strength is inevitably tied with its ability and willingness to adopt and implement adequate low-carbon policy measures.

To summarize, hierarchy-based instruments are considered an effective condition to reduce carbon emissions and are widely adopted by Chinese local authorities. Nevertheless, adopting solely such instruments could be insufficient, pushing for employing other kinds of measures and policies, like economic and market-based, as well, to achieve the set environmental goals. Pricing and tax incentives for new electric vehicles and energy-saving technologies seem to be preferred by numerous megacities, both in China and in other large cities and regions worldwide, since their application is quite simple and they require little cooperation, while private firms, communities and voluntary organizations seem to hold a major role in European urban governance.

Apart from the above-mentioned practices and proposals, according to Shmelev & Shmeleva's research (2019), there is a negative, statistically significant correlation between the percentage of people occupied in creative industries, i.e., related to art, and the total amount of carbon dioxide emissions. Creative industries, which encompass music, theater, cinema, museums, galleries, and art, seem to be crucial in stimulating smart economy and urban sustainability. Singapore has proven to be a leader in sustainability rankings from an environmental policies perspective, Tokyo dominates in terms of social and economic aspects, while London and Tokyo seem to lead in terms of smart city priorities. Los Angeles, Shanghai, and Rio de Janeiro present the worst performance.

Simultaneously, as the population in contemporary cities grows at a fast pace, energy consumption in buildings follows respectively and it has been shown that public buildings account for 10-20 times more emissions compared to residential buildings, therefore sustainable and low-carbon development of the building sector is of high importance and priority, especially for megacities. In this context, Shenzhen has been implementing energy-saving policies in public buildings, since 2010, encompassing policies both for existing

buildings, through the upgrade of their systems in use, and the construction of new ones. Such policies and measures encompass creating green zones, covered with plants, on building's rooftops, installing photovoltaic panels, as well as introducing recycling devices for air conditioning and waste heat (Public Notice of the Standing Committee of the Fourth Shenzhen Municipal People's Congress, 2006).

On top of that, energy structure affects the total amount of carbon dioxide emissions, indicating that an increase in the usage of clean energy for power production, combined with electricity efficiency, could definitely reduce carbon emissions (Huang et al., 2019). In this context, mandatory energy conservation policy can contribute to the increase efficiency and energy saving of buildings, as well as to a low-carbon development. Measures, including installing energy consumption systems, subsidizing the use of solar and photovoltaic systems, or establishing award funds for green buildings, can slow the carbon dioxide emissions growth, even though they rarely result in an absolute decrease of them.

In the case of European large cities and megacities, it is worth mentioned that they are highly appreciated and considered centers that can provide for numerous opportunities in many different levels (The European Committee of the Regions, 2021). Sustainability, as well as digital transformation, are held high on the EU Agenda. Social and economic balance, alongside with sufficient investment in mobility, digitalization, and sustainability, throughout the implementation of a polycentric urban model, similar in a manner to that of China, but also acting proactively regarding climate change and security measures compose the European urban profile.

Among others, policy recommendations for enhanced sustainability include the development of a functional land planning, the promotion of urban ecological restoration, the effective decrease of urban residential consumption and the adoption of an ecological compensation system to enhance coordinated regional development and therefore lead to a sustainable future for megacities (Qu et al., 2020).

2.5 Discussion

The available bibliography, as illustrated in this chapter, covers a broad spectrum of issues significantly associated with the sustainable and geopolitical aspects of megacities. Some of the most substantial features are summarized in Table 2.2 below.

Table 2.2. *Highlights derived from the conducted Literature Review*

No.	Description	Relative References
1	Adequate management and implemented policies magnify the benefits and minimize potential risks and downsides of megacities' development	Duren & Miller, 2012; Kennedy et al., 2015; Majd & Tabibian, 2015; United Nations-Department of Economic and Social Affairs, 2019; Qu et al., 2020; The European Committee of the Regions, 2021; Ma et al., 2021
2	Unequal and uneven development between megacities is a fact; while most of them are characterized as less developed, low-income countries, a smaller percentage has obtained excessive power, constituting powerful global cities. The latter tend to consume more resources, compared to the former, which often fall below the rates of a standard living.	Bourdeau-Lepage & Huriot, 2007; Kennedy et al., 2015; Gautam et al., 2019; Gilles et al., 2021
3	Megacities' power tends to depend more on their connectivity capabilities and innovation rather than on their size	Majd & Tabibian, 2015; The European Committee of the Regions, 2021
4	Megacities are responsible for more than 70% of global primary energy usage, while they produce 60% of the worldwide GHG emissions	Kennedy et al., 2015; Gautam et al., 2019; Türe & Türe, 2020; Gilles et al., 2021
5	Carbon Footprint (CF), highly connected to the emissions produced by a megacity, is connected to socioeconomic factors, trading, diet, transportation, electricity usage and infrastructure	Kennedy et al., 2015; Moran et al., 2018; Gautam et al., 2019; Türe & Türe, 2020; Center for Sustainable Systems, 2021; Gilles et al., 2021; Abd Alla et al., 2021
6	Decarbonization of megacity's energy mix is necessary to achieve sustainability goals	Shmelev & Shmeleva, 2019; Huang et al., 2019

Chapter 3 – Methodology

3.1 General information

Following the literature review that was carried out, based on the available bibliography, six highlights, as presented in *Table 2.2*, have accrued, and are summarized below:

1) Adequate management and implemented policies magnify the benefits and minimize potential risks and downsides of megacities' development.
2) Unequal and uneven development between megacities is a fact; while most of them are characterized as less developed, low-income countries, a smaller percentage has obtained excessive power, constituting powerful global cities. The latter tend to consume more resources, compared to the former, which often fall below the rates of a standard living.
3) The power of megacities tends to depend more on their connectivity capabilities and innovation rather than on their size.
4) Megacities are responsible for more than 70% of global primary energy usage, while they produce 60% of the worldwide GHG emissions.
5) Carbon Footprint (CF), highly connected to the emissions produced by a megacity, is connected to socioeconomic factors, trading, diet, transportation, electricity usage and infrastructure.
6) Decarbonization of megacity's energy mix is necessary to achieve sustainability goals.

Based on these findings, the aim of further reviewing and elaborating the connection between sustainability and geopolitics regarding megacities' development and performance is set and, in this specific direction, a list of questions has been established, whose thorough analysis is included in this chapter.

3.2 Tools and sample

The questionnaire created is addressed to experts in energy and sustainability, economics and management, as well as political sciences and international relations,

requesting their genuine and diligent perspective on a series of issues, based on their unique academic and professional background. It is divided into three broad categories: *Megacities and Sustainability*, *Megacities and Geopolitics*, and *Personal Perspectives* and the form of questions vary from multiple-choice-questions or open-ended questions to checkbox questions and Likert-scale questions. It was created using the *Google Forms* platform and can still be accessed in the following URL: https://forms.gle/qsNxnJD84mVUpW3R9. A copy of it has also been included in Appendix.

Regarding the sample of this research, experts on the fields of energy, environment, management, economics, international relations, and politics are selected, since they can contribute to a broader and wider scope of the correlation between sustainability, geopolitics, and megacities. Therefore, diverse perspectives on the subject are welcomed and encouraged.

As far as the research methodology is concerned, an online questionnaire provided via *Google Forms* has been chosen. The main reasons behind this decision were based on the quick and easy access it provides to experts worldwide, its cohesive and comprehensible structure, but also on the fact that it provides for both analysis and comparison of the available data.

Concerning the form of the questions included in the above-mentioned inquiry, divergent schemes were selected, namely multiple-choice, open-ended, checkbox, and Likert scale questions, for numerous reasons. Multiple-choice questions allow the interviewees to select only one answer from a list of objects. They offer convenience related to the data collection and classification, while constituting a smooth and pleasant way for participants to answer the issued questions. Open-ended questions provide more freedom to the contributors, since they are allowed to address these questions stating their own opinion and taking advantage of their own specialization and experience, although they might be a little tougher to analyze and categorize. Checkbox questions allow the responders to select multiple items for each question, promoting a better expressing basis, and a useful ground for data collection. Finally, Likert scale questions have also been included, because of their illustrative structure and their ability to visualize and quantify the outlooks of respondents.

3.3 The questionnaire

An attempt to gather the total of the questions, their particular characteristics and aims, as well as their correspondence to the bibliography under consideration is made in Table 3.2, while a detailed demonstration of the questionnaire's content, including the questions and their potential answers, would also provide a useful and interesting research basis, further elaborating each choice; hence, the following lines are devoted to this specific purpose.

3.3.1. Megacities and sustainability – part A section

Question 1: *Which megacities' characteristics would allow for a sustainable development?* Potential answers: *(a) Information sharing – Connectivity, (b) Institutions, (c) Transportation, (d) Services, (e) Energy provision, (f) Other*

Although megacities can surely be linked to unsustainable existence and development, they are characterized by certain aspects, which can support a more viable growth. Among others, information sharing capabilities, strong institutional presence, transportation infrastructure, services, and energy provision are common features related to megacities. Supposing that they are utilized effectively, they can serve as driving factors towards sustainability. Under these circumstances, aiming to quantify the importance of each of the above-mentioned factors and to show their contribution as a percentage of the total, this question has been derived from specific literature references.

According to Bourdeau-Lepage & Huriot (2007) coordination capabilities allow megacities to obtain and retain a major role in the global economy. Coordination is highly associated with the ability of global cities to provide numerous services, which, in turn, benefit the city in multiple ways. The provision of such services also requires information availability and usage. On top of that, institutions, both formal and informal, are related to the determination of economic activity, since they tend to determine the available choices of economic agents, as well as the power of economic organizations.

In their research, Majd & Tabibian (2015) declare that cities are linked to a metabolistic procedure; hence, they are considered sustainable, when their resource inputs and their waste outputs are decreasing, while their standard of living is rising. Simultaneously, sustainable development consists of the social, the economic and the ecological dimensions, while authorities can influence the connection and actions of different actors in each of these fields,

further supporting the minimization of climate change consequences. Improved coordination regarding transportation and space planning, promotion of local production and green compact cities, as well as implementation of more sustainable measures in infrastructure, are proved to be useful for the sustainable development of megacities. The latter should be considered an issue requiring governmental, economic, and social change to be achieved.

Respectively, Shmelev (2016) reports that urban sustainability is defined by a multi-dimensional capability to perform simultaneously and efficiently in social, environmental and economic fields. Moreover, the European Committee of the Regions, in its 2021 report, states that contemporary cities acquire more importance in terms of connectivity, rather than their size. Investments in transportation infrastructure, digitalization, education, cybersecurity, and environmental protection are extremely important, proving that sustainability and digital transformation, throughout the employment of a polycentric urban model, are significant goals on the EU Agenda, while performing proactively in terms of climate change and security measures compose the European urban profile.

Question 2: *Through which factors such a sustainable development could be obtained?* Potential answers: *(a) Sustainable public transportation, (b) Space planning & land use, (c) Renewable Energy Sources deployment, (d) Energy efficient infrastructure, (e) Technological advances, (f) Promotion of innovation and research, (g) Economic initiatives (taxes, subsidies, investments, etc.), (h) Coherent policies and measures, (i) Other*

The sustainable development of megacities can be the outcome of factors such as public transportation, space planning and land use, RES penetration, energy efficient infrastructure, technological advances, innovation-research and development, economic initiatives, and motives, as well as consistent policies and measures. Thus, this question is targeted towards quantifying the importance of each component and showing its contribution, as a percentage of the total.

Relevant references can be derived from chapter 2 and provide the basis for further examination of the factors that contribute to a more sustainable future for megacities. Olurode et al. (2018) argue that the power problem can be resolved through the implementation of Power Sector Reforms, as well as by diversifying power sources, improving the available network and, therefore, diminishing disruptions. In the same context, Shmelev & Shmeleva (2019) claim that it is crucial to transform and decarbonize the energy sector via reforming

the city's energy mix. A high correlation between carbon dioxide emissions and the transportation sector has been revealed, while renewable energy's contribution towards minimizing greenhouse gas emissions has been verified at an extremely high level of statistical significance. Creative industries, also, seem to be useful in stimulating smart economy and urban sustainability.

On top of that, Huang et al. 's report (2019) demonstrates that the majority of emissions in megacities is attributed to material production, reaching up to 72%, with the usage stage (15%), transportation (8%) and construction (5%) sectors following. Energy mix affects the total amount of carbon dioxide emissions, implying that an expansion in the usage of clean energy for power production, coupled with improving electricity efficiency, could result in reduced carbon emissions. Mandatory energy conservation policies have promoted efficiency and energy saving in buildings, while supporting low-carbon development. It is the way of spatial and economic growth of megacities, according to Gilles et al. (2021), that is highly associated with their social, economic, and environmental impacts in the whole world, since cities are characterized as open systems and the current value chains allow for such transmissions of positive and negative effects.

Under these circumstances, Gautam et al. (2019) support a decrease in energy consumption, resulting from certain economic constraints, and the utilization of alternative energy sources and advanced technologies, which can result in increased energy supply. According to their study, sustainable development and renewable energy sources are connected to human development and economic productivity, since green growth policies and the energy sector are tied, through the achievement of environmental and economic objectives. Such goals can be attained by utilizing innovation and research, combining productivity growth and environmental endurance, adequately and efficiently estimating the financial burden of purely managed natural resources and opportunities for the development of new markets. Energy integration and implementation are, also, important elements of policy, encircling the formation of carbon tax regimes, price-based markets, green investments, or abolition of subsidies for fossil fuels. Nevertheless, as it has already been mentioned above, urban sustainability is defined by the multifaceted capacity of cities to operate adequately in social, environmental and economic domains, synchronously (Shmelev, 2016).

3.3.2. Megacities and sustainability – part B section

Question 3: *Please rate below the importance of energy mix in contemporary megacities (1: slightly important, 10: great importance).*

Potential answers: *1-10*

Energy mix, in essence the amount of each energy source employed by the state to cover its energy needs as a percentage of the total, can be characterized as more or less important regarding the evolution of megacities. Using a Likert scale, starting from "slightly important" and extending up to "great importance", this question aims to determine the overall importance that is attributed to energy mix in contemporary societies.

As with the previous questions, chapter 2 *(Literature Review)* has contributed to the formation of the present query and, more specifically, through the content that follows. Already stated above, cities are characterized as open economic systems with numerous and multiple interactions with other entities (Gilles et al., 2021). In this context, effective mitigation of emissions could be achieved through the combination of those diversified interactions, avoiding the shifting of a carbon-intense activity from a region to another. Kennedy et al. (2015) assert that a megacity can evolve as a more or less sustainable hub, depending on its way of obtaining, sharing and managing energy and material resources. Both developed and less developed megacities can grow as sustainable regions and thrive as innovative centers, depending on the way they manage their energy and material flows.

Olurode et al. (2018) reveal that low-income neighborhoods, faced with electricity supply disruptions, quite often use alternative sources, like gas stoves, kerosene, diesel generators or solar power to cover their energy needs, while Shmelev & Shmeleva (2019) advocate the great need for and importance of converting and decarbonizing the energy sector, by changing the energy mix. Alternative energy's contribution towards this target has once again been confirmed. Towards this direction, Gautam et al. 's scientific paper (2019) has shown that almost 50% of final consumer energy is used for heating at lower temperature purposes, followed by 30% usage for transportation and mobility, 15% for electric motors and barely 10% for intensive industrial activities. Therefore, the employment of renewable energy sources and advanced technologies, able to increase energy supply, as well as the technological exploitation of alternative sources contribute towards a more sustainable future. Likewise, Low-Carbon Cities, defined by low-carbon production, low-carbon technology and

low-carbon energy use, are frequently developed in many countries, intending to reduce energy consumption and fossil fuel usage and, therefore, eliminate carbon emissions and leading to more sustainable operation (Ma et al., 2021).

3.3.3. Megacities and sustainability – part C section

Question 4: *What sort of policies should be adopted and implemented in order to promote the sustainable development of megacities?*

Potential answers: *(a) Top-down policies, (b) Bottom-up policies, (c) Market-based policies, (d) Information-based policies, (e) Network-based policies, (f) Hierarchy-based policies*

Sustainability promotion in megacities can be achieved by adopting and enforcing certain policies. Nevertheless, some of them should be considered more effective and practical than the rest. Under this scope, aiming to demonstrate the type of policies considered crucial for sustainability, according to the points of view of the experts, this question can be addressed by selecting solely one answer: top-down policies, bottom-up policies, market-based policies, information-based policies, network-based policies, or hierarchy-based policies. The available literature, as presented in chapter 2, allows for this question's composition, as it can be confirmed through the following lines.

Power sources diversification, network improvement and elimination of disruptions has resulted in significant sustainability effects for the countries that have employed such practices (Olurode et al., 2018). In essence, adopting and implementing Independent Power Plants has helped Nigeria to improve electricity provision, by including private entities in the previously purely public power market. In the same context, endorsement of suitable national strategic plans and actions to deal with climate change challenges, including low-carbon policies, can contribute to the achievement of future medium- and long-term carbon emissions reduction goals, appointed by the subject country (Yang & Meng, 2019).

Gautam et al. (2019) refer, as well, to the available options to cope with climate change, including energy consumption reduction, resulting from economic constraints, and deploying alternative energy sources and advanced technologies, which can intensify energy supply. Technological exploitation of renewable energy sources provides for a more sustainable future, while energy innovation is supposed to be supported and promoted through the adopted and enforced policies, including focusing on innovative ideas and global

entrepreneurship norms combined with the local needs. Energy integration and implementation are, also, important components of policy, encompassing the foundation of carbon tax regimes, price-based markets, green investments, or cancellation of subsidies for fossil fuels and it is concluded that energy transformation in practice is crucial for the adequacy of any policies adopted and enforced.

According to Ma et al. (2021) Low-Carbon Cities are characterized by low-carbon production, low-carbon technology, and low-carbon energy use, aiming to reduce energy consumption and fossil fuel and, therefore, eliminate carbon emissions. Numerous low carbon policy instruments have been established and implemented so far, encompassing carbon taxes and clean innovation. Such instruments can be divided into hierarchy-based instruments (i.e. forceful policy measures), market-based instruments (such as tax incentives, carbon trade policy, financial subsidies), information-based instruments (including the environmental pollution data disclosure) and network-based instruments (which support the cooperation between organizations).

As far as the total amount of carbon dioxide emissions is concerned, Huang et al. (2019) state that energy structure affects the latter, demonstrating that an increase of clean energy for power production, combined with electricity efficiency, could result in decreased carbon emissions. On top of that, sustainable and low-carbon development of the building sector is considered highly important, and in this direction, the implemented mandatory energy conservation policy has promoted an increase of efficiency and energy saving in buildings, as well as a low-carbon development. In the same direction, The European Committee of the Regions (2021) argues that great economic power can be derived by factors like urbanization, technological improvement, and capital accumulation. Sustainability and digital transformation seem to be held high on the EU Agenda, while the common European urban profile can be defined as a combination of social and economic balance, throughout the implementation of a polycentric urban model with a proactively action regarding climate change and security measures.

Finally, Qu et al. (2020) claim that among other sustainability related policy recommendations, a functional land planning development, the promotion of urban ecological restoration, an adequate decrease of urban residential consumption and the adoption of an ecological compensation system are included, raising the amount of the available potential policies and practices encountered in the bibliography.

3.3.4. Megacities and geopolitics – part A section

Question 5: *Which megacities' characteristics would allow for adequate geopolitical power?*

Potential answers: *(a) Information sharing – Connectivity, (b) Institutions, (c) Services, (d) Economic resources, (e) Natural resources - energy provision, (f) Military resources & preparedness, (g) Technology, (h) Other*

Geopolitical power can be gained, maintained, and strengthened as a result of multiple factors, choices and combinations. In this context, megacities present notable interest, because of their unique dynamic. Therefore, setting the aim to quantify the importance of each determinant and to show its contribution, the available answers to address this question, in a checkboxes form, include information sharing and connectivity, institutional activity, the provision of services, the abundance of economic, natural, and military resources and any potential technological advances, while the choice to add more fields is also available, allowing experts to adequately convey their statements. Through the available literature, certain indications regarding the geopolitical power of megacities can be extracted, which are presented in the following lines.

According to Gilles et al. (2021), in the case of Bogota, its potential alternative sourcing countries are constituting of Latin American states, since they share the same region and, therefore, better trading relations are a fact, possibly resulting in numerous benefits, even creating a more integrated and stronger region, both in economic and geopolitical terms. Bourdeau-Lepage & Huriot (2007), at the same time, claim that the power of megacities derives from their economic development. In contemporary societies, global cities have evolved, which are characterized by a great accumulation of specialized services and interactions on an international level. These coordination capabilities especially allow them to hold a major position in the global economy. Moreover, formal and informal institutions can contribute to economic activity determination by controlling the available choices for economic agents, as well as their potentials. In this context, economic performance of megacities holds a determinant role in shaping their global status, and size could only matter, if it led to the creation of sufficient diversity, information externalities and skills, which, in turn, would push towards further coordination.

The great power and influence of megacities, according to Yang & Meng's study (2019), combined with adopting and enforcing those appropriate and adequate national

strategic plans to deal with environmental challenges, encompassing low-carbon development transformation policies, can contribute to the achievement of future medium- and long-term carbon emissions reduction goals. Regarding the correlation between city size and energy consumption, Kennedy et al. (2015) articulate that even though Tokyo is larger than New York, in terms of population size, it consumes less energy, compared to the latter, since more energy is required for transportation and heating/industrial purposes in New York City. Additionally, some of the less developed megacities have promoted, so far, efficient ways to eliminate their global environmental footprint, while boosting their energy efficiency. All in all, a megacity's ability to develop as a sustainable hub is highly dependent on the way it obtains, manages, and shares energy and material resources, while more than policies, urban form, climate and economic activity greatly determine energy consumption.

The European Committee of the Regions (2021) also states that cities acquire more importance in terms of connectivity rather than because of their size. Successful cities seem to engage innovative technologies, which can enhance productivity and promote a better life quality, while they tend to be concentrated near coasts, where multiple economic and social opportunities arise thanks to the climate and the benefits obtained from the commercial usage of the sea-roads. Great economic power can be the result of numerous factors, like urbanization, technological improvement, and capital accumulation, and the future of megacities is profoundly affected by economic instability, security threats, social issues, and environmental degradation.

Question 6: *"In the forthcoming years, carbon emissions in megacities are expected to grow rapidly and to a great extent in developing countries, while at the same time they are estimated as being stable for more developed regions". How could this affect the relations between different (developed and developing) megacities?*

Potential answers: *(long answer text)*

In contemporary societies, the existence of both more and less developed megacities, combined with the fast-paced growth of each of them, creates reasonable ground for competition and insecurity, as far as the relations between them is concerned. Power shifts change the substance of the communication and the cooperation between countries, either towards a more beneficial or towards a more competitive pole. Hence, contributors, particularly those with a geopolitical background, are kindly asked to extensively express

their opinion on the issue, therefore a long-text answer is provided for this specific question. The review on the available bibliography, as conducted in chapter 2, offers adequate justification for the generation and the support of this question.

Already mentioned above, Gilles et al. (2021) thoroughly examined the potential alternative sourcing countries for Bogota, which include Latin American states, located in the same region with the subject state, hence creating better trading conditions and relations, with the potential of further collaboration and integration vivid enough. Simultaneously, Bourdeau-Lepage & Huriot (2007) support that a rapid increase in the number and the size of megacities, especially in the developing world, is a fact. At the same time, since the power of megacities derives mainly from their economic development, it has inevitably led to unequal and uneven growth between developed and developing megacities. The latter are characterized by great corruption, having to deal with coordination and institutional coherence difficulties, negatively affecting their economic growth potentials. Creation and evolution of megacities requires a minimum level of development and on this basis the poorest countries cannot create sufficient urban hubs; low development implies weak performances internationally. Under these circumstances, the development of powerful megacities around the globe may deepen inequalities among the countries, as well as increase their competition for dominance and geopolitical survival.

Therefore, there still are regions globally, where resources and energy consumption stand at extremely low levels, posing serious concerns regarding the standard of living (Kennedy et al., 2015). If such megacities, resided primarily in South Asia, continue to develop in such a way, they are obliged to increase their degree of consumption in order to sufficiently survive and evolve. It is also true that in some of the poorer megacities, citizens tend to climb in the social ladder, increasing their earnings, therefore, consuming more energy. These developing megacities have cultivated competent ways to minimize their environmental footprint, while augmenting their energy efficiency. In this context, megacity's sustainable development depends on the way it obtains, shares, and manages its energy and material resources and flows, and, even though policies have a major impact towards the sustainability goals, other factors, including urban form and economic activity influence energy consumption, as well. Megacities are linked to multiple global risks, involving geopolitical, environmental, economic, societal, and technological aspects. A considerable number of them seems unable to provide its residents with basic services, having as a result extreme levels of poverty and severe health problems.

On top of that, according to The European Committee of the Regions (2021), megacities, like Tokyo, New York and Los Angeles are linked to high percentages of global GDP, while, as far as African megacities are concerned, the pace of their continuing urbanization is likely to accelerate a necessary transformation regarding development and growth. In the parallel, European megacities are viewed as innovative centers, able to provide for numerous options and opportunities, persisting in holding sustainability and digital transformation high on their agenda. Economic instability, security threats, social issues and environmental degradation stand as forceful factors for future megacities and their great consumption is a fact that might lead to resource competition, with vague outcomes. Furthermore, megacities are considered to form and strengthen inequalities within them, between the rich and the poor, and, also, among megacities of different development backgrounds, of the West and the East. A polarization like this could result in urban conflicts, therefore certain emphasis should be granted in reunifying divided cities and regions.

In their study, Abd Alla et al. (2021) state that informal settlements, common in less developed countries, strongly demand a more sustainable development and operation, supporting, at the same time, the improvement of the quality of life. Authorities could perform more effectively regarding sustainability, if they implemented the appropriate strategies, allowing the sharing of knowledge among cities at national, regional, and international level, taking, also, into consideration the fact that the swift population growth, coupled with greater density and a subsequent rapid urban expansion result in additional climate change risks.

Undoubtedly, urban growth follows a natural increase of urban population, which, in turn, emerges as a consequence of a simultaneous rise in births and fall in deaths, of migration from rural areas within a country or from abroad, but it also results from reclassification, pushing further for a greater expansion of city's geographical area in order to cover previously rural regions (United Nations, Department of Economic and Social Affairs, 2019). In this framework, high-income countries are associated with higher rates of urbanization, compared to lower-income states and it is estimated that, among others, Africa and Asia will be characterized by greater rates of urbanization. One of the most crucial challenges regarding the sustainable future of the promptly developing cities is to embrace and enforce sufficient measures and policies, notably in the majority of low- and middle-low-income regions, which are assumed to follow a rapid growth.

Pursuing a similar path, Gautam et al. (2019) describes developed countries as specified by higher living standards, a fact that implies higher energy consumption, combined with more adequate transportation, more intense building and housing construction, as well as the provision of better public health and safety services. In contemporary society, as the number of megacities worldwide rises, the disparity between energy demand and supply increases, respectively. Energy demand and consumption are highly related to the country's GDP and sustainable development is highly tied with human development and economic productivity, since it offers numerous options and multiple opportunities for socio-economic development, increased energy access, effective energy security, mitigation of environmental consequences, as well as reduction of health impacts.

3.3.5. Megacities and geopolitics – part B section

Question 7: *What kind of risks does the rapid growth of megacities indicate?*

Potential answers: *(a) Geopolitical risks, (b) Economic risks, (c) Financial risks, (d) Environmental risks, (e) Socioeconomic risks, (f) Political risks, (g) Other*

Fast-paced evolution of megacities can be characterized by numerous types of risks, covering the whole society and its activities. More than one kind of risk can be applied simultaneously, therefore answers in the form of checkboxes allow for an aggregated approach to the issue. Contributors are able to select more than one potential answer, while this question is targeted towards demonstrating, analyzing and emphasizing the importance of each risk. The Literature Review chapter serves as a valuable basis for this question's generation, since it underlines the numerous types of risk associated with the creation and development of megacities.

According to Gilles et al. (2021), urban entities' means of geographical and economic growth is highly related to their social, economic, and environmental effects reflected in the whole world, since cities are considered open systems. Carbon footprint indicators are generated from imports of goods, consumed by the city's residents, in essence computers, vehicles, machinery, and electrical equipment. Regarding less developed megacities, Olurode et al. (2018) list corruption, deficient road network, extreme levels of poverty, and highly constrained provision of social services as some of the most outstanding issues they have to deal with. Especially energy provision differs among less developed countries, with the

poorer ones facing serious problems related to energy poverty, and energy crisis standing at quite high rates.

Concerning other kind of risks, consuming ecosystem services faster than their renewal capabilities bear is associated with the phenomenon of cities following a controversial practice, which consists of focusing on eco-friendly investments, while, at the same time, intending to provide improved lifestyles and adequate consumption levels to their citizens (Türe & Türe, 2020). In the case of Istanbul, as regards energy consumption, the main determinants of intensified carbon footprint are production, consumption, and tourism. Ecological footprint, on the other hand, appears to grow generally as an outcome of flows of energy, goods, water, information, transport, and capital, which are the human development's primitive factors, even though they may result in ecological deficits, if not adequately managed.

In determining carbon footprint, not only direct, but also indirect emissions, related to the consumption and life cycle of products and services are equally important and crucial (Moran et al., 2018). In fact, a few high-income cities hold responsibility for 30-45% of global emissions. Regarding carbon footprint in households, among other sources of emissions, food accounts for 10-30%, which includes electricity consumption for the meals preparation and transportation related emissions (Center for Sustainable Systems, 2021). In the parallel, buildings are accountable for roughly 40% of the global energy consumption and carbon dioxide emissions linked to them have been rising, since 2010, at a yearly rate of 1% (Huang et al., 2019). On the other hand, material production is connected to the vast majority of emissions, reaching up to 72%, while the usage stage, the transportation sector and the construction industry seem to follow pace, at the races of 15%, 8% and 5%, respectively.

Certainly, electricity is highly correlated with economic advancements and development, (Kennedy et al., 2015). However, there, still, are districts around the world, characterized by remarkably low levels of resources provision and energy consumption, often enough below the rates of a standard living. Growth of megacities is related to environmental sustainability challenges and their existence is associated with multiple global risks and issues, which encompass extreme poverty, health-related problems, due to poor air quality within them, as well as social-spatial fragmentation. Therefore geopolitical, environmental, economic, societal, and technological risks accompany megacity's growth, demanding for the appropriate actions and reactions.

Question 8: *These risks could be assessed, managed, and minimized effectively in contemporary megacities by:*

Potential answers: *(a) Implementing effective policies (top-down approach), (b) Encouraging citizens' initiatives (bottom-up approach), (c) Decarbonizing energy mix (RES penetrations, hydrogen utilization etc.), (d) Providing economic motives (e.g., subsidizing electric vehicles), (e) Improving information and communication networks, (f) Other*

The multiple risks and challenges that megacities need to deal with can be assessed, managed, and eliminated through the utilization of several measures and initiatives. Effective policies, as a top-down approach, encompass measures undertaken and implemented by the state, while supporting initiatives undertaken by citizens, constituting a bottom-up approach, refers to initiatives undertaken by and highly correlated to people's behavior. Decarbonization of energy mix is associated with the adoption of policies that can provide a cleaner energy mix, economic motives are connected to offering subsidies or facilitating environmentally friendly choices, while enhancement of information and communication networks can potentially serve as a supportive factor towards raising awareness and action. This question aims to demonstrate and analyze the various available methods for assessing, managing, and minimizing present risks and can be supported by certain literature review references, as outlined below.

Contemporary cities are portrayed as actors with great power and influence, whose national strategic plans and actions, generated and enforced to confront climate challenges, can support their medium- and long-term goals related to carbon emissions reduction (Yang & Meng, 2019). Economic advancements can be adequately integrated with environmental improvement, by analyzing the key carbon footprint factors and by detecting each factor's specific characteristics at the divergent phases of economic development, resulting in the adoption of targeted carbon emission policies, specialized for each stage.

Another potential manner of risk management is the shifting of import sources, suggesting a diversification in transactions (Gilles et al., 2021). Interactions between cities and other entities vary greatly, justifying their characterization as open economic systems. Moreover, in terms of energy provision and usage, a diversification of power sources, combined with network upgrading and, therefore, with reduced disruptions, can substantially contribute towards that direction (Olurode et al., 2018). Huang et al. 's study (2019) indicates

that compulsory energy conservation measures, where implemented, have enhanced efficiency and energy saving in buildings, supporting, simultaneously, low-carbon development. However, such policies seem inadequate towards elimination of carbon emissions, as their roughly 5% reduction confirms. Implemented measures, which include, among others, the installation of energy consumption systems, the promotion of solar and photovoltaic systems usage, or the establishment of award funds for green buildings, have achieved only a deceleration of carbon dioxide emissions growth, rather than a genuine decline.

According to Kennedy et al. (2015) the provision of a decent, fulfilling way of living is related to the technological development and management and megacity's potentials to develop sustainably are based on the way it acquires, distributes, and regulates energy and material resources. A reduction and careful control over energy and material flow, as well as the endorsement of new technologies and the enforcement of energy efficiency standards, support the consequent environmental problems management. Among the numerous ways to minimize carbon emissions, Ma et al. (2021) acknowledge hierarchy-based instruments, namely forcible policy measures, market-based instruments, which include tax incentives, carbon trade policy, and financial subsidies, information-based instruments, encompassing the environmental pollution data disclosure, as well as network-based instruments, the ones promoting and enhancing cooperation among organizations.

3.3.6. Personal perspectives section

Question 9: *Please, name, below, the predominant issues associated with megacities.*

Potential answers: *(long text answer)*

Following the previous questions, which provide a sound and defined context for examining the development of megacities, taking into consideration sustainability and geopolitical factors and aspects, candidates are requested to articulate their ideas on the issue. Different academic and professional backgrounds characterizing the experts lead to various results, among which some are expected to be convergent, while others divergent. The aim here is to determine the particular components related to concerns regarding megacities and the distribution of those components among the scientific community. The available bibliography offers a useful ground for brainstorming. An illustration of the research conducted within this thesis follows in the consecutive lines.

Olurode et al. (2018) refer to a series of issues detected in less developed megacities and, more specifically; corruption, inadequate road network, extreme poverty, and uncommonly confined social services provision. Energy supply seems to vary, as well, among less developed countries, with the poorer ones dealing with major energy poverty related issues. Similarly, Türe & Türe (2020) realize the consequences of a faster ecosystem services consumption, compared to its renewal capacity, resulting in ecosystem's degradation within megacities, while Gilles et al. (2021) accuse goods within megacities (in essence computers, vehicles, machinery, and electrical equipment) consumption patterns of constituting the primary carbon footprint indicators.

In the same framework, Moran et al. 's research (2018) has accentuated, as well, the importance of consumption and the life cycle of products, emphasizing the fact that a slight number of high-income cities are accounted for almost 30-45% of total emissions worldwide. Among the main sources of emissions, food acquisition and processing stand at the top, accounted for 10-30% of household carbon footprints (Center for Sustainable Systems, 2021). On city level, buildings are responsible for nearly 40% of the total energy consumption and carbon dioxide emissions (Huang et al., 2019).

Gautam et al. (2019) recognize that the provision of higher living standards in developed megacities indicates greater energy consumption, combined with intensive transportation systems, an advanced building and housing construction industry, as well as improved public health and safety services. At the same time, considering that the world population is swiftly growing, indicating that more and more megacities are emerging, the gap between energy supply and demand seems to expand, respectively. In the same context, Kennedy et al. (2015) declare that megacities account for 70% of global primary energy use, generating 60% of the worldwide greenhouse gas emissions, reaching the conclusion that their development so far has been linked to challenges and global risks regarding sustainability, such as extreme levels of poverty, health issues, or social-spatial fragmentation. Specifically in developing megacities, where the vast majority of the population lives under tough circumstances, low efficient technologies and appliances increase energy losses, resulting in higher energy consumption.

Question 10: *How could these issues be tackled, according to your opinion?*

Potential answers: *(long text answer)*

Apart from the above-mentioned issues, acknowledged by the questionnaire's sample as decisive elements associated with the growth of megacities, potential solutions to those issues are also inspected. In this context, contributors are kindly asked to propose multiple solutions, based, once again, on their unique experience. Numerous ideas can be derived from personal experiences, but can also be found in the relative literature, as it is depicted below.

Yang & Meng (2019) propose the adoption and implementation of appropriate national strategic plans and actions, as a means of dealing with climate challenges and achieving medium- and long-term carbon emissions reduction goals, while Shmelev & Shmeleva (2019) underline the importance of transforming and decarbonizing the energy sector, through changing country's energy mix. Simultaneously, creative industries are found to contribute, both in stimulating smart economy and in supporting urban sustainability. Gilles et al.'s (2021) perspective on the issue refers to the possible positive effects derived from a shifting of a megacity's import sources, while Huang et al.'s study (2019) suggests that appropriate measures shall be undertaken in the public building sector.

Reduction in energy consumption, ensued as a result of economic constraints, integrated with advancements from alternative energy sources and improved technologies, has the ability to broaden energy supply, simultaneously leading to a more sustainable future (Gautam et al., 2019).

All in all, according to Kennedy et al. (2015), less developed megacities shall multiply their consumption level, so that their residents are provided with sufficient services to sustain a living standard, while more developed megacities should diminish and properly manage their energy and material flow, linked to their activity, in order to minimize the resultant environmental problems. Undoubtedly, policies hold a major role regarding these shifts, however, other factors, as well, such as urban form, climate and economic activity can highly affect energy consumption and, therefore, should be carefully estimated and managed.

Table 3.2. *Inquiry's questions in summary*

Megacities: Sustainability & Geopolitics - Questionnaire					
No.	Question	Type	Justification	Aim	Reference
Megacities & sustainability - part A					
1	Which megacities' characteristics would allow for a sustainable development?	Checkbox Question	Sustainable development is the result of numerous components.	Quantify the importance of each aspect and show their contribution %.	Bourdeau-Lepage & Huriot, 2007; Majd & Tabibian, 2015; Shmelev, 2016; The European Committee of the Regions, 2021
2	Through which factors such a sustainable development could be obtained?	Checkbox Question	Sustainable development is the result of numerous components.	Quantify the importance of each aspect and show their contribution %.	Olurode et al., 2018; Shmelev & Shmeleva, 2019; Huang et al., 2019; Gilles et al., 2021; Gautam et al., 2019; Shmelev, 2016
Megacities & sustainability - part B					
3	Please rate below the importance of energy mix in contemporary megacities (1: slightly important, 10: great importance).	Likert scale Question	Quantitative question, which can effectively be addressed in this manner.	Determine the overall importance attributed to energy mix in contemporary societies.	Gilles et al., 2021; Kennedy et al., 2015; Olurode et al., 2018; Shmelev & Shmeleva, 2019; Gautam et al., 2019; Ma et al., 2021
Megacities & sustainability - part C					
4	What sort of policies should be adopted and implemented in order to promote the sustainable development of megacities?	Multiple-choice Question	Eliminate the possibility to choose all the potential answers and hence lead to ineffective results.	Demonstrate the type of policies considered crucial for sustainability, according to our sample.	Olurode et al., 2018; Yang & Meng, 2019; Gautam et al., 2019; Ma et al., 2021; Huang et al., 2019; The European Committee of the Regions, 2021; Qu et al., 2020
Megacities & geopolitics - part A					
5	Which megacities' characteristics would allow for adequate geopolitical power?	Checkbox Question	Geopolitical power is the result of numerous factors.	Quantify the importance of each aspect and show their contribution %.	Gilles et al., 2021; Bourdeau-Lepage & Huriot, 2007; Yang & Meng, 2019; Kennedy et al., 2015; The European Committee of the Regions, 2021
6	"In the forthcoming years, carbon emissions in megacities are expected to grow rapidly and to a great extent in developing countries, while at the same time they are estimated as being stable for more developed regions". How could this affect	Open-ended Question	The examination and evaluation of the relations between two or more countries can vary considerably among	Identify as many potential scenarios as possible and explore the feasibility of classifying them.	Abd Alla et al., 2021; The European Committee of the Regions, 2021; Bourdeau-Lepage & Huriot, 2007; Gilles et al., 2021; United Nations, Department of Economic and Social

	the relations between different (developed and developing) megacities?		experts.		Affairs, 2019; Kennedy et al., 2015; Gautam et al., 2019
Megacities & geopolitics - part B					
7	What kind of risks does the rapid growth of megacities indicate?	Checkbox Question	Megacities' growth can indicate multiple risks.	Demonstrate and analyze the different risks associated with megacities' growth.	Gilles et al., 2021; Olurode et al., 2018; Türe & Türe, 2020; Moran et al., 2018; Center for Sustainable Systems, 2021; Huang et al., 2019; Kennedy et al., 2015
8	These risks could be assessed, managed, and minimized effectively in contemporary megacities by:	Checkbox Question	Various approaches for assessing, managing, and minimizing risks are available.	Demonstrate and analyze the various methods for assessing, managing, and minimizing risks.	Yang & Meng, 2019; Gilles et al., 2021; Ma et al., 2021; Kennedy et al., 2015; Huang et al., 2019; Olurode et al., 2018
Personal perspectives					
9	Please, name, below, the predominant issues associated with megacities.	Long-answer-text	Experts are requested to provide their personal perspective, resulted from their unique professional and academic experience.	Determine the convergence and the divergence between experts in different fields.	Olurode et al., 2018; Türe & Türe, 2020; Gilles et al., 2021; Moran et al., 2018; Center for Sustainable Systems, 2021; Gautam et al., 2019; Huang et al., 2019; Kennedy et al., 2015
10	How could these issues be tackled, according to your opinion?	Long-answer-text	Experts are requested to provide their personal perspective, resulted from their unique professional and academic experience.	Determine the convergence and the divergence between experts in different fields.	Yang & Meng, 2019; Shmelev & Shmeleva, 2019; Gilles et al., 2021; Gautam et al., 2019; Huang et al., 2019; Kennedy et al., 2015

Chapter 4 – Results

4.1 Responses of the focal group

The questionnaire was addressed to a small group, consisted of seven experts specialized in the fields of energy and economics, environment, and climate change, as well as energy security and social services, whose contribution is of high importance towards the establishment of a valuable questionnaire, capable of being utilized in a future large-scale survey. Apart from their responses, which are examined in this section, the following 4.2 passage includes valuable comments and reviews from two of them, further supporting the improvement of the questionnaire.

4.1.1. Megacities and Sustainability - part A: Experts respond

The first question refers to *megacities' characteristics that would allow for their sustainable development,* providing as potential answers, in checkboxes form: (a) information sharing – connectivity, (b) institutions, (c) transportation, (d) services, and (e) energy provision. The responses provided by the experts are illustratively shown in Figure 4.1.

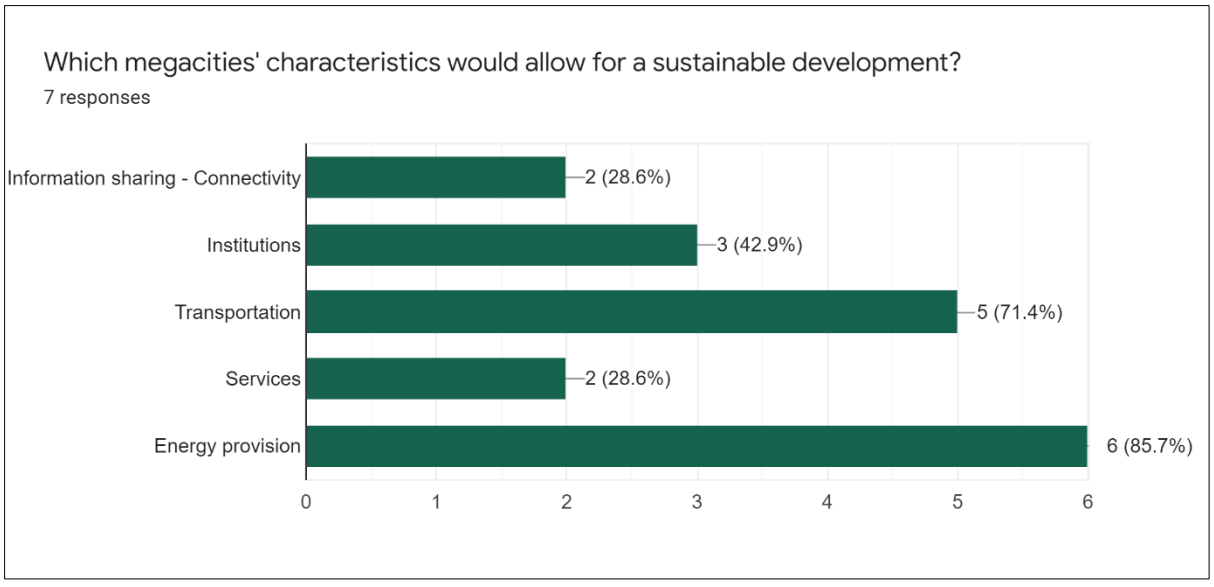

Figure 4.1 *Question 1 - Experts' responses*

It is shown that 85.7% of the sample, namely 6 professionals, have acknowledged energy provision as the most crucial factor towards the sustainable growth of megacities,

followed by transportation, which was supported by 5 experts (71.4% of the sample). Institutions stand at the third position with 3 votes (42.9%), while information sharing and services received only 2 votes (28.6%) each.

Therefore, nearly the whole focal group seems to agree upon the importance of energy provision in the attempts of megacities to obtain and sustain a more efficient and environmentally friendly approach, as well as upon the great influence of transportation towards the same direction. It has, also, been shown, within the previous chapters, that energy provision holds a major role regarding the ability of a city or country to consume energy and to generally develop in every aspect, distinguishing between developed and developing countries, with the first aiming to reduce their emissions and to obtain a sustainable growth model and the latter aiming to enhance the access of their citizens to clear and uninterrupted energy. Simultaneously, energy demand on the transportation sector emphasizes the need to lift the focus to alternative energy sources. Huge amounts of fuels are consumed within the transportation industry, in essence for planes, ships, cars, busses etc., to move, underlining the great need to promote greener methods for everyday commute.

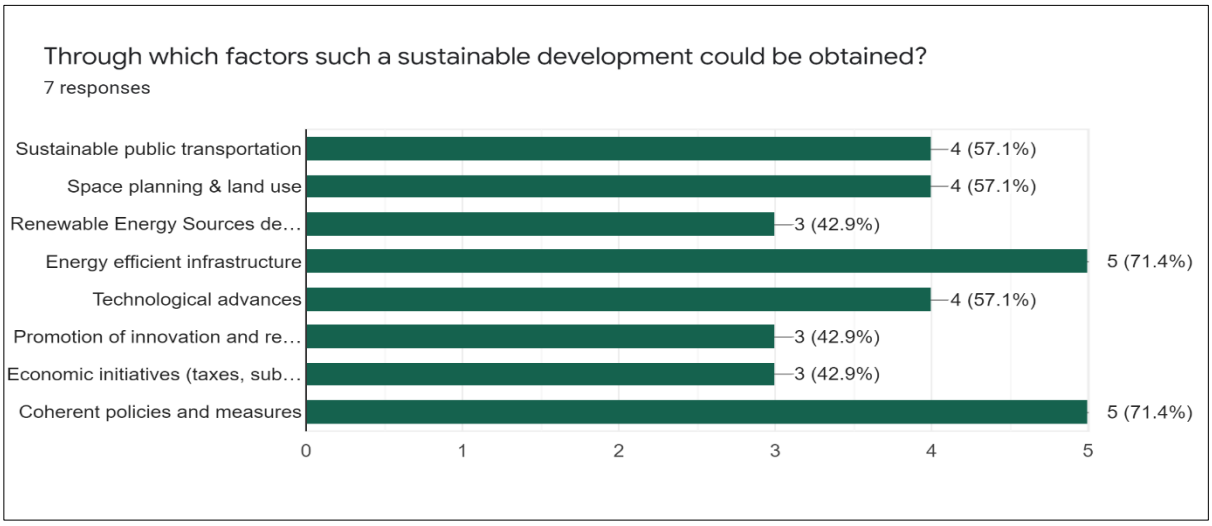

Figure 4.2 *Question 2 - Experts' responses*

The second question is associated with the *factors through which a megacity's sustainable development could be achieved*, allowing for the following answers, once again in check-boxes form: (a) Sustainable public transportation, (b) Space planning & land use, (c) Renewable Energy Sources deployment, (d) Energy efficient infrastructure, (e) Technological advances, (f) Promotion of innovation and research, (g) Economic initiatives (taxes, subsidies, investments, etc.), (h) Coherent policies and measures, (i) Other.

In this case, 5 experts (71.4%) recognize the contribution of energy efficient infrastructure and coherent policies and measures towards the accomplishment of sustainability, 4 of them (57.1%) stand for sustainable public transportation, space planning and use, as well as for technological advances and 3 of them (42.9%) seem to support the deployment of renewable energy sources, the promotion of innovation and research and the provision of economic initiatives, such as taxes, subsidies or investments.

Adopting the right policies by the government, implementing measures to enhance sustainability in megacities, as well as upgrading the energy efficiency of buildings, seem to receive the most of the group's attention. The vast majority of experts agree that the adoption and implementation of sustainable practices regarding both the construction of new buildings and the renovation of the existing ones, as well as the enforcement of coherent and horizontal measures and policies, with no exceptions, could further support the sustainable development of megacities.

In the same direction, careful space planning and use of land, combined with the promotion of sustainable transportation services and technological advances can enhance the efforts devoted towards the above-mentioned goal, since they can all contribute to fewer emissions, and better connection in terms of access to energy and energy provision. As far as the deployment of renewable energy sources, the promotion of innovation and research and the provision of economic initiatives are concerned, it is apparent that they indicate less carbon emissions, more innovative and up-to-date technologies, as well as better support in economic terms.

All in all, it is noticed that each of the factors referred in the subject question is considered valuable towards the achievement of a more sustainable development. Nevertheless, some of them are viewed as more effective and capable of accomplishing the targets set, and, therefore, they concentrate more votes compared to the rest of them.

4.1.2. Megacities and Sustainability - part B: Experts respond

The third question aims to demonstrate the importance of energy mix in contemporary megacities, allowing the candidates to choose the degree of its importance in an ascending Likert scale, on a range between 1 and 10, with 1 standing for slightly important and 10 representing the highest degree of importance. As displayed in Figure 4.3, more than 50% of the subject sample, in essence 4 out of the 7 experts, ranked the energy mix relatively high,

with 8/10 points, a lower percentage considered it as a matter of great importance (10/10 points), namely 2 experts (28.6%), while only one participant retained a modest approach slightly above the middle (6/10 points). From this viewpoint, it can be observed that the great majority of the experts recognize the significant role that energy mix holds in contemporary megacities, indicating that the composition of energy sources within nations and cities should be carefully considered.

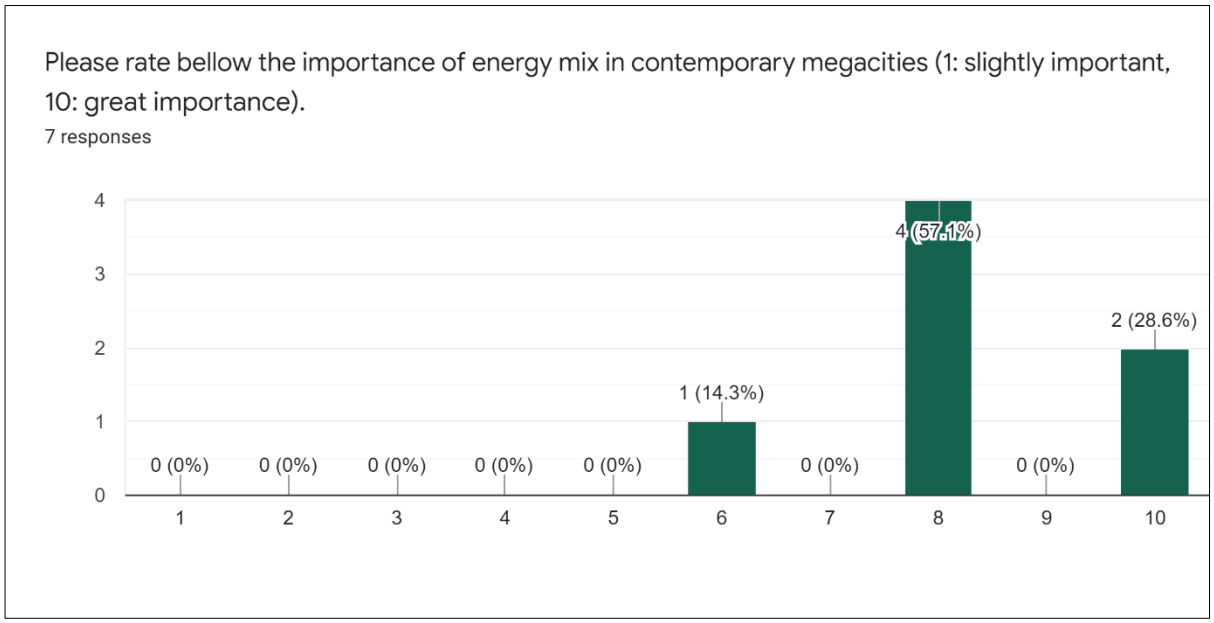

Figure 4.3 *Question 3 - Experts' responses*

Energy mix constitutes the different energy sources utilized within countries and megacities and the percentage of each particular source, allowing for distinguishing between different energy models and providing for useful evaluation of them. Indeed, whether a megacity depends more on fossil fuels or not to operate on a daily basis affects its identity, both in terms of sustainability (more or fewer emissions, bigger or smaller ecological footprint, etc.) and in terms of geopolitics (energy security or vulnerability to external events, economic and political strength or weakness etc.).

4.1.3. Megacities and Sustainability - part C: Experts respond

The fourth question is associated with the policies that could be adopted and enforced to promote sustainable growth in megacities, where a multiple-choice capability is provided, allowing the candidates to choose between (a) top-down, (b) bottom-up, (c) market-based, (d) information-based, (e) network-based, or (f) hierarchy-based policies. Responses emanated

from participants are displayed in Figure 4.4. Contrary to the previous questions, where a general agreement can be detected, in this particular case, the group's opinion regarding the most appropriate type of policies to be implemented to enhance sustainability, seem to be widely divided.

Just 28.6% of the sample (in essence 2 out of the 7 experts for each of the following options) support the top-down and bottom-up policies and solely 14.3% of the sample (namely 1 candidate for each of the following choices) recommend market-based, network-based, and hierarchy-based policies. No participant chose the information-based option. Thoroughly and cautiously examining the responses to this question, it can be assumed that the majority of the experts (57.2%) consider the policies derived either from the government (top-down approach) or from initiatives undertaken by citizens (bottom-up policies) as of great significance and effectiveness towards the adoption and support of a more sustainable future for megacities. In fact, they both serve as established practices enforced throughout the latest decades (for example, national and international laws, European directives, environmental and activistic movements etc.), therefore the preference of experts can be considered rational.

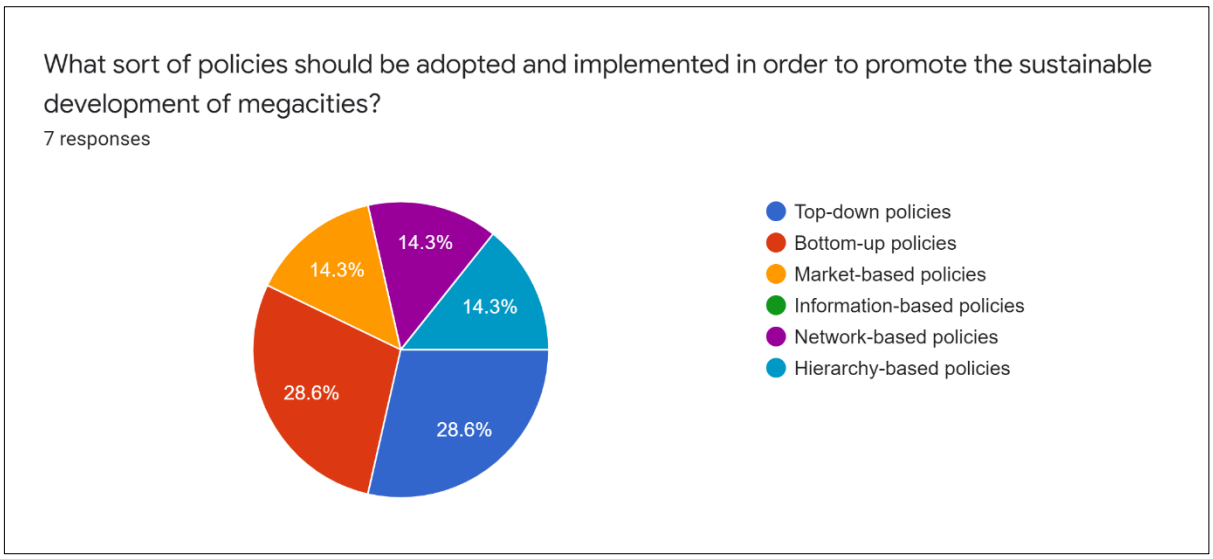

Figure 4.4 *Question 4 - Experts' responses*

A relatively low percentage seems to trust the economy's capabilities (market-based policies) towards the same direction, which could be justified by noticing corporate behavior, actions and influence regarding the sustainable present and future and businesses and industry’s impact on a wider environmental scale. Surely, the market's nature is characterized

by large consumption rates and from this point of view, certain policies could result in beneficial outcomes connected to sustainability.

Network-based policies, favored by a low percentage of the subject sample, indicate a strengthening in networking. Creating active teams and groups, further supporting the actions undertaken to reverse the current environmental situation seems to constitute a potential solution and a driving factor towards a more sustainable future. Hierarchy-based policies, the ones enforced as obligatory measures by the megacity's authorities in charge, are supported by also a low percentage of the sample. It is believed that obligatory measures, strictly enforced and managed, could prevent any actions that could result in reverse outcomes, a fact that occurs commonly, especially among greater polluters (e.g., heavy industry, fossil-fuel producers, etc.).

Finally, it has been observed that information-based policies were not chosen by any candidate. Communicative practices adopted in every field and aspect, proposing that better intelligence strategies are established and incorporated into the operational system of megacities, could possibly support a more sustainable future, thanks to the well informed and aware private and public entities. However, the focal group expresses a lack of trust towards this solution, probably because of the existence of other, more efficient policies, or maybe because there is a general lack of trust in intelligent capabilities

4.1.4. Megacities and Geopolitics - part A: Experts respond

The fifth question is connected to geopolitics and aims to identify those characteristics of megacities that would allow for adequate geopolitical power. Experts have chosen, in a check-box form, between (a) information sharing - connectivity, (b) institutions, (c) services, (d) economic resources, (e) natural resources-energy provision, (f) military resources and preparedness, and (g) technology, and their preferences are displayed in Figure 4.5. Regarding geopolitical power, the vast majority of the sample (85.7% or 6 out of the 7 experts) indicated natural resources and energy provision as the most important factor, followed by a respectively high percentage (71.4% or 5 out of 7 experts) that favored economic resources. More than half of the sample (57.1% or 4 out of the 7 experts) considered military resources and preparedness as well as technology as significant aspects of enhancing geopolitical power, while slightly less than half of them (42.9% of the sample or 3

candidates) chose information sharing - connectivity, two experts (28.6%) selected “services” and only 1 candidate referred to institutions.

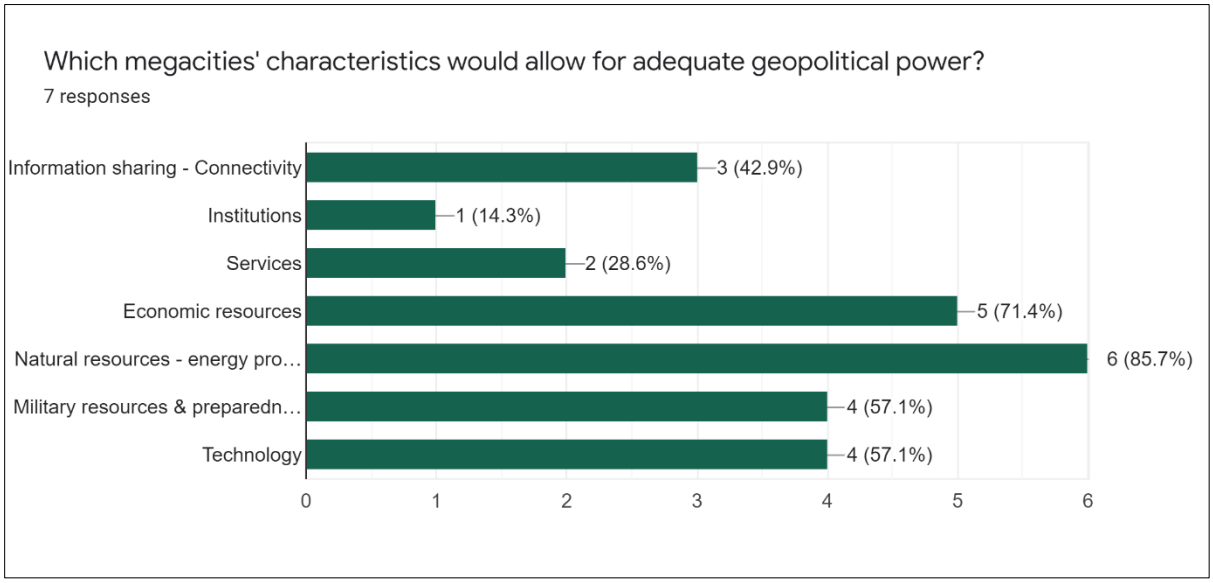

Figure 4.5 *Question 5 - Experts' responses*

In this context, it is well understood that, according to opinions expressed by the experts, natural and economic resources are regarded as significant factors and aspects that can stimulate the geopolitical power of a megacity. Indeed, geopolitics are directly connected to energy provision and economic performance since they allow for multilateral development and enhance the megacity’s negotiation power. On top of that, technological advances are the result of the previous-mentioned elements but serve also as a precondition to achieve and augment them, while military resources and preparedness provide for the necessary security, which allows the city to flourish.

Connectivity and services, two of the less favorable options, can, of course, support megacity’s geopolitical power since they indicate its ability to collaborate with the entities within it and among those of other megacities. However, they cannot be a priority in this case since the weight of the above-mentioned factors is considered greater. Finally, institutions within megacities are considered the least decisive factor regarding advanced geopolitical power, compared with the rest of the available choices, probably reflecting different perspectives of experts about their potential.

The sixth question was open-ended, allowing the experts to articulate their opinions on a long text form; *"In the forthcoming years, carbon emissions in megacities are expected to grow rapidly and to a great extent in developing countries, while at the same time they are estimated as being stable for more developed regions". How could this affect the relations between different (developed and developing) megacities?*

In this specific case, only five answers were collected, which are presented below, followed by comments and a concise analysis.

- Answer 1: "Migration will take place, resulting in conflicts among state actors" (the answer was provided in Greek)
- Answer 2: "Megacities of developing countries are already lacking necessities to facilitate their population, let alone any further population increase which will deterministically affect carbon emissions. These megacities can cooperate with the developed ones and ask for suggestions however national tensions (e.g., USA-China) will probably affect any such attempts."
- Answer 3: "Disruption of traditional megacities"
- Answer 4: "It is observed that developing countries are indeed growing rapidly the latest years at a faster pace in comparison with the developed countries. Considering the fact that most of the developing countries are usually overpopulated, energy consumption and need for more resources is expected to be increased to a great extent. This can lead to conflicts of course.

  The global community is looking for solutions, with alternative energy sources prevailing, advanced crops, changes in eating habits, etc."
- Answer 5: "It could enhance their cooperation and knowledge sharing in order to promote sustainability in developing countries. This relation could be supported by the promotion of investment programs aiming to mitigate carbon emissions"

The above-mentioned question aimed to present the different perspectives of the experts on the subject issue and to identify any potential convergence among them. Although they seem to focus on diverse issues, ranging from migration to conflicts and from the proposal of policies to the promotion of investment programs, a common ground among them can be identified and summarized in the following declarations:

1. Conflicts and national tensions are likely to occur between developed and developing megacities

2. Cooperation and search for solutions can also arise, pushing for knowledge sharing and for the utilization of multiple elements (e.g., alternative energy sources, investment fundings etc.)
3. A disruption, a change in the type and substance of the long-established megacities may ensue, combined with the changes observed in the relations between developed and developing megacities

4.1.5. Megacities and Geopolitics - part B: Experts respond

The seventh question seeks to define the types of risks associated with the rapid growth of megacities and it allows for the selection of multiple answers. The focal group can choose among the following options, in a checkbox form: (a) geopolitical risks, (b) economic risks, (c) financial risks, (d) environmental risks, (e) socioeconomic risks, and (f) political risks. Figure 4.6 displays the group's responses to this question.

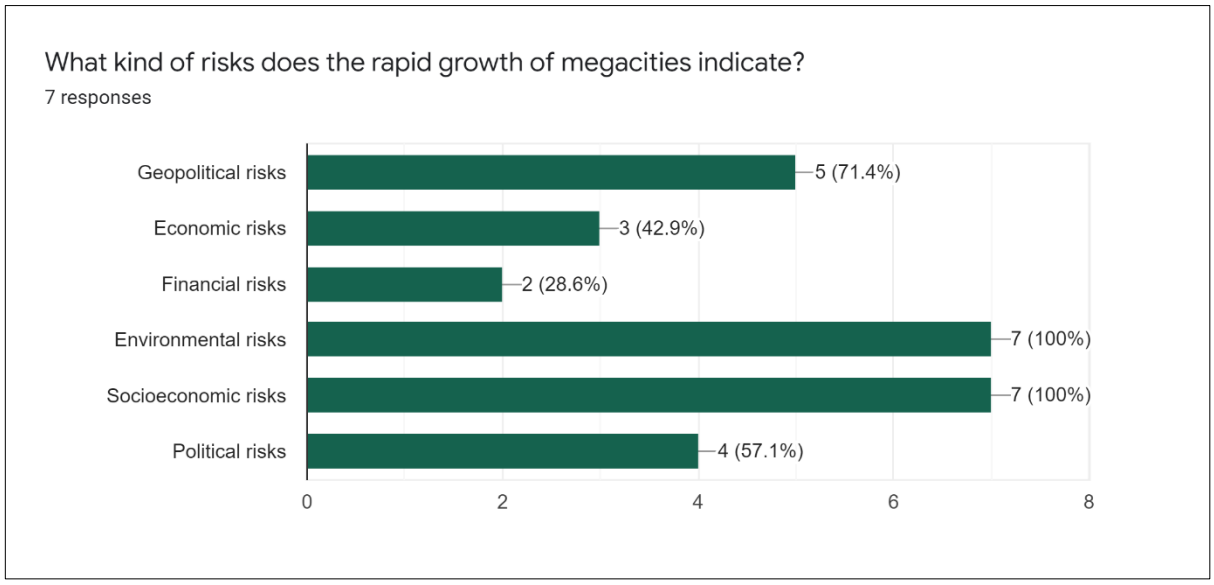

Figure 4.6 *Question 7 - Experts' responses*

Two of the available options were selected by all the experts, namely environmental and socioeconomic risks, emphasizing their severity and significance, followed by geopolitical risks, which received 5 votes (71.4% of the sample). Political risks stand at the third position with 4 votes (57.1% of the sample), economic risks were placed on the fourth position with 3 votes (42.9%) and, financial risks were ranked as the weakest kind of risks connected with the rapid development of megacities (only 2 votes or 28.6% of the sample).

Consequently, it can be observed that all the participants agree upon the importance and likelihood of environmental and socioeconomic risks, when the fast growth of megacities is examined. Indeed, some of the most direct and immense risks megacities must deal with are defined by their environmental and socioeconomic characteristics. Environmental devastation, energy inadequacy and energy poverty are only some of the most common and severe energy and environmental related problems. At the same time, conflicts within and among megacities, extreme levels of poverty and inability to cover basic needs of citizens are typical phenomena, especially in less developed countries.

Geopolitical and political risks, with 71.4% and 57.1% of the sample selecting them, are following. Since megacities are considered open systems, with multiple relations with other national and international entities, a rapid growth of their size may indicate a series of issues, including tensions based on different cultural and ideological backgrounds, terrorist attacks, rise of violence, conflicts and unrest, unfavorable changes regarding taxes or labor regulation may emerge, influencing the private, as well as the public sector.

Finally, economic and financial risks have been selected by a lower percentage of the focal group (42.9% and 28.6% respectively), probably because they occur as consequences of the rest, and they do not constitute as crucial issues as the others do. On top of that, economic and financial risks are more common in a state-level analysis rather than in the city-level, comprising another potential reason for the low ranking they gained.

The eighth question focuses on the potential ways of assessing, managing and minimizing the above-mentioned risks in contemporary megacities, allowing the experts to choose, in a checkbox form, among the following: (a) implementing effective policies (top-down approach), (b) encouraging initiatives undertaken by citizens (bottom-up approach), (c) decarbonizing energy mix (RES penetrations, hydrogen utilization etc.), (d) providing economic motives (e.g., subsidizing electric vehicles), (e) improving information and communication networks.

Seven responses were selected, with a high percentage of the sample agreeing upon the value and usefulness of four specific practices and approaches. As it is clearly illustrated in Figure 4.7, 71.4% of the sample, in other words, 5 respondents, considered the implementation of effective policies, the support the initiatives undertaken by of citizens, the decarbonization of energy mix and the improvement of information and communication

networks as adequate and effective manners, capable of evaluating, supervising, and diminishing the risks derived from the rapid growth of megacities.

The combination of top-down policies, which stem from strategies enforced by the governments and authorities, with bottom-up initiatives, which are associated with encouraging initiatives undertaken by groups of citizens, can offer an integrated approach on dealing effectively with the risks presented before, since they cover every aspect of megacity's operations. Simultaneously, providing upgraded information and communication

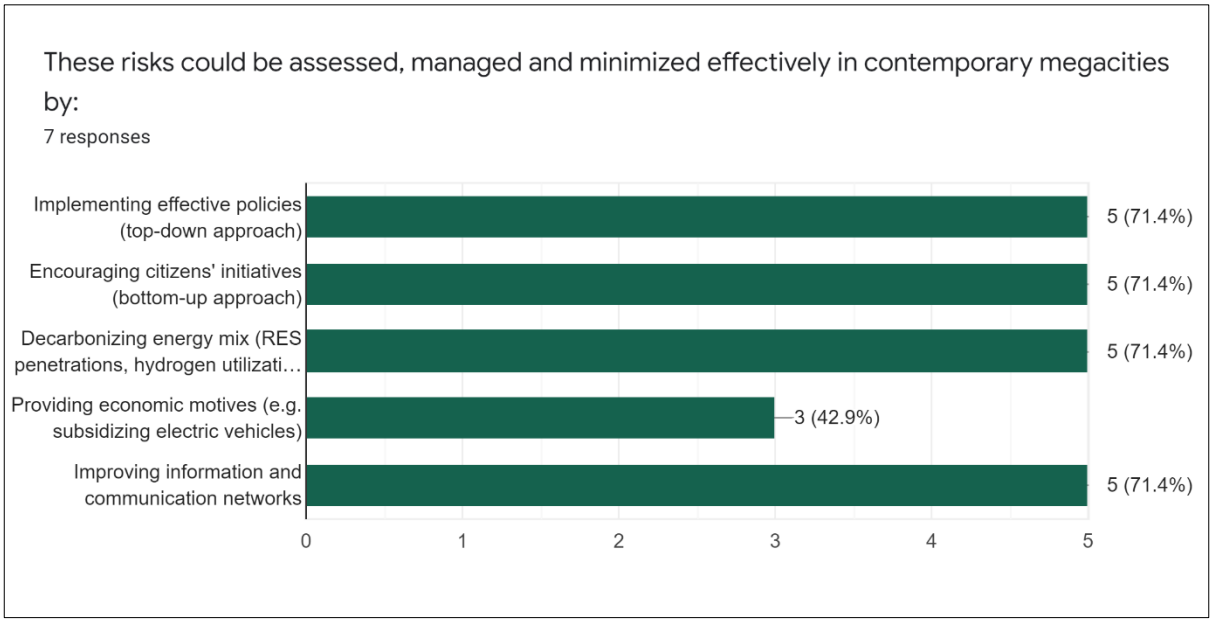

Figure 4.7 *Question 8 - Experts' responses*

related networks can constitute a precautionary method to increase awareness and to handle immediately any potential issue that may arise. The decarbonization of energy mix, by expanding the use of alternative and renewable forms of energy and utilizing contemporary technologies, can, also, lead to multiple benefits, encompassing the elimination of environmental and socioeconomic risks, by managing emissions, promoting uninterrupted and stable energy, as well as by creating new career opportunities.

Apart from these approaches, 42.9% of the focal group (3 respondents) considered the provision of economic incentives as an advantageous option. Economic incentives may include subsidies for electric vehicles, efficiency upgrading grants for buildings, as well as every other type of similar financial aid. Such motivations can support the prevention and confrontation of financial and economic risks, but stimulate, as well, environmental, and socioeconomic risks, by promoting eco-friendly policies and by assisting vulnerable social

layers. The relatively low preference of the experts on this approach may be justified on the basis that such practices are a little narrow-scoped, compared to the rest, whose influence and effects are wider, covering the vast majority of the risks identified in the previous question.

4.1.6. Personal Perspectives: Experts respond

Questions nine and ten request the experts to articulate their personal perspectives regarding the prevailing issues associated with megacities and the potential manners of dealing with them. The former question received seven answers, while the latter six, which are presented below.

According to the subject sample, among the most prevalent concerns megacities are faced with, the following can be detected:

- "Reduction of air quality and health effects, CO2 emissions, the majority of people lack detailed knowledge on environmental issues. This might affect their incentive to adopt a more environmentally friendly lifestyle and creates "not in my backyard" conditions." (Response 1)
- "Air pollution, noise pollution, natural environment degradation, increase in terms of ecological footprint, urban thermal island effect creation, traffic congestion, stress levels augmentation" (response 2, translated from Greek)
- "Environmental Pollution, massive energy consumption, climate change, socio-economic and political impact, health challenges, infrastructural deficiency, transportation congestion." (Response 3)
- "Population, resources, huge social gaps, pollution, climate change impacts resilience" (response 4)
- "Population growth, energy efficiency, energy poverty" (Response 5)
- "Wrong use of land, wrong use of common goods" (Response 6)
- "Carbon footprint" (Response 7)

It is obvious that different opinions and perspectives were expressed for the question under examination, achieving its initial aim. The experts were able to convey their viewpoints with no constraints, compounding a multilateral approach to the issue. In this context, a particular convergence among statements derived from the experts can be observed, even though each of them referred to the most crucial problems according to his/her opinion. The points of common ground are outlined below:

- Issues associated with pollution, climate change, emissions and environmental degradation seem to be held high on their agenda, since the vast majority of them (six out of seven) included such factors in their answers.
- Socioeconomic and political concerns, encompassing social gaps, energy poverty and inefficient management of public goods, have, also, been acknowledged by a relatively high percentage of the sample (namely 4 experts) as important factors, as far as problems associated with megacities are concerned.
- Health related problems, "health effects", "health challenges", as well as "stress levels augmentation" were also declared as critical, with 3 participants specifying them directly.

On top of that, other issues, comprising traffic congestion, overpopulation, overconsumption, infrastructural deficiency, energy deficiency, resource shortages and land abuse, were mentioned, as well, by the focal group members, confirming the literature review analysis that preceded.

Approaching the questionnaire's closure, the experts are asked to propose ways to deal with the above-mentioned issues. Question ten serves this objective and the total of responses collected is presented as following:

- "Social policies especially in developing megacities. Increase their urban sprawl and decentralize businesses by giving motives to companies and workers to relocate. Adopting green energy policies and technology. All megacities must develop a climate change adaptation and mitigation master plan." (Response 1)
- "Maximizing the use of the existing space, creating an online water system, urban forestry, improving mobility, co-heating, co-cooling, and co-generating, promoting urban farming, encouraging mobility on demand, and introducing smart street poles." (Response 2)
- "Promote policies that could incentivize citizens to reduce car usage. Invest in sustainable public transportation. Use information channels in order to communicate the importance of environmentally friendly actions." (Response 3)
- "By creating satisfying recreational spaces within megacities, by advancing ecomobility in private and public level." (Response 4, as translated from Greek)
- "Policies, information, research" (Response 5)
- "Right incentives to people" (Response 6)

Once again, numerous ideas are accumulated, resulting in the following observations:

- The adoption and implementation of right policies, which are highly associated with incentivize citizens and businesses towards embracing more environmentally friendly practices, including occasional relocation, reduction of car use, employing electric vehicles, etc., is considered a valuable manner of dealing with the issues referred in question nine.
- Sustainable transportation, both private and public, is viewed as another important and useful factor, combined with adequate and efficient space management.
- Research and development, utilization of state-of-the-art technologies and emphasizing in raising awareness and appropriately informing citizens could also support a more sustainable future for megacities, alleviate the previously mentioned issues they might be faced with.

All these proposals have been expressed thoroughly by the subject focal group, declaring its strong belief on their utility.

4.2 Comments and discussion

Apart from the responses selected and analyzed above, review and comments on the questionnaire's structure and its questions were issued by two participants, whose valuable feedback and contribution is incorporated in the consecutive lines.

Regarding the question 4 (*What sort of policies should be adopted and implemented in order to promote the sustainable development of megacities?*), which is addressed by selecting solely one option from a series of different policies, it was suggested that a checkbox form could serve as a better feature, since it allows a combination of multiple choices to emanate. It is stated that a mixture of divergent policies could form a more representative depiction of the ideal way to stimulate the sustainable development of megacities. Indeed, a broader selection of policies could help towards a more detailed and complete approach of the issues; hence, the subject proposal is recognized and accepted for future changes.

In question 5 (*Which megacities' characteristics would allow for adequate geopolitical power?*) an inaccuracy was detected, related to the use of the adjective "adequate" to describe

"geopolitical power". It has been argued that it is difficult to even define "adequate geopolitical power", since there is no general definition of the term, therefore it might lead to confusion or deceptive results. The adjective "more" was proposed instead, which could convey in a more accurate and reliable way the essence of the subject question. It seems reasonable enough that the adjective "more" serves more adequately and efficiently the purpose of this question, therefore it is acknowledged and accepted.

On top of that, question 6 (*"In the forthcoming years, carbon emissions in megacities are expected to grow rapidly and to a great extent in developing countries, while at the same time they are estimated as being stable for more developed regions". How could this affect the relations between different (developed and developing) megacities?*) has been portrayed as a vague question, which is hard to address and should be eradicated from the questionnaire. As a matter of fact, only five out of the seven candidates provided an answer to this particular question, revealing that it is either too specialized (therefore, only experts on the field can address it thoroughly), or too general to be replied in the context of a questionnaire like this. Therefore, it is concluded that question 6 could be discarded in a future version of this questionnaire.

Apart from the above-mentioned comments, another expert provided some fruitful recommendations, as well. Regarding the third question (*Please rate below the importance of energy mix in contemporary megacities (1: slightly important, 10: great importance)*), which was addressed by choosing from 1 to 10 points, in a Likert scale form, the professional expressed strong concerns about the type of the answers. The Likert scale structure was described as obscure and confusing. Instead of that, a "yes/no" kind of answer was proposed, with the intention to create a more transparent context, which could promote the contribution of participants.

Even though such a recommendation is valuable and could, indeed, indicate the results it refers to, the purpose of this question is to identify the weight of energy mix regarding sustainable growth of megacities, the degree of importance the candidates attribute to it. Therefore, if the goal remains as it is (defining the significance of energy mix), the Likert scale provides a more efficient way for addressing it, but, if the aim transforms into determining whether energy mix is important or not, then a closed-ended question (in a "yes/no" form) should be preferred.

The second expert suggested, also, that certain definitions are added to this inquiry to simplify and specify special terms, such as “megacities” and “information-based policies”. Although the wider scientific community might be sufficiently familiar with such terminology, incorporating short definitions of terms, probably as notes within the relevant questions, might prove to be helpful, both for the respondents and for the conclusion of the most representative and accurate results. Especially, since the subject questionnaire concerns a relatively explicit issue, this proposal should be further considered in an updated future form of the questionnaire under examination.

Chapter 5 – Conclusions

5.1 Summary and conclusions

The analysis conducted in the previous chapters, regarding the correlation between megacities, sustainability, and geopolitics, taking into account all the special characteristics and features of each term, has resulted in a series of conclusions, as illustrated, respectively, in the former sections. The utilization of both primary and secondary research, encompassing a survey, as well as thoroughly reviewing the available bibliography on the subject issues, facilitate a better interpretation of the megacity's phenomenon in contemporary societies.

The basic conclusions derived from the analysis within the subject thesis, are summarized below:

- Regarding the most notorious and crucial problems and risks associated with the development of megacities, environmental issues, including pollution, climate change, emissions and environmental degradation are acknowledged, followed by socioeconomic and political concerns, linked to social gaps, energy poverty and weak management of public goods, while health related problems are also characterized as critical. In the same context, environmental and socioeconomic risks, followed by geopolitical, and political risks, are declared as the most prominent risks megacities are faced with.
- Uneven terms of development have been noticed, comparing the more and less developed megacities. As potential outcomes of the relations constructed and maintained between them, conflicts and national tensions have been characterized as likely to occur, while cooperating and searching for solutions can also emerge, promoting the sharing of knowledge, as well as utilizing multiple elements, like alternative energy sources or investment fundings, etc.
- Sufficient management and adopted policies intensify the benefits and eliminate potential risks and flaws of growth within megacities. In this context, top-down and bottom-up policies seem to be highly appreciated and acknowledged, followed by market-based, network-based, and hierarchy-based policies. The implementation of effective measures, the support of initiatives undertaken by citizens, the decarbonization of energy mix and the improvement of information and

communication networks are considered adequate and competent approaches, capable of assessing, monitoring, and minimizing the risks derived from the rapid development of megacities.

- Decarbonizing megacity's energy mix effectively contributes to achieving the established sustainability goals. Indeed, it is widely acknowledged that energy mix constitutes a significant aspect of contemporary megacities, implying that the structure of energy sources should be carefully examined and selected.
- Population size does not necessarily constitute an indicative metric for overall performance of megacities; other factors, including population density, GDP per capita, carbon dioxide emissions per capita and Human Development Index (HDI) rates provide valuable evidence of their activities, while connectivity capabilities and innovation orientation have proven to be more important than their size.
- Among the most valuable determinants of the sustainable growth of megacities, energy provision receives the most attention, while transportation, institutions, information sharing, and services follow. The adoption and implementation of appropriate policies, which are highly related with providing citizens and enterprises the right incentives, towards embracing more environmentally friendly practices, the enhancement and promotion of sustainable transportation, both in private and in public terms, combined with adequate and efficient space management, research and development, utilization of state-of-the-art technologies and emphasizing in raising awareness and appropriately informing citizens could all support and promote a more sustainable future for megacities.
- In terms of geopolitical power, natural and economic resources are considered substantial components since they allow for multilateral development and augment megacity’s negotiation power. Moreover, technological advancement serves as the precondition to achieve and enhance the outcomes derived from natural and economic resources, while military capital and preparedness support the essential security, allowing for the city’s growth.

In conclusion, the generation and subsequent development of megacities constitute a dynamic event, whose features and characteristics are deemed to continually change in the forthcoming decades. Especially because of the importance that accompanies the performance of megacities, both the scientific community and the policymakers shall be sufficiently informed of the current circumstances and the future trends. Hopefully, the

combination of adequate and multilateral knowledge, as well as the efficient and productive cooperation, both within megacities, but also among them, could result in a more sustainable future for the whole international community.

5.2 Limitations and recommendations

The completion of the present thesis, regarding the results of both primary and secondary research in the fields of megacities, sustainability, and geopolitics, is accompanied by certain limitations and recommendations for further advancement, which could result in a wider approach of the issue.

As far as the limitations of thesis are concerned, certain ways of improving the content are concisely presented in the following lines:

- First of all, it is noted and acknowledged that the sample size is too small to allow for the application of statistical analysis and tests. Addressing the questionnaire to solely a focal group of experts and analysts, resided in the same geographical region, might contribute considerably to establishing a basis for research. Nevertheless, scientists from other regions, especially those located within megacities, should also be invited to participate, providing more coherent evidence. A larger sample size might generate more factual information, potentially leading to slightly different conclusions.
- Additionally, apart from the questionnaire created, other methods of data collection could also be implemented, including interviews, from which more detailed results could be derived. Brief interviews and discussions with professionals allow for more creative ways of thinking, leading to enhanced productivity and fresh ideas, contributing towards strengthening our understanding of the complex nature of megacities, in terms of sustainability and geopolitics.
- On top of that, the scope of research, regarding the selection of numerous megacities, with diverse characteristics, located in different continents, could be narrowed, allowing for a more targeted analysis. Focusing on a solid continent or region, or clustering megacities with regard to specific features, such as GDP or HDI, could possibly provide more solid and accurate outcomes.

The potential recommendations for further research derived from the present thesis are summarized below:

- Regarding the structure and content of the questionnaire, the particular comments and proposals made by a small fraction of the group of experts, should be further examined and incorporated into the inquiry, improving its effectiveness in addressing the issues already referred above.
- Augmenting the number of the participants in the survey would also hold a major role in providing useful input, able to be utilized both for the purpose of the current research, but also for any other scientific field, associated with the content of the present thesis, expanding our knowledge and understanding of the issue.
- Other fields of science, such as physics, psychology, sociology, etc. could also be employed in an extended version of research regarding megacities, sustainability, and geopolitics, providing a wider scope for future projects.

Appendix

A copy of the questionnaire created and used for the purposes of the present thesis is attached in the following pages.

Megacities: Sustainability & Geopolitics

Dear contributors/participants,

the following questionnaire is part of the thesis under the title "Megacities: Sustainability & Geopolitics" conducted by Eleni Zi, candidate of the Master's Program in Energy: Strategy, Law & Economics (University of Piraeus, Piraeus, Greece), under the supervision of Dr. John A. Paravantis, aiming to further review and elaborate the connection between sustainability and geopolitics regarding megacities' development and performance.

Experts in energy and sustainability, economics and management, political sciences and international relations are welcomed and requested to genuinely and diligently address the questions that follow.

Please notice that this survey is expected to be completed in 10-15 minutes and no personal data (e.g. name, address, phone number etc.) are required.

For any further information or concerns regarding this questionnaire, please resort to the following email address: ez.elenizi@gmail.com .

Thank you in advance for devoting your time and energy in completing this questionnaire.

Kind regards,
Eleni Zi

General Information

1. Mention your place of residence (country/state/city/region)

_____

2. Provide your professional experience level.

Mark only one oval.

- ◯ Junior (Entry-level)
- ◯ Intermediate
- ◯ Mid-senior (Mid-level)
- ◯ Senior (Executive-level)

3. Briefly refer to your professional and/or academic specialization.

Megacities & Sustainability - part A

4. Which megacities' characteristics would allow for a sustainable development?

Check all that apply.

- [ ] Information sharing - Connectivity
- [ ] Institutions
- [ ] Transportation
- [ ] Services
- [ ] Energy provision
- [ ] Other: _____

5. Through which factors such a sustainable development could be obtained?

Check all that apply.

- [ ] Sustainable public transportation
- [ ] Space planning & land use
- [ ] Renewable Energy Sources deployment
- [ ] Energy efficient infrastructure
- [ ] Technological advances
- [ ] Promotion of innovation and research
- [ ] Economic initiatives (taxes, subsidies, investments, etc.)
- [ ] Coherent policies and measures
- [ ] Other: _____

Megacities & Sustainability - part B

6. Please rate bellow the importance of energy mix in contemporary megacities (1: slightly important, 10: great importance).

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Slight	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Crucial

Megacities & Sustainability - part C

7. What sort of policies should be adopted and implemented in order to promote the sustainable development of megacities?

Mark only one oval.

- ◯ Top-down policies
- ◯ Bottom-up policies
- ◯ Market-based policies
- ◯ Information-based policies
- ◯ Network-based policies
- ◯ Hierarchy-based policies

Megacities & Geopolitics - part A

8. Which megacities' characteristics would allow for adequate geopolitical power?

Check all that apply.

- ☐ Information sharing - Connectivity
- ☐ Institutions
- ☐ Services
- ☐ Economic resources
- ☐ Natural resources - energy provision
- ☐ Military resources & preparedness
- ☐ Technology
- ☐ Other: _____

9. “In the forthcoming years, carbon emissions in megacities are expected to grow rapidly and to a great extent in developing countries, while at the same time they are estimated as being stable for more developed regions”. How could this affect the relations between different (developed and developing) megacities?

_____

_____

_____

_____

_____

Megacities & Geopolitics - part B

10. What kind of risks does the rapid growth of megacities indicate?

Check all that apply.

- [ ] Geopolitical risks
- [ ] Economic risks
- [ ] Financial risks
- [ ] Environmental risks
- [ ] Socioeconomic risks
- [ ] Political risks
- [ ] Other: _____

11. These risks could be assessed, managed and minimized effectively in contemporary megacities by:

Check all that apply.

- [ ] Implementing effective policies (top-down approach)
- [ ] Encouraging citizens' initiatives (bottom-up approach)
- [ ] Decarbonizing energy mix (RES penetrations, hydrogen utilization etc.)
- [ ] Providing economic motives (e.g. subsidizing electric vehicles)
- [ ] Improving information and communication networks
- [ ] Other: _____

Personal Perspectives

12. Please, name, below, the predominant issues associated with megacities.

13. How could these issues be tackled, according to your opinion?

Closure

Thank you for the time you devoted in completing this form and I remain at your disposal for any further information regarding the working thesis.

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