



The economic effects of climate change on Budapest

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Abstract

Cities – the engines of the world economy – are on the front line of climate change. As a major city, Budapest is threatened by many of these risks, especially in connection with transport, the construction industry and improving the standard of living. The study investigates the possible challenges and policy solutions related to climate change in Budapest. By reviewing the experiences of the economic effects of climate change on big cities and their practices to mitigate, nevertheless, by mapping the climate-related status of the Hungarian Capitol, the analysis creates the opportunity for recommendations. The review resulted in a projection of global warming effects on the metropolitan economies. Besides, a collection of best practices was composed about the actions made by cities to mitigate these effects. The results created the opportunity to conclude the needful actions in Budapest to prepare its construction industry, transportation system, waste management and labour market for adaptation by financial, R&D and long-term planning solutions.

Keywords

climate change, city, economy

1. Introduction

Dealing with the effects of climate change on cities presents several challenges to decision-makers (both at the city and state levels). Cities are the world's and national economies' engines, so they deserve special attention. The adverse economic effects of climate change make cities and even entire countries vulnerable. It is necessary to decide on the strategies and developments that will significantly determine the fate of cities and the global economy in the coming decades. The most pressing questions related to the topic include the following: What parameters will allow cities to be climate-proof in order to be able to maintain their role and value? Which cities will be the winners of the competition between cities? The key issues are the climate resistance of cities and the preservation of their role and value.

The study's research question is what policy actions should be taken at the municipal government level in Budapest to mitigate the impact of climate change? The aim is to uncover best practices in metropolitan governance. To conclude policy recommendations, first, the paper determines the range of economic effects on big cities caused by global warming. Then the international examples of city actions for mitigation are collected. It is followed by an overview of Budapest-specific economic challenges and impacts potentially caused by climate change. Finally, municipal policy actions are recommended on infrastructural (construction, transportation, waste management) systems, labour market, innovation and financial planning.

2. The economic effects of climate change on large cities

When analysing the effects of climate change on cities, three important points must be addressed: the topics of sustainability, global and local population movement, and the pursuit of balance and circular economy techniques. In terms of sustainability, the primary impact of climate change on cities is that the previously stable environment is disrupted, while the need to adapt requires the use of resources, which may be limited. In addition, climate change affects the habitat and causes global and local population movement. For example, when the inner city heats up, it will make people move out to the outer parts of the agglomeration. In addition, water and food shortages may occur in certain cities, leading to international migration. Pursuing balance and circular and blue economy techniques form a separate group. In connection with these, another question arises: what kind of effect does the amazing power of absorption and emission of cities have on their natural environment? In other words, in exchange for a high GDP, are there areas on the verge of destruction and which, if they were not in decline, would have a role in maintaining the environmental balance – if they did not need to adapt?



The problems air pollution poses in cities do not only include the high CO₂ concentration, nor is it the most dangerous effect. There are many other directly dangerous toxic substances, such as arsenic, whose concentration has increased to a much more threatening extent than carbon dioxide due to the industrial revolution. The doughnut model represents the visual framework of sustainable development in the shape of a doughnut, which combines the concept of planetary boundaries with the definition of social boundaries. The middle part of the model represents the proportion of people who do not have access to basic needs (such as healthcare and education), while the crust represents ecological ceilings (the Earth's limits), i.e. the factors on which life depends and which must not be exceeded. The chart was published by Oxford University economist Kate Raworth in 2012 and detailed in her 2017 book. The framework proposed to evaluate the economy's performance according to the extent to which people's needs are met without exceeding the Earth's ecological ceiling. The main goal of the new model is to reframe economic problems and set new goals. In this model, an economy is prosperous if all twelve social foundations are met without exceeding nine ecological ceilings. This situation is represented by the area between the two rings, which its creator sees as a safe and just space for humanity (Raworth, 2012; Monbiot, 2017).

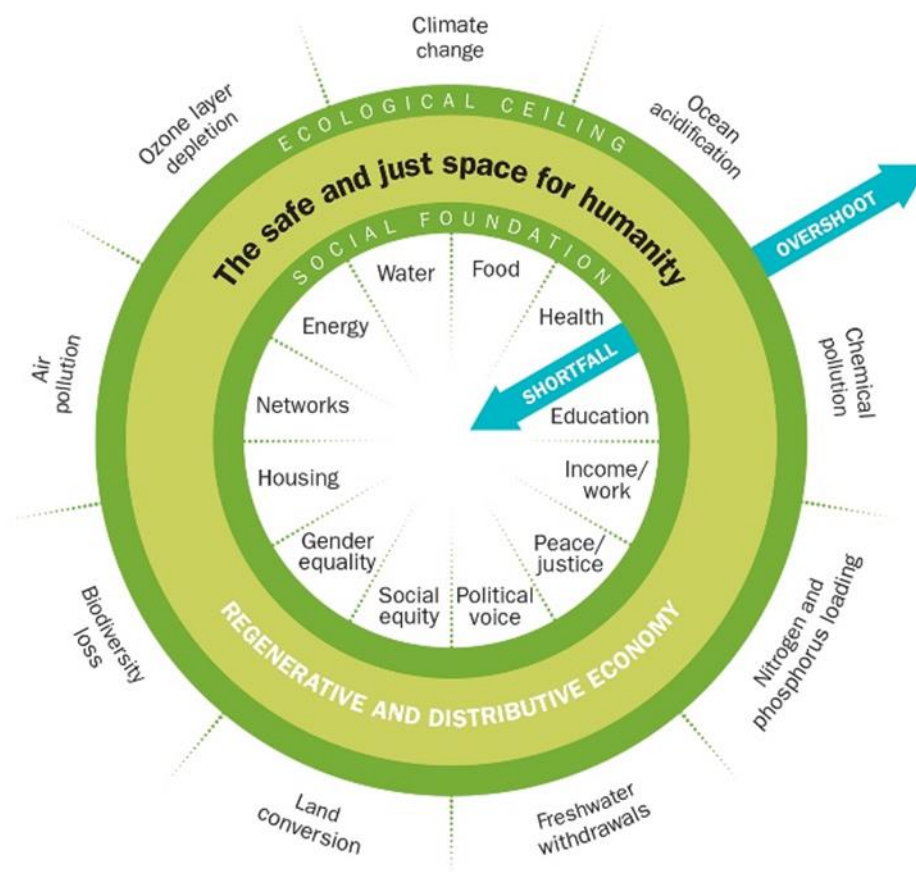


Figure 1: Doughnut model
(source: Nugent, 2021)

Cities are on the front lines of climate change. Although they occupy only about 1-2% of the world's land area, they account for 2/3 of the world's total energy consumption. In most cases, the energy sources for cities come from long distances, which presupposes maintaining infrastructure and logistics of a certain quality. However, they are the engines of economies worldwide, producing more than 80% of the global GDP. (World Bank, 2021) The World Bank works in cooperation with the UN to make cities and all other settlements more resilient, safer



and more sustainable and mitigate climate change's adverse effects on settlements. Thanks to projects like those in Tanzania, Mozambique, Belize, Turkey, and many more states, protection systems against floods and destructive storms and infrastructure have been developed. (World Bank, 2021) From the percentage of the world's global GDP, it can be concluded that if the cities around the world are unable to properly perform the important tasks associated with them as the engines of the world economy due to the adverse effects of climate change, then there will be a massive decline in the economy on a global level (World Bank, 2021):

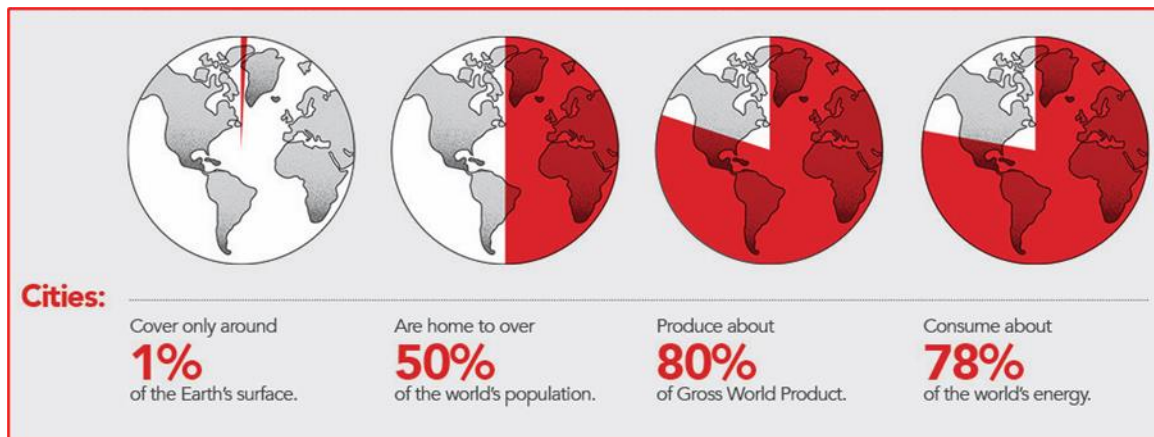


Figure 2: Important figures and ratios related to the cities of the world

(source: Cities Alliance, 2020)

In 2018, nearly 60% of the world's cities (major cities with more than 300,000 inhabitants) were exposed to the risk of at least one major natural disaster (cyclone, flood, drought, earthquake, landslide or volcanic eruption) due to the effects of climate change. These disasters and their risk also make most cities – 88.9% – economically vulnerable (Gu, 2019). Other types of damage can also occur due to climate change or the resulting human activity. These include the gradual lowering of the groundwater level, the loss of potable surface water, increasing levels of air pollution, an ever-increasing number of days with heat-warning and decreases in agricultural land productivity. The problems listed above are not disasters but disaster-like effects that burden the performance capacity of the cities' infrastructure not on a case-by-case basis but continuously. This damage is mainly caused by human activity.

Table 1. Natural disasters threaten the risk to the world's cities

	Number of cities (Total: 1860)	Percentage rate (Total: 100%)
No risk	105	5.6
Low risk	20	1.1
Medium risk	82	4.4
High risk	1653	88.9

(source: Gu, 2019)

As already noted, climate change harms GDP all over the world. According to Stanford's (2015) study, climate change will reduce GDP by more than 20%, and this downward trend will also be permanent. (Stanford, 2015, referred by Kimberley, 2021) Swiss Re Group (2021) report presents similar numbers, predicting that the world's economies will suffer a 10% decrease in GDP over the next 30 years. In addition, people living in cities are exposed to increasing financial burdens due to climate change and natural disasters – for example, insurance premiums are increasing. However, not only the cost of insurance but also the level of energy prices will increase significantly. In addition to these, natural disasters also pose a threat to security. All over the world, many military bases are located in cities, which are also at risk – and in the event of natural disasters, it would cost hundreds of billions of dollars to restore them (Wade, 2016).



According to a 2015 study conducted at Columbia University (*UNFCCC, 2015*), due to the effects of climate change, cities will have to double the amounts they spend on infrastructure development by 2025, which will amount to more than \$20 billion in total—the global costs of floods caused by climate change amount to approximately 1 billion dollars worldwide each year. However, cities alone cannot finance the costs of climate change. Globally, the costs related to climate change range between 80–100 billion dollars per year, more than 80% of which are borne by cities (*UNFCCC, 2015; UNFCCC, 2021*).

According to the “World Employment and Social Outlook 2018” report, 1.2 billion jobs directly depend on climate change and its effects – most jobs are in cities. (*ILO, 2018:7; referred by Kimberly, (2021)*) In the United States of America, 150,000 people lost their jobs due to Hurricane Sandy in 2012, with more than 11,000 in New Jersey alone. Cyclone Sidr destroyed thousands of small businesses in Bangladesh and threatened more than 567,000 jobs in 2007. Typhoon Haiyan adversely affected more than 800,000 workers in the Philippines in 2013. In addition, these natural disasters negatively impacted multinational companies, not only the settlements affected by the disaster but also workers working in other countries. (*Evans, 2015*)

According to *ILO (2019)* report, heat from climate change will reduce working hours by more than 2% worldwide, and more than 43 million jobs will be lost due to rising temperatures. Among the most affected sectors of the economy are winemaking, tourism, agriculture, fishing, the food industry and the energy sector. 60% of the global working hours in agriculture will be lost due to heat waves by 2030. *ILO (2019)* In tourism, the impact on winter sports will result in a loss of 20 billion dollars in the United States of America – and this will also negatively affect the surrounding accommodation and hotels. In addition, due to the melting of the snow caps, many ski areas will no longer be useable in the foreseeable future. Due to the rising water levels, many beaches will be flooded, adversely affecting the local workers. Many people have already lost their jobs in fishing due to climate change: in the USA, 16% of jobs related to fishing disappeared between 1996 and 2017 due to climate change on the New England coast. The global fishing sector will suffer losses of around \$2 trillion by 2100. The food industry is also severely affected by climate change. The Fresh Del Monte company lost more than \$2.5 million due to drought in Brazil in 2016, while Coca-Cola and Pepsi lost more than 1 million retailers in the Tamil Nadu region of India due to drought in 2017. More than 17,000 jobs have already been lost in wine production worldwide due to the adverse effects of climate change (*FileUnemployment.org, 2021*).

It is also worth looking at the 2016 report of the European Environment Agency. Based on this report, between 1980 and 2013, the economic losses of the European Environmental Protection Agency member countries due to natural disasters might be related to climate change amounted to more than 400 billion euros. (Storms, floods, landslides, drought, forest fires, heat waves) However, it is essential to highlight that more than 70% of losses were caused by 3% of extreme events (*European Environment Agency, 2017*).

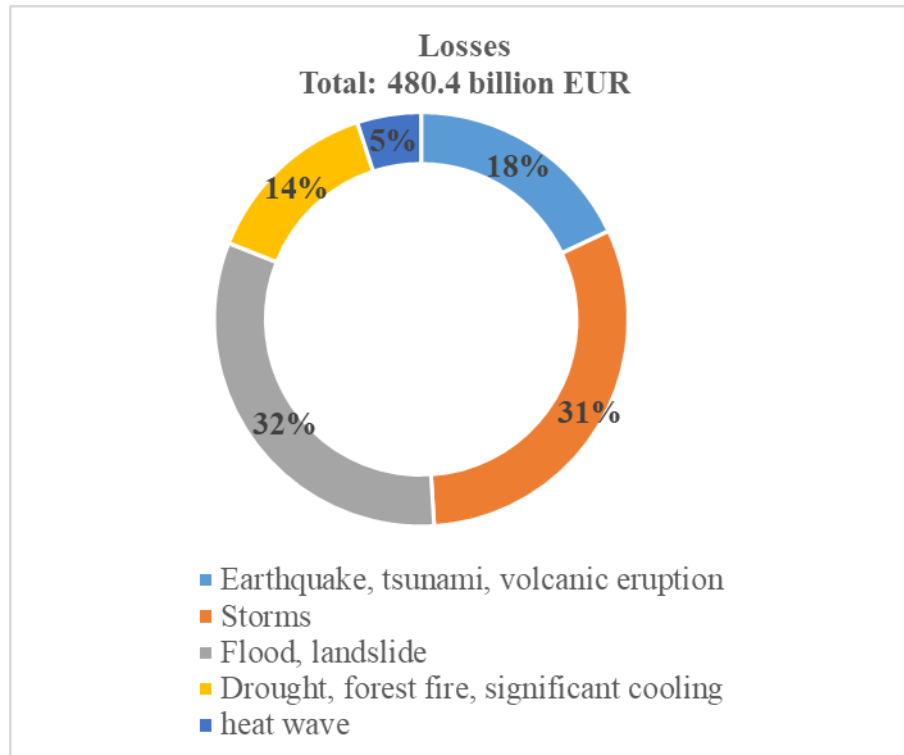


Figure 3. Losses of the member countries of the European Environment Agency between 1980 and 2013 by natural disasters
(Source: own editing based on the 2016 report of the European Environment Agency)

One of the adverse economic effects of climate change is that many people may lose their jobs. However, jobs may also be created in response to these effects, especially in the construction sector. Buildings that are more energy efficient and more resistant to the effects of climate change must be constructed, and these investments will create many new jobs (Gouldson *et al.*, 2018). More expertise will be required at all sector levels, including the planning, implementation and operation phases.

One of the adverse economic effects of climate change is that companies may withdraw from a particular city completely. It is, therefore, necessary to pay special attention to these businesses and encourage industries and businesses to stay and invest locally (Lee, Erickson, 2014).

Based on what has been described, the following questions may also arise: Which factors will render cities climate-proof in order to be able to maintain their role and value? Which cities will be the winners of the competition between cities? Will it be those that can moderate the projected GDP fall? Will it be the ‘techno cities’ that generate a continuous flow of resources and gradually strengthen their technological structure based on permanent innovation, raising productivity and GDP? Or will it be the ‘passive cities’ based on flow and circulation – based on physical laws and ecological values that result in seeking harmony with natural resources?

3. Metropolitan responses to the economic effects of climate change

Climate change is a global problem that cannot be addressed exclusively globally, but solutions should also appear locally – including in cities. Since there is no clear global action strategy for finding appropriate and practical solutions, it is left to local communities to deal with the adverse economic effects of climate change. As a result, city-level action plans need to be created to deal with the adverse economic effects of specific impacts, such as heat waves. The management of these effects is also essential because the employment rate, economic growth, the amount of investment and output of many cities around the world, as well as the personal income of their residents, depending on how these settlements respond to such effects (NASA, 2014; United States Environmental Protection Agency, 2016).



Worldwide, several examples can be found of cities successfully coping with the adverse economic effects of climate change. In 1974, victims of a devastating flood in Tulsa, Oklahoma, began to pressure the city in the aftermath of the natural disaster to begin developing a strategy that would significantly reduce the damage from subsequent floods. Thanks to this pressure, the city started planning and implementing technological developments and organised the institutional and financial framework for flood protection. Construction in the floodplain was prohibited, and most of the buildings that were already there were moved to other parts of the settlement. Another major flood occurred in 1984, when, thanks to this strategy, significant damage was almost entirely avoided, and the city's residents did not lose their homes and jobs, thus minimising possible economic losses (*Rasmussen, 2014*).

Another example can also be cited from Central America: San Salvador was often hit by floods and storms. Landslides were also a frequent phenomenon due to the heavy rains in the region. However, in 2016, based on a *UNU (2020)*¹ study, more than 25 adaptation measures to mitigate the adverse economic effects of climate change were introduced. (*Souvignet, 2020*) First, a kind of “danger map” was created for the city based on the available older data. The value of the endangered area's homes, schools, and hospitals had to be assessed, and the number of people living there had to be determined precisely. Based on the information gathered, a table demonstrates how effectively various adaptation measures can protect a given area from the adverse effects of climate change. Such measures include, for example, urban planning, encouraging household water-saving practices, the use of permeable pavements, the lining of canal pipes (to reduce water leakage), the use of a modular water retention system, the establishment of emergency/overflow canals, and the improvement of the drainage system. However, the city could not have implemented these costly developments with its scarce financial resources, so the projects were realised with the co-financing of the German Development Bank (*KFW Development Bank, 2020*). The example of San Salvador demonstrates that cities that do not have the financial means to mitigate the adverse economic effects of climate change may still, with foreign help and support, implement mitigation measures. Using the ECA method, San Salvador also solved the city's water supply problems in the event of a drought, so this phenomenon no longer threatens the city's economy (*Souvignet, 2020*).

According to a World Bank publication, one possible response to the adverse economic effects of climate change would be for cities to consider levying a real estate tax on their agenda. Tax incentives and subsidies could also be applied, along with a real estate tax in areas classified as higher risk and differentiated insurance. Internally generated revenues (taxes) are very important as they can be used for investments and infrastructure developments that mitigate the adverse economic effects of climate change. A property tax would incentivise residents to buy and rent apartments away from more vulnerable areas. Separate area taxes could also be applied, which would be higher if the given apartment is closer to the endangered area (*The World Bank Group, 2011*).

With the ever-increasing occurrence of threats related to the adverse effects of climate change, cities must invest in increasing their resilience and minimising damage. In New York, Hurricane Sandy in 2012 caused about 19 billion dollars in damage, left 2 million residents without electricity, and flooded approximately 90,000 buildings. (*Global Commission on the Economy and Climate, 2014*) However, proper urban planning and urban management can contribute to reducing such losses. Transport infrastructure, canals and utility systems must be strengthened and well-maintained. These measures both increase the city's future resilience and create jobs. As a result of the introduction of these measures, cities can operate more efficiently in terms of energy and resources, their resilience increases, and they can lure residents from the areas most exposed to dangers to safer parts of the city (*Global Commission on the Economy and Climate, 2014*).

Milan is a large city with several rivers and canals. As a result, the city faces the risk of floods during heavy rains and storms. The city's government is committed to significantly increasing the resilience of the settlement. A climate adaptation plan and a flood protection map of the city have also been created. The local authorities also

¹ECA is a decision support tool that integrates climate change vulnerability and risk assessment with economic and sustainability impact studies to determine optimal adaptation measures for various risks. ECA supports decision-makers in choosing the most appropriate investments that are consistent with the impacts and consequences of current and expected future climate conditions and increase resilience to them.



aim to increase energy efficiency. In order to achieve the goals, the city actively cooperates with the private sector, has established a car-sharing program and, as part of the development of the city's public lighting, the existing legacy streetlights are being replaced with LED lamps (CDP, 2017a). In Rio De Janeiro, the residents are threatened by significant heat waves.

For this reason, the local government has commissioned the development of an application that informs registered users about extreme weather conditions (CDP, 2017b). Taipei is an example of a big city in which the economy is driven by high-tech services (which are based in office buildings). Accordingly, the city aims to create "green" buildings. Many green walls and roofs have been created, permeable pavements are used on the streets to reduce the effects of heat, and many solar panels have been installed (CDP, n.d.).

The leaders of Chinese cities have also realised that to eliminate the adverse effects of economic growth and climate change. Cities must be developed accordingly. Traffic jams and high levels of air pollution are the main problems in Chinese cities. Because of these problems, a national urbanisation conference was held in China in 2013, where it was determined that the level of environmental pollution should be reduced. A national urbanisation plan was drawn up for 2014–2020 to reform cities to address the effects of climate change. The various conferences and forums where the problems of cities can be discussed are, in many cases, a very good starting point for solving those problems (*Global Commission on the Economy and Climate, 2014*).

Houston, located in the United States of America, is one of the world's most sprawling, low-density cities with a high level of car usage and ownership – and where spatial planning and development policies are lacking. By 2035, Houston residents will spend 145% more time in their cars than in 2014. The city administration is trying to control the city's expansion and implement sustainable investments. It launched a programme offering investors up to \$15,000 to build more single-family homes in the city centre. An urban light rail system has also been launched. A significant proportion of the bus fleet is now made up of hybrid vehicles, and a car-sharing system has also been established involving cars owned by municipalities. The city and the private sector have contributed hundreds of millions of dollars to an initiative that has created more than 150 miles of new hiking and biking trails (*Global Commission on the Economy and Climate, 2014*).

The urban development strategies that cities can pursue to mitigate the negative economic impacts of climate change vary from city to city. Key determinants include carbon dioxide emissions, electricity supply and population density. The development path may therefore be different for cities as various as Denver, Toronto, Rio de Janeiro or Beijing. In cities experiencing rapid growth and a corresponding increase in the demand for electricity supply, the expected future greenhouse gas emissions from electricity supply must be considered.

An initiative aimed at the development of the "clean technology" sector was created in Singapore. This sector has created thousands of new jobs and generated billions of dollars in profits. The essence of this initiative is that international companies can apply for support and use the city as a test site for developing sustainable technologies and as a way of making them known as widely as possible. For example, one company built the city's first "green" business park with an intelligent electrical grid. (Flater, Rode, 2014). Stockholm also sees opportunities for development in clean technologies. The city has created so-called eco-districts in its former industrial areas, where clean and low-carbon technologies are also developed. (Flater, Rode, 2014). Baoding in China's Hebei Province is a major hub for renewable energy production. Traditionally known as a manufacturing centre, this city's main fields of expertise are textiles and automobiles. Using more than 200 renewable and energy-efficient technologies, the Baoding manufacturer created more than 20,000 jobs in 2009 and generated a turnover of more than 1 billion dollars. The Chinese government has designated the city as a High-Tech Development Zone, imitating the industrial model of California's Silicon Valley (Flater, Rode, 2014).

In this analysis based on data from 60 world cities, researchers found that switching from coal-based energy production to renewable energy sources would create more than 1 million new jobs. In addition, the number of premature deaths would also decrease, fewer residents would have to be cared for in the health sector, and the time off work due to illness would also decrease – which would also have a very positive effect on the labour market (C40 Cities Climate Leadership Group; 2021).



According to some experts, the world's largest cities should develop a model in the next 10-20 years to help them positively influence the future of urbanisation. This model should include smart infrastructure (such as LED street lights and electric buses), the creation of low-carbon districts (with the development of bus and bicycle infrastructure), and the introduction of various energy efficiency measures. An analysis of five cities at different levels of development (Leeds, Kolkata, Lima, Johor Bahru and Palembang) suggests a considerable potential to improve energy efficiency in the transport sector, the energy sector and the construction industry (*C40 Cities, 2021*).

Strategies that contribute to mitigating the adverse effects of climate change can involve additional costs and require significant investment on the part of cities. Since city governments worldwide do not all have the necessary level of resources, the involvement of the private sector and/or international cooperation in their development is often essential. Maintaining the developed “intelligent” new infrastructures also entails higher city costs. Within the framework of international cooperation, cities can share their development ideas, techniques, and policies. International players can help cities improve their creditworthiness and mobilise significant funds on the domestic and international financial markets. Uganda, for example, managed to increase its revenues by 86% within a year. International collaborative initiatives have emerged to help more cities mobilise private finance, such as the World Bank-led Creditworthiness Initiative and the Cities Climate Finance Leadership Alliance (launched at the 2014 Climate Summit to accelerate additional capital flows to cities) (*Gouldson et al., 2015*).

Floods and inundations are other adverse effects of climate change, resulting from which cities suffer enormous economic damage. In order to mitigate these damages, in the framework of a project called MOSE, mobile gates were created in Venice to protect the city from large sea waves and floods. These gates “close” the lagoon at high tide, thus preventing seawater from rushing into the city. (*CDP, 2017c*)

Medellin struggled with the adverse effects of heat waves for many years. However, a solution to the situation was found within the framework of a project implemented in recent years. Thirty-six green corridors – running throughout the city – were created from various plants. These contributed to a decrease in the temperature of the air and the surrounding surfaces, keeping the surrounding areas in the shade, significantly reducing the exposure of the city and its inhabitants to extreme heat and have had a very positive effect on the health and well-being of the residents. The positive economic effects of the measure/project include job creation and increased labour productivity (*C40 Cities, 2019*).

As clients of the World Bank, cities can benefit from a financial program, support and analysis services that are much larger and more significant than in other countries. São Paulo, Jakarta, Mexico City and Cairo are also clients and partners of the World Bank. Various international climate funds have benefitted many large cities, including Mexico City, Bangkok and Cairo. In the last decade, a large-scale urban development took place in Bangkok, which was realised based on the investments of the Clean Technology Fund approved in 2009 (for example, energy-efficient buildings were created within the program's framework). The carbon financing unit of the World Bank launched a city-wide carbon financing methodology called Carbon Expo in 2009. The first version of the program was implemented in Amman, Jordan. The World Bank is working to increase the number of cities participating in the project and to make the methodology even more effective. In 2010, a program aimed at mitigating climate change was launched in Tokyo (*World Bank, 2010*).

Another promising approach is that of so-called smart cities. These settlements prepare and implement their integrated settlement development strategy using the smart city methodology. This involves a process, a path of continuous development, in which the smart city methodology is the Smart City Development Model (*Lechner Tudásközpont, 2017*). In these settlements, sustainability is applied, and efficiency and broad participation are prioritised. The strategy of these cities focuses on four main areas: improving the quality and efficiency of services; more economical use of energy and other resources; involving citizens and improving their quality of life; and the creation of economically self-sustaining systems (*Lechner Tudásközpont, 2017*).



4. The effects of climate change on Budapest

As in other cities, the economic effects of climate change can be felt in various aspects in Budapest. These include the development of transport, the construction industry and the standard of living. As Budapest is the capital city of Hungary, it has been the subject of most analyses and specialist literature on the topic in the country.

Révész and Zalai (2012) use two types of models to analyse the economic effects of climate change on Hungary. Their computable equilibrium model, HUMUSGE, divided production and consumption into 25 sectors. They examined several scenarios using a model of the impact of climate change on tourism. “According to the third simulation, labour productivity in agriculture deteriorates by 3% and material services by 2%. These are the sectors most exposed to climate change. This productivity loss causes approximately HUF 43 billion in additional wage costs if the production level unchanged should remain unchanged. Due to deteriorating labour productivity, GDP will decrease by 0.65%” (*Révész and Zalai, 2012*). The projection puts the challenge of food and resources supply based on geographically long supply chains in the spotlight. Resource seeking in the city's vicinity can be a solution, like livestock herding in the agglomeration's green areas or using local energy sources, e.g. geothermal heating. The city governance is recommended to focus on demographics of the agglomeration labour market, organisation of supply chains by city management and city diplomacy. The local government should find a way to promote investment toward more productive food manufacturing and energy-supplying firms to settle them in the agglomeration.

The SOCIOLINE model examines natural, social and financial sustainability, for which it depicts the degree and consequences of external and internal indebtedness (risk premiums). Alongside productive and financial assets, the model treats infrastructure, the environment, the workforce and social capital as forms of capital (*Révész and Zalai, 2012*).

Farsang et al. (2015) present climate change's expected economic effects. In Budapest, energy efficiency can increase significantly by renovating its legacy prefabricated concrete tower blocks, the so-called “panel apartments”. In the 3rd district, the ambitious reconstruction programme of one of Hungary's largest apartment complexes completed in 2009 generated more than 50% of energy savings. There is room for extensions of energy-saving renovation of buildings, green roofs for lower tempering by tax and subsidies incentives, like carrot and stick.

In the welfare times, the protection of historical monuments has a high priority for cityscape and tourism purposes, though the protection and renovation of century-old buildings in the non-tourist areas are against the energy efficiency of a modern city. The role and weight of the protection of historical monuments can be reconsidered. The city's structure and stock of buildings are recommended for more concentrated residential areas and tower buildings to concentrate the population. This can reduce the length of citizens' daily routes of personal mobility by settling the individual needs close to them.

In 2021, Budapest Capital City Planning Ltd. published an action plan for climate change in the capital city. This analysis identified the problems threatening the capital linked to climate change and proposed solutions. These include, for example, improving the energy efficiency of the capital's transport infrastructures. CO₂ emissions from elements of the transport sector totalled 1.7 million tons in 2015. To determine the CO₂ emissions related to transport, the CO₂ emissions of the vehicles of local government institutions and companies, the capital's public transport system, and private and commercial transport were calculated using the SECAP methodology (*Tatai et al., 2021*).

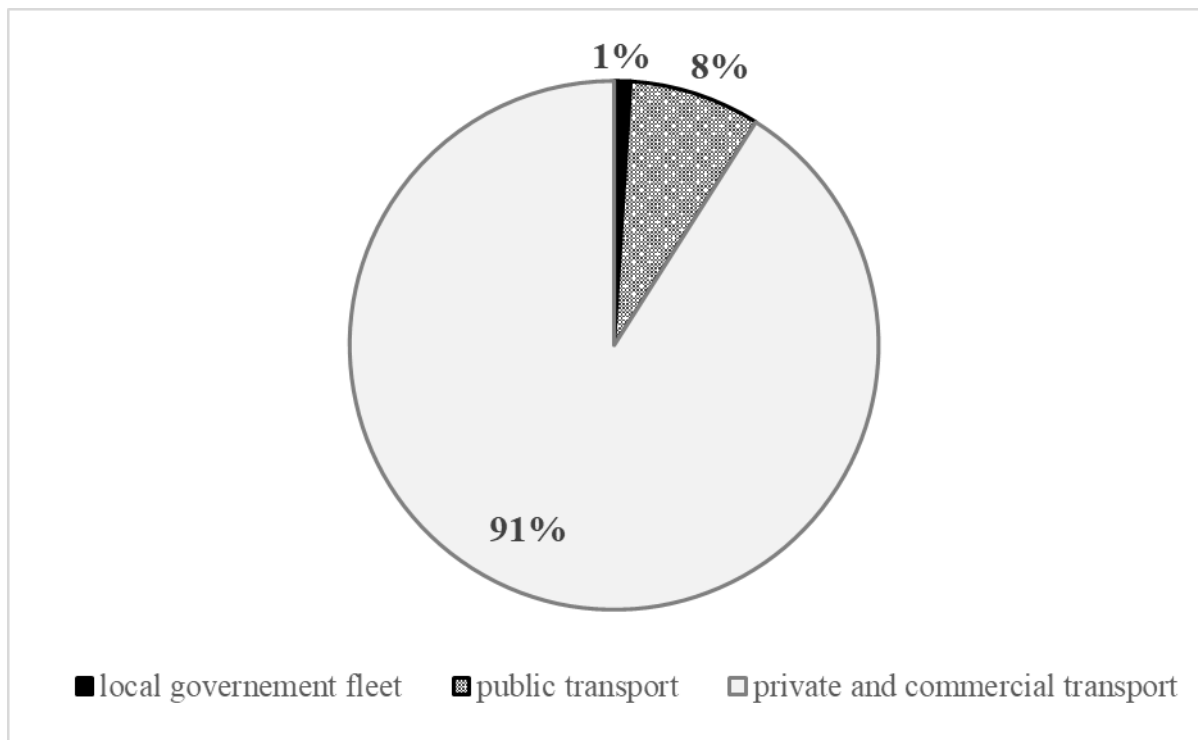


Figure 4. Distribution of transport CO₂ emissions in Budapest
(Source: Budapest Capital Municipality, 2021)

Transport emitted the most carbon dioxide in the European Union between 1990 and 2016, followed by the energy sector, agriculture, households, and industry. In 2019, however, the energy sector was the largest greenhouse gas (GHG) emitter. (European Parliament, 2021) Figure 5 demonstrates the distribution of CO₂ emissions from transport. Based on the data, 91% of transport CO₂ emissions can be attributed to private and commercial road transport. (Tatai et al., 2021)



Greenhouse gas emissions in the EU by sector* in 2019

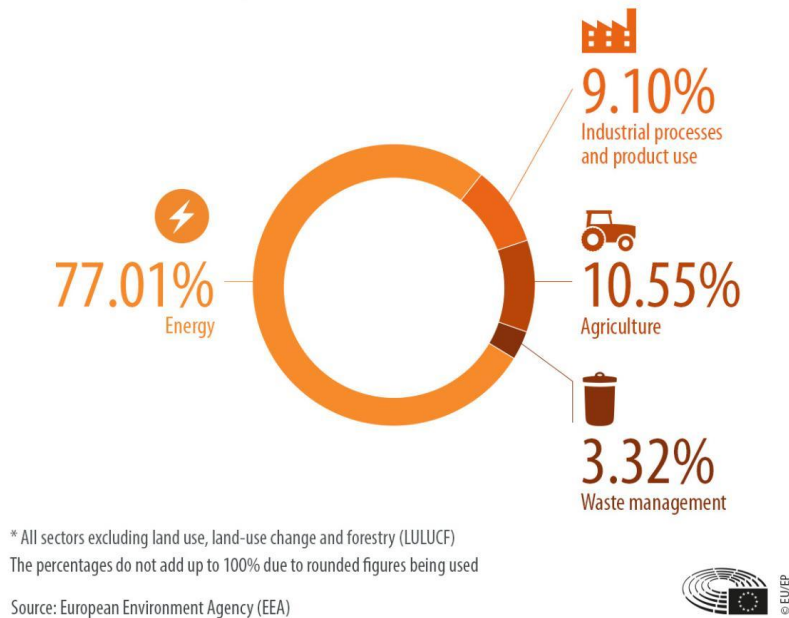


Figure 5. Greenhouse gas emissions in the EU by sector in 2019.

(Source: European Parliament, 2021)

Based on the conclusions about the sources of GHG emission, the city-level energy policy should turn toward the local green sources in the energy sector, just as geothermal, solar and biomass technologies. Besides, the city's policymakers should divert freight and passenger transportation toward emission-free vehicle technologies. Moreover, passenger transport is recommended to use fixed track and electrified public transportation, which shall be the focus of the public transport development strategy. The zero-emission vehicles should be combined with renewable charging energy sources. The carbon emission can be reduced if the supply chains get shorter in transportation. This highlights, again, the importance of local energy sources.

According to a study by *Baranyai and Varjú (2017)*, the relationship to climate change can vary by county and settlement. They claim that social status significantly affects the attitude towards climate change. In the counties classified as having a favourable social composition and in Budapest, the proportion of low-status persons was at most 18%, and the proportion of high-status persons was at least 20%. In counties with an unfavourable social composition, the proportion of low-status people exceeded 25%, and that of high-status people did not reach 15%. In Budapest, they found that the inhabitants are less sensitive to changes in the climate than people living in villages. According to the authors, due to climate change, the desire to emigrate may also increase in parallel (*Baranyai and Varjú, 2017*).

For efficient mitigation, the city government needs the cooperation of the local citizens. Not merely policy actions but policy communication is a part of the instruments, too. Communication campaigns can raise the citizens' climate conscientiousness. Additionally, tax, cost and subsidy incentives can guide the local society and businesses to join climate-neutral networks and systems.

An article by *Buzási, Pálvölgyi and Szalmáné Csete (2021)* deals with the economic effects of climate change. Hungarian cities face significant challenges due to the impacts of the changing climate. For this reason, the authors advocate the development of a climate-oriented evaluation methodology to assess the performance of urban development interventions (*Buzási et al., 2021*).



Among the various indicators related to the climate and cities, special attention should be paid to Sustainable Development Goals (*UNIS Vienna, n.d.*). These include, for example, promoting sustainable industrialisation and innovation, ensuring sustainable, modern energy, making cities more sustainable and increasing their adaptability, and taking action to mitigate the adverse effects of climate change. A similar indicator can be found among the goals of the Sendai disaster risk reduction framework, which the document related to the UN Framework Convention on Climate Change also calls essential (*United Nations Statistics Division, 2021; UNDRR, n.d.*)

5. Conclusions

Cities are significantly affected by climate change. According to *Gu (2019)*, nearly 60% of the world's big cities (cities with a population of at least 300,000) have already been exposed to the risk of at least one major natural disaster caused by climate change. These risks also make cities economically vulnerable. This vulnerability affects, among other key areas, the labour market, the construction industry, the energy sector, infrastructure, and transportation.

In terms of sustainability, the impact of climate change on cities is that the previously stable environment is disrupted, while the need to adapt requires the use of resources, which may be limited. Climate change transforms human habitats; and, therefore, causes global and local population movement. For example, as the inner city heats up, people move to the outskirts or surrounding settlements. In addition to these challenges, water and food shortages may occur in certain cities, thus accelerating international migration.

Climate change might reduce cities' GDP by 10-20% in the coming decades, according to *Stanford (2015)* and *Swiss Re Group (2021)*. This is a high risk because cities are the engines of the world economy and generate more than 80% of the global GDP. Labour productivity deteriorates (due to heat waves, for example), many people lose their jobs, and infrastructure development also involves enormous costs. The high concentration of carbon dioxide and increased incidence of air pollution place greater burdens on the health sector, so the operation of the health care system also entails higher costs.

The following economic impacts are expected in Budapest related to climate change. Higher temperatures can deteriorate the productivity of workers. Air pollution and warming can lead to illnesses and increase health care costs, leaving less income for other purposes. The mitigation demands infrastructural investment in public transportation and building stock for energy efficiency.

As a result of climate change, economic effects can be felt in Budapest, particularly in the transport and construction industry. Most of the properties in the city need to be modernised in terms of energy use and energy efficiency, which imposes significant additional costs on the city. Public transport must also be developed to achieve the lowest possible carbon dioxide emissions.

This literature highlights that Budapest has broad room for carbon reduction in the energy and transportation sectors. The city management should strive to extend local renewable energy and carbon-free transportation via investment, development and incentives toward the private sector. Besides, the city's structure and stock of buildings should be rationalised to concentrate the population, reduce the route lengths in transportation, and settle the individual needs close to the citizens. Nevertheless, citizens can be incentivised by taxes, costs and subsidies, moreover, convinced by appropriate communication.

The development of cities is also essential for the development of national economies. Cities must continuously work against the adverse economic effects of climate change. Based on all of these challenges, the following recommendations can be formulated for city administrations to be climate-proof and to combat the adverse economic effects:

- Construction industry: Energy-efficient buildings must be constructed while existing buildings must be modernised in terms of energy efficiency. Buildings that are sustainable in the long term should be preferred, and developments should be based on business models that are also functional in the long term. The construction materials used should be selected based on their impact on the environment, and the planning of their lifespan should also be emphasised.



- Transport: Public transport should be developed, and residents should be encouraged to walk more and use bicycles more often. Self-powered devices should be preferred over energy-consuming convenience devices (i.e. a healthy lifestyle should be preferred instead of comfort).
- Waste management: Recycling waste and transitioning to waste management with lower carbon dioxide emissions is necessary.
- Energy sector: The so-called clean energies should be increasingly used, i.e. the shorter supply chain, the local use of renewable (solar) and green (geothermal) energy, and the creation of energy communities should also be advocated.
- International examples: It is worth analysing and adopting the best practices of foreign cities. Importantly, these examples should only be followed closely in certain specific cases. However, their adoption usually involves adapting the system created abroad, even though every settlement is unique. Instead of entirely adopting strategies, focusing on the analysis and appropriate exploitation of local resources would be more worthwhile. In this way, cities could become much more innovative.
- Infrastructure: Developing an intelligent urban infrastructure and using new technologies is necessary.
- Financing: In addition to the cities' resources, state resources and the private sector's contribution may also be needed to carry out the necessary developments. Self-sustaining models should be preferred in this regard.
- Workforce: Investments to develop cities must be encouraged because many new jobs will be created this way.
- Research and development: Indicators and metrics must be developed to accurately indicate the effect of the measures implemented in the city. The state must support research and development activities, e.g. innovations that can make the existing infrastructure work more efficiently, i.e. at a lower cost.
- Planning: It is necessary to identify the areas within the city where the most investment and development are required. Developing urbanisation strategies is also useful (Gouldson et al., 2018; Global Commission on the Economy and Climate, 2014).

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