Sustainable Cities and Urban Climate Adaptation

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1. Climate change effects in the cities

Cities nowadays are facing a number of sustainability challenges in the context of climate change. Cities are vulnerable to the impacts of climate change and the need to connect climate change adaptation and mitigation with broader assessment of sustainability is becoming increasingly important.

By 2030, nearly 60% of the global population is projected to be urban with the developing world housing nearly 80% of this population. Urban centres are drivers of global warming because they concentrate industries, transportation, households and many of the emitters of greenhouse gases (GHG); they are affected by climate change; and they are sources of responses i.e. of initiatives, policies and actions aimed at reducing emissions and adapting to climate change.

Urban areas occupy less than 2% of the Earth's land surface. Urban activities release greenhouse gases (GHGs) that drive global climate change directly (e.g. fossil fuel-based transport) and indirectly (e.g. electricity use and consumption of industrial and agricultural products). 80% of global GHG emissions are estimated to be attributable to urban areas. Cities are also potential hot spots of vulnerability to climate change impacts by virtue of their high concentration of people and assets. Urban areas concentrate populations, economic activities and built environments, thus increasing their risk from floods, heat waves and other climate and weather hazards. Urban centres are drivers of global warming and from the existing data three factors are relevant determinants of carbon emissions, namely: a) population; b) affluence as measured by GDP per capita; and c) technology.

Sustainability and resilience can be promoted through a combination of strategies such as integrated urban planning, identifying synergies between disaster risk reduction and adaptation, building efficiency of urban service quality and delivery and promoting green buildings and sustainable transport.

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Climate impacts in urban areas and the most pressing issues of relevance to engineers seeking to adapt cities to the following urban climate effects:

- Urban heat islands are caused by the storage of solar energy in the urban fabric during the day and release this energy into the atmosphere at night: the process of urbanisation replaces the cooling effect of vegetated surfaces by imperviously engineered surfaces with different thermal properties.
- Air pollution may increase as warm, still days reduce air quality because high temperatures and ultraviolet light stimulate the production of photochemical smog, ozone and other compounds from traffic and industrial emissions and plants.
- Infrastructure damage from extremes, such as wind storms including hail and storm surges, floods from heavy precipitation events, landslides, tropical cyclones and heat extremes including fires and droughts.
- Sea level rise (including the effects of changes to storm surges) will increase the risk of storm-surge flooding and rates of coastal erosion, extreme flows in urban drainage systems and rivers.
- Water availability will decrease in many areas, with implications for water resources in terms of both quality and availability for human consumption, industry and agricultural areas.
- Health impacts may include changes to heat- and cold related mortality, food- and water-borne disease from higher average temperatures and/or extreme events.
- Biodiversity and urban ecology have already been affected by changes to temperature and precipitation that have resulted in exotic circumstances.
- The urban economy may be affected in a diversity of ways. Extreme weather-related disasters can be impacted in multiple and complex ways and can take a long time to recover fully. The impacts can lead to direct damage to infrastructure and other urban assets.

2. The effect of urban heat island

The Urban Heat Island mitigation strategies need to provide expertise in various specialised fields, such as urban planning, land use planning, architecture, civil engineering, building engineering, transportation and energy-saving technologies. There are many urban heat island mitigation strategies and they draw on the expertise of various professional fields, including urban planning, architecture, natural resources management and transportation. These mitigation strategies have a positive impact on both local and global climate.

The term Urban Heat Island refers to the observed temperature difference between urban environments and the surrounding rural areas. Urban Heat Island effect is shown in Figure 1, where the day surface temperatures vary widely by surface type and the day air temperatures vary much less. The night surface temperatures are hotter over urban surfaces and the night air temperatures follow the same pattern as surface temperatures.

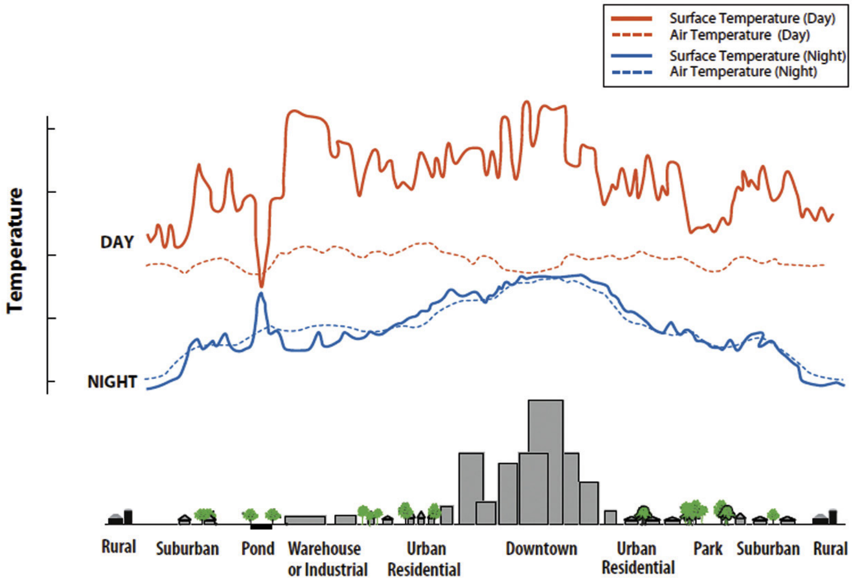

Figure 1.
Urban Heat Island – Variations of surface and atmospheric temperatures
Source: Urban Heat Island Basics 2008, 4.

The Urban Heat Island can have impacts on the environment, such as: deterioration of outdoor air quality, deterioration of indoor air quality, increase in energy demand, increase in demand for potable water; impacts on health, food availability, social impacts, thermal comfort, air conditioning, etc.

An urban heat island mitigation strategy must be based on an integrated and multidisciplinary approach (Figure 2) to urban development and requires the participation of various actors, as well as various sectors, for example public health, urban planning, architecture, transportation and natural resources.

The strategies for reducing Urban Heat Island have benefits for reducing energy demand and source reduction of water and air pollution, including greenhouse gas emissions.

The mitigation measures for reducing urban heat islands can be grouped into four categories:

- Greening measures
- Urban infrastructure-related measures (architecture and land use planning)
- Storm-water management and soil permeability measures
- Anthropogenic heat reduction measures

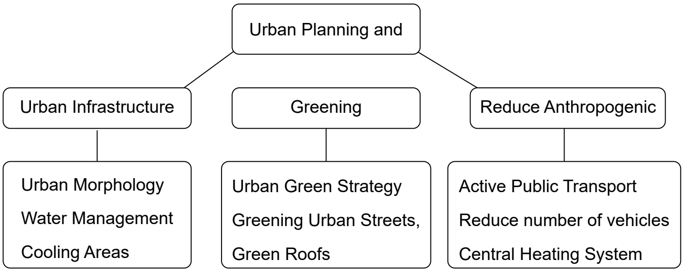

Figure 2.
Sustainable organisation of Urban Planning and Development in reducing Urban Heat Island
Source: drawn by the authors

Urban greening strategy (Figure 3) provides complementary benefits in urban areas, including:

- Improving air quality through oxygen production, CO_2 capture, filtration of suspended particulate matter and reducing energy demand for air conditioning.
- Improving water quality through retention of rainwater in the ground and soil erosion control.
- Health benefits for the population, including protection from ultraviolet (UV) radiation, reducing heat stress and providing spaces for outdoor exercise.
- Seasonal shading of infrastructure.
- Evapotranspiration; cooling provided by vegetation. (Highly developed urban areas have less surface moisture available for evapotranspiration than natural ground cover, Figure 3.)
- Minimising ground temperature differences.

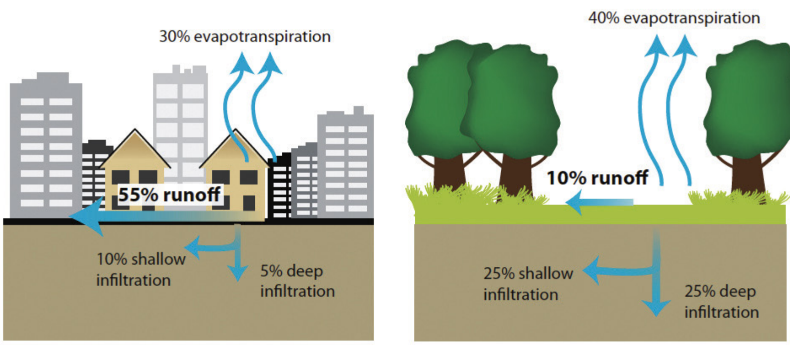

Figure 3.
Evapotranspiration on different surfaces of intense urban built environment and vegetation
Source: Urban Heat Island Basics 2008, 4.

Urban planners and policy decision-makers need to plan for sustainable urban development. They need to have holistic approach and integrated urban planning that will focus specifically in reducing urban heat island and climate changes in the cities. Simultaneous use of several urban heat island mitigation measures can have greater impact in lowering urban temperatures. For example, using a combination of complementary measures provides better overall protection of the building envelope from *solar radiation,* which improves thermal comfort in the building.

3. Urban climate adaptation planning

Urban planners and decision-makers need to integrate efforts to mitigate the causes of climate change (mitigation) and adapt to changing climatic conditions (adaptation).

Cities face a specific set of challenges and in many ways will be most profoundly affected by climate variability and change. This is for two main reasons.

- Cities are focal points of vulnerability.
- Cities rely on complex infrastructure in order to function (e.g. transport, drainage, water and energy supply); this infrastructure is at risk from climate change.

In general, engineering responses to addressing climate change fall into two categories:

a) Mitigation to reduce GHG emissions and enhance any processes (natural or artificial) that remove GHG emissions from the atmosphere.
b) Adaptation to reduce the impacts of harmful changes and exploit potentially beneficial changes.

Integrated urban planning requires holistic, systems-based analysis (Figure 4) that takes into account the quantitative and qualitative costs and benefits of integration compared to stand-alone adaptation and mitigation policies. Analysis should be explicitly framed within local priorities and provide the foundation for evidence-based decision support tools. Plans should clarify short, medium and long-term goals, implementation opportunities, budgets and concrete measures for assessing progress.

Assessments and tools of adaptation strategies need to be predicated on a regional and local level data and assessments. Particularly important are the availability of regional climate change scenarios, risk assessments and modelling, impact and vulnerability assessments and mapping tools, as well as economic assessments.

Strategic urban planning directly supports urban resilience as a tool for sustainable development that: 1. directs land use and transportation systems; 2. reduces population vulnerability to climate change by facilitating improved access to resources, services and amenities; and 3. generates sensitivity towards the environment whilst incorporating social and economic goals.

Integrated city climate action plans should include a variety of mitigation actions – those involving energy, transport, waste management, and water policies, and more, with adaptation actions, those involving infrastructure, natural resources, health and consumption policies, among others – in synergistic ways.

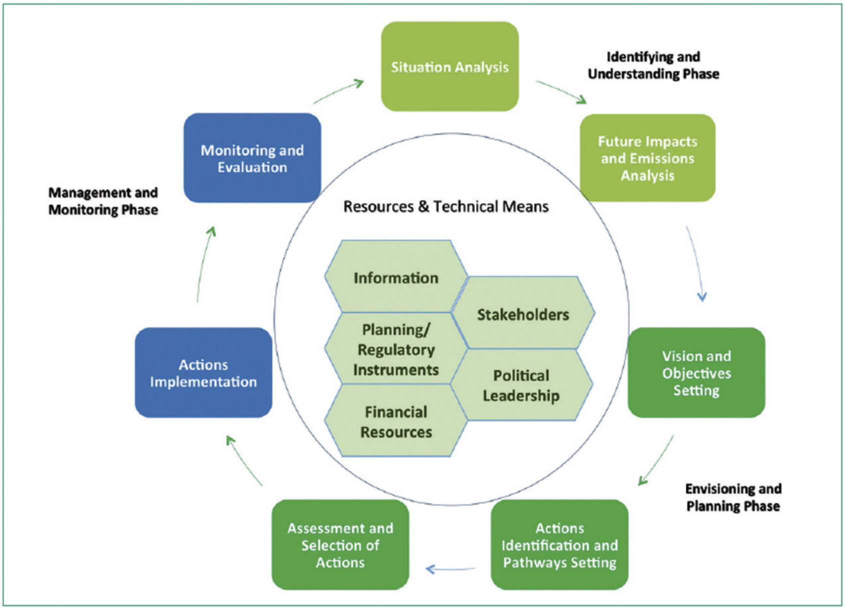

Figure 4.

Planning Cycle in the Cities for integrating mitigation and adaptation

Source: EEA 2016

4. Urban climate mitigation scenarios for Macedonia

The Strategy for sustainable development in the Republic of Macedonia includes the following sectors:

- Climate change and clean energy – mitigating climate change and its negative effects on society and the environment through the use of renewable sources of energy and structural change in industry, benefiting facilities that do not have large energy and electricity needs and which have a cumulatively lower impact on the environment.
- Sustainable transport – ensuring that our transport system meets society's economic, social and environmental needs whilst minimising its undesirable impacts on the economy, society and the environment.
- Sustainable consumption and production – decoupling economic growth from environmental degradation.
- Conservation and management of natural resources – improving management and avoiding the overexploitation of natural resources, while recognising the value of ecosystem services.

In the Strategy for sustainable development of the Republic of Macedonia, specific resources have been identified as priorities:

- The natural environment and geo-diversity – improving management and avoiding excessive natural resource exploitation, recognising the value of ecosystem services, and developing international corridors that secure economic, social and environmental needs.
- Renewable sources of energy – increasing the share of renewable energy use from water, sun, wind and biomass.
- Diversity in traditional high-quality agricultural and forest products – emphasising organic farming and agriculture, production of healthy food and traditional products such as cheese, wine, honey and spices, and integrated management of agriculture and forestry based on a sustainable economic and environmental approach.

The Green gas emissions scenario in Macedonia is that the total GHG emissions shall increase from 9,030 kt in 2012 to 18,340 kt in 2035, or by 100% (Figure 5). With the commissioning of the new coal TPPs in the period from 2028 to 2032 the highest growth of the emissions can be seen. During this period of time, the most dominant will be emissions from the power sector (60% to 70%), but the highest growth of GHG emissions shall be present in the commercial sector with an average annual growth of 4.2%, followed by the transport sector with 3.7% and the residential sector with 3.2%.

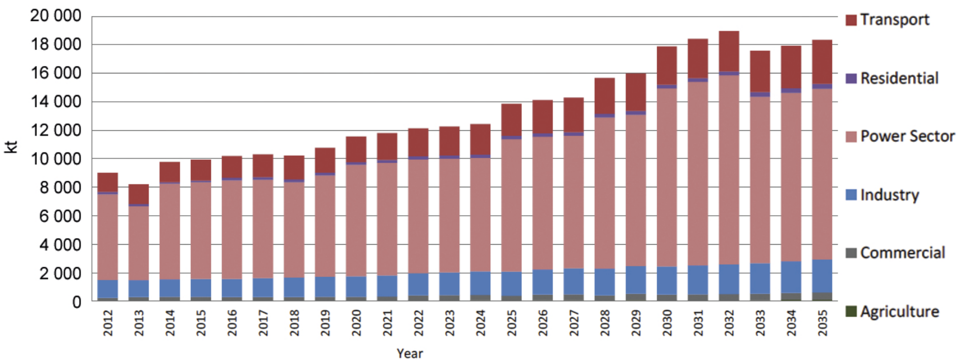

Figure 5.

GHG emissions according to the WOM scenario Macedonia

Source: First Biennial Update Report on Climate Change 2014, 52.

In Macedonia there are scenarios for final energy consumption in different sectors (Figure 6); the highest growth is evident in the transport sector, of 126% (annual growth of 3.6%), followed by commercial and services sector with overall growth of 115% (annual growth of 3.4%), industry sector with 84% (annual growth of 2.7%) and last is the residential sector with a growth of 82% (annual growth of 2.6%).

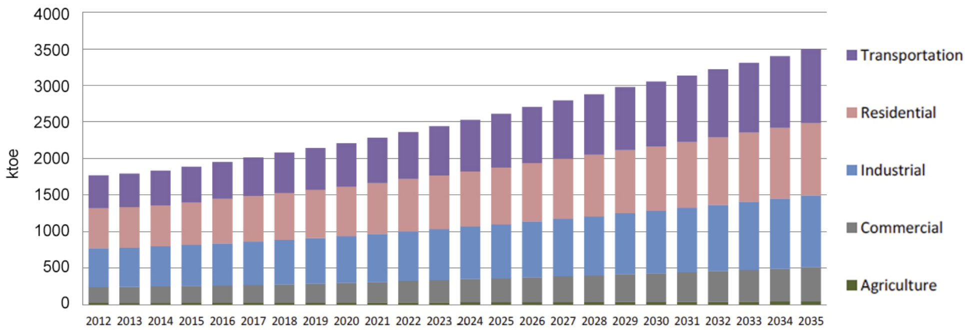

Figure 6.

Final Energy Consumption by sectors according to the WOM scenario Macedonia

Source: First Biennial Update Report on Climate Change 2014, 50.

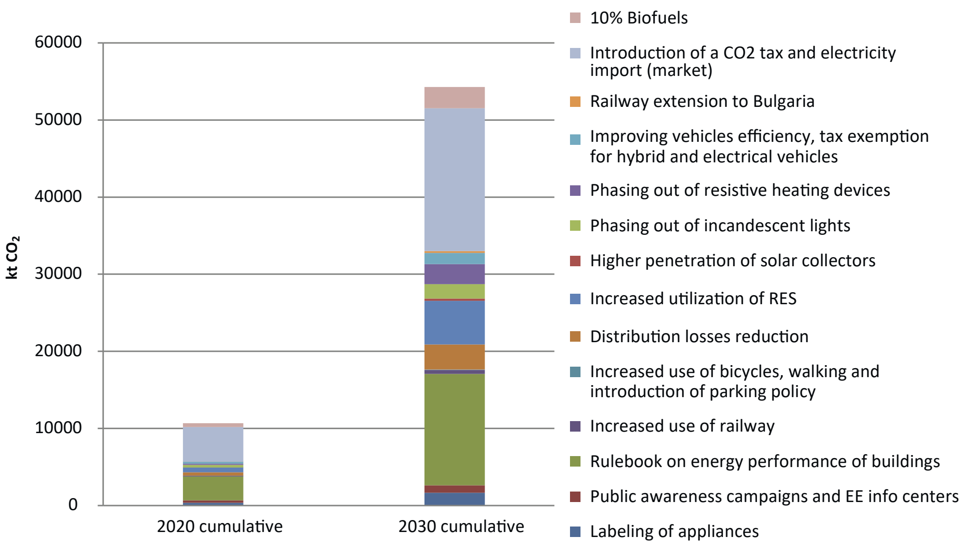

Figure 7.

Cumulative savings of CO_2 by 2020 and 2030 in the WOM scenario Macedonia

Source: First Biennial Update Report on Climate Change 2014

The cumulative CO_2 emissions savings scenario in Macedonia until 2020 amount from 11,000 kt, and by 2030 will increase for five times and amount to 55,000 kt Cumulative emissions, compared to the WOM scenario, by 2020 shall decrease by 12%, while by 2030 they decrease approximately by 22% (Figure 7). The highest reduction is achieved by introducing CO tax and electricity import (market) which generates 34%, and next is the

Rulebook on Energy Performance of Buildings with 27%, higher participation of RES with 10% and decreasing losses in distribution with about 6%.

5. Sustainable development in the cities – Conclusions

The expected outcome results in this scientific paper are creating urban climate mitigation and adaptation planning that will focus on the complexity of the cities: energy supply, transport, buildings, energy demand, low-carbon technologies. Targets for urban mitigation of carbon dioxide emissions are now urgent and imply reconfiguration of urban energy systems, transport and the built environment. Urban adaptation of cities requires integrated thinking that encompasses a whole range of urban functions. A sustainable *city* can be defined as a city that is significantly decoupled from resource exploitation and ecological impacts and is socio-economically and ecologically sustainable in the long run.

The methodology approach in this scientific paper focuses on defining the measures for risk management and vulnerability of the urban climate, overcoming urban adaptive capacity aspects and creating urban climate adaptation planning that will be a factor for sustainable development in the cities.

This Scientific paper will contribute to the wealth of information already available on climate change by going beyond context specific urban case studies and to an understanding of the common ingredients that can help urban centres become better prepared and more resilient to respond changes in climate. It provides an overview of the current state of knowledge and practice, but also of existing gaps in our knowledge and new directions for work in this area.

The strategic approach to sustainable development according to the Macedonian WOM Scenario implies new ways of thinking and working so as to:

- Move from developing and implementing fixed plans, ideas and solutions towards operating an adaptive system that can continuously improve.
- Move from a view that the state alone is responsible for development towards one that sees responsibility with society as a whole.
- Move from centralised and controlled decision-making towards sharing results and opportunities, transparent negotiation, co-operation and concerted action.
- Move from a focus on outputs (e.g. projects and laws) towards a focus on outcomes.
- Move from sector-related towards integrated planning.
- Move from a dependence on external assistance towards domestically driven and financed development.
- Move towards a process that can accommodate monitoring, learning and improvement.

Integrated city climate action plans should include a variety of mitigation actions – involving energy, transport, waste management, and water policies, and more, with adaptation actions, those involving infrastructure, natural resources, health, and consumption policies, among others – in synergistic ways. Because of the comprehensive scope, it is important to clarify the roles and responsibilities of key actors in planning and implementation. Interactions among the actors must be coordinated during each phase of the process.

Strategies that reduce the urban heat island effect, improve air quality, increase resource efficiency in the built environment and energy systems, and enhance carbon storage related to land use and urban forestry are likely to contribute to greenhouse gas emissions reduction while improving a city's resilience. The selection of specific adaptation and mitigation measures should be made in the context of other sustainable development goals by taking current resources and technical means of the city, plus social needs of citizens.

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