RE-CITY

PLATAFORMA INTERNACIONAL
PER A LA SOSTENIBILITAT SOCIAL

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RELATORIES FEM FRONT AL CANVI CLIMÀTIC

"LES CIUTATS, MOTOR DEL CANVI CLIMÀTIC?"

SESSIÓ AMB **KOEN DE RIDDER.**

FUNDACIÓ CATALUNYA EUROPA

Cities at the Front of Climate Change

Invited Speaker: Dr. Koen De Ridder. Flemish Institute for Technological Research, Belgium

CONTENTS

This report is a synthesis of the debate carried out with Dr. Koen De Ridder in the conference series “Facing climate change” organised by Catalunya Europa Foundation in the context of the Re-City project. This session, entitled "*Cities at the Front of Climate Change*" consisted of a public lecture, a seminar with participants from the academic sector of Catalonia and a lunch-debate that brought together personalities from the economic, social, political and business sector of Catalonia. The mentioned activities were held in Barcelona at the Antoni Tàpies Foundation on November 2018. The content order along the report is thematic and does not represent the order in which it was exposed by Koen De Ridder. The conference series “Facing climate change” is developed in collaboration with BBVA, Generalitat de Catalunya, Àrea Metropolitana de Barcelona and Barcelona City Council.

Biography

Dr. Koen De Ridder is a senior researcher at the Flemish Institute for Technological Research (VITO), where he has been working since 1997. In 1988, De Ridder graduated in Theoretical Physics at the University of Antwerp (UA). After that, in 1994, he obtained his DEA in Environment at the University of Louvain-la-Neuve (UCL). Three years later, De Ridder obtained his PhD in Climate Science at the same university with a thesis about climate change in semi-arid regions.

During the academic year 1988/1989, De Ridder was a teacher of Physics and Mathematics at the College van de Heilige Familie of Antwerp. For the next three years, he collaborated with Doctors Without Borders in Congo and Pakistan as a humanitarian aid worker, helping with the logistics and administration. In 1997, De Ridder worked in the BELSPO-project "Integration of satellite remote sensing data into regional climate models" for 9 months as a research associate at the Royal Meteorological Institute of Belgium of Brussels. Five years later, from 2002 to 2005, De Ridder was a visiting professor in Atmospheric Science and Climatology at the Faculties of Science (Geography) and Bioscience Engineering of UCL. Finally, since 2014, he has been a visiting professor in the postgraduate programme Weather and Climate Modelling at the Faculty of Science of the University of Ghent (UG).

Since 2001, De Ridder has participated in projects about numerical mesoscale modelling of the atmosphere. Nowadays, he is focused on the "Pan-European Urban Climate Services" (PUCS) project (EU-H2020, 2017-2019). The objective of this project is to establish a service that translates the best available scientific urban climate data into relevant information for public and private end-users operating in cities.

Throughout his career, De Ridder has published more than 60 papers, most of them on mesoscale atmospheric modelling, urban air quality simulation, satellite remote sensing, and urban climate modelling. The two most recent publications, published in 2018, are "Urban Heat Island and Future Climate Change – Implications for Delhi's Heat" (Sharma *et al.*, 2018) and "A New Method for Fine-Scale Assessments of the Average Urban Heat Island over Large Areas and the Effectiveness of Nature-Based Solutions" (Lauwaet *et al.*, 2018).

Summary

"Heat stress at the end of the century will skyrocket in a way that we cannot even imagine." This was one of the warnings of Professor Koen De Ridder of the Flemish Institute of Technological Research (VITO) of Belgium in his conference on November 15th within the "Facing Climate Change" series of the Re-City platform organized by the Catalunya Europa Foundation with the collaboration of BBVA and the support of the Barcelona City Council, the Metropolitan Area of Barcelona and the Generalitat de Catalunya.

The expert in urban climate and air quality, Koen De Ridder, has developed in the VITO Institute the **UrbClim model**, one of the few that offer information in detail at the local level on indicators such as climate, temperature, pollution, extreme weather changes or the so-called heat islands in cities (Urban Heat Island, UHI). UHIs carry temperatures higher than their rural environment with direct effects on health and well-being of cities. Unlike this model, most existing ones only offer macro data at the regional or global level.

Specifically, UrbClim model is a European program that allows simulations of the climate in 100 European cities and explains microclimatic effects such as the urban heat island. Thus, simulations have been carried out with a high degree of certainty in cities such as Barcelona, Paris, London, Berlin, Athens or Brussels, following the scenarios of the UN Intergovernmental Panel on Climate Change (IPCC) until the end of the 21st century. In Barcelona and its metropolitan area, this research is carried out by Xavier Rodó's team at the Global Health Institute of Barcelona (ISGlobal), taking into account indicators such as temperature, rainfall, number of hot days, air pollution, energy and transport, forest fires, heat-related diseases or aquatic ecosystems, among many others. According to these studies, urban heat islands can cause higher mortality rates, higher hospital admissions, more premature births, less economic and labour productivity, infrastructure damage and an increase in energy consumption.

Cities amplify climate change effects. Therefore, people living in cities are going to face harder conditions. Koen De Ridder warned that episodes of extreme heat will increase tenfold in European cities by the end of the century. Currently, cities have on average twice as many days of extreme heat as their rural surroundings. Heat islands in cities are mainly manifested at night and are already causing significant differences in temperature in relation to their rural environments. For example, in Paris the temperature in the heat islands is 5ºC higher than its surroundings, and in the case of Barcelona the difference is 2.5ºC.

As mentioned by De Ridder, a heat wave is usually very dangerous. For instance, in 2005 Hurricane Katrina left less than 2 thousand deaths, while in 2003 the European Heat Wave caused about 70 thousand deaths. During this heat wave, there was an excess of urban mortality, particularly in biggest cities, as the UHI effect causes

additional heat stress at night and the night rest period is the moment that people recover from the heat suffered during the whole day.

Some of the alternatives that De Ridder proposes are infrastructures and green areas that help to cool cities and avoid exceeding the heat thresholds from which people's health and well-being are put at risk. According to the two experts, Koen De Ridder and Xavier Rodó, these are proposals that, beyond the scientific debate, require a political commitment for the leaders to develop them.

Heat stress at the end of the century will skyrocket in a way that we cannot even imagine

During the last decades, most people have been aware of the need to reduce greenhouse gases emissions as a main measure to mitigate climate change, altogether with reforestation. The goal that must be achieved is to limit the temperature rise to 1.5ºC above the pre-industrial value. However, according to De Ridder **we should be focusing more intensely in adapting to high temperatures and water scarcity because short-term climate change is unavoidable.** This does not mean that mitigation is not relevant. Indeed, mitigation has to be a main target of policies, but adaptation must be considered as well. Some of the alternatives that De Ridder proposed are the infrastructures and green areas that help to cool cities and avoid exceeding the heat thresholds from which the health and well-being of people is put at risk.

Urban heat island

The urban heat island (UHI) is the effect that causes cities to be warmer than their rural surroundings. Consequently, the UHI intensity can be measured as the difference between urban and rural temperature, which can rise up to 7-8ºC. For example, in Paris during the summer season, the temperature in heat islands is 5 degrees higher

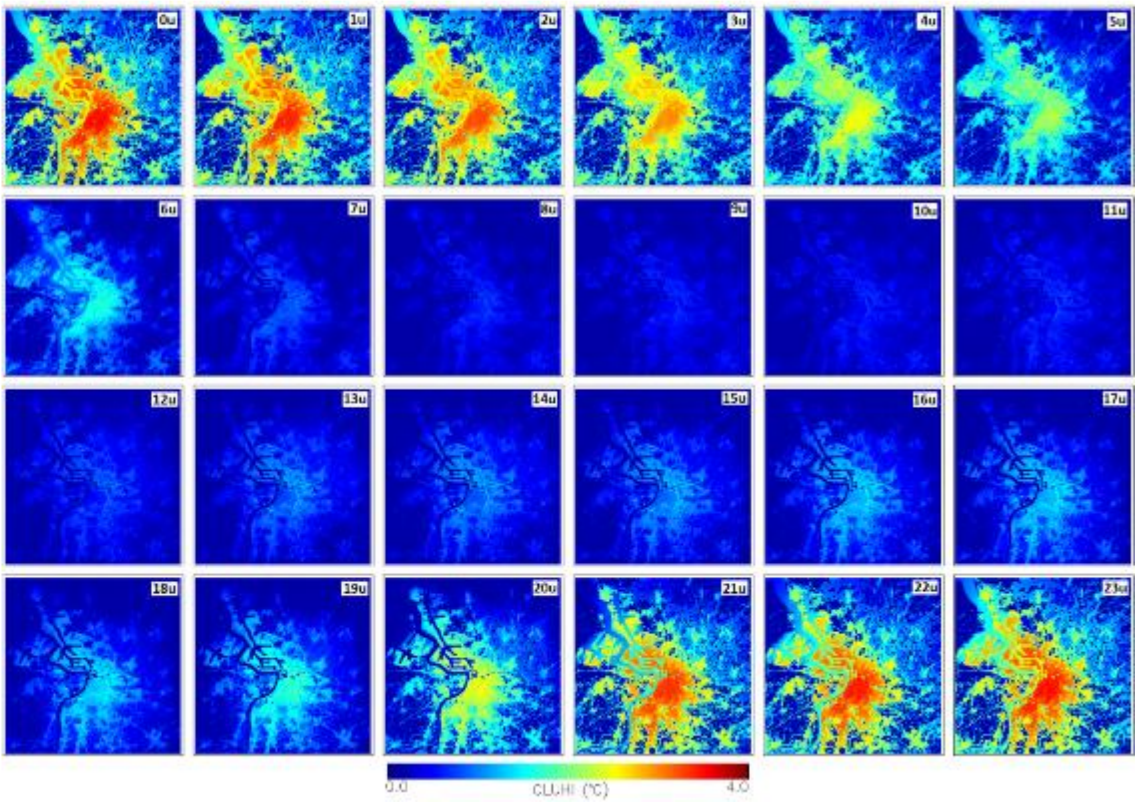

Figure 1. Urban heat island intensity (ºC) throughout a day in the city of Antwerp, Belgium, during summer 2013. Extracted from: Lauwaet *et al.* (2013).

than its surroundings. Other less marked examples can be found in Barcelona, Antwerp and Ghent, where the difference is 2.5ºC, 2.4ºC and 3ºC, respectively. This warming effect is stronger at night, while during the day is almost absent (Figure 1).

The main causes of urban heat islands are (Mills, 2004):

- Lack of vegetation, which provides shadow and evapotranspiration.
- Low wind speed, leading to a poor ventilation of hot surfaces.
- Trapping of radiation between buildings.
- High thermal inertia of urban materials.
- Release of anthropogenic heat from buildings, cars, etc.

According to De Ridder and his partners at VITO, even small cities experience the UHI effect, although it is not as marked as in big cities. However, the relation is not linear but logarithmical, as showed in Figure 2. Therefore, the UHI intensity increases more

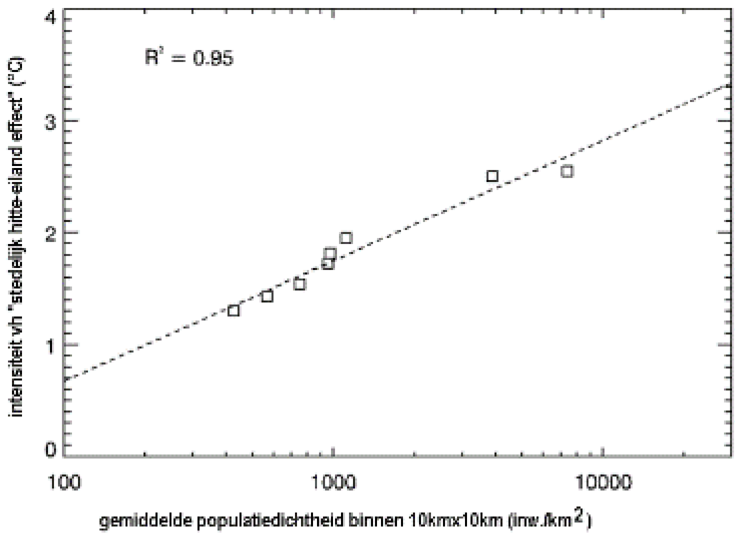

Figure 2. Urban heat island intensity (ºC) in relation to urban population (ind./km²) of different Belgian cities. Extracted from: Aertsens *et al.* (2012).

slowly as the population grows.

Furthermore, UHI intensity is also influenced by air temperature. During hot periods, the UHI intensity increases, whereas it is not very marked when the weather is cold (Figure 3).

In Belgium, a heat wave day is a day on which both the three-day running minimal and maximal temperature exceed a threshold (18.2ºC and 29.6ºC respectively) between April and September. On the other hand, the approach of a heat wave is different in Spain. Here, it is defined as a at least three-day period in which 10% of the weather stations measure environmental temperatures above the 95th percentile of the July-August daily maximum temperatures considering the 1971-2000 period. In Barcelona, this threshold temperature is about 33.1ºC (AEMET, 2018). Sometimes, society does not consider heat waves as a main health issue. However, as mentioned by De Ridder, a heat wave is usually very dangerous. For instance, in 2005 Hurricane Katrina left less

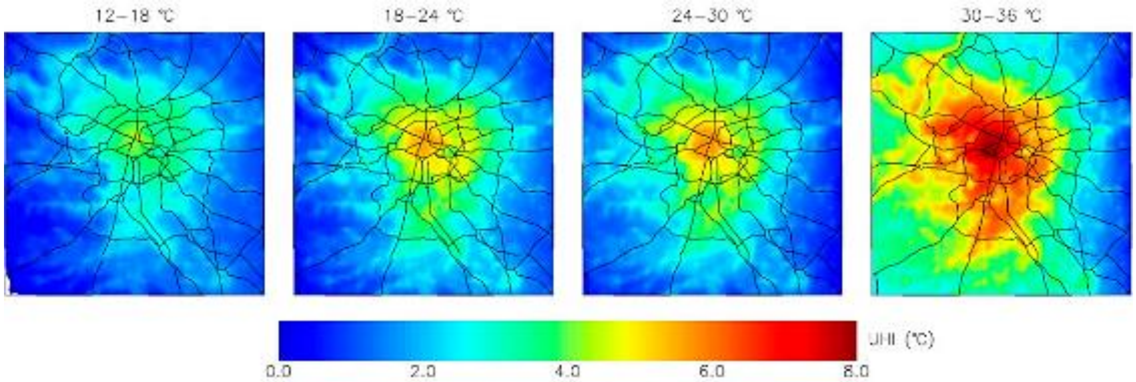

Figure 3. Night time (10 p.m. UT) 2-metres air temperature field relative to the average temperature of the 1% coolest grid cells occurring in the domain, in Paris area. Each panel corresponds to a daytime (2 p.m. UT) temperature range as specified above each panel (i.e. 12-18ºC, 18-24ºC, 24-30ºC, and 30-36ºC). Extracted from: De

than 2 thousand deaths, while in 2003 the European Heat Wave caused about 70 thousand deaths. During this heat wave, there was an excess of urban mortality that was associated to the UHI. Since the UHI effect causes additional heat stress at night, it is more difficult for urban residents to recover from the heat suffered during the whole day. Indeed, when comparing deaths during this heat wave to the same period in 1999-2002, Paris and Lyon experienced an increase of 140% and 80% in mortality (Vandentorren *et al.*, 2004). On the other hand, small towns experienced a lesser increase in the number of deaths.

Besides having an influence on health and mortality, heat also causes damage in infrastructure and energy use. Many types of infrastructure are affected by extreme heat, including roads, rails and air travel. High temperatures increase the risk of pavement deterioration. Moreover, extreme heat also causes the warping or buckling of the railroads. Further, in terms of energy use, access to air conditioning will be vital in many places as heat waves worsen, thus placing a significant stress on the power system during these periods (UCS, 2018).

The increase in heat wave days in the future will account for an increase in the use of air conditioning in order to reduce the temperature-related shock. In this context, De Ridder remarked the need to shift into renewable power sources that will supply the energy needed to cool the buildings. However, this increased energy use will emit heat outdoor, thus increasing the UHI.

Since the 19th century, people have moved from rural to urban areas because the industrialization process tends to concentrate people near the industries by creating economic growth and job opportunities. This flow has caused cities to be denser, thus increasing the urban heat island effect. However, high-density cities are more efficient in energy and transport system. Therefore, there is a conflict between high and low-density cities. Although De Ridder believes that he cannot assure which will be the best option, he is more entrusted with compact cities with green infrastructures that will help to reduce the UHI.

UrbClim model

Climate models are an important tool for scientists to understand the complexities of Earth's climate. These computer simulations incorporate both theory and direct observations of the past and present and provide climate maps as outputs. Climate models allow to simulate the present and project climate into the future.

The **UrbClim model developed at VITO is a computer model that simulates scenarios based on mathematical expressions of atmospheric physics**. The inputs of this model are maps of terrain and large-scale weather maps. As a result, an hourly gridded temperature, humidity and wind speed map is produced. To validate the model, it has to be compared to real observations (Figure 4). Validations have been done for several cities, such as Antwerp, Ghent, Brussels, Almada, Bilbao, Barcelona, London, Berlin,

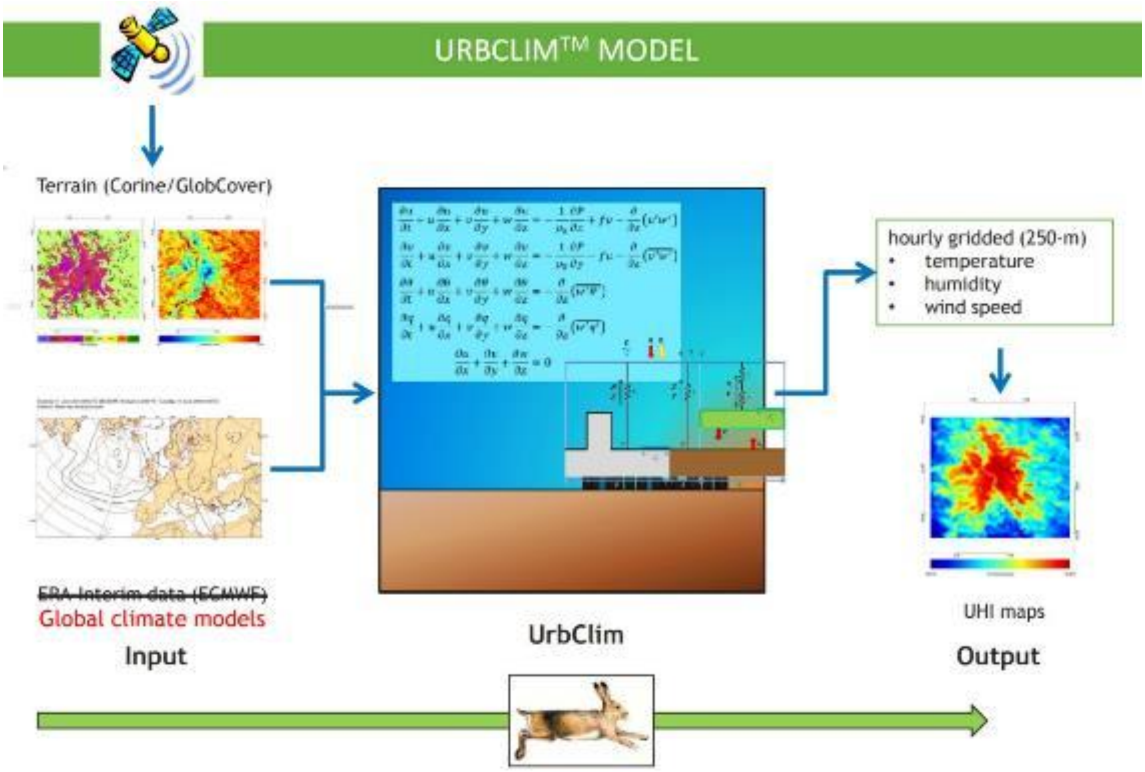

Figure 4. The VITO's UrbClim model. Modified from: "UrbClim - A Fast Urban Climate Model" (VITO).

Athens, and Skopje.

The UrbClim climate model has meant a great advance in climate forecasting. One of the biggest revolutionary advantages of the **UrbClim model** over previous models is that it **works with a very high resolution, up to 100 meters** –corresponding to a city block in Eixample district–, at an affordable computational cost, while not compromising accuracy**.** Thus, it offers something that is not available, i.e. to resolve the microscale and thus the spatial heterogeneity within the city. For instance, it is not the same living in Collserola than in Plaça Catalunya, and this difference can create social inequalities. Moreover, collected data inform about the weather on the Earth's surface and not at a certain high in the atmosphere. This is important because the weather on the surface is that which affects our society in terms of health, productivity, etc. Another main advantage of the UrbClim model is that it integrates climate with social-economic data. For instance, the model can show us that urban areas with lower incomes are those that have lowest accessibility to green areas, worst thermally isolated buildings, highest temperatures within the city, etc. Therefore, it has to be addressed to protect more vulnerable people.

In Barcelona, the model was validated for the warm season (May-September) in the study of García-Díez *et al.* (2016), in which De Ridder collaborated. They found that the average UHI in the city of Barcelona during the warm season reaches 2.5ºC at night. This information is relevant for the study of climate impacts on health care systems, infrastructures, etc. In addition, the UrbClim model was compared with the Weather Research and Forecasting (WRF) model, which is an opensource, non-hydrostatic limited area model that works at lower scale than UrbClim. Indeed, the resolution achieved in the study using the UrbClim model was 250 m, while with WRF was between 10 and 1.1 km. However, WRF has the advantage of providing a more detailed and complete description of atmospheric winds and rainfall, which is required in some applications –e.g. pollutant dispersion or urban effect in rainfall. UrbClim has been proven to be as accurate as WRF at reproducing the UHI of Barcelona during the warm season, and several orders of magnitude faster. According to De Ridder, this allows the performance of multi-decadal simulations of urban heat stress in a large number of cities at a reasonable computational cost. However, the study found that in cities affected by strong mesoscale flows –e.g. sea breeze–, such as Barcelona, it must be considered that UrbClim will be subject to inaccuracies caused by a misrepresentation of the wind, in case that it is nested in a low-resolution model.

Another aspect to consider is that heat emissions are different throughout the day and the night. Commercial buildings emit heat during the day whereas residential buildings are more active at night. However, the situation changes during the weekend. Hence, a heat daily pattern is created according to this information and is included in climate models like UrbClim model.

Finally, the last-mentioned problem regarding the use of UrbClim model is that more available data is needed. As mentioned above, the UrbClim model requires, as one of its main inputs, information about the terrain, so land cover maps and satellite vegetation index must be provided to know where the vegetation is, and the proportion of land covered by vegetation and by urban area. The model accounts for physical effects of urban built-up areas and vegetation, such as evaporation and transpiration. However, the 3D structure cannot provide information about where heat is generated and emitted, although it can be used to calculate buildings' shades. A problem that Dr. Xavier Rodó –an ICREA researcher at ISGlobal– has found when modelling is that they do not have access to the urban topology of Barcelona. **Using UrbClim model in Barcelona needs more data available.** This is a global issue in

Catalonia, where data sets are particularly protected. In Rodó's opinion, some of the substantial problems concerning our people might be solved if there was a wide rearrangement of the knowledge of the city, including pollution levels and monitoring network. Knowing this situation, the Department of Territory and Sustainability of Government of Catalonia is willing to share the information and the data sets that they have in order to use them for research works. After that, the researchers would be the ones that should coordinate and transmit the knowledge to the people.

De Ridder remarked that there are only few measuring stations in the cities. For this reason, the VITO's group research has installed its own stations to obtain the data required for subsequent modelling process. According to De Ridder, it is very important to invest in measurement of climate change indicators in order to obtain the most reliable models. Moreover, Rodó stated that cities should replace their measurement stations, with data almost displayed in real-time. This is an effort that the administrations and industries must make, and scientists who work on that should be set together. For instance, De Ridder exposed that a cheap station which measures wet bulb global temperature may cost few hundred euros. These stations can be installed in every public building and calibrated with a more expensive station.

Satellites and weather monitoring systems have a limited number of chemical parameters that they measure. There is a group of scientists that are promoting measurements in Earth areas in which there are not many or any stations, such as Artic, Africa and cities. In this context, **Rodó proposed Barcelona as a leadership in climate measurements**. To achieve this, Barcelona will need equipment's worth from 5 to 10 million euros to stablish one thousand measurement sites.

Urban heat projections

Heat projections are vital to understand how water resources, agriculture, electricity generation and public health can be affected in the future by droughts and heat waves. Further, projected heat trends allow the identification of adaptation and mitigation strategies. Forecasts are generated using information of weather models. However, most of these models cannot work at high-scale level. In this context, the UrbClim model has the advantage that can be used to obtain heat projections within the cities.

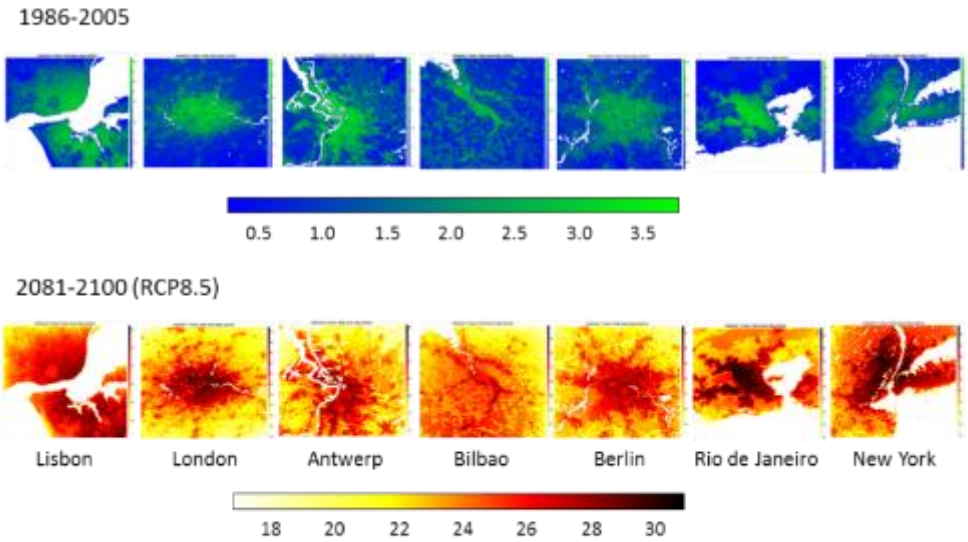

Figure 5. Current and projected number of annual heat wave days. The model used for simulations is the VITO's UrbClim Model. Modified from: "D4.2 Agglomeration-scale urban climate and air quality projections" (Hooyberghs *et al.*, 2015).

As it can be seen in Figure 5, main cities from around the world are going to follow the same pattern. Nowadays, annual heat wave days a year move from 0.5 in rural to 3.5 in urban areas. According to UrbClim model, if we simulate using RCP8.5 IPCC's scenario, in which emissions continue to rise throughout this century and temperature rises 3.7ºC from 1986-2005 to 2081-2100, these values will increase tenfold in late 21st century compared to now, thus reaching the amount of 30 heat wave days per year. However, variability must be considered –this means that in late 21st century some years may have less than 30 heat wave days, but some others may have more than 30.

Xavier Rodó and his team worked with De Ridder's UrbClim model in the area of Barcelona to generate simulations that are opened to public access at "Climate-fit.city" (ISGlobal & ASPB, 2018).

2004-2015 **RCP4.5 2041-2070** **RCP8.5 2041-2070**

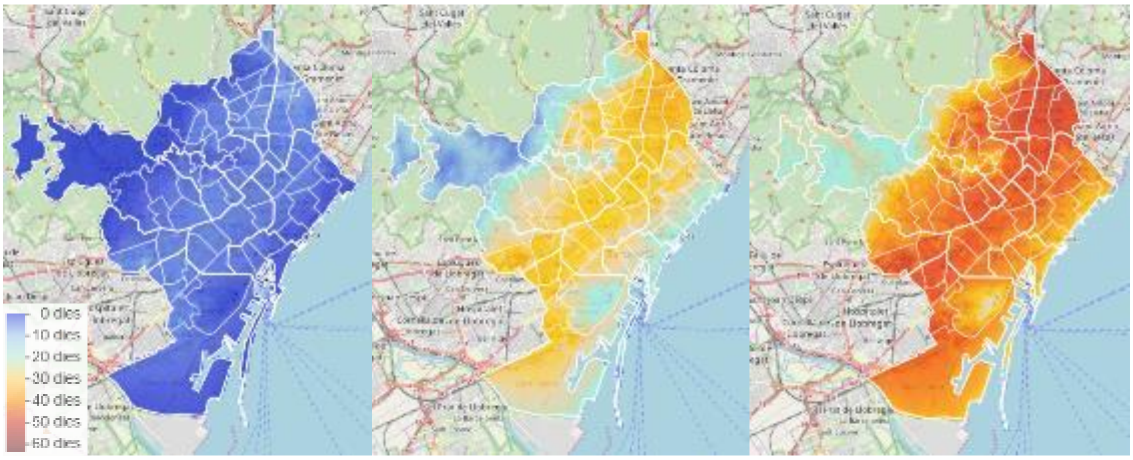

Figure 6. Current and projected number of annual heat wave days. The model used for simulations is the VITO's UrbClim Model. Modified from: "Climate-fit.city" (ISGlobal & ASPB, 2018).

As seen in Figure 6, **Barcelona currently experiences on average less than 5 heat wave days per year**. If we consider the second-best mitigating scenario predicted by the IPCC group –i.e. the RCP4.5 scenario, which assumes that global annual GHG emissions peak around 2040 and decrease thereafter, limiting the temperature increase by the end of the century to 1.8ºC in relation to the 1986-2005 average–, **the number of heat wave days will increase on average to 22 by 2041-2070.** Further, if we use the scenario that we are currently experiencing –i.e. the RCP8.5 scenario–, the number of heat wave days will increase on average to 35 by 2041-2070. Moreover, Rodó and his team have observed that there are differences in environmental temperature among Barcelona's neighbourhoods. Therefore, once the socio-economic factors are adjusted and removed, it can be seen that people have different morbidity depending on where they live, thus creating inequalities that must be responsibly managed.

Projections of damage costs for climate change impacts typically assess costs of local damages, including infrastructure, and do not provide an adequate consideration of cascade effects –for example, value-added chains and supply networks– at national and regional scales. De Ridder stated that it is very important and interesting to consider these effects. However, the research concerning cascade effects is usually very complex and difficult. Despite their complexity, cascade effects should be considered. Therefore, **many efforts must be put into the research to obtain a good understanding of cascade effects**.

For example, the paper "The Impact of the 2009 Heat Wave on Melbourne's Critical infrastructure" (McEvoy *et al.*, 2012) includes a very profound description of the effects that occurred because of the Australian heat wave in 2009. The direct impact of heat affected all parts of the electricity system, with unplanned events that included faults with transformers and ultimately power blackouts for some Melbourne residents. Moreover, there were also additional cascading effects from the electricity outages that affected many other parts of the urban system. These ranged from simple inconvenience -such as failure of traffic lights or train cancellations- to economic and even life-threatening implications. Moreover, blackouts can hinder emergency services and further enhance the risk to vulnerable groups (NCCARF, 2013).

Short-term forecasts are sometimes more useful than long-term projections

Xavier Rodó and his team have found that, nowadays, there are from 0 to 10 days annually in which temperature is above 35ºC in Barcelona. The large-scale predictability is about 5 days or even 7 days. This kind of model could be used in heat wave alert situations, thus protecting the most vulnerable people. Although climate change forecasts may be very accurate, transforming this climatic information into mortality can lead to uncertain results as our adaptability and vulnerability to future heat is unknown –in fact, society is getting less and less vulnerable. Therefore, in order to deal with health issues, short-term (week-scale) forecasts are required.

UrbClim's climatic projections are important and necessary in order to develop heat alert systems, but also **for the industry sector**. For example, concrete is not produced at the end of October in Belgium because it cannot be used under 10ºC. However, lately the temperatures in that period have been warmer than previous years, thus remaining above 10ºC. Therefore, companies make orders for concrete, but manufacturers cannot supply it because they have not planned it, since they normally don't provide concrete at this time of the year. In this context, manufacturers are not interested in knowing the climate of the next year, but they want to know next month's climate forecast to organise their logistics.

Good practices to avoid exceeding the heat thresholds from which people's health and well-being are put at risk.

De Ridder stated that an effective response to climate change will require radical changes in the way we live. Good practices discussed with Koen De Ridder during his session are detailed below. According to him these are proposals that, beyond the scientific debate, require a political commitment for the leaders to develop them.

Green infrastructure as a cooling measure

In Ghent, De Ridder and his partners studied how heat waves' magnitude and occurrence varies among different sites within the region (Figure 7). They saw that the temperature excess during a heat wave was lower in the little park of Plantentuin than in the city centre. Although the effect is not very evident because it is a park with a small area, De Ridder remarks the benefits of any green area regardless of his extension. Further, the heat wave was not even reached in Melle, which is a small town near Gent, because the minimum temperatures did not surpass their threshold during more than three consecutive days.

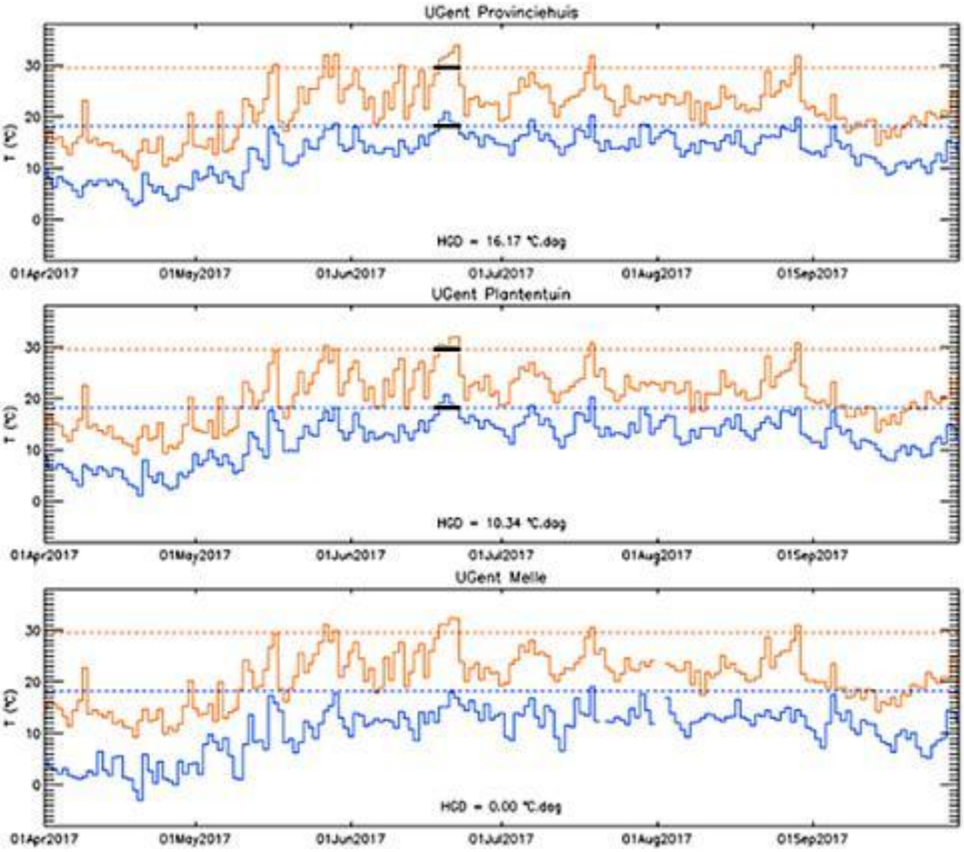

Figure 7. Environmental temperature in Gent's city centre (Provinciehuis) and little park (Plantentuin) and in Melle. The orange and blue lines are the maximum and minimum temperatures, respectively. Discontinued lines represent the temperature thresholds to reach a heat wave day in Belgium. Extracted from: "Cities at the Front of Climate Change" (De Ridder, 2018).

Further, De Ridder and his partners studied which areas in Ghent were warmer than others using a one-day measurement. They observed that air temperature difference compared to a rural reference station between the built-up area and the park or the riverside were not very marked, as they were usually around 0.5ºC and at most 1ºC (Figure 8). Hence, the results obtained were a bit disappointing. Consequently, De Ridder and his partners wondered that maybe air temperature is a good indicator for heat but was not good enough to represent human heat stress. Therefore, they moved to another indicator, the **wet bulb globe temperature** (WBGT). This variable **accounts for temperature, humidity, wind speed, sun angle and cloud cover (solar radiation), thus being an indicator of heat stress.** This differs from thermal comfort, which only takes into consideration temperature and humidity. The increase in WBGT index can reach 10ºC under the sun in relation to a shady place. For this reason, shading must be calculated. Considering the day of the year and the season, shades can be calculated using the 3D model of buildings and large green elements (mainly trees), and the incident radiation. From this, The VITO's group has validated the WBGT index using its

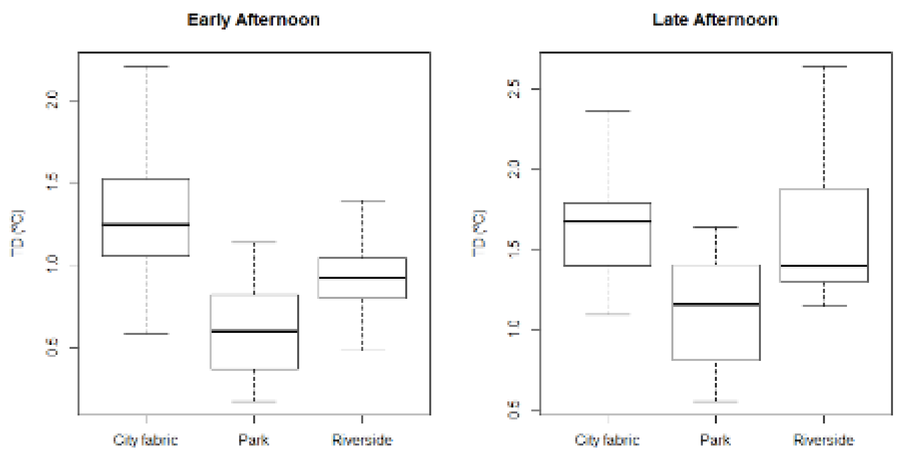

Figure 9. Air temperature difference (TD) compared to a rural reference station, at 3 different places in Ghent. Extracted from: "Cities at the Front of Climate Change" (De Ridder, 2018).

model. According to De Ridder, the WBGT is a good element to monitor people working or exercising in direct sunlight, as it is the most representative indicator of how people experience heat stress in these conditions.

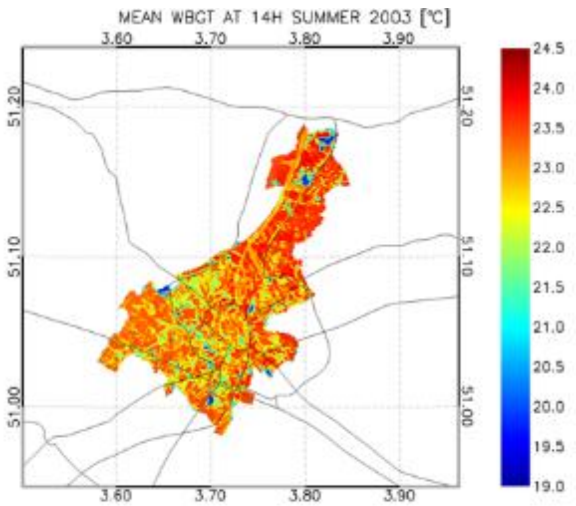

Figure 8. Mean WBGT at 14 p.m. in Ghent during summer 2003. Extracted from: "Cities at the Front of Climate Change" (De Ridder, 2018).

Figure 9 shows that there is a bit of variation from the results obtained from air temperature (Figure 8), even at very small scale. Colour changes from reddish to bluish –i.e. **WBGT diminishes up to 5ºC– over very short distances**. **This is the effect of small patches of vegetation or, less frequently, of water bodies or canals**. Hence, the effect you may expect from vegetation or from blue elements is much bigger if you consider the WBGT rather than if you just consider air temperature, as it can be seen when comparing Figure 8 and Figure 9. Indeed, as argued by De Ridder, if you represent this map but only considering air temperature, it would be red almost everywhere with slight changes to orange –i.e. temperature would decrease up to 0.5-1ºC.

A very high-scale simulation achieved by De Ridder is the reconstruction of Antwerp's Groenplaats square. This model, with a few metres' resolution, allows to estimate the temperature scenario when different amounts of vegetation are added into the square. Figure 10 shows that the thermal comfort index diminishes up to 4ºC in

Groenplaats square when vegetation is added. The effect obtained is quite strong but localised, as it can be observed when comparing the red code area in the middle of the square –where no vegetation is added– with the green code areas at the sites where trees are placed.

The message that De Ridder sent is that green does help, but it has a very localised influence. Therefore, environmental administrators and urban planners should be aware of it and must think very hard where to put the vegetation. For instance, green areas should be created considering vulnerable places where people would obtain more benefits from them. UrbClim's climatic projections can be a useful tool for doing so.

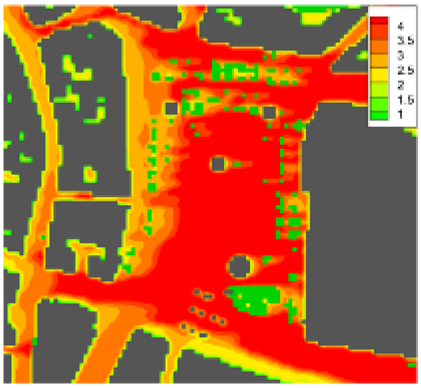

Figure 10. Reconstruction of Antwerp's Groenplaats square. Architectural design bureaus had to include spatial designs involving additional green infrastructure. The reconstruction aims to show what the effects on a thermal comfort index of putting vegetation within the square would be. Modified from: "Cities at the Front of Climate Change" (De Ridder, 2018).

Watering slightly reduces air temperature but also relieves heat-stressed people

De Ridder studied the effects in environmental temperature of the Blaarmeersen lake in Ghent, which is 1 km long. He found that the air temperature at 2 metres above the lake was 2ºC below the average. Moreover, there are trees surrounding the lake, thus helping in reducing the air temperature and the pollutants. De Ridder states that watering the city is not only important because it reduces air temperature, as blue areas in the cities tend to be too small to cause a marked effect in temperature, but it also relieves heat-stressed people. Since water reaches 20ºC at most, even in the summer period, heat-stressed people can refresh themselves during a hot day using the water in the city.

Future water scarcity should not be a limiting factor for greening

De Ridder and many other researchers propose greening and even watering the city as an adaptation strategy. However, this may not be compatible with other effects of climate change such as reduced rainfall. Nevertheless, it must be considered that summers will be warmer, but winters will be wetter. Therefore, if we are able to catch and store water during the winter and use it during the dry period, there will be no problem for water scarcity.

Greening the city is a possible solution, but other actions must be developed, particularly reducing GHG emissions

De Ridder mentioned that there are studies in some areas in the Middle East and Asia in which the expected increase in temperature will be such that people will not be physiologically able to live there because our bodies cannot refrigerate above 50ºC. These conditions will be faster achieved in cities because of the excess heat. Hence, **greening the city is a possible solution, but might not be enough for some cities**. As we may not be able to live in some cities, we might have to find other ways to organise society, economic and production activities. This approach is very relevant to De Ridder because he considers that cities must help in mitigating climate change, but it is increasingly gaining importance the need to adapt to climate change effects as they are in short-term unavoidable.

Although it has been shown that average temperature may not decrease markedly with greening –e.g. putting 60% vegetation everywhere in the city may only account for a 1 or 1.5ºC reduction–, De Ridder remarked that it may cause UHI to diminish 45%. Moreover, De Ridder stated that **greening cities is always a good measure since it has other beneficial effects that are equal or more important than reducing air temperature, such as modifying wind speed, improving people's mental health and removing CO_2 from air.** De Ridder indicated that greening the cities is required to adapt to and mitigate climate change **but is only part of the solution**. Other actions must be developed, particularly those involving a reduction in GHG emissions. **In terms of transportation and energy**, a more sustainable way to move people around the city is needed, thus **enhancing the use of public transport and working with renewable energies**. According to De Ridder, incentives and subsidies are useful actions to regulate the energy system. This will lead to a reduction of the air pollution and, therefore, deaths and diseases associated to it.

Urban climate services

Our economic system needs to have benefits, but it will also require to be sustainable. According to economists, winning money and reducing impacts at the same time is a challenge that is difficult to achieve. Urban climate services provide **tools to enable climate change mitigation and adaptation strategies by policy makers and businesses, at the same time that enhance the economic system in a sustainable way.** Accordnig to De Ridder working with climate services for cities will probably help in dealing with climate change challenge. For example, Copernicus has historical climate data that could be used for forecasting, but no one is using it. In fact, one of VITO's goals is to help businesses to face climate change effects using information provided by its forecasts. Some urban climate services are explained in this section.

Building energy model EnergyPlus

In the study of Hooybergh *et al.* (2017), the UrbClim model is used to calculate outdoor urban climatic variables (temperature and wind speed, among others). These outdoor climatic data are subsequently used as input for the building energy model **EnergyPlus** (Crawley *et al.*, 2000), **which simulates the energy management and indoor climate of individual buildings** by performing hour-by-hour computations of internal and external heat fluxes. In this case, EnergyPlus is used to model two versions of a prototype building, which only differ in the presence or absence of an active cooling system. By using these two models, they calculated lost working hours in relation to wet bulb global temperature. For Belgian people, if the WBGT is smaller than 27.6ºC, normal work takes place all the time, while the worker has to rest during a fraction of the time if the threshold of 27.6ºC WBGT is exceeded. When 31.9ºC WBGT is reached, work can no longer resume. However, some considerations must be taken into account. For instance, outdoor workers work under the sun and their bodies warm quickly –therefore, their environmental temperature threshold to stop working is lower than indoor workers. According to the Spanish Royal Decree 486/1997 of 17th April 1997, the indoor temperature of a working place has to be between 17 and 27ºC. However, it is not specified what to do when the temperature goes out of this range.

As shown in Figure 11, the number of lost working hours in a building without active cooling quadruples between the reference period and the far future (2081-2100) in Antwerp, if emissions keep tracking along the RCP8.5 scenario. There are much larger negative effects for similar buildings in Bilbao, where additional work breaks are six times as frequent as those in Antwerp. The study proved that the most effective adaptation measures are solar blinds and increased (active) ventilation, which respectively reduce the amount of lost working hours by approximately 60% and 90% for the far future period. Moreover, moving employees to cooler rooms within the building has a significant positive effect, reducing the number of lost working hours by 75%. In case these hard adaptations were technically unfeasible, soft measures such as adapted working hours would provide an alternative. The largest beneficial effects are observed for a schedule with a morning (7:00–11:00) and a late-afternoon (17:00–20:00) working shift, which halves the lost working hours.

Figure 11. Current and projected fraction of lost working hours in the south-facing room during an average summer (May-September), in Antwerp. The model used for simulations is the UrbClim model and the EnergyPlus model. Extracted from: Hooyberghs *et al.* (2017).

Climate-fit.city

Climate-fit.city (JOANNEUM *et al.*, 2017) is a service of the "Pan-European Urban Climate Service" (PUCS) ongoing project, started in June 2017. Climate-fit.city service will quantify the impacts of climate, particularly climate heat and flooding effects, on a range of urban sectors and propose relevant solutions to customers. Their ambition is to reach tens to hundreds of European cities and towns, servicing them with urban climate information through a flexible and ever evolving network of business partners operating throughout Europe (and beyond), responding to the need for cost-efficient and reliable urban climate information. In Barcelona, Climate-fit.city urban climate service is working in collaboration with ISGlobal and Barcelona Public Health Agency (ASPB). Relationships between summer temperature and daily mortality studied by overlaying high-resolution temperature data from UrbClim and spatially-detailed mortality and sociodemographic data from ASPB (ISGlobal & ASPB, 2018).

GISAT

GISAT (1990) is operating since 1990 as the first privately run remote sensing and geoinformation service company in the Czech Republic. The educational background of the GISAT team –a small and medium-sized enterprise (SME) company– is in agriculture, cartography, geography and natural sciences, land management, surveying and informatics.

The company mission is to provide its clients with wide range of value added, complete, high quality, affordable and 'state-of-the-art' geoinformation services based on the Earth Observation technology. GISAT brings a complete portfolio of services starting from satellite data and geomatics software distribution, through specialized image and GIS data processing and analysis, up to advanced geoinformation products and services. De Ridder stated that this can be used to modify cities adding parks or removing buildings and observe how models respond.

Copernicus Climate Change Service (C3S)

The C3S (COPERNICUS, 2014) supports society by providing authoritative information about the past, present and future climate, **as well as tools to enable climate change mitigation and adaptation strategies by policy makers and businesses.** C3S is providing its reanalysis data to VITO, who then refines and runs its UrbClim model at a resolution of 100 metres for cities.

It is interesting to consider the relationship between climate and social-economic data. In the Copernicus project, VITO is working with social-economic experts providing climate data and information about income, status, age, etc. Particularly in Antwerp, they have observed that the city's zones most exposed to heat stress also contain most vulnerable people. Therefore, there is a negative correlation between income and climate stress that people experience. Furthermore, it can be detected that people living in green urban zones have a lesser use of the air conditioner.

Barcelona shows a huge difference in income among districts and this has consequences on water and energy access (Figure 12). The two districts with higher GDP within the city –i.e. Les Corts and Sarrià-Sant Gervasi– are those with the lowest energy poverty index. On the other hand, the district with less GDP –i.e. Nou Barris– is the second with higher energy poverty.

Figure 12. Disposable household income (RFP) and energy poverty (PE) by district in Barcelona (2014). Extracted from: "Climate Plan" (AjBCN, 2018).

The **European Health Service** (COPERNICUS, 2018), as a part of C3S, provides users with tailor-made climate information for the health domain. This information consists of climate-health indicators concerning heat and cold stress, vector-borne diseases and allergenic pollen. This service will provide high-resolution urban climate data for 100

European cities, including Barcelona. These data will include a snapshot of temperature distribution and other climate variables, focusing on so-called heat islands.

Flemish Climate Portal

The Flemish Climate Portal (FEA *et al.*, 2016) provides an objective frame of reference for the development of (local) climate adaptation policy, and thus aims to be a compass for a climate-proof and resilient Flanders.

The Flemish Climate Portal brings together the most recent information on climate change and maps it out in detail for Flanders down to the district level. This information includes both current and future projections of primary climate indicators –temperature, precipitation, evaporation and wind–, climate effects –heat, flood, rising sea levels, drought– and vulnerabilities –people affected, buildings– on the basis of climate scenarios. VITO's Urban Climate Service Centre has produced unprecedented high-resolution heat stress maps for the entire Flemish region for the current climate (2000-2016) and future projections (up to 2100), which serve as an input for the Flemish Climate Portal.

RAMSES

RAMSES (PIK *et al.*, 2012) was a European research project ended in September 2017, which aimed to deliver much needed quantified evidence of the impacts of climate change and the costs and benefits of a wide range of adaptation measures, focusing on cities.

Urban characteristics and their inter-linkages were identified and used to provide the local context for the assessment (Figure 13). In an integrated top-down and bottom-up approach, risks vulnerabilities and damages from climate change were quantified. Associated costs and benefits of adaptation were then estimated to support the design of sustainable transition strategies in urban areas. RAMSES engaged with stakeholders

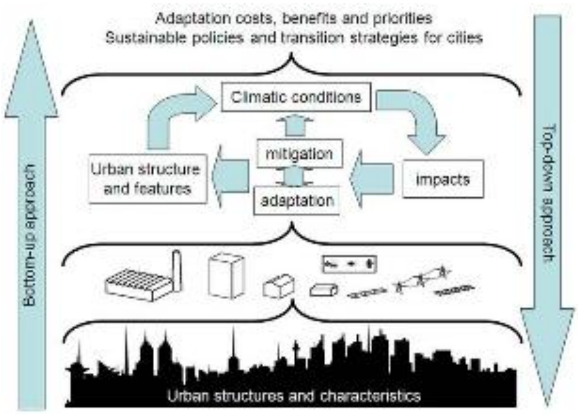

Figure 13. Illustration of the overall concept of RAMSES project. Extracted from: RAMSES (PIK *et al.*, 2012).

to ensure this information was policy relevant and ultimately enabled the design and implementation of adaptation strategies in the EU and beyond.

According to De Ridder this project can be very important in terms of providing interesting information for Barcelona City Council, for instance.

In order to present all the knowledge generated to cities in a synthetized and practical fashion that can be used to take decisions on climate change adaptation, the project partners have developed the current Transition Handbook and Training Package (PIK *et al.*, 2017). The Transition Handbook embeds the key RAMSES findings in a process management cycle, using widely known methodologies. Furthermore, the Training Package complements it by taking stock of existing toolkits to support adaptation management in cities and proposes worksheets and exercises that cities can use to progress on their adaptation endeavours.

Supranational organisations can help cities to face and mitigate climate change

In current times, cities' budgets are usually constrained. Therefore, it is very important to find ways to safe as much money as possible. In this context, it could be argued that investing in climate models for cities may be a waste of time and money because the government and the City Council will not act to face climate change as it would require a great amount of money. De Ridder, who is aware of this situation that most European cities are going through, believes that supranational organisations can provide some kind of subsidies and donations in order to help cities to cope with and mitigate the effects of climate change.

Promoting the SMEs can lead to the social change needed

De Ridder said that involving SMEs would make a real change in terms of urban climate services. However, SMEs do not have enough money to develop these needed actions. Further, while research institutes and universities can obtain investment coming from the UE to develop urban climate services, SMEs do not have access to these grants. Therefore, political regulations should be transformed in order to make more feasible SMEs' viability and entrepreneurship.

The role of Fundació Catalunya Europa in Barcelona's transformation

Cities must play a key role in facing climate change because they are affected by this issue as well. Furthermore, the need to limit the temperature increase to 1.5ºC can be more relevant in cities as they experience climate change more intensely because of the UHI effect. For this reason, cities must invest more in new models and tools, which will allow us to understand where we are, where we are going and what measures can be applied.

The Fundació Catalunya Europa's Observatory is working in collaboration with Metropolis, the world association of major metropolises, to define proper climate change indicators and how to measure them among Àrea Metropolitana de Barcelona (AMB) and the 137 cities around the world that belong to Metropolis. However, there are some gaps in the information availability, which sometimes lead to inequalities – i.e. there are large amounts of data available for Barcelona and for the metropolitan area but not for many municipalities that belong to AMB. An agreement is needed between researchers, institutions and other actors that work with the data. The Foundation proposes to create an interdisciplinary debate space to determine how the climate data can be improved in Catalunya and how to create the information status that will allow future planning.

Bibliography

AEMET. (2018). *Olas de Calor en España desde 1975*. Retrieved from Agencia Estatal de Meteorología: http://www.aemet.es/documentos/es/conocermas/recursos_en_linea/publicaciones_y_estudios/estudios/Olas_calor/Olas_Calor_ActualizacionOctubre2018.pdf

Aertsens, J., De Nocker, L., Lauwers, H., Norga, K., Simoens, I., Meiresonne, L., Turkelboom, F. & Broekx, S. (2012). *Daarom Groen! Waarom U Wint bij Groen in Uw Stad of Gemeente*. Retrieved from VITO: https://emis.vito.be/sites/emis.vito.be/files/articles/1125/2013/LITERATUURSTUDIE_GROEN_LOONT_v99_finale%20versie.pdf

AjBCN. (2018). *Climate Plan*. Retrieved from Ajuntament de Barcelona: http://lameva.barcelona.cat/barcelona-pel-clima/sites/default/files/documents/eng_climate_plan_def.pdf

BE. (2014). *Reports on the State of the Environment (2011-2014)*. Retrieved from Brussels Environment: https://www.environment.brussels/state-environment/report-2011-2014

COPERNICUS. (2014). Copernicus Climate Change Service. Retrieved from Copernicus: https://www.copernicus.eu/services/climate-change

COPERNICUS. (2018). European Health Service. Retrieved from Copernicus: https://climate.copernicus.eu/european-health-service

Crawley, D. B., Lawrie, L. K., Pedersen, C. O. & Winkelmann, F. C. (2000). EnergyPlus: Energy Simulation Program. *American Society of Heating, Refrigerating and Air-Conditioning Engineers Journal, 42*(4), 49-56.

De Ridder, K. (2018). Cities at the Front of Climate Change. Retrieved from Re-City: https://www.re-city.net/en/activitats/15/koen-de-ridder.html

De Ridder, K., Maiheu, B., Lauwaet, D., Daglis, I. A., Keramitsoglou, I., Kourtidis, K., Manunta, P. & Paganini, M. (2016). Urban Heat Island Intensification during Hot Spells—The Case of Paris during the Summer of 2003. *Urban Science, 1*(1), 3. doi: https://doi.org/10.3390/urbansci1010003

FEA, WER & KU-LEUVEN. (2016). Flemish Climate Portal. Retrieved from Flemish Environment Agency: https://klimaat.vmm.be/nl

García-Díez, M., Lauwaet, D., Hooyberghs, H., Ballester, J., De Ridder, K. & Rodó, X. (2016). Advantages of Using a Fast Urban Boundary Layer Model as Compared to a Full Mesoscale Model to Simulate the Urban Heat Island of Barcelona. *Geoscientific Model Development, 9*, 4439-4450. doi: https://doi.org/10.5194/gmd-9-4439-2016

GISAT. (1990). Gisat - the Czech Leader in Remote Sensing. http://www.gisat.cz/content/en

Hooyberghs, H., Lauwaet, D., Lefebvre, W., Maiheu, B., De Ridder, K., Gonzalez-Aparicio, I., Acero, J. A. & Mendizabal, M. (2015). *D4.2 Agglomeration-scale Urban Climate and Air

Quality Projections. Retrieved from RAMSES: http://www.ramses-cities.eu/fileadmin/uploads/Deliverables_Uploaded/D4.2_Agglomeration-scale_urban_climate_and_air_quality_projections.pdf

Hooyberghs, H., Verbeke, S., Lauwaet, D., Costa, H., Floater, G. & De Ridder, K. (2017). Influence of Climate Change on Summer Cooling Costs and Heat Stress in Urban Office Buildings. *Climatic Change, 144*(4), 721-735. doi: https://doi.org/10.1007/s10584-017-2058-1

ISGlobal & ASPB. (2018). Climate-fit.city. Retrieved from Agència de Salut Pública de Barcelona: https://aspb.shinyapps.io/climate-fit-city/

JOANNEUM, VITO, ISGLOBAL, KU-LEUVEN, T6, METEOTEST, INES, BIKE-CITIZEN, GISAT, ARCTIK, ANTWERP, SSCOLOSSEO, ASPB & IURS. (2017). Climate-fit.city. https://climate-fit.city/

Lauwaet, D., De Nijs, T., Liekens, I., Hooyberghs, H., Verachtert, E., Lefebvre, W., De Ridder, K., Remme, R. & Broekx, S. (2018). A New Method for Fine-Scale Assessments of the Average Urban Heat Island over Large Areas and the Effectiveness of Nature-Based Solutions. *One Ecosystem, 3*, e24880. doi: https://doi.org/10.3897/oneeco.3.e24880

Lauwaet, D., Maiheu, B., Aertsens, J. & De Ridder, K. (2013). *Opmaak van een Hittekaart en Analyse van het Stedelijk Hitte-Eiland Effect voor Antwerpen*. Retrieved from Antwerpen Morgen: https://www.antwerpenmorgen.be/files/download/66130141-d647-4b7f-848a-81c211241a61

McEvoy, D., Ahmed, I. & Mullett, J. (2012). The Impact of the 2009 Heat Wave on Melbourne's Critical infrastructure. *Local Environment, 17*(8), 783-796. doi: https://doi.org/10.1080/13549839.2012.678320

Mills, G. (2004). *IAUC Teaching Resources: The Urban Canopy Layer Heat Island*. Retrieved from US Environmental Protection Agency: https://www.epa.gov/sites/production/files/2014-06/documents/heatislandteachingresource.pdf

NCCARF. (2013). *Case Study: Impacts and Adaptation Responses of Infrastructure and Communities to Heatwaves*. Retrieved from National Climate Change Adaptation Research Facility: https://www.nccarf.edu.au/business/sites/www.nccarf.edu.au.business/files/attached_files_publications/Pub%2013_10%20Southern%20Cities%20Heatwaves%20-%20Complete%20Findings.pdf

PIK, LSE, UNEW, VITO, UVSQ, TECNICALIA, NTNU, WHO/EUROPE, T6, ICLEI, SPRL, CMF & IVE. (2012). Reconciling Adaptation, Mitigation and Sustainable Development for Cities (RAMSES). Retrieved from RAMSES: http://www.ramses-cities.eu/home/

PIK, LSE, UNEW, VITO, UVSQ, TECNICALIA, NTNU, WHO/EUROPE, T6, ICLEI, SPRL, CMF & IVE. (2017). *RAMSES Transition Handbook and Training Package*. Retrieved from RAMSES: http://www.ramses-cities.eu/fileadmin/uploads/Deliverables_Uploaded/RAMSES-Handbock-and-Training-Package-final-www.pdf

Sharma, R., Hooyberghs, H., Lauwaet, D. & De Ridder, K. (2018). Urban Heat Island and Future Climate Change - Implications for Delhi's Heat. *Journal of Urban Health*, 1-17. doi: https://doi.org/10.1007/s11524-018-0322-y

UCS. (2018). *Heat Waves and Climate Change. The Effects of Worsening Heat on People, Communities, and Infrastructure*. Retrieved from Union of Concerned Scientists: https://www.ucsusa.org/sites/default/files/attach/2018/08/extreme-heat-impacts-fact-sheet.pdf

Vandentorren, S., Suzan, F., Medina, S., Pascal, M., Maulpoix, A., Cohen, J. C. & Ledrans, M. (2004). Mortality in 13 French Cities during the August 2003 Heat Wave. *American Journal of Public Health, 94*(9), 1518-1520. doi: https://doi.org/10.2105/AJPH.94.9.1518

VITO. UrbClim - A Fast Urban Climate Model. Retrieved from Urban Climate Service Centre: http://www.urban-climate.eu/c/urbclimDescription/

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