LESSON 8 URBAN HEAT ISLANDS (UHI)

MAIN SUBJECTS
Physics
Natural Sciences
Geography

DURATION
Preparation: 10 min
Activities: 3h (2 x 1h30)
Wrap-up: 20 min

AGE GROUP
15+ year-old students

TEACHING METHOD
Documentary analysis
Multimedia animation

LEARNING OUTCOMES
Using a multimedia animation, students understand what urban heat islands are. They differentiate mitigation and adaptation scenarios, as well as their trade-offs and gains regarding the SDG's.

TARGETED SUSTAINABILITY COMPETENCE
Domain 2 – Embracing complexity in sustainability
Competency – 2.1 Systems thinking

CONCEPTS COVERED
UHI, adaptation, mitigation, SDGs, societal choices, climate projection, cooling solution, maladaptation, temperature anomaly

PREPARATION 10 MIN

This lesson will be divided into **2 activities of 1.5 hours each** to match the different parts of the multimedia animation. Both are linked, but you can focus on only one of them with your students.

The first activity aims to study the importance of models when predicting the evolution of climate at a global scale between 2020 and the end of the century, with the implementation of mitigation options to face climate change.

The second activity aims to zoom in on cities experiencing the urban heat island (UHI) effect in 2020 and the different solutions that can help limit this effect in 2020 (adaptation options) and confirm their lasting efficiency by the end of the century.

Common equipment for both activities: computer, internet connection or UHI multimedia animation set up on each computer, video projector. All the scientific references used in this animation, which is based on data from real climate models, are available here.

INTRODUCTION

In sequence A, students saw that mankind is responsible for the current climate change caused by large amounts of greenhouse gases emitted into the atmosphere since the Industrial Revolution.

The main learning objectives addressed in this lesson are:

- Without any mitigation solutions the global temperature on Earth will continue to rise above the limit set by the Paris Agreement.
- The urban heat island effect (UHI) corresponds to a positive temperature anomaly measured in urban areas compared to the surrounding rural areas.
- Implementing adaptation solutions today can reduce the UHI effect.
- The implementation of solutions (mitigation, adaptation) to face the UHI effect can also limit the temperature increase by the end of the century; we talk about synergies.
- Some solutions that are implemented today for their efficiency can turn out to be less or no more efficient in the future; we talk about maladaptation.
- The UHI effect issue is closely connected toa number of SDGs

ACTIVITY 1 1H30

PART 1: GETTING STARTED WITH THE ANIMATION 25MIN

1. Students become familiar with the animation on their own to understand the goal and purpose of using it in the context of studying climate change. Guide them by asking them to think about the objectives of the animation.

2. Together, briefly recap what they did, why, and how to use the animation.

PART 2: LIMITING GLOBAL WARMING TO 1.5°C 55MIN

3. Students work in small groups of 2 or 3. Explain that they have one mission: to limit the temperature increase in 2100 under/at the Paris Agreement objective (around +1.5°C of warming with respect to the 1850-1900 era). Let them research the meaning of the logo next to the global thermometer on the internet. Ask them if the colour of the logo changed after implementing their solutions and what could be the meaning of this change of colour. (It is the logo of COP21 that is displayed as a signal next to the global thermometer: green when the Paris Agreement is achieved, red when the global temperature is too high).

4. Discussion: Each group can present its solution(s) and discuss their feasibility in terms of cost,

cultural and ethical implications, and the scale of action (individual, local and/or collective), etc.

PART 3: CONCLUSION 10MIN

There are several ways to stay under +1.5°C.

5. Ask students what mitigation means and why it is important.

6. Ask students if it is possible to reach the Paris Agreement by making efforts in one sector only. Actually, the transformation of all sectors of our society is required (you can even introduce the term **'systemic transformation'**).

7. Optional (depending on remaining time): divide the classroom into two groups, one has to find the best combination to achieve the lowest temperature increase by 2100, and the other has to find the best combination to reach the highest temperature increase by 2100.

ACTIVITY 2 1H30

For this part, print out and use **WORKSHEETS 8.1** and **8.2** for each pair of students.

PART 1: SOLUTIONS TO FACE THE UHI EFFECT IN 2020 45MIN

1. Starting point: short offline brainstorming session altogether *1)* ***What is the UHI effect?*** From what they can guess or have heard on the television/internet, students should mention a difference of temperature between urban areas and the countryside. *Why are we interested in it?* and *2) How can we explain this anomaly of temperature in cities?* **Students have to propose hypotheses to answer these questions.**

2. Then: Each group (2 students per group, one selecting and clicking on the options, the other checking the impact on the city and the temperature levels) chooses one city to begin with (it is up to you to impose the same city for every group or to let students pick the city of their choice).

Students first use the animation in 2020. They should observe a positive temperature anomaly in cities compared to countryside temperature.

- They focus on one or two cities.
- For each city, they have to implement and report various solutions in different sectors (building, agriculture, mobility, energy, urbanism and nature) to reduce the UHI effect represented by the temperature anomaly in the animation.
- Each group presents to the rest of the class the local context before testing their adaptation scenario in the chosen city(ies) and the different tested solutions that led to the reduction of the UHI effect (the presentation of some solutions that have no effect can also be of interest).

The class comes to the conclusion that there are some solutions that can be implemented to mitigate the UHI effect (in 2020).

3. Ask the groups to fill in the table in **WORKSHEET 8.1** and assess the feasibility of one solution they deem pertinent (economically, culturally, technically, etc.).

They must also make connections between these solutions to reduce the UHI effect and the relevant SDGs (available on this website: https://sdgs.un.org/goals or in the **WORKSHEET 8.2**).

PART 2: SOLUTIONS TO FACE THE UHI EFFECT IN 2100 45MIN

The idea in this second part is to look at the changes in 2100 in terms of both global warming and UHI.

1. Start by asking students what they think will be the evolution of both these parameters (countryside temperature and urban temperature anomaly) by the end of the century with the solutions they chose in 2020 (e.g. increase of T° and UHI, increase of T° and decrease of UHI, decrease of T° and UHI, etc.).

2. Students reset the animation (by clicking on the looping arrow), click on 2100, then zoom in on the city(ies) they already studied. In many cases, they will observe an increase in global temperature (represented by the countryside temperature) between 2020 and 2100 as a consequence of global warming with a constant UHI effect. That means that even if the UHI effect does not increase, urban areas are still warming because of climate change.

3. Then, they apply all the solutions they previously selected in the 2020 case study. They observe that the UHI is indeed decreasing, but two variations may arise: on one hand, sometimes the UHI effect does

not decrease by the same amount as it did in the 2020 simulation; on the other hand, applying cooling solutions may also have an impact on the countryside temperature. We shall focus on the latter observation.

4. Finally, their objective is to find which cooling solutions have an impact (be it beneficial or aggravating) on climate change, while still decreasing the temperature in the city. Point out synergies to your students (like 'killing two birds with one stone').

5. Encourage students to make **connections between the solutions they found to reduce the temperature of the city and the relevant SDGs.**

In this last section, guide students through an example to illustrate that some efficient cooling solutions implemented in 2020 to reduce the UHI effect are no longer effective in 2100 and can sometimes even lead to an increase of the UHI effect.

In the multimedia animation, use the example of Moradabad, India, with the implementation of 'Green and Dry roofs' (go to building > roofs) in 2020 and 2100.

6. Ask them to fill in the following table collectively:

	BEFORE THE IMPLEMENTATION OF GREEN AND DRY ROOFS	**AFTER** THE IMPLEMENTATION OF GREEN AND DRY ROOFS	**EFFICIENCY ON THE UHI EFFECT**
TEMPERATURE ANOMALY IN THE CITY **IN 2020** (°C)	+2.84	+2.32	++
TEMPERATURE ANOMALY IN THE CITY **IN 2100** (°C)	+2,94	+2.89	+/-

This solution helps reduce the UHI effect. However, if we look at the evolution of the temperature anomaly in the city by the end of the century, the temperature is barely lower than before the implementation of vegetation on roofs. This is a great example to discuss **maladaptation** (i.e. short-term solutions that lose effectiveness over time).

7. The implementation of most of the previously mentioned solutions helps achieve the SDGs. Fill in the table below to recap the different solutions implemented in the choosen city to reduce the UHI effect and/or global warming by 2100.

TEACHER TIP (QUESTION 6)

The cooling effect of green roofs comes from plant evapotranspiration. However, evapotranspiration is very low for plants adapted to an arid climate. Climate change will alter Moradabad's climate from humid subtropical to semi-arid: as the evapotranspiration of plants adapted to a dry climate is lower, even vegetated roofs will behave like a bare soil surface. For this solution to combat urban heat islands to be effective, it would be necessary to irrigate to make way for another type of vegetation. But adding an irrigation system is costly and technically complicated, and seems unnecessary in 2020 in climates that are still humid. This is why, in India, non-irrigated green roofs are only a short-term adaptation solution. This is known as maladaptation: the solution loses its effectiveness over time.

THE FOLLOWING TABLE IS JUST AN EXAMPLE OF HOW STUDENTS CAN FILL IT.

SOLUTION Solar Thermal Collectors on roofs

			SYNERGIES BETWEEN ADAPTATION AND MITIGATION
SCALE TO ACTION	☑ Individual	☑ City/Country	
HELPS TO LIMIT	**IN 2020** ☑ Urban Heat Island Effect (adaptation)		☑ Yes
	BY 2100 ☑ Urban Heat Island Effect (adaptation)	☑ Global warming (mitigation)	☐ No

SDGS ACHIEVED THROUGH THIS SOLUTION

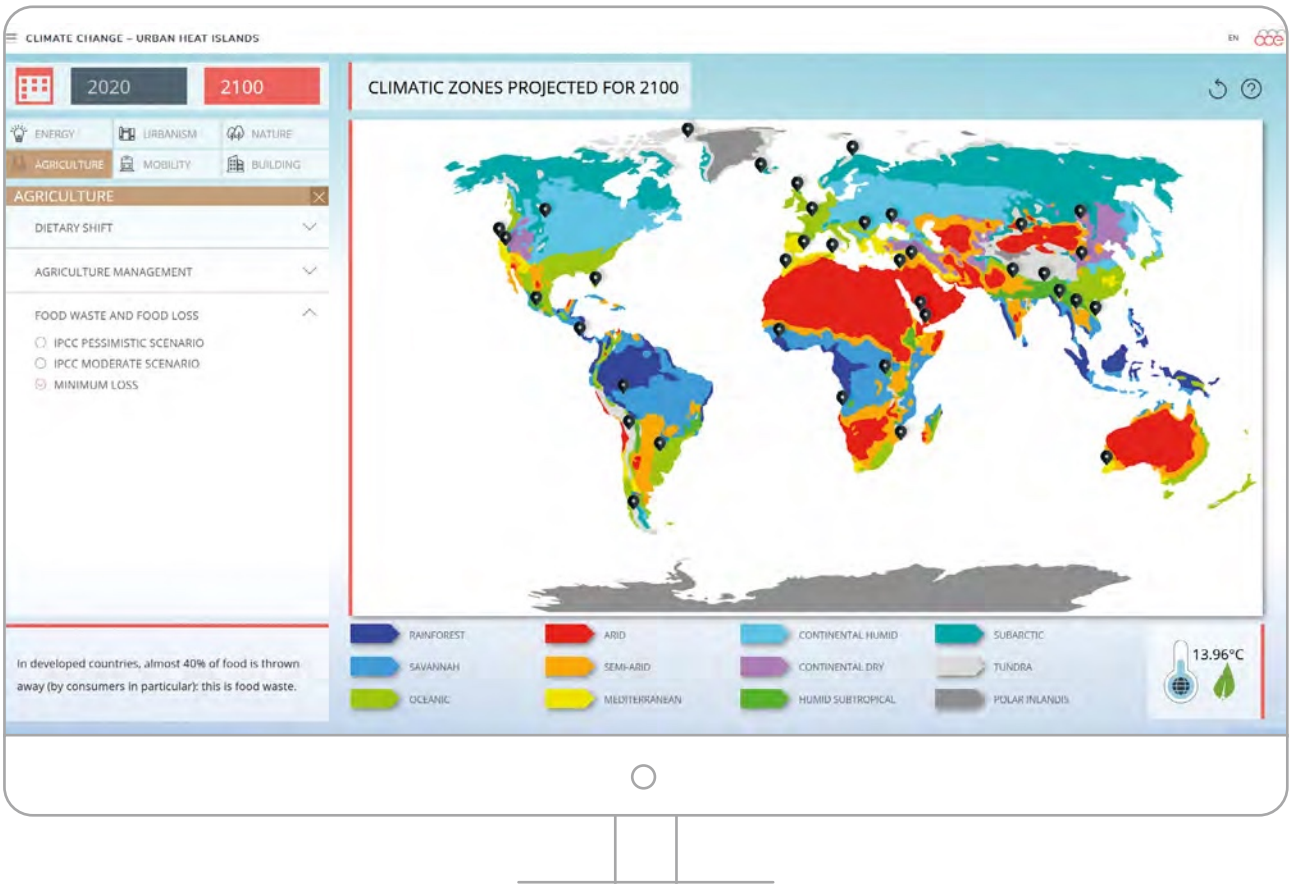
SDG N°: 7 — **TITLE:** Affordable and clean energy

SDG N°: 11 — **TITLE:** Sustainable cities and communities

SDG N°: .....

TITLE: .....

SCREENSHOTS OF THE MULTIMEDIA ANIMATION ON THE URBAN HEAT ISLAND.



Here, students are looking at a world climate map in 2100 and the average global temperature (13.96°C). They have chosen a range of mitigation solutions (including limited food waste and loss, as well as solutions in other sectors). Here we see the climate projection therefore: they have succeeded in limiting global warming by the end of the century to well below +1.5°C (the Paris Agreement has been reached: the little logo is green).

Moradabad, 2020. Here, students see an Indian city, Moradabad. They have chosen to plant the roofs to combat the urban heat island effect (adaptation solution: 'Green and Dry roofs').

Moradabad, 2100. Now, students see the result of the same adaptation solution in this city at the end of the century. They can see that planting green, dry roofs to combat the urban heat island effect is far less effective.

WRAP-UP 20 MIN

To conclude this activity, students can go to the 'Conclusion' part of the animation by clicking on the paper-like icon on the top right corner of the screen (it appears after your second visit to the global map). It will help them summarise what they have learned i.e.

1) Some solutions can be implemented worldwide to limit global warming, it will require **greater efforts in all sectors and at all levels** (individual and city/country) but we can still manage to respect the upper limit of the Paris Agreement.

2) **Cooling solutions can be implemented** at a local level in 2020 to reduce the UHI effect in the short term; carefully selecting these solutions and modelling their efficiency in the future will help avoid maladaptations. In addition, some of these local solutions can also help reduce global warming by 2100: this is called 'synergy'.

BACKGROUND FOR TEACHERS

In this session, there are several learning objectives for students that encompass different scientific notions:

Without any **mitigation solutions,** the global temperature on Earth will continue to rise above the limit set by the Paris Agreement in 2015.
During the COP21 in 2015, 195 countries agreed to limit global warming below +1.5°C. The only way to stay below this limit is to reduce our greenhouse gases emissions and reach net-zero CO_2 emissions by 2050.

The **urban heat island effect (UHI) corresponds to a positive temperature anomaly** measured in urban areas compared to the surrounding rural areas.
This UHI effect corresponds to higher temperatures in urban areas compared to outlying rural ones. It mostly results from the higher population density that influences the heat production by human activities, and from the soil artificialisation that limits the vegetation cover. The UHI effect is independent of global warming, one of the first occurrences was in 1820 when it was discovered by Luke Howard in London. However, even if not directly related, global warming amplifies the UHI effect by increasing the global temperature and aggravating the dangerousness caused by the extra heat in cities. Since the urban population is expected to double by the end of the century, cooling solutions must be implemented to dampen the UHI. Yet, because of the complexity of the urban geometry at local, meso, and large scale, models need to be run to come up with projections on the efficiency of these aforementioned solutions.

The implementation of **adaptation solutions today can reduce the UHI effect.**
Adaptation solutions aim to reduce the impact of the UHI effect on population in urban areas and to cool cities by reducing the emission and/or the trap of heat (ex: planting trees, cool/green roofs, cooling centres, switching to electric transports, changing the way of planning and designing built environment, incorporation of vegetation, and so on.)

The implementation of **solutions to address the UHI effect can also limit the temperature increase by the end of the century,** we talk about **synergies.**
Adaptation solutions implemented to face the issue of the UHI effect in cities at a short time scale and at a local level can also limit the temperature increase in surrounding areas by 2100. These adaptation solutions are therefore also considered as mitigation solutions, in this case we can talk about synergies between adaptation and mitigation solutions.

Some solutions that are implemented today for their efficiency can turn out to be less or no longer efficient in the future, we talk about **maladaptation.**
Typically, green solutions (relying on the greening of artificial surfaces and/or the planting of trees) are highly dependent on the local climate. Not all tree essences will be able to survive future conditions if climate change modifies too deeply the local climate. As such, all cooling conditions should be assessed regarding their efficiency in the actual current climate **and** their potential efficiency in the plausible future climate.

The UHI effect issue is tightly connected to some Sustainable Development Goals (SDGs), and some solutions to face the UHI effect are in line with the achievement of these SDGs.
In 2015, United Nations members adopted 17 Sustainable Development Goals (SDGs) to take action in a global partnership aiming to end poverty, to improve health and education, to reduce inequality, etc. while also taking actions to face climate change. Some actions to reduce the UHI effect also follow some of the SDGs: e.g. encouraging vegetarian diet is in line with SDG 2 (zero hunger) and SDG 3 (good health and well-being); encouraging public transport development is in line with SDG 10 (reduced inequalities) and SDG 11 (sustainable cities and communities).

TO GO FURTHER (OPTIONAL)

The animation represents at a global scale the evolution of climate zones between now and in 2100, according to various scenarios.

You can work with your students on a specific activity on how the changes in climate zones may affect various ecosystems. For this, you may get inspired by activities from OCE's handbook (see lesson C2 or C4 in the 'The climate in our hands' series 'Climate Change and Land').

Make the students associate each climate zones with local adapted plants, animals species but also local human populations.

Ask them to reflect on the effect of such climate change, to evaluate the impact for human populations and for ecosystems.

WORKSHEET 8.1

A SCENARIO FOR MY OWN CITY

→ Fill in these tables to recap the different solutions you implemented in the city of your choice in order to reduce the urban heat island (UHI) effect and/or global warming by 2100. The implementation of solutions to face the UHI effect can also limit the temperature increase by the end of the century, we talk about synergies (like 'killing two birds with one stone'). Tick the 'synergies' box if this is the case. Finally, indicate the SDGs achieved through the implementation of this solution.

SOLUTION .....

			SYNERGIES BETWEEN ADAPTATION AND MITIGATION
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SOLUTION .....

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LIST OF THE 17 SUSTAINABLE DEVELOPMENT GOALS (SDGs)

The fight against climate change is one aspect of Sustainable Development.

Approved in 2015 by the 193 member states of the United Nations, the 2030 Agenda for Sustainable Development sets targets to address international societal challenges.

These include the 17 Sustainable Development Goals (SDGs), which aim to ensure an ecological and inclusive transition while eradicating poverty and inequality.

The fight against climate change is specifically covered by SDG 13. The other SDGs all encourage the implementation of actions that will also contribute to the fight against climate change, with the aim of transforming society as a whole.

Reduce the vulnerability of the poorest populations to the consequences of climate change.

Develop low-carbon agriculture that is resilient to climate hazards to ensure food security.

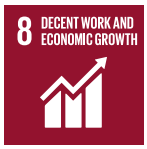
Reduce the spread of vector-borne diseases and those caused by pollution.

Introduce climate issues into the educational curricula of future generations.

Promote the role of women in the fight against climate change and involve them in local political decision-making.

Reduce impacts on sanitation services and threats to water resources.

Promote moderation, energy efficiency and the development of renewable energy.



Begin the transition to a low-carbon economy based on sustainable growth and job creation.

Promote industrial transformation through low-carbon technological innovation.

Include equity and justice in the fight against dimate change.

Promote the development of low-carbon, resilient cities that encourage the use of public transport.

Adopt modest consumption habits and promote a climate-friendly circular economy.

Take urgent action to combat climate change and its consequences.

Protect the oceans to strengthen their role as carbon sinks and dimate regulators.

Preserve forest ecosystems and their biodiversity and increase soil carbon storage.

Mitigate climate change to reduce the number of climate refugees and curb geopolitical tensions.

Mobilize governments, businesses and civil society to achieve the objectives of the Paris Climate Agreement.