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Learning to Chill: The Role of Design Schools and Professional Training to Improve Urban Climate and Urban Metabolism

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Abstract: The increased frequency of heat-related mortality and morbidity in urban environments indicates the importance of urban climate studies. As most of the world's population lives in cities, the education of designers, planners and policy makers is crucial to promote urban sustainability This paper, firstly, focuses on the different factors causing the urban heat islands in large cities. Secondly, it considers how these factors are reflected in higher education programmes. Examples are shown from courses in UK higher education, explaining the common software tools used for simulating urban spaces, and student field measurements are drawn on to illustrate how urban climate studies are included in higher education curricula. Urban metabolism is used to conceptualise the main approach to systemic resource-use assessments and as a holistic framework to investigate the main drivers of the urban heat island phenomenon. To sum up, this paper reflects on the importance of training climatically-aware graduates from design schools.

Keywords: Design schools; urban heat islands; surface properties; material flow analysis; resource management; urban metabolism

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1. Introduction

City centres have higher air temperatures than their surrounding areas. This is called the urban heat island (UHI) phenomenon [1–3]. Luke Howard (1772–1864) was probably the first scholar who recognised the temperature and climatic differences between city centres and their corresponding suburbs (see [4] for his meteorological observations in London). The urban heat islands are more evident during the night (after the sunset), and during the summer-time. Several studies have shown that large cities like Los Angeles (CA, USA) and Tokyo (Japan) have higher degrees of the UHI compared to smaller cities [5]. The UHIs can affect cities and citizens in three ways:

(a) Heat stress and thermal discomfort

Urban heat islands in cities affect activities in urban open spaces. If urban spaces are not thermally comfortable for pedestrians, they will not do outdoor activities. Besides the social and mental problems associated with this phenomenon, people will be encouraged to use their personal vehicles for commuting. This will add more heat to the urban environments.

Thermal comfort is defined as: "*Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment*" [6]. Several factors affect human thermal comfort like air temperature, relative humidity, wind speed, solar radiation, our metabolism, and the amount of clothing that we wear. Some studies have shown that the most important factor affecting human thermal comfort is the mean radiant temperature [7–10]. It is suggested to reduce the mean radiant temperature in summer-time to avoid thermal discomfort. To reduce mean radiant temperature, the physical properties of the built environment play important roles. These could refer to the building and urban shapes, materials used and other factors. During a summer heatwave in Europe in 2003, thousands of heat-related mortalities occurred, mostly in France [11]. Design schools can use these experiences to improve the thermal conditions of the cities. For example, where it is not possible to change the urban morphology or materials, using street trees to provide more shading for pedestrians is an effective way to improve thermal comfort in open spaces [12,13].

(b) Higher energy use

Higher air temperatures in cities increase the air conditioning and cooling energy use of buildings [14,15]. This happens during the peak hot hours and increases the energy demand from power plants. This additional demand adds up more pollution and heat to cities. As an example, a study in the US showed that for each 1 °C higher city temperature, 2%–4% more electricity is needed during the hot hours in summer [16]. Therefore, if cities become cooler, lower pressure will be on the grids and less pollution will be emitted to the atmosphere. Moreover, the ongoing global warming increases the energy use of cities. Several studies have predicted how energy demand will change in the future. For instance, Tokyo as a metropolitan area would need 26% more electricity by 2030 [17]. Therefore, cities need to prepare themselves for the consequences of current and future climate changes.

(c) The need for a holistic approach to urban flows

Mitigating the resource intensity of cities is nowadays ubiquitously recognised as a key challenge in the short to the long term, across engineering, environmental and social science research as well as by design professionals. This challenge has recently received increased attention due to predicted urban population growth [18] and updated projections of the effects of climate change on human health and wellbeing [19]. Buildings are responsible of nearly half the whole amount of energy consumed at the national level. For example, the International Energy Agency reports that in the UK buildings consume 47% of the energy, followed by transportation (34%), and industry (19%) (2015 data). Carbon emissions and waste-heat rejections in the atmosphere are direct consequences of the burning of fossil fuels. Anthropogenic heat released from the combustion of fuels through transportation, industries, and the energy used by buildings makes cities warmer than their suburbs. Urban metabolism (UM) provides a holistic approach to investigate drivers of resource demand in cities through quantification of energy, water, and materials flows as well as rejected waste and emissions [20]. Beside energy inputs to fulfil electricity and heating demand, an UM approach can be particularly helpful for understanding drivers of waste heat or anthropogenic heat that increase UHI in cities as well as the carbon emissions (UM outputs) associated with energy usage. The popularity of UM assessment methods reflects an increasing need for considering the whole spectrum of input and output flows in cities to achieve integrated resource management and counter the negative effects of a growing resource demand such as the UHI effect [21].

To clarify the main reasons behind the UHI phenomenon, we shall seek the urban characteristics that develop higher air temperatures as well as the UM drivers that exacerbate energy demand in cities. This paper will review two main reasons and the urban metabolism approach to tackle the UHI phenomenon in a systemic fashion. Subsequently, the role of university (higher) education and of training programmes for professionals in fostering UHI knowledge will be discussed.

2. Causes of the Urban Heat Islands (UHIs), and the Role of Design Schools

2.1. Building and Urban Climate Design

The shape of buildings and cities can affect their solar absorption [1]. Compact urban canyons (with narrow streets and less open spaces) tend to exchange less heat with their environments. Heat in urban canyons could have other sources like the waste heat from buildings or vehicles. In contrast, suburbs are more open to the sky. This characteristic is defined as the sky view factor (SVF). SVF ranges from 0 (completely blocked) to 1 (completely open to the sky). With higher SVF, heat could dissipate easier in cities [22,23]. Furthermore, ventilation (that can cool the urban spaces and people) is more limited in city centres than suburbs [24,25].

Building shape and urban morphology are taught in design schools where architecture engineering, landscape design or urban design programmes are offered. Related courses are covered in both design studios and theory (seminar) courses. A number of universities in the UK offer building and urban physics courses that enhance students with energy efficiency and urban climate design knowledge. These courses can empower students by learning the consequence of their design decisions.

Figure 1 shows a field campaign by students as part of a Master module in Coventry University (UK). This module is Construction Technology and Environmental Design for the Master of Architecture programme with the expectation that students will reflect the outcome of this module in their design module. One of the focuses of this module, which contained 25% of the final mark, was to elevate the students' understanding about urban climate and urban design. For this reason, students were assisted by their tutors to undertake a real-life project and a group activity assessing the pedestrians' thermal comfort in the different zones across the city centre of Coventry (UK). The aim was to select a populous site where thermal comfort was very important. The following four steps followed to make sure that students benefit from this this part of the study:

1. Preparation stage: at this stage students were prepared for this study by having a comprehensive lecture about outdoor thermal comfort. Following that, a workshop was run focusing on how to use the survey tools. At this workshop, students became familiar with using the equipment, questionnaire and ethical procedure in data collection.
2. Survey stage: at this stage, students were divided in three groups, and were sent out to the allocated zones to collect data. Each group was responsible for collecting environmental factors (i.e., air temperature, mean radiant temperature, air velocity, relative humidity) and pedestrian thermal perception in two zones using a prepared questionnaire by tutors (see Table A1 as Appendix A). Students were also asked to take thermal photos with a thermal camera from different locations in the zones that are paved with different materials. Solar radiation was also measured to have a better understating on how the solar intensity influences a microclimate, and consequently pedestrian thermal perception.
3. Analysing stage: at this stage students were trained to how to transfer and analysis the collected data using Excel and SPSS, and also interpreting thermal photos. Students were assisted to analyse thermal photos by their tutor. To undertake the comprehensive analysis, students were divided into small groups of three and each group was responsible to focus on one factor that influence thermal comfort such as age, behaviour, activities, etc., and support their findings by looking at the previous related research.
4. Reporting stage: at this stage, students were asked to deliver a full report of their findings about the outcome of this survey and present it as a group work as one of the outcomes of this module on the submission day. Student were asked to highlight what was the relation of the outcome of this survey to urban design and also in their design module.

This research which was carried out by students, and the support of their tutors were appreciated by the external examiner as a suitable approach to engage students with a real-life project, introducing them to the research domain and its connection with a design project. Students were also pleased with this survey and gave positive feedback to the tutors about their depth of understanding and the principles of urban climate design.

Figure 1. An example of a student project to explore outdoor thermal comfort. Master of architecture students used questionnaires and data loggers in the city centre of Coventry, UK.

Building energy simulation in some design schools (like University College London (UCL), and the University of Salford) are taught to support students with their early design ideas. By simulating a building (or blocks of buildings), students can estimate the energy required for the heating, cooling, lighting, and air conditioning of their design projects. Table 1 shows the simulation tools used for building energy modelling. The input data for these tools are:

- the local weather data: this is required for the tools to run the simulations for a specific site and climate.
- the physical model (of a building or blocks of buildings). This normally includes the physical objects in the simulation domain, and the materials used in the building(s) and in the surrounding urban environments.

Table 1. Common simulation tools taught in design schools in the UK.

Site Analysis	**Climate Consultant**
Heating and cooling	Revit, DesignBuilder, IES-VE, Green Building Studio, ESP-r
Lighting	Velux, Radiance, Daysim, Dialux, Calculux
Ventilation	TRNSYS, Fluent, FloVent
Thermal comfort	ENVI-met, RayMan

The outputs of these tools are mostly the combination of the physical domain with the climatic factors (or illumination results for lighting simulations).

Another reason for the development of the urban heat islands is the geographical location of cities, and their interaction with their surroundings. Cities close to the coastlines of oceans or seas have the benefit of cool breezes [3,26]. Moreover, heat in cities located in higher elevations can be dissipated easier than in cities in canyons. These concepts are normally covered in urban and regional planning studies (and barely in design schools).

2.2. Urban Surface Materials and Natural Elements

Most of the man-made (artificial) materials used in urban spaces have low solar reflectivity (i.e., albedo), such as dark asphalt and concrete. These materials absorb solar radiation during the day [27,28], and store energy in urban environments that leads to higher UHI intensity [29,30]. With the vast amount of high albedo materials in highways, concrete pavements and brick buildings, heat is accumulated in cities; thus, suburbs will be cooler than cities. In fact, asphalt pavements and buildings absorb heat during the day, and release it back to the urban environment during the night, causing higher UHI intensity during the night. Natural surfaces (like grasslands and permeable surfaces) reflect their absorbed solar radiation much faster than man made materials. With the ongoing impacts of global warming, policy makers encourage urban and landscape designers to use high albedo materials in their design projects [31]. Figure 2 shows the dark urban surfaces in Manchester, UK- latitude 53.48°N- (left panel) versus Santorini, Greece- latitude 36.39°N- (right panel). As this figure shows, traditional buildings in hotter climates were built and covered with high albedo materials like plaster. While the UHI in Manchester was 2.3 °C in summer 2018 (meaning that the city centre of Manchester was 2.3 °C hotter than its surrounding) [32], Akbari et al. [33] showed that Santorini is cooler than its surroundings.

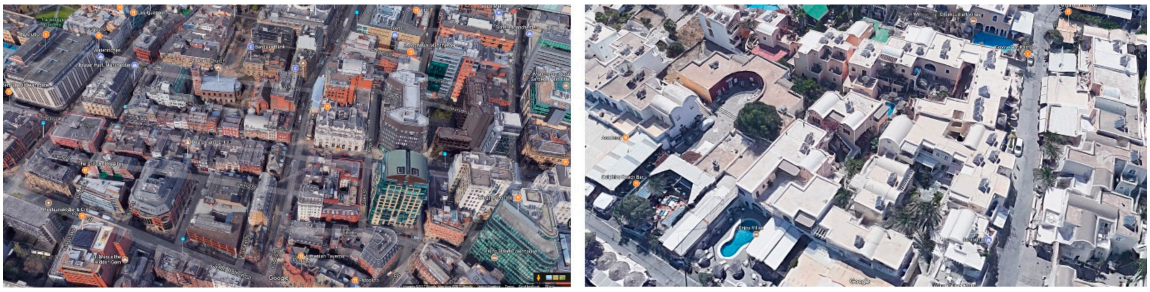

Figure 2. Urban surfaces in Manchester (**left**) versus Santorini (**right**). Images are from Google Earth.

In addition, most of the man-made materials are impervious (like asphalt and concrete). As one of the main drivers of the UHIs, this characteristic of some urban materials (imperviousness) leads to less evaporation in cities compared to suburbs. Several studies have shown the UHI intensity is closely related to the imperviousness of the surfaces [30,34].

Vegetation and water bodies are replaced with buildings and roads in cities. Vegetation can reduce air temperatures in urban environments with their shading and evapo-transpiration effects [35–37]. Transpiration needs energy, and trees take it from their surrounding environments. The combination of transpiration from the vegetation, and evaporation from the soil forms the evapotranspiration effect. The presence of vegetation in cities is measured through different indices like the Normalised Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), and Fraction of green Vegetation Cover (F-Cover). Vegetation in cities could be used as green roofs and walls, urban parks and street trees. Figure 3 demonstrates the contrast between the natural environment that is green, and the man-made environment in the city of Portland (OR). The city is covered with dark materials like asphalt and concrete which are known as impervious materials.

Figure 3. Downtown Portland (OR, USA). The contrast between the nature and the city. Image from Google Earth.

The impact of building and urban surfaces on energy use and the urban climate is taught in building and urban physics courses in design schools. It is worth highlighting that this topic is extensively taught in mechanical and environmental engineering courses. For example, UCL offers these modules in their MSc of Architecture Engineering programme: (a) Building Physics and Energy; (b) Urban Physics, and (c) Environmentally Responsible Building Systems. Design schools are becoming more aware of the role of early design decisions on the long-term impact of surface properties on the local and urban climates [38–40]. Building and urban designers can decide what man-made materials will separate indoor environments from outdoor; and what will cover urban spaces to provide a comfortable environment for pedestrians [41].

Urban and microclimate modelling through simulation tools are being introduced more often in the curriculum of design schools. A main reason for this is the recent progress in developing user-friendly software packages like ENVI-met [42,43], RayMan [44,45], SOLWEIG [46,47], and Revit for designers.

2.3. Environmental Issues in Urban Spaces

According to World Health Organisation, seven million premature mortalities globally are associated with air pollution (each year) [48]. The UHIs can increase air pollution level in city centres [49]. In fact, some new pollutants (secondary pollutants, e.g., ozone) develop where excess heat and ultraviolet (UV) radiation interact with primary pollutants [50]. Li et al., [51] did a study on the temporal variation of air pollution in Berlin. They showed that urban aerosol pollution island is larger during daytime. They also showed that the concentrations of air pollution on cold days are higher due to the lower height of urban boundary layer (the inversion phenomenon). Several studies have shown that proper ventilation can reduce air pollution levels [52,53]. Several studies investigated how plants can ease ventilation in urban canyons; or trap the dispersion of different pollutants [54–56]. Design schools could use these principles to improve urban air quality. Some cities have certain rules for the shading impact of buildings in highly dense urban areas; however, urban ventilation that can affect air pollution level is neglected in design schools.

It is worth mentioning that the UHIs can affect water use, and phenology. A study in Phoenix (AZ) shows that higher air temperatures due to the UHI may significantly increase water use [57]. They found out that by increasing 1 °F (0.6 °C), water use in a single-family house would increase by 1300 litres per month. Furthermore, Meng et al., [58] studied the impact of the UHIs on spring phenology in 85 cities in the US. They showed that by the increase of global warming in the conterminous United States, spring phenology occurs earlier for plants.

To wrap up, some environmental issues in urban spaces like air pollution, water usage, and phenology are neglected in design schools. One of the reasons for this could be the lack of quantifying these issues for urban dwellers.

3. Urban Metabolism Approach

3.1. Understanding Drivers of Energy Inputs and Outputs

Resource consumption patterns in cities have a substantial impact on the UHI effect. This impact can be expressed in terms of both input and output flows that sustain the city's metabolism. UM outputs, such as waste heat and the carbon emissions resulting from the burning of fossil fuels, are among the main causes exacerbating the UHI effect. As mentioned in the introduction, the magnitude of these output flows depend on the quantity of energy inputs to fulfil electricity, heating, and transportation demand. The Eurostat Economy-Wide Material Flow Analysis (EW-MFA) [59] is nowadays the most used mass balance method for UM assessments [60]. It has been initially developed for material flow accounting at the national level and then applied at the city scale since the work of Hammer and colleagues [61]. The EW-MFA model is based on a breakdown of the following main resource-use assessment categories: Inputs (including "Local Sourcing" and "Imports" as sub-categories); Internal Stock and Cycling of flows (including "Material Accumulation to Stock" and "Recycling"); and Outputs (including "Exports" and "Outputs to Nature") (Figure 4).

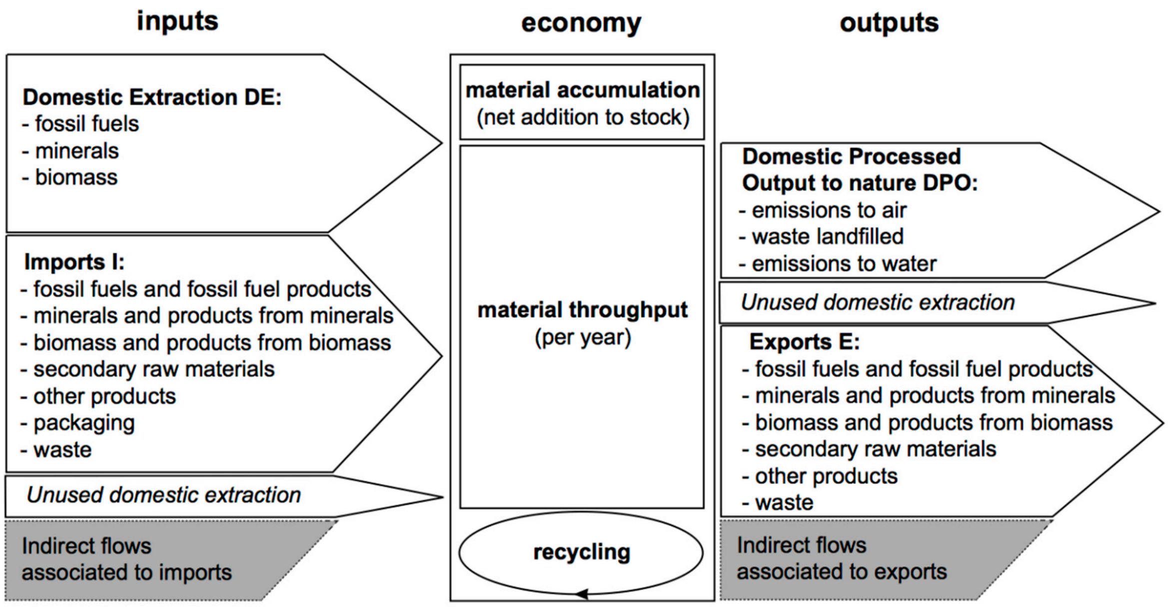

Figure 4. Eurostat's Economy-Wide Material Flow Analysis (EW-MFA) with the main Inputs, Internal Stock/Cycling, and Outputs categories. Adapted from Eurostat, 2001 [59].

Waste heat is not explicitly mentioned in the original version of the model proposed by Eurostat but logically falling within the "Output to Nature" category (emissions to air) alongside atmospheric carbon emissions. Subsequent works have led to an extended framework for flow accounting based on the EW-MFA model in which waste-heat flows are explicitly mentioned [62] (in red in Figure 5). The framework aimed to express the potential of UM methods to address a wider spectrum of urban sustainability issues including the UHI effect.

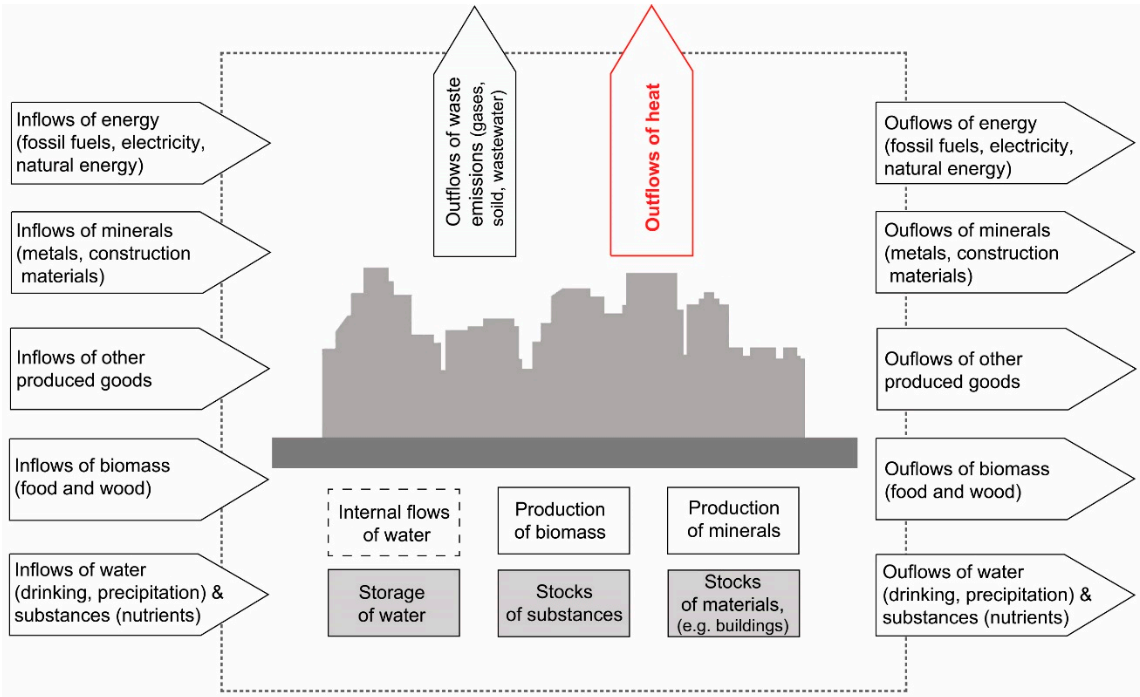

Figure 5. Extended EW-MFA framework including heat outflows among other emissions to air. Adapted from Kennedy and Hoornweg, 2012 [62].

From a UM perspective, fossil fuels consumed in the building, transportation and industry sectors represent a high share of the total input flows of urban systems especially for big cities or megacities; hence, energy flows have been widely studied to understand drivers of sustainable urbanisation and wellbeing in cities [63]. Moreover, growth in building and transportation energy is significantly correlated with growth in gross domestic product (GDP) [64]. A recent EW-MFA of the city of Amsterdam for the year 2012, showed that fossil fuel imports represent more than 58% of all input flows sourced outside the municipality boundary (approximately 48,000 kt out of total 82,322 kt for all imports) [65]. In terms of relative share of electricity used in each sector, a study of the energy metabolism of 27 world megacities showed that the residential and commercial/institutional sectors are the main drivers for electricity consumption, followed by the industrial and the transportation sectors [66]. Applying an UM approach to analyse drivers of energy flows and associated exhaust gases (e.g., carbon emissions and waste-heat rejections) can help understand the causes of the UHI as well as foster strategies to optimise heat fluxes and offset carbon sequestration in an integrated way.

3.2. *The Role of Urban Metabolism (UM) Training for Planning and Design Professionals*

The rise of UM methods in architecture, urban planning and design results from increasing consensus that a holistic approach to resource management, and a focus on energy flows and carbon cycles more particularly, can advance designers' understanding of UHI drivers. However, the educational background of practitioners can create barriers to the uptake of UM assessment methods in professional practice. This is due to the lack of structural integration of UM assessment methods (e.g., EW-MFA) in Architecture, Planning and Design teaching curricula. In general, in Europe UM methods are mostly taught in Industrial Ecology and Engineering Master's programmes (e.g., The Netherlands, Denmark, Norway, Sweden, UK). The teaching of basic knowledge of the UM concept and approach for urban and architectural design students are mostly confined to summer schools of limited durations (one to two weeks on average) which only scratch the surface of the wide and complex UM field. Some Urban Planning and Urban Studies Master's programmes in Europe (e.g., France, Belgium, The Netherlands) offer optional modules illustrating the basic principles of mass-balance methods and resource-flow accounting tools but are generally taught at late stages of the curriculum (e.g., professional projects) or even at post-Master's levels and mainly target a professional (rather than student) audience.

The poor integration of UM teaching to date in architectural and urban design curricula has resulted in architecture and design professionals' limited familiarity and acquaintance with UM knowledge and tools. Consequently, in real-world practice, the incorporation of UM thinking in design at both the building and urban scale is still in its infancy [67]. In some cases, the contribution of designers and planners to tackling UHI challenges can be limited to end-of-pipe solutions focusing on ex-post adaptation of urban spaces and their use for tackling the consequences of UHI. Instead, optimising design solutions since the early stages of the design process can contribute to preventing the UHI phenomenon through the mitigation of its causes. To face UHI challenges in practice, UM is nowadays gaining popularity as an emerging topic in training programmes for architects and urban designers such as continuing education. Such programmes respond to the need for practitioners to be better equipped for tackling resource-intensity challenges and better meet the industry demand for future climate-proof construction. This includes, for example, energy certification for buildings or quality certification standards for construction materials and structures including embodied carbon. At the urban scale, a growing challenge consists of the application of energy and carbon balance methods in optimised resource management strategies and urban planning [68,69].

Recent research conducted in Helsinki, Finland, on knowledge-transfer processes in UM studies showed a series of barriers that can hamper the uptake of UM study results and the use of UM data in urban planning [67]. Interviews conducted with urban planning practitioners having participated in an UM study of a neighbourhood in Helsinki showed that consideration of planners' educational background since the early stages of the research was essential for the successful uptake of UM data. The research also showed that no knowledge prerequisites should be given for granted in science–practice collaboration. Education received by planners (e.g., in Finland mostly within architecture programmes) can influence the way in which environmental indicators are chosen and weighted in a study (e.g., albedo of building materials, rate of vegetated/sealed surfaces at neighbourhood and city scales exacerbating the UHI phenomenon), as well as the interpretation of research data and results. Moreover, the cost of UM training/continuing education for staff in public authority services (infrastructure, urban planning, green spaces and facilities) should be factored in since early stages of project design, in order to bridge the knowledge gaps influencing decision on UM assessment methods and the interpretation of environmental data and results. As observed in other studies, the increasing compartmentalisation of public services and outsourcing of expertise to consultancies often result in additional costs for public authorities which could be abated through more structural integration of continuing education programmes in employees' work schedules [70]. If the need for transdisciplinary collaboration between scientists and planning/design professionals is ubiquitously expressed in research and practice, it is crucial to set the conditions for practitioners to increase their knowledge of UM assessments by providing them with proper training opportunities. Information and data included in UM frameworks are increasing in scope and complexity, also due to the growing availability of governmental data platforms and open-access data from the independent profit and non-profit entities to monitor and (in some cases) map resource use in cities [71]. This increasing complexity requires a broad spectrum of technical competencies by practitioners and policy makers, including increased urban analytics skills and becoming acquainted with the digitalisation of data management processes.

Last but not least, the interest in effective science-practice communication is likely to grow in the future, in response to the increasing demand for more participative research methods by funding agencies worldwide [72]. UM training and continuing education programmes for professionals can play a central role in bridging science–practice communication gaps in order to better face present and future challenges caused by the UHI phenomenon and associated risks for human health and wellbeing. For example, a growing portfolio of studies highlights the added value of integrating tacit and technical knowledge from professional and industry stakeholders into collaborative research processes on urban sustainability issues [67,70,72]. This evidence base shows that the incorporation of different communities of knowledge and practice into the same problem-based research can foster a better understanding of the drivers and impacts of the studied situation/problem, as well as facilitate the delivery of effective guidance for strategies and solutions at the local level [73]. In urban metabolism research, the rising popularity of participatory methods demonstrates an increasing interest from all sides in bridging the science–practice communication gap in order to better face sustainability challenges and translate targets into actionable measures [74]. Additionally, increased access to UM training programmes by professionals can help address major issues in collaborative research and knowledge-transfer approaches as identified in previous works [67]. These include, among others, clear identification of the expected impacts of the research projects in real-world practice (considering expectations on both sides of the knowledge transfer) and explicit demarcation of practitioners' roles in the feedback loop since early stages of research projects. Finally, some studies go as far as challenging the role of UM scientists as the sole "experts" and providers of reliable knowledge of urban metabolic flows and associated governance systems; they suggest that UM scientists should possibly aim at empowering local private and public stakeholders through enhanced decision-support processes [75].

4. Conclusions

Higher education can play a significant role in preparing new generations of designers and planners to deal with energy and environmental issues. Most of the engineering programmes (e.g., architecture, landscape design, and urbanism) offer sustainability-related courses.

Among different challenges that large cities face, this paper focused on the UHI phenomenon. Different parameters that contribute to this phenomenon were discussed. Furthermore, the role of higher education in addressing these parameters was reviewed with examples.

Design schools mostly focus on building and urban climate design courses that cover building shapes, openings, and energy use. The importance of materials used in building and urban spaces are also taught as one of the main contributors to climate change. These courses are offered in seminar (theory) and design studio classes. Furthermore, simulation tools to model the building energy performance are taught in computer labs. A set of simulation programmes used in UK design schools to model heating cooling and lighting were also reviewed.

Urban metabolism has been discussed as a valuable, holistic method to address the link between the UHI effect, atmospheric emissions, and resource consumption patterns. Knowledge of the UM is key to advancing professional planners' and designers' understanding of UHI drivers as well as to face urban design challenges associated with UHI consequences at both the regional and local scale. However, practitioners' non-specialised background and the limited integration of basic knowledge of the UM concept and assessment methods in architecture and design curricula can be an obstacle to implementing "UM thinking" in real-world resource-use mitigation strategies.

Finally, this paper article discussed a major urban issue, and how design schools reflect on that. As climate change is a global threat, future research could be done on how other higher education programmes (medical schools, social sciences, etc.) educate new graduates to deal with its negative impacts.

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Appendix A

Table A1. Outdoor thermal comfort questionnaire. The aim of this survey is to evaluate thermal conditions of the public spaces in Coventry City Centre. We appreciate your feedback in this evaluation. Please tick the square box where applicable.

Time:	**Location:**

1- Gender Female□ Male□

2- Age □ Age ≤ 30 □ 30 < Age < 60 □ Age ≥60

3- Your main activity for the last 15 min?
□ Seating □ Standing □ Slow walking □ Brisk walking □ Running □ Other . . . . . .

4- Have you checked the today's weather? □Yes □No

5- What is your purpose for being in city centre now? □ Leisure □ Work □ Other . . .

6- Please describe your current thermal sensation:

Very cold	Cold	Cool	SlightlyCool	Comfortable	Slightly Warm	Warm	Hot	Very Hot
□	□	□	□	□	□	□	□	□

7- What are your preferences in regard to meteorological parameters?

Temperature	Higher □	Unchanged □	Lower □
Wind speed	Stronger □	Unchanged □	Weaker □
Humidity	Damper □	Unchanged □	Drier □
Solar radiation	Stronger □	Unchanged □	Weaker □

8- Please describe your overall comfort level: □ Uncomfortable □ Acceptable □ Comfortable

9- What are you wearing right now:

(1) T-shirt (long sleeves) Thin □ Thick□ **(2)** T shirt (short sleeves) Thin □ Thick □
(3) Short or short skirt Thin □ Thick □ **(4)** Trousers or long skirt Thin □ Thick □
(5) Vest □ **(6)** Cardigan □ **(7)** Jacket or coat□

(10) Are you born and raised in the UK Yes □ No □

(11) If no, How do you compare the weather of your home town with Coventry

Colder □ Similar □ Warmer □

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