Envisioning green solutions for reducing the ecological footprint of a university campus

Envisioning green solutions for reducing the ecological footprint of a university campus

Chiara Genta
chiara.genta@polito.it
Interuniversity Department of Regional & Urban Studies and Planning
Politecnico di Torino and Università di Torino
Viale Mattioli, 39 10125, Turin (Italy)
Silvia Favaro
silvia.favaro@polito.it
Interuniversity Department of Regional & Urban Studies and Planning
Politecnico di Torino and Università di Torino
Viale Mattioli, 39 10125, Turin (Italy)
Giulia Sonetti
giulia.sonetti@polito.it
Interuniversity Department of Regional & Urban Studies and Planning
Politecnico di Torino and Università di Torino
Viale Mattioli, 39 10125, Turin (Italy)
Caterina Barioglio
caterina.barioglio@polito.it
Department of Architecture and Design, Politecnico di Torino,
Viale Mattioli, 39 10125, Turin (Italy)
Patrizia Lombardi
patrizia.lombardi@polito.it
Interuniversity Department of Regional & Urban Studies and Planning
Politecnico di Torino and Università di Torino
Viale Mattioli, 39 10125, Turin (Italy)

Abstract.
Purpose: This paper reports strategies toward a green campus project at Politecnico di Torino University, a 33000 students Italian Higher Educational Institution (HEI) and estimate the avoided EF of different scenarios accounted for open spaces.
Design/methodology/approach: A consumption-based study has been developed to analyse the current EF of the main campus site. Data were collected from different departments and administrative units to identify the measure of the pressure exerted by the campus activities on the ecosystem. Then, possible scenarios were accounted for open spaces along five different design layers: energy, water, landscape, food and mobility. Acting on the spaces by means of biophilic design and user-driven design requires complex considerations on university's anticipated future needs as well as a wide-ranging evaluation of the most appropriate pathways forward according to all university stakeholders, far beyond the mere accounting of avoided EF.
Findings: A reduction of the 21% of the current EF can be achieved through the solutions envisaged in the green campus project along the open spaces layers. Moreover, universities have the opportunity to not just improve the sustainability of their facilities, but to also demonstrate how the built environment can be designed to benefit both the environment and the occupants.
Research limitations/implications/Practical implications: The acknowledgement of predicted behavioural change effects is a question left open to further researches on methods and indicators for social impact accounting and reporting in truly sustainable university campuses.
Originality/value: This is the first research that estimates the EF of an Italian HEI. The research represents also an innovative approach integrating the EF reduction scenarios in the design process of the new masterplan of open spaces, trying to identify the connection between environmental impact reduction and improvement in users perception.
Keywords: Ecological Footprint analysis, Higher Education, Sustainability assessment, Green Areas, Research by Design, Biophilic Design.

Paper type: Case study

Introduction

Sustainable urban design, organizational planning, and human factors have all been recognized for their potentially significant roles in facilitating to reduce energy consumption and related environmental impacts (Jenks and Dempsey, 2005; Jabareen, 2006; Goudie, 2018). Higher education institutions (HEIs), with their long development timeframes, centralized administrations, and monitorable populations, are ideal places to study carbon alleviation policies (Ferrer-Balas, Buckland and de Mingo, 2009; Evans *et al.*, 2015; Sonetti, Lombardi and Chelleri, 2016). From a community perspective, campus sustainability as an area of sustainability research has a crucial role to play in expressing the ways in which campus communities are shaping a sustainable vision of the future, reflecting on the visions and ideals they represent and exploring the potential pathways that might realize such a vision (Lozano *et al.*, 2014; Ramos *et al.*, 2015; Sonetti *et al*, 2019). It is a vital area of research considering the significant role of universities in shaping worldviews, training of human capital and generating new knowledge for sustainable development (Disterheft *et al.*, 2014; Leal Filho, Manolas and Pace, 2015). In line with this realization, a number of universities worldwide have been engaged in transforming their campuses to become more sustainability-oriented. Based on past review papers by Lozano et al. (Lozano *et al.*, 2014), areas of transformation include education, research, community outreach, campus operations, assessment and reporting, institutional policy and framework and on-campus experiences (Leal Filho, 2000; Arroyo, 2015; Lombardi and Sonetti, 2017). More recently, there is a trend to use universities as the loci for Living Labs and as a micro-level exemplar for sustainability transitions (Segalàs *et al.*, 2009; Ferrer-Balas *et al.*, 2010; Evans *et al.*, 2015). In spite of this potential, measuring and reporting the progress of carbon reduction initiatives remains in its infancy within higher education (Lozano, 2010). This can be attributed to the view that sustainability reporting is an overly complex endeavour given that results should provide reliable information that enables environmental performance to both be compared with other institutions and tracked through time (Ramos *et al.*, 2015). Indeed, only a few studies around the world have undertaken a comprehensive analysis of a university's carbon footprint (Townsend and Barrett, 2015).

This paper tries to fill this gap by calculating the ecological footprint (EF) of the University Campus of Politecnico di Torino (PoliTO) in Italy adopting the ecological footprint method. As found in many works (Chambers, Simmons and Wackernagel, 2014; Lambrechts and Van Liedekerke, 2014) the EF was shown to be a robust basis for reporting, enabling consistency and comparability in results. The EF results were also presented to university procurement staff who saw them as beneficial for guiding sustainable procurement practices. The EFs are readily acknowledged as a means for measuring campus sustainability (Klein-Banai and Theis, 2013; Larsen *et al.*, 2013), and thus its application here is fit for purpose.

In this study, the authors applied the ecological footprint methodology for estimating a reduction of the total campus EF as envisaged in some design output of the masterplan project (MP) currently undergoing at the PoliTO campus. This has been chosen as a case study since its strategic plan acknowledges since years the pivotal role that higher education institutions and scientific research organizations should play in supporting responsible development, both at global and local levels. With reference to what the Brundtland Commission defined as Sustainable development, as the one "that meets the needs of the present without compromising the ability of future generations to meet their own needs [...]", Politecnico di Torino encouraged several actions for current environmental, economic, and social challenges, to find solutions for reducing inequalities in the benefits distribution, and to protect the planet ensuring identity protection and prosperity for the widest. Also, a large amount of data made available from the living lab, the Masterplan team and the Green team structures allowed a relatively easy data collection phase. Working on real possibilities of changes is believed to be crucial also in terms of educational purposes (Corcoran, Walker and Wals, 2004; Dillon and Reid, 2004; Sipos, Battisti and Grimm, 2008; Baldissara *et al.*, 2014), therefore justifying the focus of this work in the whole context of studies in which it is inserted.

This study is important since it represents a visual and immediate tool to help to actuate campus sustainability in several ways. First of all, in the wider National Network of Italian Sustainable Universities (RUS), the development of a common, nationally applicable EF calculation framework is necessary to achieve many of the goals and objectives of sustainable campuses. Transformation hypothesis, both spatial and strategic, communicated via an EF model, would help sustainable communities across Italy to:

- Advocate for policy change in the university sector by making the EF relevant and practicable to the decision-making processes on campus.
- Compare sustainability performance across individual campuses using a common methodology and indicator set. This would help campuses that are leading the way towards sustainability to understand how they compare to their colleagues. It would also inspire lagging campuses to take action. Beyond the mere accounting of EF, the data collection phase would help campuses to assess a wide range of different sustainability issues, many of which are not always considered important when campuses work individually to design their assessment scope.
- Build bridges of communication and understanding about campus sustainability amongst faculty, staff and students. These communities tend to have very different realities, concerns, and languages. Building these bridges around sustainability issues requires a tool that is theoretically sound and practically grounded, transparently designed, useful, appropriate, and clear to all campus community users. Problem spatialization, as well as ecological footprint other ICT tools, may allow conflicts to emerge and be discussed easily among different stakeholders (Sonetti, Naboni and Brown, 2018).

The structure of the contribution goes as follows: the Politecnico di Torino case study is presented in par. 2, along with the university's general information and its undergoing masterplan project.
Par. 3 describes the methodology used for calculating the Politecnico di Torino current Ecological Footprint. Par. 4 describes the EF in the business as usual scenario, while in 4.2, a sensitivity analysis shows possible alternatives for reducing the campus EF acting on open spaces along five different design layers: energy, water, landscape, food and mobility. Discussions (par. 5) highlight that a reduction by the 21% of the current EF can be achieved through the solutions envisaged in the MP overarching strategies of open spaces. Conclusions (par. 6) reflect on how acting on open spaces by means of biophilic and user-driven design requires complex considerations far behind the mere accounting of avoided EF. Working on university's anticipated future needs require a wide-ranging evaluation of the most appropriate pathways forward according to all university stakeholders, as done in the current MP, as well as a structured methodology of "research by design" that presents promising development opportunities in university campuses.

Case study: Politecnico di Torino

University general information

The Politecnico di Torino (PoliTO) is organised on a rather wide arrangement in distinct geographical locations with very different features from the architectural, urban and functional points of view. The main site of Corso Duca degli Abruzzi,144000 sqm, opened in November 1958 and was then extended in the 90's with the Cittadella Politecnica. The historic and representative base of PoliTO is in the city: the Valentino Castle, a 17th-century residence of the House of Savoy. It is the main teaching campus for Architecture and Design, with an area of 23000 sqm. The Cittadella Politecnica is a modern complex of 93000 sqm adjacent to the main building, including areas set aside for students, research activities, technological transfers and services and potential expansion area of 75,000 sqm. The newest campus is the Cittadella of Design and of Sustainable Mobility, in an area next to the manufacturing establishment of Mirafiori, the refurbished former FIAT manufacturing facility now mainly devoted to the Automotive degree and Master degree courses. Finally, the Lingotto, located in an old FIAT manufacturing complex, is currently hosting Masters and sites for the national public transport regulation authority.

In 2017, more than 34000 students were distributed along more than 90 courses and 25500 sqm of classrooms. 850000 sqm for research activity is used every day by more than 1700 employees, including 900 teachers and researchers.

PoliTO energy data collection relies on a web-based and open infrastructure (managed via the ARCHIBUS software) and a dedicated officer for energy data analysis. The facility management office collaborates with the living lab manager to match energy data and related square meters, energy source and number of occupants, gathering info both from smart metering disseminated around the campus and from bills by the energy providers and the facilities interventions log. This wiring is used to monitor drinking water consumption, PV panels, electric and thermal energy production and consumption, alongside other variables specific for some control rooms (CO_2 concentration, light, people passages, photocopies, etc). The heart of the monitoring system is the Living Lab, where all data streams are collected from on-site sensors and then processed and analysed. The main aim is to provide decision support for the energy management, but there are also regular requests for research support and various educational initiatives searching for real case studies in problem-based and project-based pedagogical methodologies (Brundiers and Wiek, 2013; Wiek *et al.*, 2014).

The Masterplan project

The Polytechnic of Turin is a community of people, but also a set of spaces de facto promote inter-relationship dynamics. As described in the previous paragraph, those spaces were designed at different times along PoliTO's history, for communities that were very different in number and in needs than the current ones.

Questioning about how do people image the spaces of the Polytechnic of tomorrow, how can the design of classrooms and outdoor areas meet the new requirements of the training and research of the future, to favour interdisciplinary work, technology transfer and knowledge sharing, preserving energy, water and all other natural resources, is of utmost importance.

The masterplan project (MP) aims to outline an answer in a shared, participated and dynamic process. This represented a precious opportunity to collectively discuss strategies (regarding educational, innovation, internationalization, cultural promotion, research) also through their spatial translation.

Moreover, the University Masterplan also had another task: to be an example of sustainable management of an important part of the city.

The sustainability objectives complemented the general direction of the MP from the beginning and rely on the expertise within the Polytechnic and the sustainability policy aiming not only at reducing energy consumption and rationalizing water or waste management but also at contributing to awareness and hands-on towards the sustainable development issues.

A real laboratory has therefore been started – and it is still underway - with the aim of redefining a program that collects and puts into system opportunities and problems, needs and intentions, visions for a "future home" of the University and operational constraints. The challenge was to hold together the transformations from the building to the urban scale, with PoliTO's policies, the missions of teaching, research and knowledge sharing, and also to reconfigure strategies for dialogue and an exchange with local authorities, firms and institutions.

The balance between contingent scenarios and long-term oriented plans is a dimension proper to sustainability. Indeed, the obliged translation of these visions into a complex spatial re-composition made the requests of each group of internal and external stakeholders emerge. To put each stake in a hierarchy is another physiological product of a sustainable process, conducting to a participated and transparent MP in all phases and in all the strategic axes of physical transformations.

Globally, these interventions, sometimes even "microsurgical" in terms of spatial identity and of response to the needs of small communities, aim to plant seeds for a culture of sustainability at all levels, going beyond the mere reduction of energy and resource consumption. The ability to face shocks and the social flexibility in dealing with them could be indeed attributed to a sounder foundation of the community sustaining the transition toward a low carbon campus, as envisaged in the very core of the MP strategy. This has been termed in the larger sustainability literature as 'adaptive governance' (Chaffin *et al.*, 2016) - the evolution of formal and informal institutions to increase the resilience in managing socio-ecological interactions in the face of uncertainty. From the lens of the cyclic process platform, the spatial dimension of the MP provides the informal strengthening of the process, but it has to co-evolve in a way that constructively supports the more formal hardware (spatial) and software (people management) processes to follow through. This ability for adaptive governance is increasingly viewed to be an essential systems condition for long term sustainability transitions (Loorbach, 2007; Westley *et al.*, 2011) - but is currently not often investigated in the campus sustainability literature. Although there have been attempts on theoretical deliberations (Stephens and Graham, 2010; Brammer and Walker, 2011), empirical work at the moment rarely investigate the endurance of these formal and informal processes in the long run, and their co-evolution throughout the campus sustainability and the research-by-design journeys (Roggema, 2009; Roggema, Vermeend and Dobbelsteen, 2012).

Methodology

Ecological footprint (EF) assessment has been used internationally in different types of administrations (private and public authorities, ONGs, HEIs) and at different scale level (individual level, organizations, cities, regions, countries). Universities also analysed their ecological footprints, in order to integrate sustainability into their core business, to submit a sustainability report, to use as a didactic tool with students, to pave the road to new policies. In general, performing an ecological footprint analysis is a way for higher education to 'practice what they preach', to monitor sustainability performance and raise awareness among the university's community (Rees and Wackernagel, 1996; Lambrechts and Van Liedekerke, 2014).

Beyond the eco-efficiency, with a wider breadth, the EF method was developed in the 1990s and it is now quite widespread in the world, despite the fact that it has received many critiques (Munier, 2011). The ecological footprint is indeed not a comprehensive indicator of sustainability since it does not take into account economic and social aspects, and other components, such as the mission and commitments made by the institutions, which today are fundamental. It refers exclusively to the environmental impact, but starting from it, it is possible to obtain a snapshot of the current situation, make forecasts for the future and encourage sustainability. Despite being a complex indicator to calculate, comprising a multiplicity of factors, it turns out to be easy to communicate and understandable to a wider university/city community, thanks to its simple and "tangible" measurement unit. The method used to calculate the EF of Politecnico di Torino (PoliTO) was the componential method, as developed by the Global Footprint Network, based on Rees and Wackernagel theory (1996). In this method, the land used to provide in our daily production and consumption needs is estimated.

In a first step of the analysis, (one month, January 2017) the components necessary to calculate the EF of Polito were selected:

- direct energy use (including the use of heat, natural gas, oil and electricity),
- water (tap water and rainwater),
- mobility (including commuting, travel by air and other service trips),
- waste (recycled and non-recycled),
- food (consumption in campus restaurants and bar) and
- infrastructure (construction of buildings).

In a second step (six months, from February to July 2017), the reference data within this study were defined and collected: the EF is calculated using data of the reference year 2016, at the level of the Corso Duca degli Abruzzi main Campus site and per capita (PoliTO' students, n = 33000). In addition to the EF, also the carbon footprint (CF) has been calculated.

In the third step, in three months (from September to November 2017) the total EF of the PoliTO main site was calculated and sensitive analysis on alternative hypothesis was conducted. The main flows of energy, water, food resources and other assets have been accounted as external sources that are used and processed on campus in the moment of their consumption, and then re-emitted into the environment as waste and greenhouse gas emissions. The calculation methodology was based on the literature review as well as on case studies in other European universities and cities. The calculation was carried out in the six categories listed above, and only in the final phase, they were aggregated in the total area, expressed in global hectares (gha) of ecological footprint. The final figure was eventually divided by the number of students regularly enrolled in PoliTO in 2016. The choice of normalizing the result on students is related to the main function carried out by the university, namely the educational one;

moreover, in this way the result obtained can represent the impact linked to the training of a student and thus be compared with the results of other universities.
The fourth step of this analysis calculated a possible reduction of the total EF is some proposed interventions on the open spaces design as envisaged in the MP could be realised.

The Ecological Footprint (EF) of the Politecnico di Torino

Total EF in the current scenario

The final result was obtained as the sum of the ecological footprints related to the different consumption categories as in Table *1*.

COMPONENT	Ecological Footprint [gha]	% of Total EF	Carbon Footprint [tCO2]	% of Total CF
ENERGY	2495	40,1%	6997	40,4%
Electricity	1810	29,1%	5077	29,3%
Heating	685	11,0%	1920	11,1%
WATER	33	0,5%	93	0,5%
Water use	33	0,5%	93	0,5%
MOBILITY	3071	49,3%	9144	52,7%
Commuting students	2120	34,0%	5946	34,3%
Commuting staff	294	4,7%	1354	7,8%
Work trips	657	10,6%	1844	10,6%
LAND USE	44	0,7%		

Impermeable surfaces	44	0,7%		
WASTE	94	3,7%	639	3,7%
Recycled waste	47	0,8%	131	0,8%
Unsorted waste	181	2,9%	508	2,9%
FOOD	356	5,7%	462	2,7%
Canteen	286	4,6%	382	2,2%
Cafeterias	70	1,1%	80	0,5%
Total for all components	6227	100,0%	17335	100,0%
EF/CF per person (students)	0,19		0,53	

Table 1. *The sum of the ecological footprints related to the different consumption categories at PoliTO.*

Given the uncertainty of the data on mobility and the consequent decision to analyse two extreme scenarios, a "more eco-friendly" and a "less eco-friendly", for the final results an intermediate situation, the one closer to a probable scenario has been presented. The transport category accounts for 40% of student commuting and professors transportation and mission for 10%. As already specified, the ecological footprint is the measure of the pressure exerted by human activities on the ecosystem, more precisely it is the measure of the biologically productive surface necessary to produce all the resources consumed by an individual or a community, and to absorb the waste generated by them in a specific period of time, conventionally one year. To do so, each category of consumption is associated with one or more corresponding land types, depending on the type of products that the latter can generate.

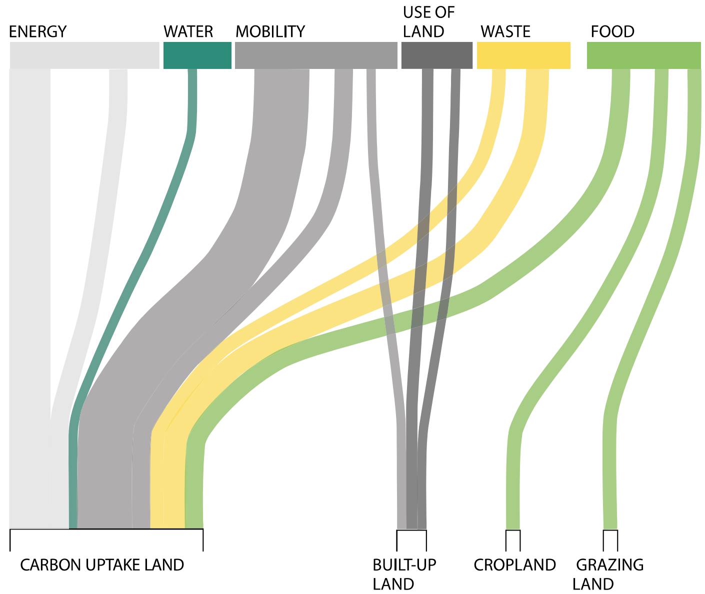

Figure 1: Types of land corresponding to the different consumption categories of the overall ecological footprint

Figure 1, therefore, represents the types of land corresponding to the different consumption categories. The overall ecological footprint is mostly composed (usually about 85%) by the surface associated with the carbon footprint of a process and the remaining part consists of built-up area, agricultural land and pasture.

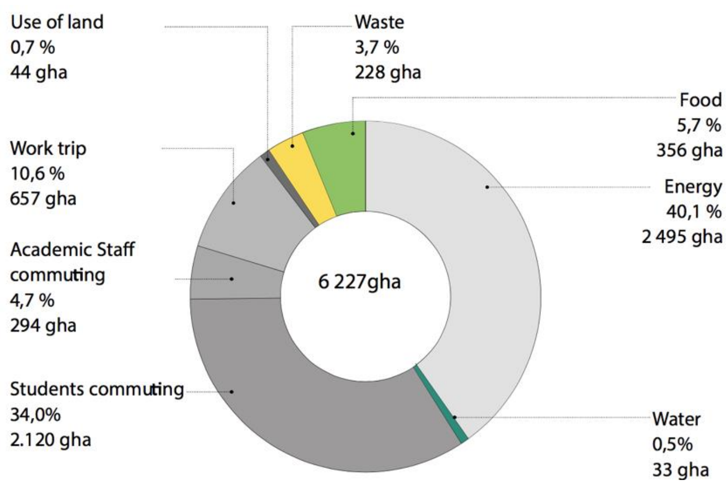

Figure 2. Pie chart of the ecological footprints related to the different consumption categories at PoliTO.

From the calculations performed it can be estimated that PoliTO needs a surface of about 6200 gha for its livelihood (3800 gha just for travels) (Figure 2). If compared to the actual area occupied by the university, about 20 hectares, the Politecnico needs an area 310 times larger than its area, which corresponds to about 48% of the city of Turin. This value, normalized to the number of students, gives a figure of 0.19 hectares per student. This value seems to be in line with other European universities, in particular, that of Valencia (already analyzed in the literature review) and the Oxford Brookes University whose ratio is 0.22 hectares per student. The total emissions issued by the Polytechnic in 2016 are about 14,500 t CO_2 (considered an average between the more eco-friendly and less eco-friendly scenarios and 9,800 t CO_2 in the case in which the home-university movements are not considered). Indicatively, if considered that a tall tree located in the city can absorb between 10 and 20 kg CO_2 / year, about 720,000 trees would be needed to absorb all emissions.

Sensitivity analysis on possible EF reduction by MP campus design solutions

In view of the results obtained from the calculation of the current PoliTO's ecological footprint, strategies that could be adopted in order to reduce the ecological impact of the campus were proposed and accounted in terms of avoided EF. The ecological footprint method does not directly identify the activities to be undertaken, but it represents an important starting point to define some guidelines for further improvements. In fact, the results pointed at architectural design and open spaces use as priority areas.

In developing a strategy to reduce the overall environmental impact of PoliTO, the sensitivity analysis relates to different layers (Figure 3), overlapping with a complex system of actions, connections and additions of different dimensions. Interventions are conceived along the frame of the general MP strategy, working on open places to strengthen the dialectical relationship between buildings and evolution of the community' "sense of place".

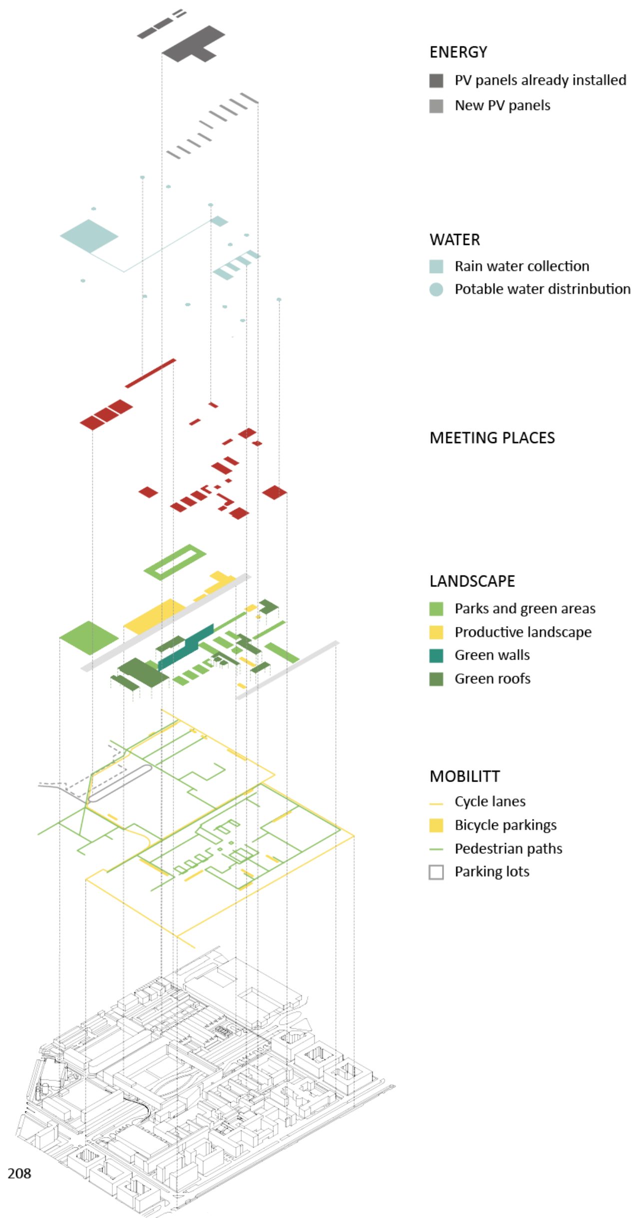

Figure 3. Layers of interventions.

As in a catalogue, the single proposed interventions can be read individually (even if they are not isolated, but influence each other), as precise starting points on which to intervene even in different phases. Proposed actions do not want to be the one exclusion of the other, but from their sum, interaction or overlap, a final configuration in the MP hypothesis catalogue can be suggested.
In the following subchapter, the assessment of avoided impact by proposed architectural operations is accounted in quantity of avoidable EF.

Energy
In November 2016, the production of energy by PV panels *in situ* at PoliTO was the 0,2% of total electric energy consumed yearly.
Within the energy layer, new plants of solar energy production plus PV panels on roofs of the nine higher and best-exposed buildings of the campus are planned.
Surface occupied by PV panels with optimal southwest exposition is about 1750 sqm. Flat roof of laboratory buildings can offer a potential usable surface of 2800 sqm.
In the renewable energy production model, loss by external shading (other buildings, chimneys, trees) was considered. PV cells with significant losses (more than 8%) were removed.
Final expected production of the 4500 square-meters whole plants appears to pass the 5 MWh/y.

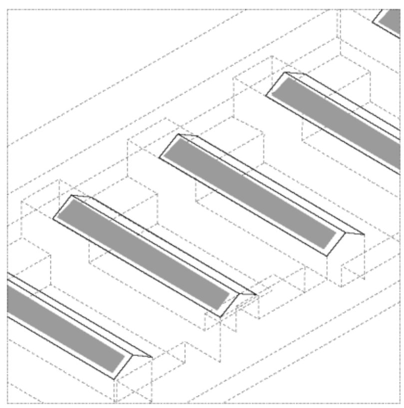

Figure 4. Axonometric scheme of PV plant covered departments building.

Mobility
Mobility accounts the major part of the ecological footprint of the campus: more than 45% for daily commuting and 10% for work trips. In view of Green House Gases (GHG) emissions, urban spaces are crucial to allow a new type of mobility which focus on the user's needs, rather than the vehicle ones. This approach implies a more efficient local transport system and improves the overall sustainable performance of the city (Albers and Deppisch, 2013; Shafie, 2015).
In these terms, the MP mobility layer (
Figure **5**) develops a new crossing path in the campus, starting from the redefinition of the main entrance, going through the inner courtyards till a system of platform roofs, texturing a homogeneous green path along the whole university. Renovated paving also improves a unified perception of place, and besides, it intensifies the accessibility of the outdoor spaces.
A buffer zone is planned in correspondence of the main entrance, abating the noise of the adjacent busy streets and offering a slow mobility area for the university community arriving at the campus. The new pathway increases the accessibility by bike and the safety of the streets in and around PoliTO's campus. Bicycle stands and fixing stations are planned all around the campus, encouraging the use of bicycle mobility.

Figure 5. Axonometric schemes of the pedestrian entrance elevated cycle lane and covered paths.

Food

Since the '90s, urban agriculture has contributed to improving food security in low- and middle- income countries. Now, it is implemented as a multifunctional intervention that can influence various determinants of health (eg, food security, social relationships) (Nasr, Komisar and Gorgolewski, 2014; Sage, 2014). However, it is crucial that planners start recognising the importance of urban farming in the rich mix of activities that characterises modern cities.

The food layer (Figure 6) elaborates various kind of actions to reduce the impact linked to the transportation of the food: productive spaces are redefined in relation to the functions of the buildings. The area next to the canteen is planned as a farm, with vegetable gardens and greenhouses that could be used directly by students and PoliTO's administrative and teaching staff. Parts of the roofs and other small areas next to campus borders are individuated as cultivable areas with a strong vocation to educational and community-making projects. It is possible to use 0,5 ha of total plantations to produce about 8 ton of mixed vegetables, covering the 10% of the consumption of the students' canteen. 0,5 ha dedicated to the orchard can be located next to the lunch room, where local fruits such as apples, pears and plums can be cropped covering the annual requirement of the dining hall (about 20 ton of mixed fruits). The interventions do not reduce the amount of land needed to produce food, but 60 gha of EF are saved for the absorption of CO_2 emissions related to food transport. Moreover, visible areas dedicated to the cultivation of locally-consumed food help to educate to a fresh and local consumption and convert the campus into a more attractive urban landscape.

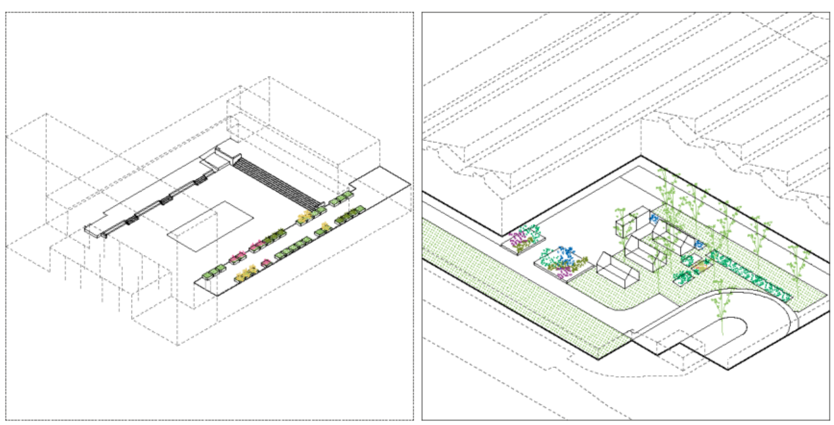

Figure 6. Axonometric schemes of productive landscape: vegetable gardens and orchard

Landscape

The PoliTO campus, as embedded in the MP strategy, as part of a larger, interconnected urban ecosystem: its green areas enrich the whole territorial biodiversity and the personal well-being of users according to the principle of biophilic design (Braiterman, 2010; Schuetze and Chelleri, 2015; Brown, 2016).

The landscape layer (Figure 7) is characterized by a new green lung integrated in the existing MP grid but with a "free" evolution according to users' desires, with possible plantation of local species or spontaneous ones, giving value to the aesthetic and the sense of placemaking of a self-cared green space (Koester, Eflin and Vann, 2006). This park could become a system of phytoremediation for the recovery of the area (previously occupied by a railway industry), in which benefits can be measured both in environmental, economic and social terms.
The relative scarcity of surfaces available for green areas within the campus, developed in a fragmented process of construction in time and space, led to the design of several green roofs and green walls. The benefits of these surfaces are multiple: trees absorb CO_2 by releasing oxygen, green roofs accumulate rainwater in the substrate (in summer up to 70% of rainfall). Such water accumulations are then released into the atmosphere through transpiration and evaporation. Lowering the roof temperature, they reduce the energy demand for summer cooling, limit heat loss in winter and in general the heat island effect by the substitution of black surfaces with a breathable green layer. The presence of green surfaces also improves air quality, since these systems capture pollutants and harmful gases.

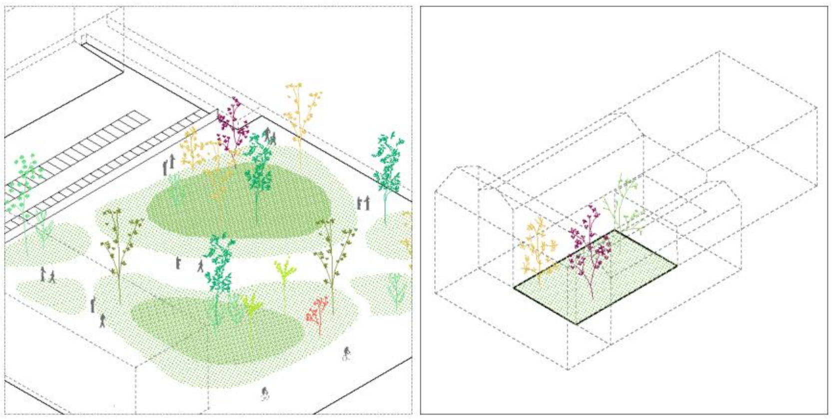

Figure 7. Axonometric schemes of conversion of paved area in park and green areas.

Discussion

Proposed interventions in par.4.2 decrease the total EF in the engineering campus of Corso Duca and Cittadella by 21%. Main benefits are due to the production of energy by renewable sources, the increment in the use of public transport and slow mobility modes, and the decrease in imported food. The advantages can be a fly-wheel to develop new sustainable policies and awareness campaigns for local waste and recycle processes, alternative and non-polluting mobility modes, local reduction of energy demand and responsible consumption of food and water.

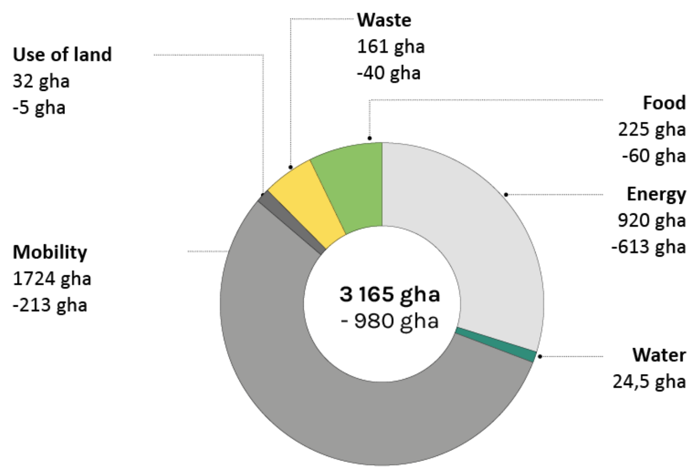

Figure 8. Pie chart of EF after intervention scenario and associated reductions.

From the calculation of the possible improvement scenarios in Figure 3, reductions in different consumption categories are calculated (Figure 8).

The new PV plant can produce the 40% of energy consumed yearly by PoliTO, diminishing 400 gha in the total EF. In accordance with the MP policies, aiming at fostering the use of public transport instead of private cars, an increase of 10% of commuting by bicycle and splitting in favour of public transport is envisaged. New cycle paths and a more integrated slow-mobility network can reduce by the 30% carbon emissions in the mobility layer. Interventions related to food do not reduce the amount of land needed for the production, but with the new local production of fruits and vegetables, 60 gha less could be needed for the absorption of CO_2 emissions related to food transport. The design of the green spaces provides 350 new trees, which can absorb 4 tons of CO_2 and 27300 sqm of new grassland, absorbing 165 tons of CO_2. Paved areas, decreased by the 12%, leave a permeable green layer that reduces by 5 gha the total PoliTO EF.

Results constitute a valuable example of analysis of the urban ecosystem services as a starting point for biophilic design strategies. While EF does not take into account benefits and impacts related to an intangible aspect of quality of life, an advantage of EF methodology is the results communicability, that allows comparison of initial and future scenarios even to non-expert stakeholders. However, this study has its weak points mainly related to the subjective definition of system boundaries, to the use of a closer scale (usually EF is used to analyse national consumption) and to the non-homogeneous quality of data collected from the different PoliTO offices. However, acting on open spaces, aside from the mere reduction of the total EF of Polytechnic, allowed a discussion to:

- reinforce a "sense of belonging"; ensure "grammatical" continuity with the rich architectural and spatial heritage already occupied by some Polytechnic offices, leaving room for the change and innovation that new research and new teaching requires;
- promote a sense of place and an ethos of a creative, accessible and sustainable community, with structures designed in harmony with what is already around;
- denounce for itself attention to the mission of inclusiveness of the non-university population, exiting from the *turris eburnea* of vertical and absolute knowledge and connecting to their socio-economic and socio-technical context.

Research Limitations

Limits of this study regard several aspects. The scale on which the ecological footprint methodology has been applied is quite wide, hence not providing detailed propositions in the results. However, it allowed an analysis of the urban ecosystem of a university campus in a metabolic perspective. In some cases, such as in the mobility impacts calculation, poor availability and reliability of data forced the study to simulations and credible hypothesis, rather than relying on primary data sources. The multiple sources enrolled during the data collection, both by means of sensors, data logger and semi-structured interview and field observation, make the model of calculation scarcely replicable. This, however, made the current EF visible and communicable to a wider range of stakeholder, thus providing information that is relevant to campus government and management structures. The *alea* in identifying the boundaries of the system make the results strictly dependent on a subjective choice, but overall this experimental study on EF calculation in spatial planning hypothesis helped in applying an interdisciplinary and multi-scale approach, difficult and limited per se.

Conclusions

This paper reports strategies toward a green campus project at Politecnico di Torino, Italy. A consumption-based study for Politecnico di Torino, a 33000 students Italian Higher Education Institution (HEI), has been developed to analyse the current EF of the main campus site. Data were collected from different departments and administrative units of the Politecnico di Torino to estimate emissions and identify the measure of the pressure exerted by the campus activities on the ecosystem. Among all initiatives to reduce the total EF, possible scenarios of avoided EF are accounted for open space along five different design layers: energy, water, landscape, food and mobility. A reduction of the 21% of the current EF can be achieved through the solutions envisaged in the green campus project along the open spaces layers. These strategies contribute to a sustainable campus using:

- photovoltaic generation: a -40% of energy consumed yearly by PoliTO could diminish by 400 gha the total EF.
- local fruits plants: 60 gha less could be less needed for the absorption of CO2 emissions related to food transport.
- bike paths: an increase of 10% of commuting by bicycle and a splitting in favour of public transport can reduce by the 30% the total carbon emissions
- green areas: 350 new trees, which can absorb 4 tons of CO2 and 27300 sqm of new grassland, absorbing 165 tons of CO2. Paved areas, decreased by the 12%, leave a permeable green layer that reduces by 5 gha the total PoliTO's EF.

This paper concludes posing two conceptual and methodological provocations. Conceptually, the paper highlights the role of problems' spatialization and open space design in strengthening campus sustainability transitions, far beyond the mere accounting of avoided EF or a sole design project of individual interventions. This action-oriented, cyclical and longitudinal approach of the research-by-design methodology is a dimension embedded in sustainability assessments and presents great opportunities when applied to university campuses. Indeed, university sustainability policies can reduce environmental impact indirectly, encouraging change in users behaviour, while precise architectural interventions can directly reduce the university ecological footprint limiting the demand of resources and creating a more circular system of campus.

The future prospects, as far as the evolution of the topic of EF is concerned, can help universities in not just in improving their sustainability performance on the operational part, but to also in demonstrating how the built environment can be designed to benefit both the environment and the occupants. The masterplan project, with its problem spatialization and the elicitation of conflicts plus the ecological footprint impacts of each choice, act as a wide-ranging dialogue platform to evaluate of the most appropriate pathways forward, according to all university stakeholders.

List of acronyms

EF: Ecological Footprint
GHG: Green House Gas
HEI: Higher Education Institutions
MP: Masterplan Project
PoliTO: Politecnico di Torino

SDGs: Sustainable Development Goals
HEIs: Higher Education Institutions

References

Albers, M. and Deppisch, S. (2013) 'Resilience in the Light of Climate Change: Useful Approach or Empty Phrase for Spatial Planning?', *European Planning Studies*. Routledge, 21(10), pp. 1598–1610. doi: 10.1080/09654313.2012.722961.

Arroyo, P. (2017) 'A new taxonomy for examining the multi-role of campus sustainability assessments in organizational change', *Journal of Cleaner Production*, 140, pp. 1763-1774.

Baldissara, B. *et al.* (2014) 'Rapporto energia e ambiente. Scenari e strategie. Verso un'Italia low carbon: sistema energetico, occupazione e investimenti'. ENEA.

Braiterman, J. (2010) 'City branding through new green spaces', in *City Branding: Theory and Cases*. London: Palgrave M, pp. 70–81. doi: 10.1057/9780230294790.

Brammer, S. and Walker, H. (2011) 'Sustainable procurement in the public sector: an international comparative study null', *International Journal of Operations & Production Management*. Emerald, 31(4), pp. 452–476. doi: 10.1108/01443571111119551.

Brown, M. (2016) *FutuREstorative: Working Towards a New Sustainability*. 1st edn. Newcaste upon Tyne: RIBA Publishing.

Brundiers, K. and Wiek, A. (2013) 'Do we teach what we preach? An international comparison of problem-and project-based learning courses in sustainability', *Sustainability*. Multidisciplinary Digital Publishing Institute, 5(4), pp. 1725–1746.

Chaffin, B. C. *et al.* (2016) 'A tale of two rain gardens: Barriers and bridges to adaptive management of urban stormwater in Cleveland, Ohio', *Journal of Environmental Management*. doi: 10.1016/j.jenvman.2016.06.025.

Chambers, N., Simmons, C. and Wackernagel, M. (2014) *Sharing nature's interest: ecological footprints as an indicator of sustainability*. London: Routledge.

Corcoran, P. B., Walker, K. E. and Wals, A. E. J. (2004) 'Case studies, make-your-case studies, and case stories: a critique of case-study methodology in sustainability in higher education', *Environmental Education Research*. Taylor & Francis, 10(1), pp. 7–21.

Devine-Wright, P. (2014) *Renewable Energy and the Public: from NIMBY to Participation*. London: Routledge.

Dillon, J. and Reid, A. (2004) 'Issues in case-study methodology in investigating environmental and sustainability issues in higher education: towards a problem-based approach?', *Environmental Education Research*. Taylor & Francis, 10(1), pp. 23–37.

Disterheft, A. *et al.* (2014) 'Sustainable universities – a study of critical success factors for participatory approaches', *Journal of Cleaner Production*, 106, pp. 11–21. doi: 10.1016/j.jclepro.2014.01.030.

Evans, J. *et al.* (2015) 'Living labs and co-production: University campuses as platforms for sustainability science', *Current Opinion in Environmental Sustainability*. Elsevier B.V., 16, pp. 1–6. doi: 10.1016/j.cosust.2015.06.005.

Ferrer-Balas, D. *et al.* (2010) 'Going beyond the rhetoric: system-wide changes in universities for sustainable societies', *Journal of Cleaner Production*. Elsevier Ltd, 18(7), pp. 607–610. doi: 10.1016/j.jclepro.2009.12.009.

Ferrer-Balas, D., Buckland, H. and de Mingo, M. (2009) 'Explorations on the University's role in society for sustainable development through a systems transition approach. Case-study of the Technical University of Catalonia (UPC)', *Journal of Cleaner Production*. Elsevier, 17(12), pp. 1075–1085.

Goudie, A. S. (2018) *Human impact on the natural environment*. John Wiley & Sons.

Jabareen, Y. R. (2006) 'Sustainable urban forms: Their typologies, models, and concepts', *Journal of planning education and research*. Sage Publications Sage CA: Thousand Oaks, CA, 26(1), pp. 38–52.

Jenks, M. and Dempsey, N. (2005) *Future forms and design for sustainable cities*. London: Routledge.

Klein-Banai, C. and Theis, T. L. (2013) 'Quantitative analysis of factors affecting greenhouse gas emissions at institutions of higher education', *Journal of Cleaner Production*. Elsevier, 48, pp. 29–38.

Koester, R. J., Eflin, J. and Vann, J. (2006) 'Greening of the campus: a whole-systems approach', *Journal of Cleaner Production*. Elsevier, 14(9), pp. 769–779.

Lambrechts, W. and Van Liedekerke, L. (2014) ‘Using ecological footprint analysis in higher education: Campus operations, policy development and educational purposes’, *Ecological indicators*. Elsevier, 45, pp. 402–406.
Larsen, H. N. *et al.* (2013) ‘Investigating the Carbon Footprint of a University - The case of NTNU’, *Journal of Cleaner Production*, 48, pp. 39–47. doi: http://dx.doi.org/10.1016/j.jclepro.2011.10.007.
Leal Filho, W. (2000) ‘Sustainability and university life’, *International Journal of Sustainability in Higher Education*. Emerald Group Publishing Limited, 1(1).
Leal Filho, W., Manolas, E. and Pace, P. (2015) ‘The future we want: Key issues on sustainable development in higher education after Rio and the UN decade of education for sustainable development’, *International Journal of Sustainability in Higher Education*. Emerald Group Publishing Limited, 16(1), pp. 112–129.
Lombardi, P. and Sonetti, G. (2017) *News from the Front of Sustainable University Campuses*. Roma: Edizioni Nuova Cultura.
Lombardi, P. and Trossero, E. (2013) ‘Beyond energy efficiency in evaluating sustainable development in planning and the built environment’, *International Journal of Sustainable Building Technology and Urban Development*, 4(4), pp. 274–282. doi: 10.1080/2093761X.2013.817360.
Loorbach, D. (2007) *Transition management: new mode of governance for sustainable development*. Utrecht: International books.
Lozano, R. (2010) ‘Diffusion of sustainable development in universities’ curricula: an empirical example from Cardiff University’, *Journal of Cleaner Production*, 18(7), pp. 637–644. doi: 10.1016/j.jclepro.2009.07.005.
Lozano, R. *et al.* (2014) ‘A review of commitment and implementation of sustainable development in higher education: results from a worldwide survey’, *Journal of Cleaner Production*, 108, pp. 1–18. doi: 10.1016/j.jclepro.2014.09.048.
Munier, N. (2011) ‘Methodology to select a set of urban sustainability indicators to measure the state of the city, and performance assessment’, *Ecological Indicators*, 11(5), pp. 1020–1026. doi: http://dx.doi.org/10.1016/j.ecolind.2011.01.006.
Nasr, J., Komisar, J. and Gorgolewski, M. (2014) ‘Urban agricolture as ordinary urban practice:trends and lessons’, in *Second Nature Urban Agricolture*. Routledge. New York.
Ramos, T. B. *et al.* (2015) ‘Experiences from the implementation of sustainable development in higher education institutions: Environmental management for sustainable universities’, *Journal of Cleaner Production*. Elsevier, 106, pp. 3–10.
Rees, W. and Wackernagel, M. (1996) ‘Urban ecological footprints: why cities cannot be sustainable—and why they are a key to sustainability’, *Environmental impact assessment review*. Elsevier, 16(4–6), pp. 223–248.
Roggema, R. (2009) *Adaptation to climate change: a spatial challenge*. Heidelberg: Springer Netherlands.
Roggema, R., Vermeend, T. and Dobbelsteen, A. van den (2012) ‘Incremental change, transition or transformation? Optimising change pathways for climate adaptation in spatial planning’, *Sustainability*. Multidisciplinary Digital Publishing Institute, 4(10), pp. 2525–2549.
Sage, C. (2014) ‘The transition movement and food sovereignty: From local resilience to global engagement in food system transformation’, *Journal of Consumer Culture*, 14(2), pp. 254–275. doi: 10.1177/1469540514526281.
Schuetze, T. and Chelleri, L. (2015) ‘Urban Sustainability Versus Green-Washing—Fallacy and Reality of Urban Regeneration in Downtown Seoul’, *Sustainability*, 8(1), p. 33.
Segalàs, J. *et al.* (2009) ‘What has to be learnt for sustainability? A comparison of bachelor engineering education competencies at three European universities’, *Sustainability Science*. Springer, 4(1), p. 17.
Shafie, F. A. (2015) ‘Urban Sustainability in Barcelona: Living and Learning the Experience’, *Procedia - Social and Behavioral Sciences*, 168, pp. 381–388. doi: http://dx.doi.org/10.1016/j.sbspro.2014.10.244.
Sipos, Y., Battisti, B. and Grimm, K. (2008) ‘Achieving transformative sustainability learning: engaging head, hands and heart’, *International Journal of Sustainability in Higher Education*. Emerald Group Publishing Limited, 9(1), pp. 68–86.
Sonetti, G.; Brown, M.; Naboni, E., (2019) ‘About the Triggering of UN Sustainable Development Goals and Regenerative Sustainability in Higher Education’, *Sustainability* 2019, 11, 254.

Sonetti, G.; Naboni, E.; Brown, M. Exploring the Potentials of ICT Tools for Human-Centric Regenerative Design. *Sustainability* 2018, *10*, 1217.
Sonetti, G., Lombardi, P. and Chelleri, L. (2016) 'True Green and Sustainable University Campuses? Toward a Clusters Approach', *Sustainability*. Multidisciplinary Digital Publishing Institute, p. 83. doi: 10.3390/su8010083.
Stephens, J. C. and Graham, A. C. (2010) 'Toward an empirical research agenda for sustainability in higher education: exploring the transition management framework', *Journal of Cleaner Production*, 18(7), pp. 611–618. doi: 10.1016/j.jclepro.2009.07.009.
Townsend, J. and Barrett, J. (2015) 'Exploring the applications of carbon footprinting towards sustainability at a UK university: reporting and decision making', *Journal of Cleaner Production*. Elsevier, 107, pp. 164–176.
Walker, G. and Cass, N. (2007) 'Carbon reduction, "the public" and renewable energy: engaging with socio-technical configurations', *Area*. Blackwell Publishing Ltd, 39(4), pp. 458–469. doi: 10.1111/j.1475-4762.2007.00772.x.
Westley, F. *et al.* (2011) 'Tipping toward sustainability: emerging pathways of transformation', *AMBIO*, 40(7), pp. 762–780.
Wiek, A. *et al.* (2014) 'Integrating problem-and project-based learning into sustainability programs: A case study on the School of Sustainability at Arizona State University', *International Journal of Sustainability in Higher Education*. Emerald Group Publishing Limited, 15(4), pp. 431–449.

Corresponding Author
Giulia Sonetti is the corresponding author and can be contacted at: giulia.sonetti@polito.it

About the author(s)
Caterina Barioglio is a research fellow at the Politecnico di Torino (Italy) where she holds a Ph.D. in History of Architecture and Urban Planning in 2016. Her research activities relate to urban regeneration processes (especially between New York, Turin and Milan), focusing on the network of actors into decision making processes, and on the role of the spatial design into public discourses. She currently works as teaching assistant and adjunct professor in history, architectural and urban design, while carrying her researches at *FULL- The Future Urban Legacy Lab* interdepartmental center. She has been member of the Masterplan Team of the Politecnico di Torino, since its establishment in September 2016.

Silvia Favaro graduated with honours in Architecture Construction City at Polytechnic of Turin in 2017 with the thesis "PoliGround. The ecological footprint and scenarios for a post-carbon campus". The dissertation has received the Green Team Award and it has been selected for different conferences, including the ISDRS 2018 meeting. During her studies she spent six months at the Technische Universiteit of Eindhoven. She is actually holding a scholarship for the research project "Masterplan of Polytechnic University Campus in Turin" coordinated by professor Antonio De Rossi. Her main scientific interests include sustainable urban developments, participatory processes and the design of innovative spaces for teaching.

Chiara Genta is a PhD student in urban and regional development at the Politecnico di Torino and Università di Torino. She graduated with honors in architecture at the Politecnico di Torino in 2017 with a master thesis that evaluated the ecological footprint of a university campus and proposed green strategies to reduce the environmental impact and improve wellbeing and sense of belonging of users. Since 2018, she is a chartered architect obtaining an honourable mention in the international design competition Europan14. Her main research interests are focused on sustainable urban development, urban metabolism and behavioural patterns, using inter-disciplinary research methods.

Patrizia Lombardi, PhD, MSc, BA/MA is Deputy Rector of the Politecnico di Torino. Full Professor in Planning Evaluation and Project Appraisal, she is Chair of the Green Team Office since 2015. She is an established figure in the field of sustainable urban development evaluation and management for over 20 years, publishing widely in the subject area and coordinating, or serving as lead partner in several interdisciplinary Pan-European Projects related to Sustainable built environment, Smart Cities, Post carbon society and Cultural heritage. She is Rector' delegate for the Sustainable campus initiatives, plus the president of the Italian Network of Sustainable Universities (RUS). Since 2010, she is Chair of the UNESCO Master "World Heritage and Cultural Projects for Development" managed by the Turin School of development of the International Labour Organization (ILO). Awarded received in 2012 by the Alumni of Salford University of the Great Manchester for her career achievements.

Giulia Sonetti, PhD, Msc, MArch+BArch, is chartered architect and sustainability advisor at the Green Team of Politecnico di Torino, while being a multidisciplinary assistant professor in sustainability management and evaluation currently appointed at the Interuniversity Department of Regional & Urban Studies and Planning (Turin, Italy). She has been visiting scholar at the University of Hokkaido (JP), the École Polytechnique Fédérale de Lausanne (CH), the University of Cambridge (UK), the Barcelona Super Computing Centre (ESP), the Royal Danish Academy of Fine Art of Copenhagen (DK), the Norwegian University of Science and Technology (NO), and the Instituto Superior de Economia e Gestão (PT), while being organiser, speaker and facilitator of several shared-science and multi-stakeholder workshops around Europe. She designed and implemented many national, EU FP7 / H2020 research projects about inter-transdisciplinary approaches, sustainability management strategies and socio-technical pathways towards a post carbon society embracing the 17 SDGs.