Evaluating and Managing the Energy Transition Towards Truly Sustainable University Campuses

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Abstract

This thesis is about the current role of university campuses to contribute to a fair and sustainable transition towards a low-carbon society. The fundamental argument is that there is a serious gap between the aspiration of higher education institutions in relation to sustainability and the current reality. Whilst formally moving towards sustainability within their curricula and resources management, universities are still immersed in all the complexity, the uncertainty, the scarcity of resources and the leading green-washing paradigm of the cities they are in. This thesis uses the Politecnico di Torino as the main case study, compared with universities in Italy, the UK, Japan, and Mexico, to answer the following questions: (1) What are universities doing in their sustainability efforts that has the potential to be measurable and transferable? And (2) How can we evaluate if universities are truly sustainable? This thesis treats university campuses as small cities nested in bigger cities; *heterotopies* expressing otherness and maintaining reciprocal relationships within the context. It is proposed that the immediate impacts deriving from educating and practising a wiser use of waste, water, energy and the built environment in universities help to create long term effects toward resilient, fair, and environmentally aware communities. Comparable clusters of universities, bottom-up management schemes and transferrable lessons for the wider urban and global practices are presented and discussed across the different case studies. To facilitate the dialogue between the economic, the social and the environmental fields of action, embedded within university's sustainability metrics and the attempts to operationalise urban resilience determinants in the campus management, this thesis helps in tailoring appropriate assessment methodologies and operative strategies towards truly sustainable university campuses.

Keywords: *University Sustainability Evaluation, Transition Management, Socio-technical Approach, Motivational Behaviours, Urban Resilience Indicators*

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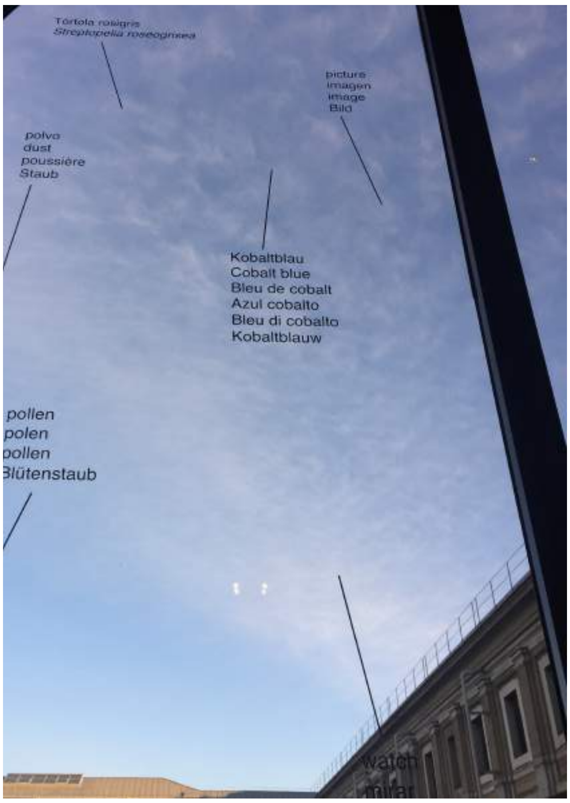
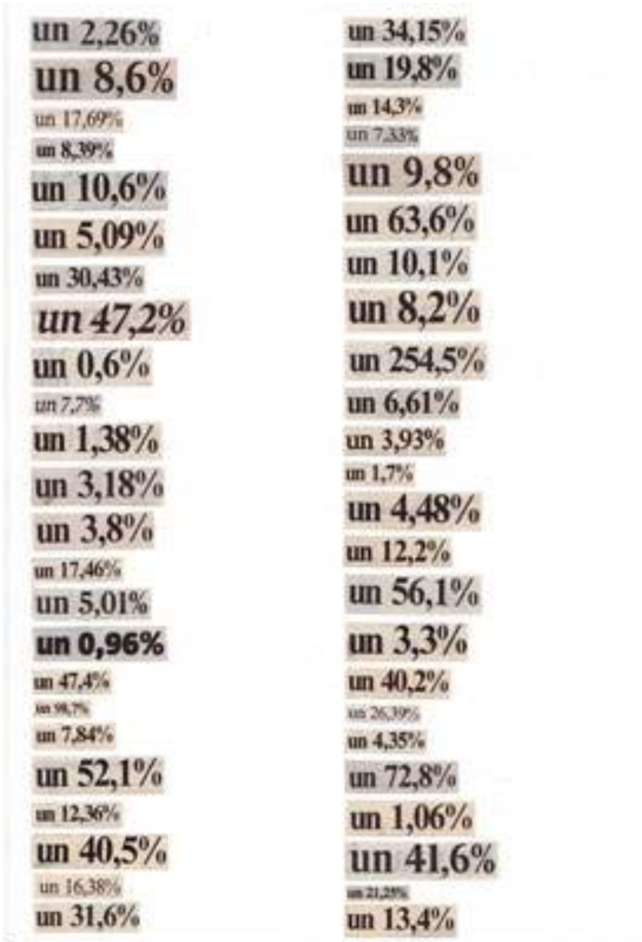
Ignasi Aballí— *Un paisaje posible*, 2006. Vinyl on glass, variable dimensions

(Source: [http://www.ignasiaballi.net/index.php?/projects/un-paisaje-posible/ and author's photo)](http://www.ignasiaballi.net/index.php?/projects/un-paisaje-posible/)





Ignasi Aballí— *Listado (%) III*, 2008. Digital print, 150 x 105 cm
(Source: http://www.ignasiaballi.net/files/-bajaporcentaje.jpg)

Ignasi Aballí—*Listado (Ismos) I*, 2009. Digital print, 150 x 105 cm

(Source: http://www.ignasiaballi.net/files/-bajaismos.jpg)

Foreword

The tale of the end of the world

- Dad, tell me the story of the men of the millennium!

- Okay, but then you go to bed. In the year two thousand, men had a lot of things: sleeping pills, football leagues, fashion shows, silicone, computers...

- Even pizza?

- Even pizza. But, despite having all this, their lives began to deteriorate. It would not be catastrophic if they had admitted and behaved accordingly. But they were used to the idea that history was like a car, to be always new and beautiful, even if there were no roads to make it go. The climate and the environment went wild, but the men seemed almost happy to beat all records of heat and cold. The weather was the only sport where performance grew monstrously and nobody asked anti-doping measures. In cities became impossible to breathe and the air was privatised: the richest used the Fiat-Aeolus cylinders with mountain air.

Young people wore the Wallmart backpack rockstar-breath-flavoured, while the poorest settled with the "pneumocenter", the cheap cylinder diffusing just four breaths per minute. Agriculture was messed up, but scientists were busy in building three-steps-grown celeries and pigs with handles; there were droughts and fizzy drinks, yacht and floods, holiday clubs and abnormal waves.

- What does it mean abnormal?

- When you let something lord it over and enlarge out from every law and rule, and you've also done business with it, and then you can not take it off from the balls. Then, call it abnormal.

- Like Berlusconi?

- Who told you those things?

- Ponding, my playmate: he is highly educated, he lives in the old library. He also told me that in the year two thousand they were afraid above all of three things: soccer slow motions, wrinkles, and immigrants.

- Yes, once no one was caring if banks, building speculators, or industries, took possession of the whole city, razed to ground entire neighbourhoods, making the area uninhabitable. But if someone occupied an empty house, they got mad like hyenas.

- That's how they began to go back?

- Exactly. The transport became increasingly slow and chaotic. Since the esoteric and divination were fashionable at that time, a famous newspaper substituted tarots with Alitalia flights schedule as a free gift. There were people who reserved a flight from Malpensa just to stay there all night doing wife-swapping. Trains were hiding in the tunnels for the shame. The highways became five-lane ones, so that the remaining empty three on the right were for the only Prinz who was not ashamed to go there. And then there were fires.

- And how were they extinguished?

- By blowing them out. As soon as a big one was breaking out, they began to quarrel, regions were accusing the minister, the minister the regions, and both the strong sirocco wind, while the army remained in the barracks to guard the colonel’s ficus.

- And did they had other problems?

The atomic bombs were exploding, but they were still deterrents; wars were smart; the arms merchants were called weapon technology exporter. From poor countries, desperate were trying to land in rich countries. Some were welcomed in a right-wing-way (a kick in the ass and go), others were welcome in the left-wing-way (a kick in the ass and a glass of tonic water). This is because rich countries at that time were afraid of everything: African mosquitoes, the Asian stock market, black people (except black football players), white people (except the one from Bergamo). And they invented a magic word: emergency. Ozone emergency, fire emergency, mafia emergency, immigrants' emergency. Emergency wanted to say "do not worry, it will pass". Eventually they came to the ''emergency of the emergencies ", and they did not come out of their houses anymore.

- And no one denounced these things?

- Of course they did. There were catastrophe movies, charity concerts, the Benetton ads. And the super scientist's congresses, after which the participants met all together and threw a cry of alarm. It was a very funny ceremony, someone even shouted "goal" or mimicked hoopoes, then they come back home smiling and happy. Television had a hundred channels but always the same faces. So that people thought: "Well, if they are still there, it means that things are not getting worse too much". Maybe if they would had seen a presenter on fire, a political hit by a wave, or a raft of refugees plunged in the middle of a quiz show, they would have been concerned. But the bad things saw on the news were considered only bad fairy tales.

- And then what happened?

- Well, I've already told you. One day, the pole melted and the sea level stood up by seven meters. American televisions showed Lewinsky's mother trying to prove that the presidential findings got stuck in the zipper of her daughter were not, as claimed by Clinton, a piece of his inch. Russia was begging. Italy, between a parade and a festival, was discussing the role of Perry Mason in the Moro kidnapping. Everything sank in thirty seconds of TV live stream - and four ads. Only floating junks remained. On the last raft, a certain Gasparri were hitting with his oar an Albanian who wanted to climb over. Then was all silence. Only us survived, while life on earth carried on.

- So Dad, I'm really lucky to be born mouse.

- That's right, son. Did you study the lesson for tomorrow?

- Yes: in the history of the evolution of the mice are three major periods: the Neanderthal, the Emmental and the Simmental.

Bravo, I'm proud of you. Now sleep. Good night.

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This was an article by Stefano Benni titled "The tale of the end of the world". It was published on the 13th of August 1998 (20 years ago) in "la Repubblica". I translated it maintaining the structure and updating just some minor political/contextual references, but nothing has really changed. Since then, actually, everything got worse. I feel the responsibility to act against the trend described ironically and cleverly in the tale, with all the strengths and the tools I possess now, in this time of the world and of my life. Unfortunately, the only thing I can do by now is devote my research to environmental awareness, intellectual honesty and the role the academia should carry to put our defences up, against the verbal hypocrisies created by the system assuring enduring inequality, taste downgrading, and contagious stupidity. We are the first society in the world that has to worry about the risk of self-destruction. As the future were not the time where we will pass our next days. We have to act now to re-establish our identity, our values, our duties towards the forthcoming generations.

After almost three years of PhD studentship, I felt totally lost when being told to focus and narrow my research and give to birth a final thesis. If a blank page is always a scary moment in any young academics' life, nothing appears more grieve than a blank page titled "thesis".

Much before my engagement in a PhD programme, in many occasions I've been travelling and staying in different Universities, ranging from Naples to Cambridge and passing from Sapporo, Seville, Barcelona, Nottingham, Lausanne, Rome, and of course Turin. All of a sudden a sensational idea came to me in a flash: to get the most of all these experiences, the University itself would have been the perfect object of my investigation.

A part from my very personal point of view, University is a very urgent topic in today's world. Although digital platforms have radically transformed other industries (music, media, fabrication, publishing), education is still based on an old-world model. Economic growth from the 1980s until 2008 transformed academia itself into a commodity system, in which not only education but also our social and cultural reality became "schooled". Yet before this period, in 1971 the philosopher, social critic and priest Ivan Illich published a book called "Deschooling Society", in which he referred to the revolutionary potential of *deschooling* and outlined the possible use of technology to create institutions serving personal, creative, and autonomous interaction. Illich's concept of *deschooling* is clearly relevant today, given the contemporary relationship between digital tools and learning, free access to information, and new economic models.

Numerous non-site-specific initiatives have sprung up, from open-air classes to on-line courses. Practices of giving talks or teaching whole courses remotely and in real-time began a few years ago with wikis, blogs and podcasts, and have now evolved on a broad scale. One of the best-known formats currently in use is the MOOC (Massive Online Open Course), in which professors offer courses or talks for an unlimited number online students to follow. #webinar[s], now found on Twitter, are invitations to a "web seminar" open for anyone interested in whatever topic is at hand.

Having been a mobility student myself, I reflected many time on the role University should carry on in this time, even with a sheer physical presence in the city that is not necessary anymore: I had most of my meeting in cafes, I studied in libraries and colleges common rooms, or even on a bench outside, if the weather was clement.

As with any paradigm shift, people take extreme positions on all sides, providing profound critiques of the emerging ways to diffuse and infuse knowledge. Despite the success of some courses, the MOOC model, for instance, has been severely criticised; its detractors refer to the difficulty of maintaining academic standards. The most interesting developments in education may have yet to take place. All these new, intangible educational infrastructures that form part of our daily life implicitly have an enormous learning potential, but firstly, as Ethel Baraona concludes in her essay "Deschooling society"[1], we must un-learn. We must un-learn the traditional models that are based on unequal exchange. We must un-learn the academic model created more than a century ago, which aimed to produce "workers" according to the canons of the Industrial Revolution and which so far have only evolved in step with the model of capitalism. From this perspective, it could therefore be the case of a critical evaluation of the radical innovation and the strategic rethinking needed by universities. The concept of living lab scales the length of the urban border condition to the campus' one, and takes students, teachers and administrative staff as "citizens" of this portion of the city; the support of private industries and governmental task forces foster the role of university in the co-creation of sustainable life conditions. The vast partnerships among universities and among academia and its environment (thanks to European funded project for advanced education schemes, collaborative researches, consultations with local government for urban reforms or real estate development projects, industry preferred tests beds, or among society through economic exchanges as it will be specified in the following paragraphs) lead many universities to assume a highly ambitious role of collaborating with diverse social actors to create societal transformations in the goal of sustainability. This is also seen as part of the so-called "third mission" of universities which refers to a further goal to add to the universities traditional teaching and research missions: the perceived need to engage with societal demands and link the university with its socio-economic context. From this perspective, it could therefore be the case that a critical evaluation of starting studying the transition towards sustainable universities, to understand the further resilience and sustainability management of the wider urban environment. As well as any other urban district, different campus plan does influence the sustainability performance of the overall city - this is the main aspect to consider when scaling from building to neighbourhood sustainability evaluations. However,

[1] http://www.uncubemagazine.com/articles/14333943

when investing in the social dimension of the energy transition problem, the Well-being, Land Use, Mobility, Social Equity, Urban Economic Sustainability and Energy Sources and Infrastructure are special factors in a Campus Community. Of course, this scale-up is not costless: decision making at urban level requires complex methods to evaluate different features and guarantee the sustainability and the resilience for a large number of stakeholders, that in the case of a University are far from homogeneous: short staying students (from one month or one year) to long-staying one (5 years or more) to permanent staff and daily visitors are a community difficult to target in term of differentiated strategy and communication level. Plus, the quadruple helix approach highlights problems related to the contemporary satisfaction of all the stakeholders interplaying with the university as a place of knowledge transfer, urban node and variegate social actors: decision makers/urban planners, investors/developers/construction companies, designers (engineers, architects), grant managers, building owners, SMEs/IT solutions providers, citizens, and finally students, professor, peer universities, research centres, not to mention the legislative (regional and ministerial) compliances.

In this perspective, some of the criteria for the resilient city seem to be applicable to the campus dimension even without the disaster response, with the hypothesis that resilient community building as a fertile ground for user behaviour leverages for energy reduction in university campus. Institutions now have the responsibility, more than ever before, to integrate sustainable development and resilience requirements into all their teaching, research, community engagement and campus operations to make the difference into the run to innovate a the new urban and citizen paradigm toward a low carbon society. In the end, what appeared of immediate connection was that observing the criticality of university campuses could have served as a test for proposing new scalable strategies for improving sustainability in the wider urban realm. As in many smart city programmes, it's time to rethink the revolutionary potential of technology and networks, both analogue and digital, to create institutions serving personal, creative, and autonomous interaction, respecting the availability of resources of all the other connected systems. Research themes could have included open access and knowledge creation, information technologies, education economies, campus configuration, the future classroom, and urban integration. Yet, the final deliverables of an Environment and Territory / Estimate and Evaluation address' PhD course shall be a list of indicators for the research object. With the aim of leveraging tools and knowledge from diverse experiences and expertise, I organised a summer school about sustainable campuses. Attendees designed a set of criteria, shared priorities and visions for a sustainable and resilient university campus, translating them into a framework of indicators. Temporal longevity and multidimensional resilience (ecological, social, methodological) have been of fundamental importance, but crucial would be to address the non-normative systems approach where cities are viewed as open systems connected to the rest of the world in many ways. Suggested subtopics for emerging issues were:

Urban Integration: many dimensions of the campus-city relationship, including transportation, ecology, economics, arts and culture, can drive the two resources: the academic population and the public/private/academic triangle in developing, implementing and sustaining complex and resilient urban systems.

Economic shift: We must think in terms of relevance rather than efficiency and economic growth, and this includes retaining knowledge in the area, valorisation of labour and how to prepare students to translate their intellectual and aesthetic work into effective contributions to their communities, aware of all the others communities that could be affected by their choices.

Politics of academia: How can we measure the students' involvement in the management of their university, and maybe the one of their children? Which can be the role of the students and professors to include a political thinking inside the academia?

Creativity, identity and culture: is the campus a place where students and teachers understand why it's important to respond to the current cultural inputs, and then, are there examples of works on how to design a proper response?

Learning by doing: is university finding a disposition for accepting change, failure, and trial and error? Interpersonal and spatial interaction will be of fundamental importance to be evaluated in terms of community resilience building.

Said so, the problem of reducing the field of action for a thesis plan was everything but solved. The campus as a portion of city offered the same amount of research questions of a complex system like a city. New modes of sharing information, spaces of learning, applied work and living labs are breaching the doors of the classic classroom to define the university of the 21st century, thought ecologically, socially and methodologically resilient without renouncing to be sustainable. The way I set up this thesis relies on all the experiences recalled above, made through project in many field works and capitalised on articles I've been sharing toward my vision of truly sustainable campus.

Introduction

I.1 Cities at the Centre of the Sustainability Debate

There is little doubt in the scientific community that significant and reliable evidence reveals that anthropogenic Greenhouse Gases (GHGs) directly influence the climate system (Collier et al., 2013; Roome, 2015; Solomon, 2007).

Current reports on the state of the world and the levels of consumption show that very little progress has been done in the field of sustainable development in cities (Bulkeley et al., 2009). Cities are responsible of the 75% of natural resources depletion and about 67-76% of energy consumption (Gu et al., 2009). Moreover, considering energy vulnerability, the availability and price of energy is particularly crucial for cities, which totally import their primary energy (Sonetti, Cifarelli, Wagner, & Wiersma, 2013). Furthermore, cities are responsible for the majority of the world's GHG emissions (71-76%) (Seitzinger et al., 2012).

But cities are intrinsically unstable entities: they suffer downturns, face unexpected events, and take some time to recover from crises (if that). They are large, open and dispersed. They gather life but also distribute it. They are full of variety, latency and multiplicity (Deakin, Lombardi, & Cooper, 2011; Lombardi, 2011). They are territories but also nodes in multiple networks (Bentivegna et al., 2002; Deakin, Curwell, & Lombardi, 2002; Ferretti, 2015; Lombardi & Basden, 1997). They are constantly evolving, often in unpredictable ways and in new directions. Much of this change brings turbulence, uncertainty and insecurity (Brandon & Lombardi, 2010). Yet, in the normal course of events, this instability does not cause cities to fall apart or descend into uncontrolled decline, and when things do go off course, recovery and readjustment swiftly follow. In the course of time, cities have endured all manner of difficulty, hedging against risk and bouncing back from adversity, small and large (Lombardi & Trossero, 2013). If cities are unstable, they are also in some ways resilient: while some cities have declined after suffering adversity, many others have managed to recover or stave off the worst, albeit by paying a price.

Although sustainability, resilience, smartness and eco-approaches gain intermitted consensus, a transition vision for the city of tomorrow is still far away (Loorbach, 2007). The debate has certainly stimulated carbon reduction policies leading to a relative decoupling in some industries, but these again were offset by ever continuing growth. Both in terms of availability of renewable resources and in terms of the environmental impacts of our consumption and production, we are pushing beyond the limits.

According to a number of scholars (Adams, Larrinaga-González, Adams, & McNicholas, 2007; Loorbach, 2007) sustainability has become an element of "standard practice" in the climate debate, and therefore has part of the problem. In particular, Loorbach (2014), points out that we have developed dominant societal regimes based upon (past) problem solving through central (government) planning and control, based on cheap fossil resources and linear modes of innovation. These regimes, on the foundations of modernity, are dependent on sustaining an unsustainable *status quo*, problem-industrial complex - and, therefore, systemically unsustainable in a fundamental way.

The EU MILESECURE-2050 project, "Multidimensional Impact of the Low-carbon European Strategy on Energy Security, and Socio-Economic Dimension up to 2050 perspective" (SSH.2012.2.2-2) has revealed that policy-makers may be ignoring the human factor in energy transition to the detriment of rapid and significant change across Europe. This implies significantly less emphasis on technology and on top-down planning and more emphasis on the enabling of both individuals and social groups to articulate themselves and participate in the energy transformation.

In industrialized, emerging and middle economies, cities are bearing a considerable responsibility in sustainable development and climate change. On one hand, population growth creates pressure on: urban economic system (financing of infrastructures, financing of public services); social system (health impacts, air pollution, noise pollution; employment; social integration, quality of life); environment (resource consumption, especially energy and land use). On the other hand, urban areas are exposed and vulnerable to climate change. Indeed, they can be struck by direct impacts of climate change: global warming, change in precipitation patterns, higher frequency and intensity of extreme events (heat waves, floods, droughts, etc.) or sea rise. These expected risks are extremely likely to increase, especially in a local level where single towns will have to face their cost and to adapt to them. In addition, cities are becoming the focal point of climate change mitigation strategies because they are able to respond to disturbances in their external environments in addition to internal environments (Stewart & Oke, 2012). As an example, in energy systems, electric vehicle deployment requires some new infrastructures that cannot be developed without a strong commitment from local authorities. Cities' authority on land and urban planning through regulation allows setting up a long-term vision on what they will look like in the future. In addition, they are able to organize urban metabolism through public transportation and local mobility management, or make coherent and sustainable choices thanks to their competence in social housing, urban heating and natural hazard protection. Finally, cities can make use of their economic and financial power. For instance, differentiated taxation depending on land use may be a tool to raise revenue for the municipality and in the same time gives incentives to change selected behaviours (e.g. alleviating urban sprawl, promoting energy retrofitting of buildings and/or energy savings, etc.). Of course, this considerable power has to be nuanced due to the private sector's influence on many of these triggers. Cities, not only as local authorities but as local ecosystem of inhabitants, companies, public utilities and local governments, are today recognized at the international level for their key role in the fight against climate change. Drawing support from associations or active networks such as Local Governments for Sustainability (ICLEI) in the 1990's, Climate Alliance and Energy-

Cities, some cities voluntarily became involved in Climate Plans, energy-transition experiments, eco-district projects and, more recently, resilient cities. Some of these initiatives and experiments have become symbolic, but the movement has far higher aspirations. The Covenant of Mayors for sustainable local energy was launched in 2008, under the leadership of the European Commission. It requires signatory cities to submit, within one year, an energy action plan for reducing its CO_2 emissions by at least 20% by 2020. Energy and climate are essential issues, at the same time as long term target (reduction of GHG) and as short term requirements (resilience with regards to oil price rising and supply disruption). Cities are here understood not only as local authorities bus as complex, adaptive, social-ecological systems, including local ecosystem of inhabitants, companies, public utilities and local governments.

According to MILESECURE-2050 (Caiati, Quinti, Kazakopoulos, & Sitko, 2013), the process towards post carbon city is the aggregation of a number of underlying transitions and incremental processes of experimentation, breakthrough, institutionalization, and behavioural and cultural change. These processes are mainly driven, in our Western democracies, by distributed control, renewable resources and systemic innovation. Loorbach, (2014) says that it is a “socio-economic revolution”, representing a “fundamental power shift away from powerful elites controlling resources, money and power towards diverse and distributed forms of collaboration between professionals and citizens”. It is made up by a growing number of both citizens and professionals as individuals that increasingly decide to develop an alternative currency, produce their own energy, get their food from the farm, collectively organize care and set up a collective pension fund. (Lombardi, 2014).

I.2 An alternative view

Current sustainability definition seems to be led by an eco efficiency approach (Korhonen & Seager, 2008a), defined as the increasing of productive output while using fewer resources. The result is almost universally seen as advantageous to the economy and the environment, as well as encouraging sustainability. From a strategic business perspective, the eco efficiency approach allows measurable objectives that are consistent with a continuous improvement philosophy or quality-focused management culture; eco efficiency is therefore convenient within the frames of current theory and magnitudes of business economics.

Despite all the benefits of eco efficiency, we have now realised that these improvements can bring price reductions that in turn may provoke increased consumption. Talking about environmental sustainability, it is the well known "rebound effect", i.e. the phenomenon by which improved efficiency on an intensive (or per product) basis creates new demands for products that adversely impacts the environment on an extensive basis (total consumption). From a broader systems perspective, eco-efficiency may have counter intuitive effects regarding long-term sustainability (Alcott, 2005), reducing flexibility, increasing externalisation and losing spare capacity, in one word, decreasing resilience. It is here the case to introduce this arising paradigm for cities of tomorrow and try to clang it in the sustainability debate.

Resilience can be defined as adaptive capacity of urban systems is the capacity of an urban system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker, Holling, Carpenter, & Kinzig, 2004). It is the ability of stakeholders – i.e., human actors – to improve its resilience to fluctuating environmental and socio-economic pressures, such as long-term changes in urban resident demographics, city and rural migration patterns, and potential city health concerns (Folke et al., 2004).

Resilience thinking involves exploring interacting hierarchies of nested systems: higher-level systems are driven by slow variables and lower-level systems are driven by fast-changing variables (Chelleri, Schuetze, & Salvati, 2015). Currently, most urban resilience research focuses on the societal capacity to respond and adapt to natural disaster events. These processes, oriented around maintaining security and stability, are most often viewed from a short-term engineering resilience perspective, referring to the time needed for a system to return to a stable equilibrium state. However, there is an increasing interest in exploring how to incorporate approaches around longer-term systemic transformation (incorporating risk mitigation within the recovery processes). The main criticism of the engineering “bouncing back” perspective relates to the probability that old and unsustainable urban patterns will be maintained. The need to return to a stable state prevails over possible transformation and a long-term view, which sustainable development requires. A generalized example of a hidden “lock-in” (mainstreaming old patterns of consumption) is the dependency on energy consumption and its consolidation through installing air conditioning when adapting buildings to increasing temperatures (Chelleri, Waters, Olazabal, & Minucci, 2015). According to the different possible long-term scenarios related to any short-term decision, building resilience in social–ecological systems never fully removes vulnerabilities, but can alter the configuration of system resources and capacities, which implies a shift in space and time of system vulnerabilities (Fatorić & Chelleri, 2012).

The new resilience-thinking approach may make some processes poor in terms of eco efficiency, but supportive of a systemic and wide sustainability overview (Korhonen & Seager, 2008b), since resilience, for social-ecological systems, is then related to (i) the magnitude of shock that the system can absorb and remain within a given state; (ii) the degree to which the system is capable of self-organisation; and (iii) the degree to which the system can build capacity for learning and adaptation. Management can destroy or build resilience, depending on how the social-ecological system organises itself in response to management actions (Ernstson et al., 2010). Thus, resilience, for social-ecological systems, can be defined as the capacity of a system to cope with change, either trough persistence, adaptation or transformation. The study of the transition towards future production and consumption systems that involve the not only a more efficient usage resources but also a resilience building among communities requires the presence of innovative case studies. In Europe there are a number of case studies representing “anticipatory experiences of energy transition”

(AEs). These are about 1500 cases (but 90 have been deeply analysed by the MILESECURE-2050 project) which have developed environmentally sustainable ways of producing, consuming and transporting energy. Such experiences have been understood as already existing "parts” of a future post-carbon society allowing to focus on concrete factual elements and not mere hypotheses. AEs have incorporated the basic features of a more complex transition to an environmentally sustainable society and that anticipate the basic features of a broader and more complex transition to environmentally sustainable ways of producing, consuming, and distributing energy. Their anticipatory character may be assimilated to their ability, at the present time, to take decisions and develop practical solutions to resolve issues related to the future. The main result of the analysis of AEs is that energy transition does not seem to present itself as a gradual change. In fact, it does not take the form of the mere penetration into society of new greener and efficient technologies (technological drive); nor it is "merely" the introduction of new rules or restrictions that citizens must accept (normative drive or consent drive); neither it consists only in new attitudes toward consumption (and savings) to be interiorised by the population (ethical or lifestyle drive). Each of the above drives is present in the experiences considered, but all three are based on a vision of change in which both the social and the anthropological/individual dimensions are relegated to a function of "acceptance" of measures and decisions that come from the outside. Although these visions of energy transition recognize the importance of social and anthropological impacts and feedback, they tend to consider the human factor as a mere receptor, not an agent of change. Therefore, what is actually lacking is the perspective of human agency, as a constitutive element of the transformation of the energy systems.

In short, the human factor becomes the driver of energy transition in at least three distinct levels:

- The set-up of energy production and consumption becomes more visible and closer to citizens. In this framework we witness citizens gaining the ownership of the means of energy production; the spread of new technical skills; the activation of social networks for the installation and maintenance of low-carbon technologies (Voytenko, McCormick, Evans, & Schliwa, 2012);

- The energy issue becomes a direct interest of citizens who actively participate in the regulation, orientation, management (also in economic terms) and monitoring of measures and policies of energy transition (Spaargaren & Oosterveer, 2010);

- There is a strong personal effort on the energy transition through an intense emotional involvement; a highest attention to several aspects of everyday life (food, waste collection, energy consumption, body care and health); an increased use of physical effort in the field of mobility (but not only), i.e. through the use of bicycles or with an increased inclination to move on foot or by public transport (Li, Tan, & Rackes, 2015).

I.3 Urban Sustainability: Literature Remarks

This introduction has argued that a new paradigm shift is necessary in order to progress toward truly sustainable cities. This is related to urban resilience when we have to assure that the capacity of an urban system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks may also not undermine the same capacity of other cities or peri-urban contexts (Lopez, 2011). The rapid technology advancement made humans incredibly adapting, but here comes the paradox of urban resilience: cities have been designed to remove or minimise environmental disturbances, thus not able to react to them when they come shifted in space and time (Johannessen & Hahn, 2012). The resilience approach demonstrates the importance of living with disturbances when a city is likely to be unpredictably tackled by climate change effects, and therefore favour the blooming of self-organised tools and measures to face the quick change. When the urban community is well self-organised, and can rely on traditional knowledge about coping with changes without external help, resilience increases and disaster/emergency response gives better outcomes (Adger, Hughes, Folke, Carpenter, & Rockstrom, 2005; Jones et al., 2010; Vale & Campanella, 2005). This concept implies significantly less emphasis on technology and on top-down planning and more emphasis on human factor in the analysis of energy transition. The study of the transition towards future production and consumption systems that involve the not only a more efficient usage resources but also a resilience building among communities requires the presence of innovative case studies (Vandergeest, Idahosa, & Bose, 2010). From this perspective, it could therefore be the case of a critical evaluation of the radical innovation and the strategic rethinking needed by universities, as nested cities in a city. That is the concept of Living Lab (Shafie, 2015), which scales the length of the urban border condition to the campus' one, and takes students, teachers and administrative staff as "citizens" of this portion of the city; the support of private industries and governmental task forces foster the role of university in the co-creation of sustainable life conditions. The vast partnerships among universities and among academia and its environment (thanks to European funded project for advanced education schemes, collaborative researches, consultations with local government for urban reforms or real estate development projects, industry preferred tests beds, or among society through economic exchanges as it will be specified in the following paragraphs) lead many universities to assume a highly ambitious role of collaborating with diverse social actors to create societal transformations in the goal of sustainability (Dentoni & Bitzer, 2015). This is also seen as part of the so-called "third mission" of universities which refers to a further goal to add to the universities traditional teaching and research missions: the perceived need to engage with societal demands and link the university with its socio-economic context (Bulkeley et al., 2009). As well as any other urban district, different campus plans do influence the sustainability performance of the overall city - this is the main aspect to consider when scaling from building to neighbourhood sustainability evaluations (Veldkamp, Polman, Reinhard, & Slingerland, 2011). However, when investing in the social dimension of the energy transition problem, the Well-being, Land Use, Mobility, Social Equity, Urban Economic Sustainability and Energy Sources and Infrastructure are special factors in a Campus Community. Of course, this scale-up is not costless: decision making at urban level requires complex methods to evaluate different features and guarantee the sustainability and the resilience for a large number of stakeholders, that in the case of a University are far from homogeneous: short staying students (from one month or one year) to long-staying one (5 years or more) to permanent staff and daily visitors are a community difficult to target in term of differentiated strategy and communication level. Plus, the quadruple helix approach (Lombardi, 2011) highlights problems related to the contemporary satisfaction of all the stakeholders interplaying with the university as a place of knowledge transfer, urban node and variegate social actors: decision makers/urban planners, investors/developers/construction companies, designers (engineers, architects), grant managers, building owners, SMEs/IT solutions providers, citizens, and finally students, professor, peer universities, research centres, not to mention the legislative (regional and ministerial) compliances (Folke et al., 2002; Jabareen, 2013).

In this perspective, some of the criteria for the resilient city seem to be applicable to the campus dimension even without the disaster response, with the hypothesis that resilient community building as a fertile ground for user behaviour leverages for energy reduction in university campus (McKenzie-Mohr, 2013). Institutions now have the responsibility, more than ever before, to integrate sustainable development and resilience requirements into all their teaching, research, community engagement and campus operations to make the difference into the run to innovate a the new urban and citizen paradigm toward a low carbon society.

I.4 Thesis Structure and Methodology

This thesis moves from the assumption that a mentality shift is needed to transit towards a more sustainable and fair society (Shove & Walker, 2007). Universities play a key-role in the behavioural and attitudinal shift in the current and the forthcoming generation of citizens and governor, who are or will have to tackle the main consequences of the unsustainable lifestyle of the last century (Cortese, 2003). Also, universities can be regarded as smaller cities, still containing complexity and uncertainties of the wider context, but more controllable in term of their metabolism and of the efficacy of policy and actions toward a wiser use of resources.

Although many are trying to step out from the "green gates" of the green-washing temptations and the functionalism paradigms, higher education institutions are struggling to realize the opportunities offered by ubiquitous information, smart technologies, social media, public engagements and philanthropic supports in the context of unprecedents global conditions and systemic pressures (Saavedra & Budd, 2009; Schuetze & Chelleri, 2015).

This is why this thesis aims at updating the debate on current sustainability assessment framework in Universities, demonstrating gaps and barriers for a truly sustainable university campus, and suggest strategies to overcome the common difficulties by learning from success cases and analysing failures factors among different case studies.

In fact, this thesis is composed by chapters written as scientific papers to be submitted (or already submitted) to peer-reviewed and indexed journals. As story-told in the foreword, this is in order to fully profit of the thesis-writing occasion to disseminate the three-years research results in an editable and reader-friendly way, ready for discussions and further multi-disciplinary connections.

This introduction explains why sustainability in university has been chosen as the object of this study, zooming from the climate change issue and the role of cities into the limits of current assessment framework and definition of urban sustainability indicators and criteria. Essential, for the development of this theoretical framework, was the participation to the masterclass and the mobility exchange held within "Territories in crisis"[2], a collective research coordinated by Politecnico di Torino and

[2] www.territoridellacondivisione.wordpress.com

the École Polytechnique de Lausanne. The output has been presented at the "XVII Conferenza nazionale SIU, L'urbanistica italiana nel mondo", and published in the acts of the conference by Planum in 2014.

The first chapter set the border conditions for the sustainability issue within the university context. It is made by the article published in the *Sustainability*[3] journal: "True Green and Sustainable University Campuses? Toward a Clusters Approach". It introduces the gap between current energy efficiency indicators and the lack of methods for a meaningful comparison among similar universities and for addressing social (users) aspects related to long term sustainability transitions. This chapter aims to introduce a critical perspective on sustainability university frameworks through: (i) a review of current Campus Sustainability Assessments (CSAs); (ii) performing and comparing the results obtained from the application of two internationally recognized CSAs (namely, Green Metric and ISCN) to two case studies (the Politecnico di Torino (POLITO), in Italy, and the Hokkaido University (HOKUDAI), In Japan) and, finally, (iii) proposing a new CSA approach that encompasses clusters of homogeneous campus typologies for meaningful comparisons and university rankings. The proposed clusters regard universities' morphological structures (campuses nested within city centres *versus* outside of a city compact ones), climatic zones and functions. At the micro scale, the chapter introduces the need for indicators beyond measuring pure energy efficiency, but which are attentive to local and societal constraints and provide long-term tracking of outcomes. This, better than a sheer record of sustainability priority actions, can help in building homogenous university case studies to find similar and scalable success strategies and practices, and also in self-monitoring progress toward achieving truly sustainable university campuses.

The second chapter goes deep into the POLITO case study, to analyses strengths and weaknesses of the current energy management and monitoring activities put in

[3] Sonetti, Giulia; Lombardi, Patrizia; Chelleri, Lorenzo. 2016. "True Green and Sustainable University Campuses? Toward a Clusters Approach." *Sustainability* 8, no. 1: 83.

practice even before a sustainability scheme was put in place. It is made after a paper invited and under revision by the Journal of Cleaner Production (Impact factor 3.844 in 2014) after having been presented at the SDEWES 2015 conference[4]. It is titled: "Giving Quality to the Quantity of Big Data from Living Labs: Energy Data Management in University Sustainable Reporting". It starts with a literature review of university energy data management and monitoring; then it moves toward the analysis of the POLITO studying the campus setting, the energy data acquisition and the living lab structure, and the energy data set from 2008 to 2014. Major limits of data acquisition without targets or meaningful comparison thresholds are outlined. The HOKUDAI case, seen as a similar campus and studied during a field-work in Sapporo for the UNI-Metrics project, is presented to compare the campus setting, the energy trends and the building functions and operational times. Extremely different factors affecting different consumption paths are outlined and then coupled with the University of Turin energy data set to demonstrate the need of specific clusters of energy absorption according to function hosted and climate condition. The role of living lab manager and a human factor that interact with the IT infrastructure is also highlighted, as well as the need for different weighting criteria for the energy and climate indicators in international university ranking such as the Green Metric one.

<u>The third chapter</u> analyses the aspects of sustainability management schemes in Universities. It is titled "Sustainability Management in University Campuses: the Road from Scattered Good Practices to Systemic Transformations", and it will be presented to the SBE16 – Toward Post-Carbon Cities conference[5] to be held in Turin on February 2016. This chapter aims to contribute to the emerging dialogue about how to accelerate the progress towards an institutionalised commitment to campus environmental sustainability. It will analyse three cases of good practices made to

[4] The 10th Conference on Sustainable Development of Energy, Water and Environment Systems – SDEWES Conference, hold in Dubrovnik in 2015. Speaker, poster presenter and co-chair of the special session on sustainable campuses

[5] http://sbe16torino.org

date in the field of "green universities" management, looking deeply into these experiences, interviewing their main stakeholders and revealing the main sustainability activators and barriers to transfer and widespread similar institutional transformation. A range of data is presented, from reports and interviews about lessons learned and approaches emerging from different environmental strategies to quantitative indicators analysis from the green metric reporters. One Italian, English and Mexican University are taken as success cases for different sustainability topics. The subject matter is wide ranging as it is intended as a starting point for the reader to pick and choose ideas that may warrant further investigation in their own university context. Even though many of the ideas presented need further exploration and development, in their current state they may prove of some value to the reader as a catalyst for a different level of institutional analysis. This chapter draws from the mobility exchange spent at the University of Cambridge in 2015 for the POLITOWARD project and from the Memorandum of Understanding co-signed with the Universidad Autonoma de Tamaulipas (MEX).

The fourth chapter shifts the bar to the importance of the user engagement to obtain not only valuable result in the short terms, but to ensure the durability of the actions planned in the direction of a sustainable community building. It will be presented at the International Sustainable Development Research Society (ISDRS)[6] 22nd Annual Conference to be held in July 2016 an it is titled: "Human Factors and Energy Consumption: Hints from Social Practice Theory and User's Comfort Definitions for Effective Energy Policies in University Campuses". It starts from the arguing the concept of "sustainable development", born having mainly production-oriented policies as institutional outcomes. The responsibility of the resource management was attributed to the productive sectors, while corporate actors should have reduced their environmental impact. This paradigm then expanded and reached a progressive adherence to the concept of co-responsibility of consumers, by means of purchase

[6] http://www.isdrsconference.org

choices and the adoption of more sustainable lifestyles. As result, demand-side policies were elaborated through the active involvement of the users giving new sense to apparently consolidated concepts about the energy transition and the role of the society. Adopting this socio-technical approach, the chapter investigates the changing definitions regarding quest for comfort and the decision-making mechanism as basis and strategies for energy reduction policies, especially in university building. The co-design of an app with the "Design Studio Methodology" was adopted to collect users feedbacks about thermo-hygrometric, air quality, brightness, crowding and noise discomfort. The case study involved classrooms of a university campus in Turin (IT) to explore how to identify and localise discomfort peaks and their possible remedies from the student's point of view. The re-evaluation of the concept of comfort has been the main results to step forward the conventional theories on energy policies design. Taking advantage of users' expressed needs may be shift the attention to several aspect impacting the workplace comfort, sometimes cheaper and more controllable than energy supply and monitoring. This can be a further step to effectively reduce energy consumption in public building acting wisely on human factors rather than just via smart appliances or real time building response.

The conclusions sum up the main findings of all the previous chapters and relaunch further research outcomes in the direction of new assessment methodologies and metrics for defining a truly sustainable, and resilient, university campus. They constitute the main prompt for a paper that will be presented in the 3rd World Symposium on Sustainable Development at Universities (WSSD-U-2016) to be held on the 14-16 September 2016, at the Massachusetts Institute of Technology (MIT), Cambridge, USA. The starting assumption is that few institutions are really leading the road toward a new model for sustainability management, and the reasons for these dissipative forces are shown throughout this thesis. Recalling the living lab model, this last chapter enquires about the current failures the opportunities for a shared vision of the sustainable university of the future. Global analysis about current sustainability management is carried out criticizing the lack of comparability and the non-effective indicators for catching meanings of resilience and social equity. Sustainability issues in the different areas are coupled with the peculiarities found in the different resilience achievements of different university campuses. A special emphasis is given to the catalysers or barriers which help or prevent the quadruple helix model to run smoothly along the city council, the private companies and the civic society engaged in each university's wider context of action. In the final section, frameworks for driving the operationalization of resilience in university campuses are suggested through KPIs drawn from urban resilience determinants. Although very primordial and schematic guideline, examples from study cases analysed in this thesis, from Japan, Mexico, UK and Italy are used to frame resilience into the university sustainability dimensions (education and research, physical infrastructures and human capital) and urban influences knots. Finally, some concrete steps which may be undertaken in order to allow universities to integrate feasible sustainability and resilience targets in their strategic plan are outlined, as well as some proposal for a framework specially tailored for university campuses. The focus among the different case studies analysed through the chapters was used as an opportunity to explore urban resilience indicators rappelled down the university campus has been energy. After that, other relevant and intersecting factors (water, ICT, waste, food) contributing to the function and the input-output model of a university campus could be analyses via the same framework. Although the monitoring via livings labs seems a shared step for a sustainable university management, none of the universities explored via literature reviews and fieldworks undertaken around the globe in these the three years of PhD study present any long-term resilience/sustainability plan of targets. However, the many stakeholders met on this challenging and mind-feeder path, coupled with practical evidences and "brave" intuitions, gave birth to the ultimate contribution, synthetizing the aim of this work: to enrich the critical perspectives on how to operationalize and un-pack resilience and sustainability synergistically, far from being merely metaphorical labels fitting on business as usual campuses management agendas, toward truly sustainable university campuses.

References and appendices are inserted at the end of each chapter, so that the reader may find easier to cluster references and tables per each topic. A final reference list is presented after the conculsions.

The following abbreviations are used in this manuscript:

POLITO: Politecnico di Torino (IT)

HOKUDAI: Hokkaido University (JP)

UNICAM: University of Cambridge (UK)

UAT: Universidad Autonoma de Tamaulipas (MEX)

CSA: Campus Sustainability Assessment

EE: Eco Efficiency

ISCN: International Sustainable Campus Network

PE: Primary Energy

Foreword and Introduction References

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1 True Green and Sustainable University Campuses? Toward a Clusters Approach

Abstract: Campus greening is often the first step universities take towards sustainability. However, the diffusion of sustainability reporting methodologies and rankings is still at an early stage, and is biased in mainly measuring energy efficiency indicators while omitting basic features enabling meaningful comparisons among centres or addressing social (users) aspects related to long term sustainability transitions. This chapter aims to introduce a critical perspective on sustainability university frameworks through: (i) a review of current Campus Sustainability Assessments (CSAs); (ii) performing and comparing the results obtained from the application of two internationally recognized CSAs (namely, Green Metric and ISCN) to two case studies (the Politecnico di Torino, in Italy, and the Hokkaido University, In Japan) and, finally, (iii) proposing a new CSA approach that encompasses clusters of homogeneous campus typologies for meaningful comparisons and university rankings. The proposed clusters regard universities' morphological structures (campuses nested within city centres *versus* outside of a city compact ones), climatic zones and functions. At the micro scale, the chapter introduces the need for indicators beyond measuring pure energy efficiency, but which are attentive to local and societal constraints and provide long-term tracking of outcomes. This, better than a sheer record of sustainability priority actions, can help in building homogenous university case studies to find similar and scalable success strategies and practices, and also in self-monitoring progress toward achieving truly sustainable university campuses.

Keywords: *University Campus; Sustainability Assessment Frameworks; Energy Indicators*

1.1 Introduction

The key role of higher education institutions in the transition to a more sustainable society has been recognized and highlighted for almost three decades (Wright, 2010). In respect to the most pressing urban and planetary sustainability challenges (Seitzinger et al., 2012), universities are identified as key hubs within cities for innovation and environmental education, representing a precious opportunity for enabling the necessary generational behavioural change toward taking on more sustainable attitudes in daily lives (Jackson, 2011; Tukker et al., 2008). To be credible in this guidance role, the university *in primis* has to behave responsibly and wisely in response to sustainability issues in the management of the energy and human resources of the campuses. A sustainable university has been defined as a higher educational institution that addresses, involves and promotes, on a regional or a global level, the minimisation of negative environmental, economic, societal, and health effects generated in the use of their resources in order to fulfil its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable lifestyles (Hordijk, 2014). At the same time, Cole highlighted the key role of sustainable campus communities, since "they actively engage the knowledge of the university community to address the ecological and social challenges that we face now and in the future" (Cole, 2003, p.30) The younger generations can indeed play a major role in addressing sustainability (Green, 2013; Zsóka, Szerényi, Széchy, & Kocsis, 2013) by understanding and implementing "holistic and trans-disciplinary approaches that address the four dimensions of sustainability and their interrelations" (Lozano, 2010, p.140). However, the management of this social responsibility transition, and the adaptation of campuses' built environment toward a more sustainable system, is not a trivial matter (Alshuwaikhat & Abubakar, 2008). For instance, educational functions account for 17% of the overall non-residential building stock in the EU (Caeiro et al, 2013). Knowing that buildings are responsible for about 40% of total final energy requirements in Europe, the educational sector accounts for 6.8% of the total EU energy consumption. To give an idea of magnitude beyond the European case, the educational sector in China accounts for 40% of the total energy consumption in public buildings (Trencher et al, 2013), with 30 million students and 1.87 GJ/m^2 of energy consumed in 2007 (Eagan & Orr, 1992). In this way, universities are not only hubs for innovation and environmental education, but important actors within the urban setting, which must draw on a complex set of accounting indicators, dealing not only with environmental performances, but critically addressing economic, political, social and ethical issues (Filho, 2000). In this context, campus sustainability assessments (CSAs) have been emerging, and have been used for more than a decade, as tools for identifying best practices, communicating goals and experiences, and measuring progress towards achieving the concept of a sustainable campus. Even if the literature in the late 1990s proposed detailed environmental reports, mostly by different North American universities voluntary initiatives (one of the first was "The Student Environmental Action Coalition—Campus ecology in 1993), there was not much relying on empirical data or common reference frameworks (McIntosh et al, 2016; Del Alonso-Almeida et al, 2015). However, with the growing interest in campus environmental impacts, as a consistent part of the built environment, many projects launched wider initiatives for cross comparison and campus assessment (Shriberg, 2002). In the last decade, different CSAs have been proposed at national and regional scales around the globe (Rauch & Newman, 2009), varying greatly in purpose, scope, function, state of development and closeness to an "ideal tool"(Derrick, 2013). Recent research on CSAs has focused on defining and examining the role of metrics, even questioning the necessity of them (Caeiro et al, 2013; Adams et al, 2007). Shriberg reviewed eleven assessment tools and found that many excel in capturing data on environmental and sustainability performance, as well as process-oriented information, or they also provide the grounds for strategic planning, by stating goals and methods (Derrick, 2013). However, they do not provide mechanisms for comparison (nationally and internationally), because they traditionally stress material utilization, CO_2 emissions, and regulatory compliance, which is different from country to country. Furthermore, measuring sustainability requires a major leap beyond the energy efficiency paradigm, addressing social, economic and environmental impacts. For instance, an eco-efficiency indicator would provide the amount of kWh per square meter per year, while a sustainability indicator should look at the trend in consumption reduction over the years, or the percentage of people satisfied with the comfort level in their working environment (Verhulst et al, 2014). Because of this, CSAs could be powerful tools for both triggering and supporting the organizational change process, or dangerously used as a mere *façade*, contributing to green-washing the business as usual unsustainable campus management (Calder & Clungston, 2003). In line with this special issue topic and objectives, the study reviews some of the current CSAs, underlining their limits implementing effective improvements in the overall sustainability performance assessment method.

The *Politecnico di Torino* (POLITO), in Turin (Italy), and the Hokkaido University (HOKUDAI), in Sapporo (Japan), are assessed according to "Green Metric" and "ISCN report" CSAs. The research design justifying such international (European–Asian) comparison relies on POLITO scoring relatively low positions in world university rankings (in the Green Metric one, for instance, it occupies the 280th/361 *vs.* the 209th position of HOKUDAI, in 2014) but not reflecting a quite virtuous energy consumption path and wise resource management practices as revealed by in-depth, focused research. Although Turin and Sapporo Campuses do not have many similar characteristics in terms of urban settings, population, density per square meters and functions, they are still considered in the same international ranking as many other campuses around the globe, with evident comparability limits and sustainability performance mismatching. A new approach is therefore proposed, aiming at capturing current sustainability performances and local constraints both at the macro assessment level (*i.e.*, within the frameworks) and at the micro-level (*i.e.*, within indicators). The objective is to overcome the institutional and intrinsic limits of current CSAs, and help sustainability managers to translate strategic plans into powerful tools for self-tracking, goal setting and the promotion of transferable practices toward truly achieving sustainable university campuses and communities.

1.2 Method

The critique of current CSAs, and their limits, has been developed through an extensive literature review, and by proposing two case studies. The Politecnico di Torino (POLITO), in Turin (Italy), and the Hokkaido University (HOKUDAI) have been measured by the two most used typologies of CSAs: the "Green Metric" ranking (based on quantitative metric) and the "ISCN report" (based on individual and qualitative display of sustainability initiatives). The reason why the Green Metric and the ISCN have been selected is twofold: they are not country-related sustainability report tools. They are also largely diffused, with more than 360 (Green Metric) and 70 (ISCN) participants from 20 countries. Moreover, they stand as examples of the two main functions of CSAs: the auditing of local initiatives (ISCN), and the reporting of sustainability indicators according to a fixed set of criteria (Green Metric). The first type encompasses a list of self-elected criteria adherent to general areas of impacts (mobility, energy, third mission). The second one allows comparing universities' performances (communicated via self-compiled questionnaires and retrieving public data display) at the same ranking. Indicators to compile the two CSAs for the Turin case (Appendix B) have been calculated drawing data from surveys, focus groups, interviews, the POLITO living lab (so from smart metering systems and bills) and literature (official documents, maps, *Archibus* facility management systems) available at POLITO. For the Hokkaido case, different fieldwork was undertaken at the HOKUDAI campuses, recollecting the necessary data from the Hokkaido University Sustainability Office and from stakeholders' meetings and surveys (interviewees were selected mainly based on their level of involvement with sustainability initiatives and their organizational position in the university). To identify potential candidates, an extensive list was initially developed for both studies, and adjusted based on referrals provided by the first interviewees (Appendix C). Each of the 23 interviews lasted on average 60 min, and was conducted in Italian or English. Four main themes were covered during the interviews: sustainable campus initiatives (according to the area of expertise and knowledge of the interviewed), *in fieri* activities, governance of the decision-making process and management control systems (and more particularly about data collection and use). The interview protocol was adapted to each event (focus group, meetings, and surveys) and to the stakeholder profile. The various degrees of engagement in sustainability initiatives of the interviewees, and the numerous uncoordinated sustainability initiatives that have been carried out by students and professors, opened up the opportunity to develop a dedicated team in order to manage the different stakeholders that emerged. This level of management would be useful both regarding the effectiveness of the actions indicated in this report and the relationships that the University must inevitably establish with a series of third parties. The research on this topic may also enrich the outcomes of the evaluation procedures aimed at informing and communicating data in different ways through different indicators.

The other relevant source of information to complement the information obtained from the interviews came from a review of all the internal and external documents. The chronology of university sustainability initiatives (both public and private documents consisting with annual reports, websites, activity reports, campus assessments, internal mail, PowerPoint presentations and the POLITO *Archibus* database) was obtained online or provided by the interviewees. The catalyser for all these crosscutting sustainability initiatives resources was the POLITO living lab and the Hokkaido Sustainability Office. The monitoring system in POLITO is based on the acquisition of data from different plants and flows equipped with meters, smart meters and a heterogeneous data logger[7]. The Sustainability Office in HOKUDAI acts as a collector of bills, purchases and facility management and works closely with

[7] Most of these information are accessible to everyone retrieving the website http://smart-greenbuilding.polito.it/.

departments, institutes and other related organizations in taking steps to achieve campus sustainability.

1.3 CSA Frameworks: Why They Are Not Mirroring Actual Sustainability Practices?

As remarked in the introduction, although some virtuous universities disclose activities correlated to their green image, and have for 20 years, the diffusion of systematic sustainability reports (SR) is still in early stages overall in Europe. Many literature reviews focused on different reasons for this gap, trying to seek out a new taxonomy for examining the multiple roles of campus sustainability assessments in organizational change, barriers in the organizational framework (Arroyo, 2015), lack of integrated strategy among the core areas of university stakeholders (Spira et al, 2013), different purposes and drivers for their adoption (Coulemans, 2015), sheer green-washing goals, or lack of metrics for comparability (Filho, 2000). The different classes of problems related to the current sustainability framework development and adoption are shown in Fig.1, to highlight the focus of this study and the reasons for it. In particular, In Fig. 1, the left yellow boxes indicate the responsibility for the implementation of solutions related to the absence of sustainability (SUS) initiatives (first block), of SUS reporting (second block) and the inefficacy in reporting such initiatives in terms of practical outcomes (third block). In the light blue rectangle on the right, the process needed to maintain the achieved "truly sustainable campus" (blue ellipse) is detailed. The effective translation of the CSA framework into practice (red rhombus step) is the evaluative gap this study wants to bridge. The red arrows coming from it points to the area of weaknesses more directly related to current CSAs, which can be broken down into two main levels: at the macro-level, the inability to compare different campuses; at the micro-level, the inefficacy of some indicators in representing actual sustainability performance.

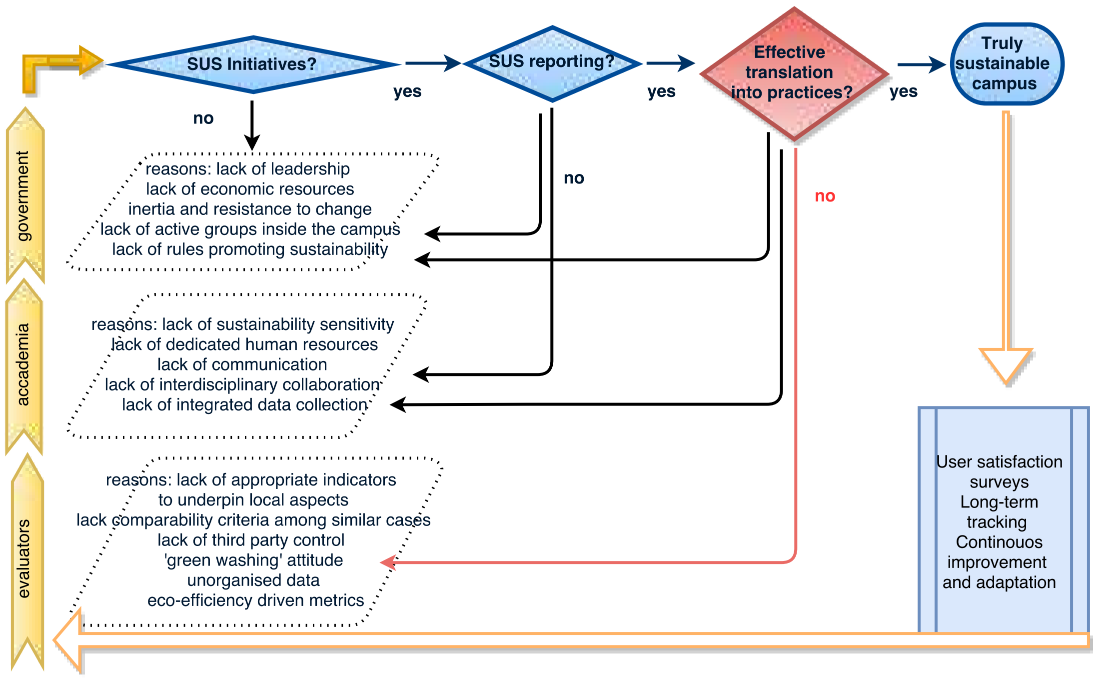


Fig.1.Different classes of problems related to current sustainability framework development and adoption. Source: elaborated from authors.

Of course, there is no black/white correspondence among the boxes and the categories of problems outlined in the diagram. For instance, there could be no correlation at all among sustainability assessment and reporting activities, while some authors consider the two as synonymous. Derrick even raised the questions whether these indicators actually measure what sustainability is and why, and also whether the data used for ranking systems is just another signal of institutional performativity (Derrick, 2013). Few studies have yet assessed and thoroughly explored the change agents' roles and implications for CSAs in truly contributing to higher education institutions' sustainability transitions (Coulemans et al, 2015). Lang even warns that "there are very limited correlations between institutional environmental performance and adoption of campus sustainability initiatives, be they targeted operational or coordination and planning best practices, or curricular, co-curricular or research activities. Conversely, there are strong correlations between environmental performance and campus characteristics, namely, institution type and climate zone" (Lang, 2015, p. 474). This is a macro-gap recorded also by the Ministry of Education in Japan (MEXT, 2012), in a chart (Figure 2) where different energy consumptions of

Japanese universities are set against their related area in km². Three different types of universities are therefore identified as displaying a second homogeneous trend of consumption, namely medical colleges, "megaversities"[8], and colleges of education. This, plus other evidence from the cited gaps in the literature on CSAs, led this research to focus on how to merge similar campuses into clusters. This article proposes clusters including similar institution types, climate areas and urban contexts are suggested in order to bridge the gap found at the macro-level regarding the lack of comparability criteria of different campuses using the same CSA.

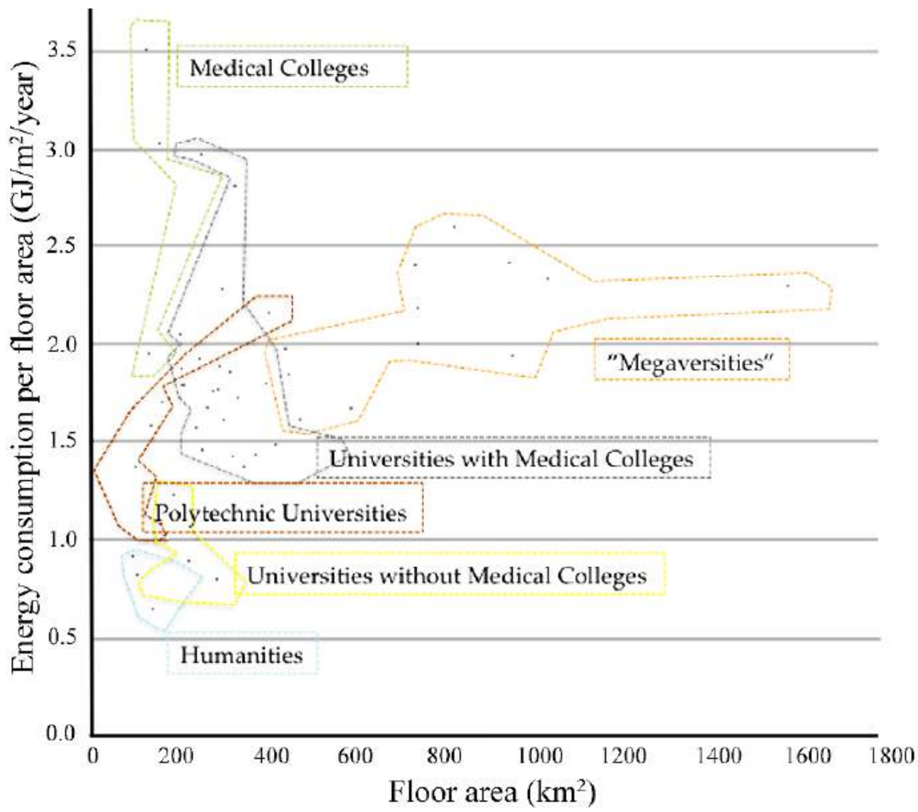


Fig.2.A benchmarking method for facility management in Japanese universities. Source: (Sonetti & Kikuta, 2013).

Regarding the micro-level gap in current CSAs, the indicators' inability to communicate effectively the sustainability initiatives and performance was a pitfall already outlined by Shriberg in 2002. At the base of this issue lies the lack of measurability (and therefore indicators and their potential translation into practices)

[8] i.e. the American-style huge and mixed campus, after Clark Kerr's famous neologism.

of certain social and environmental inputs and outputs. Furthermore, the old "what gets measured, gets done" management paradigm explains why going beyond the eco-efficiency approach remains hard. In Shriberg (2002), 11 sustainability assessment tools developed specifically for universities were compared. This paper added to these another four protocols (Green Metric, UNI-Metrics, ISCN, STARS), to include recent—and more related to the EU/Italian background—CSAs. Their major weaknesses and strengths have been summed up in Table 1.

Table 1. Summary of the major strengths and weaknesses of some of the current sustainability assessments. Source: authors, adapting the table in [19].

Assessment Tool	**Major Strengths**	**Major Weaknesses**
National Wildlife Federation's State of the Campus Environment	Comprehensive Combines eco-efficiency and sustainability Identifies barriers, drivers, incentives and motivations Identifies processes and current status	Little use of the term, "sustainability" Small sample within each college/university US- Canada related
Sustainability Assessment Questionnaire	Emphasizes (cross-functional) sustainability as a process Useful as a conversational and teaching tool Probing questions that identify weaknesses and set goals	No mechanism for comparison or benchmarking Difficult for large universities to complete
Auditing instrument for sustainability in higher education (AISHE)	Flexible framework for institutional comparisons Process-orientation which helps to prioritise and set goals through developmental stages Created through international consensus	Difficult to comprehend Motivations are potentially excluded
Higher Education 21's Sustainability Indicators	Process-orientation that moves beyond eco-efficiency with a relatively small set of indicators Recognises sustainability explicitly and strategically	Difficult to measure and compare Indicators may not represent most important issues
Environmental Workbook and Report	Useful in strategic planning and prioritising Collects baseline data and best practices	Operational eco-efficiency and compliance focus Difficult to aggregate and compare data Motivations are largely ignored

Greening Campuses	Comprehensive, action orientation incorporating processes	Calculations and comparisons difficult
	Explicitly and deeply addresses sustainability	Focus on Canadian community colleges
	User friendly manual with case studies, recommendations	Resources out-of-date
Campus Ecology	Cross-functional, practical "guide" and framework	Environmentally focused (*i.e.*, not sustainability)
	Baseline for current tools	No "state-of-the-art"
Environmental performance survey	Process-oriented	Operational eco-efficiency focus
	Compatible with environmental management systems	Neglects sustainability and cross-functional initiatives
Indicators Snapshot/Guide	Quick, prioritized environmental "snapshot"	Operational, eco-efficiency focus
	Opportunity for more depth on issues of concern	Little reference to processes, motivations, benchmarking and sustainability
Grey Pinstripes with Green Ties	Model for data collection and reporting	Not sustainability specific
	Links programs and reputations	Neglects decision-making processes and operations
EMS Self-assessment	Rapid self-assessment focused of processes	Meaningless indicators for most campus settings
UNI-Metrics	Comprehensive	Very difficult to calculate
	Related to shared view on local issues	Too many new indicators sometimes impossible to retrieve
Green Metric	Continuously improved through users' feedbacks	The use of generic quantitative indicators doesn't underpin local dimensions
	Large diffusion	Lack of the social dimension
People & Planet's	Emphasis on environmental policy	UK related
	Bottom-up approach (developed and monitored by	The questionnaire changes every year, making difficult to make

	students)	comparison
International Sustainable Campus Network (ISCN)	Joined by the top-tip university	The report does not assure the agreed ISCN/GULF Sustainable Campus Charter will be put in practice
	Provides a global forum to support sustainability in the University	
STARS by AASHE (Association for the Advancement of Sustainability in Higher Education)	Answers verified by AASHE Staff	Each institution is treated the same—although can say that some sub-cat do not apply
	Evaluation based on answers/results and current situation.	US based
	Credits weighted by impact not difficult to apply	Each category has the same worth but subcategories are weighed.
	Prioritizes performance over strategy	

Global rankings like the Green Metric have a number of positive features, like openness and accessibility, and the contribution to academic discourse on sustainability in education and the greening of campuses. On the other hand, sometimes, the generality of these criteria cannot simply underpin the local dimensions and local constraints, which sometimes penalise the university for weaknesses outside its realm of responsibility. Voluntary reporting initiatives like the ISCN report are a good start for collecting data inside the athenaeum, but then there is no common ground to compare one university sustainability performance with others, since there are no common frameworks (neither qualitative nor quantitative). Still, despite historical, social, urban and political differences and similarities, leaders of Signatories University have accepted the principle that the future belongs to education and science, and can benefit if the ISCN mutual learning platform to improve their own performance.

As emerging from the table, none of the tools underpin any motivation or commitment behind the actions, which is indeed a dangerous gap. While the role of change agents and campus communities and the reasons why sustainability actions are defined are crucial to igniting sustainability processes, current CSAs seem to be an instrument for "tick-the-box" possible indicators fostering the green campus image within the sustainability reports.

1.4 The POLITO-HOKUDAI Comparison

In this section, the POLITO and HOKUDAI case studies are presented. Data collected via surveys, direct measurements, living-lab downloads, interviews and official document consultations are shown in Sections 4.1 and 4.2 (and were used to fill out the Green Metric and ISCN CSAs reports available in Appendix B). Results of evaluations are presented in Section 4.3. The "fit to purpose" feature of some indicators regarding energy efficiency strategies and appliances is criticised, proposing alternative ways to underpin the "wise use of energy" criteria. The comparison aims to demonstrate how focusing the indicators on a local and long-term oriented approach, and grouping universities according to their "cluster" of similar structure, climatic zone and functions, can overcome many of the current problems in the dissemination of mutual learning practices and sustainability management in university campuses.

1.4.1 The POLITO Campus

The POLITO setting includes five campuses dispersed throughout the city, in buildings dated from the 17th century (the *Castello del Valentino*, with an area of 23,000 m^2) to the late the 1950s (the main extended complex in *Corso Duca degli Abruzzi*, 122,000 m^2), and to 2000 (*Cittadella Politecnica*, 170,000 m^2 of student residences, research activities, technological transfers and services buildings). Far from the centre, two former industrial sites were also refurbished and used for teaching activities (*Mirafiori* and *Lingotto*, former FIAT manufacturing sites). In total, in 2012, the whole campus accounted for a surface area of 870,700 m^2, 33,600 users (students and staff), and a yearly primary energy (PE) consumption of 225,475 kWh/m^2. In 2015, POLITO, in collaboration with the Higher Institute on Territorial Systems for Innovation (SiTI), carried out a project titled "Sustainable Path", aiming to track down all the sustainability initiatives of the *Politecnico*. The first outcome is a report compiled for the International Sustainable Campus Network (ISCN) that serves as a basis for further strategic plans. In the light of what emerged in the scouting of the different hidden, but virtuous, sustainability actions in the energy, waste, mobility, communication and urban management fields, the ISCN report was shown to be useful in rounding up all the university stakeholders dealing with sustainability issues and eventually to set a long-term group work, a "green team", which will be in charge of the overall sustainability strategy of the Athenaeum. Current internal managers of the aforementioned fields could make up the core, and be supported by the existing Living Lab. The status quo reported in the ISCN shows the *Politecnico* to be in a very good position to move along this path. For instance, 100% of the electric energy consumed at the campus comes from renewables, and a consistent proportion of the thermal energy comes from district heating. A new photovoltaics (PV) plant of 400 kWp has recently been approved, new double-framed windows has substituted all the old ones, and thermal insulation has been provided for the most dissipative walls of the main building. Car-ride, car-pooling, electric vehicle charge stations, subsidised public transport seasonal tickets and closed bike parking are some of the mobility manager's recent achievements. Zero-kilometre food, green product procurement, paperless communications, campus differentiated waste collection points, and water dispensers are other tangible and visible efforts towards building sustainability education, as well as the introduction of open night lectures, sustainability-dedicated courses and several international projects on campus sustainability management.

However, POLITO is one of the many (typical European) cases of a "town-embedded campus". Nested within the city structure, it receives most of its strengths and assets, but also most of the constraints that penalise POLITO in international university green rankings (*i.e.*, lack of green spaces, poor waste management, and no dedicated mobility system, to cite just a few of them) from this structure.

1.4.2 The HOKUDAI Campus

Hokkaido University was founded in 1876 and is located in the centre of the city of Sapporo (1.9 million population, 2011 census) on the northern Japanese island of Hokkaido. It encompasses 31 schools (12 undergraduate and 19 graduate) and at the time of the survey (2012), had over 18,000 students. The campus is situated in downtown Sapporo and covers an area of 1,776,249 m^2 including the entire park in which buildings are located. Hokkaido University follows a series of sustainability initiatives in order to reduce its environmental impact. These initiatives could be categorised in four key groups: sustainable campus core schemes, sustainability programs, human resource development and education, leading sustainability networks and campus sustainability assessment schemes. The university runs periodical stakeholder meetings in order to bring expertise from outside the university regarding implemented programs and feedback on areas requiring improvement. A series of voluntary student activities to enhance campus sustainability (e.g., "Hokudai Genki project", "Sustainable Campus Contest", "Candle Night", "Sustainable Campus tour", "Hokkaido University Campus Visit Project", *etc.*) are held by different university departments and groups. Efforts are being made as well to cultivate human resources by fostering a series of sustainability programs among the student body.

However, as shown in Fig. 3, energy consumption per source has been basically steady or even slightly increasing (for gas and total PE) since 2008.

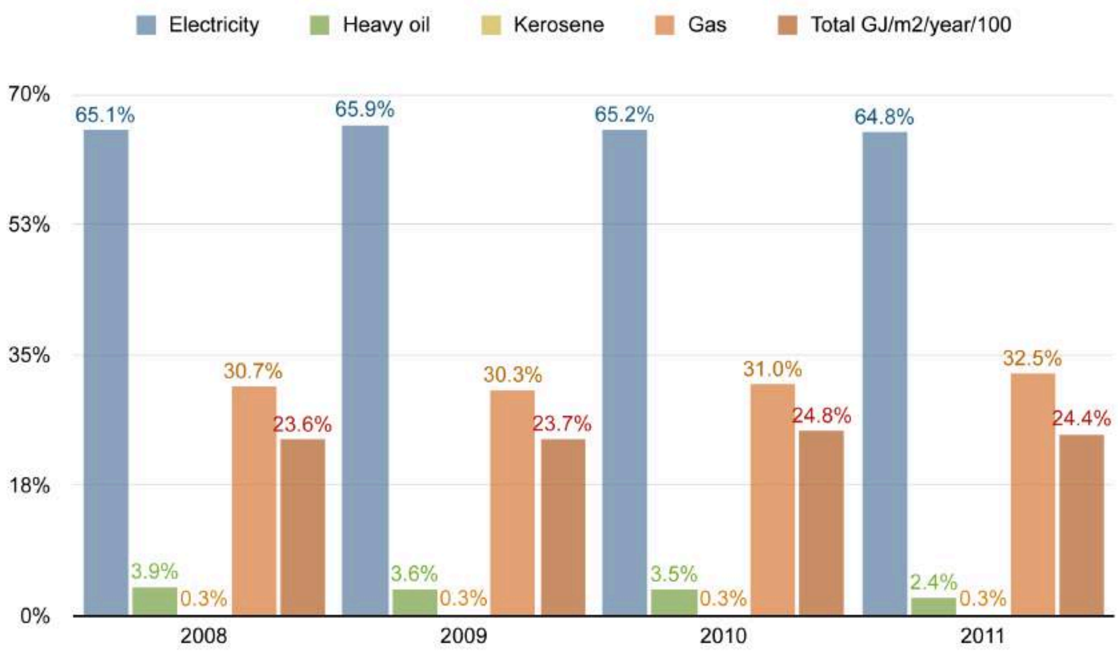


Fig. 3. Energy consumption trends from 2008 to 2011 weighted for energy source at the Hokkaido University Campus. Source: author elaboration of data by the Hokkaido University Sustainability Office.

ISCN and Green Metric Results: Campus Comparison

In this section, critical insights on metrics and report results are used in order to compare two very different campuses. Indeed, HOKUDAI's 516,509 m² of university campus area is 40% smaller than that of Turin. Its 16,418 users consume 1,731,798 GJ of PE. To put this into perspective, while PE consumption per capita in Turin is 6.71 GJ, in Sapporo it is 105 GJ (1471% more). The cost of this (calculate for the year 2014) is 117 € per capita in Turin, *versus* 2779 € in Sapporo (a difference of 2275%). These data are displayed in Fig.4.

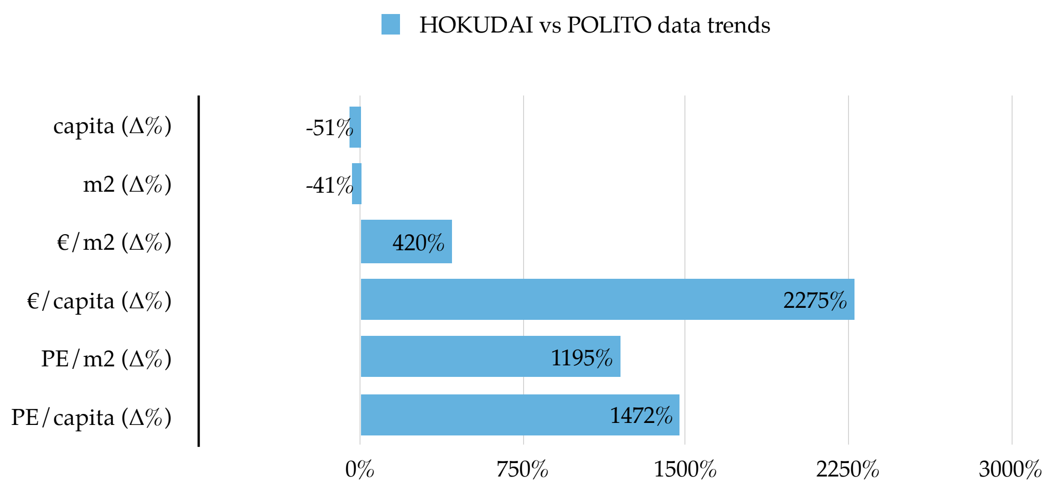
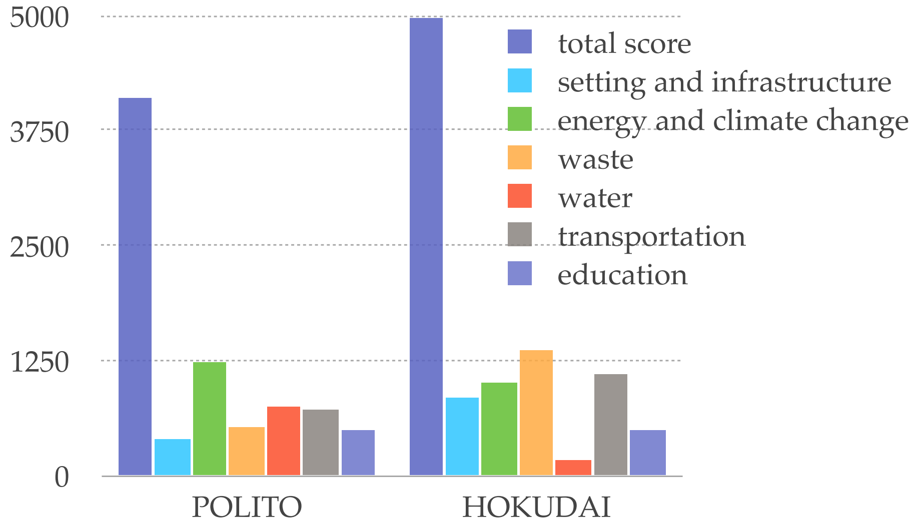


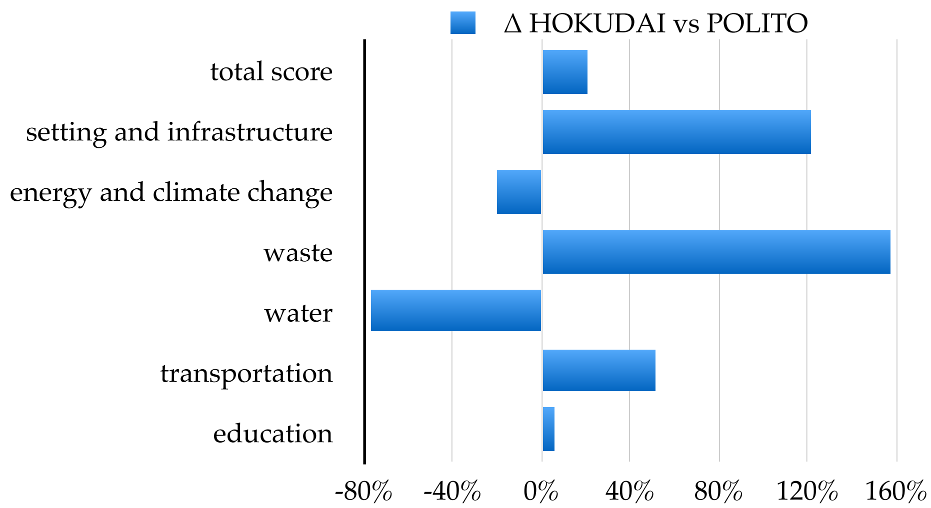
Fig.4. Comparison of HOKUDAI vs. POLITO for total university users, surface, yearly costs of primary energy consumption (PE), and PE per capita and square meters. Source: author's elaboration from data collection at Hokkaido University Sustainability Office and Politecnico di Torino's Living Lab.

Back to CSAs, the ISCN annual report only outlines the gold standard practices and celebrates the diversity of responses to challenges of campus sustainability according to each campus's peculiarities. The aim is to pool global knowledge on how universities can best support sustainable development through their research and education, and putting principles into practice in their own operations, showcasing their achievements. However, this can result in a too auto-referential and limited vision of the actual situation of the campuses. Neither POLITO nor HOKUDAI displayed any negative data or ways to overcome real problems for sustainability implementation.

Fig. 5 stresses the Green Metric scores for POLITO and HOKUDAI in 2014, with the differences (in percentage) on the total points acquired for each category of criteria. According to these metrics, the position of HOKUDAI is higher than POLITO's by 71 positions. However, if energy consumption per capita and per square meter (Fig.4) is taken into account, metrics would have suggested totally different rankings and results. Of course, energy consumption is not, as it should not be, the only and main criteria, but it is still the main output of a good sustainability performance (in terms of emissions reduction and minimum wastage of resources). While having more than 10 times less energy consumption, POLITO is penalised for being located within a city that does not allow, due to physical and legal framework constraints, more green spaces (owned by the university), a special waste treatment system, or a dedicated transportation system.



(a)



(b)

Fig. 5. Green Metric scores for POLITO and HOKUDAI in 2014 (a), with the differences (in percentage) on the total points acquired for each category of criteria (b). Source: author elaboration of data from the Green Metric website.

1.5 Discussion: toward a "Cluster Approach", beyond EE Indicators

From the above illustrated comparison, it can be observed that both types of frameworks (Green Metric and ISCN) present limits related to: (i) action-based approaches, which are quantitative, precise, but not very flexible, in the case of Green Metric; and (ii) ISCN is definitely open, and within its objective-based approach suggests actions and indicators, but these are not mandatory, not forcing institutions to apply certain "minimum" standards. In order to overcome those gaps, this research proposes a twofold approach: (i) from one side it introduces the need to cluster university campuses according to homogeneous features (allowing meaningful comparisons) and (ii) it frames a set of indicators enabling the underpinning of broad, integrated and long term sustainability transitions beyond improving energy efficiency only. Three clusters are therefore proposed in the following subsections (respectively related to urban morphology, climatic zone and hosted functions) while a set of indicators are suggested in Subsection 5.4.

1.5.1 Cluster 1: Urban Morphology (Delimited Units or Town-Scattered)

As mentioned in the results section, notwithstanding POLITO is more than 10 times less energy consuming than HOKUDAI, it is penalised in green metrics for its low performances in terms of green spaces, special waste treatments or dedicated transportation systems. Because it is dispersed within a city, those indicators are simply nonsense, due to the physical and legal frameworks constraints (POLITO indeed is using city centre green spaces and cannot own them, or build more because of the prohibitive costs of building new green spaces within a dense historical Italian city centre, and the same justifications can be used for waste treatment or mobility). Indeed, indicators in the "Setting and Infrastructure" criteria, asking for instance the "1.9—Area on campus covered in vegetation in the form of forest", or "1.10—Percentage of area on campus covered in planted vegetation (include lawns, gardens, green roofs, internal planting)" or "1.11—Non-retentive surfaces on campus as percentage of total area for water absorption" (Green Metrics reports, Appendix B) account for 15% of the total score, penalising POLITO for issues not relating to its own failing, but to constraints embedded in all the campuses nested within city centres. Therefore, in order to make sense of university comparisons within green rankings, two (at least) macro categories are proposed: (i) universities that could be considered as "urban units" themselves, outside the city centre, defined as the college typology by Le Corbusier[9] (HOKUDAI campus best fits this category) and (ii) a scattered group of buildings and infrastructure nested within the town (like POLITO). Most notably, the two typologies allow consistent comparison when dealing with

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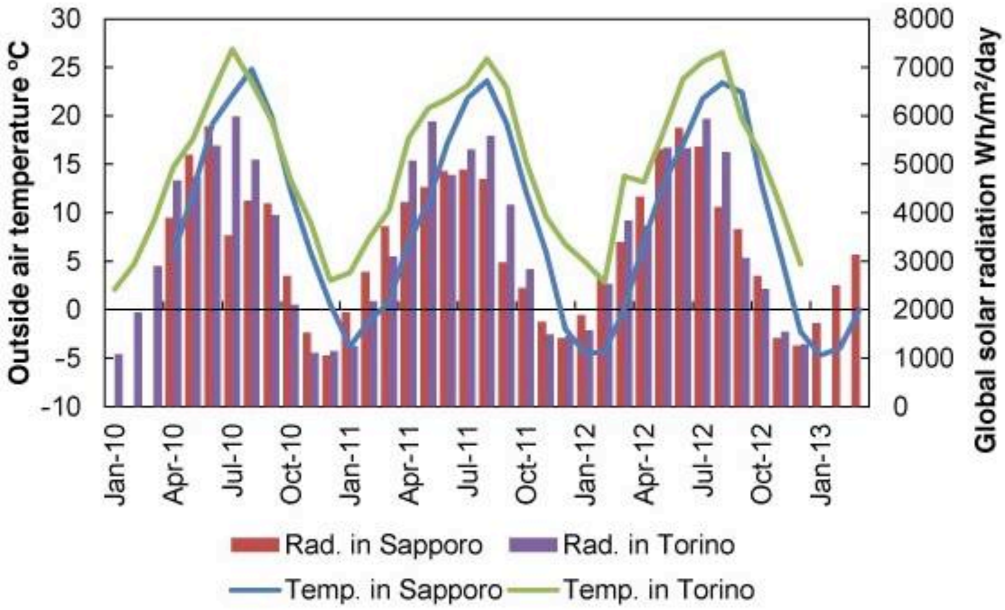
[9] ("College? Americans constantly say: 'At college...' It reflects the presence in their hearts of a great and fine period—the fine period in their lives.... Colleges and universities, then, have a very particular character. Everything in the interest of comfort, everything for the sake of calm and serenity, everything to make solid bodies. Each college or university is an urban unit in itself, a small or large city. But it is a green city. Lawns, parks, stadiums, cloisters, dining halls, a whole complex of comfortable quarters. Often the style is Gothic-that's the way it is! -rich, luxurious, well made. The American university is a world in itself, a temporary paradise, a gracious stage of life." (Corbusier, 1964, p. 135)

indicators of setting and infrastructure, transportation and waste management criteria. A comparison with a third campus like the Polytechnic of Milan, could be the test for such clusters, since it fits with the POLITO morphology type and bypasses all the problems related to the lack of a defined border of university properties. Indeed, the indicators "5.2a—Number of cars entering the university daily", "5.2b—Number of motorcycles entering the university daily" or "5.6—Campus bus service" as found in the Transportation category (see Green Metric Reports in Appendix B), presume the existence of urban unit and its border to allow suitable measurements, while the embedded campus would ask for dedicated types of indicators to underpin users' adoption of sustainable transport systems.

1.5.2 Cluster 2: Climate Zone

As shown in Fig. 6, comparing the two cities hosting the universities in question, over the previous three years, the average outside air temperatures were 9.4 °C for Sapporo and 14.7 °C for Turin. The annual range for Sapporo was wider than for Turin. The average global solar radiation was 3377 Wh/m^2/day and 1234 kWh/m^2/year for Sapporo and 3473 Wh/m^2/day and 1271 kWh/m^2/year for Turin. Looking only at July and August, the solar radiation for Turin tended to be much higher than in Sapporo, while the pattern over the months seems to follow the same curve. A cluster related to different climate zones appears essential as far as building energy performances evaluation is always related to relative regional weather patterns (Kottek et al, 2006; Briggs et al, 2003) or even, more recently, to the relative urban climate (Stewart & Oke, 2012).



	Outside air temperature °C		Global solar radiation Wh/m²/day	
	Sapporo	Torino	Sapporo	Torino
Average	9.4	14.7	3377	3473
Maximum	24.8	26.9	5778	5985
Minimum	-4.7	2.1	1056	1082
Standard deviation	9.9	7.9	1397	1702

Fig. 6. Comparison between Torino and Sapporo weather data from for 2010, 2011, 2012. Source: Ecotect archives.

1.5.3 Cluster 3: University Functions

The need for this third cluster comes directly from the observation of outliers in the consumption profiles of different buildings within the HOKUDAI campus. It represented a perfect case to study this cluster, since, differently from POLITO, each department occupies a single building, allowing to accurately measure consumption thresholds and patterns. Indeed, from the chart in Fig. 7, it appears clear the differences in the electricity consumption of a humanities department (bar No.1), engineering department (No.9), hospital (No.30) or library (No.38).

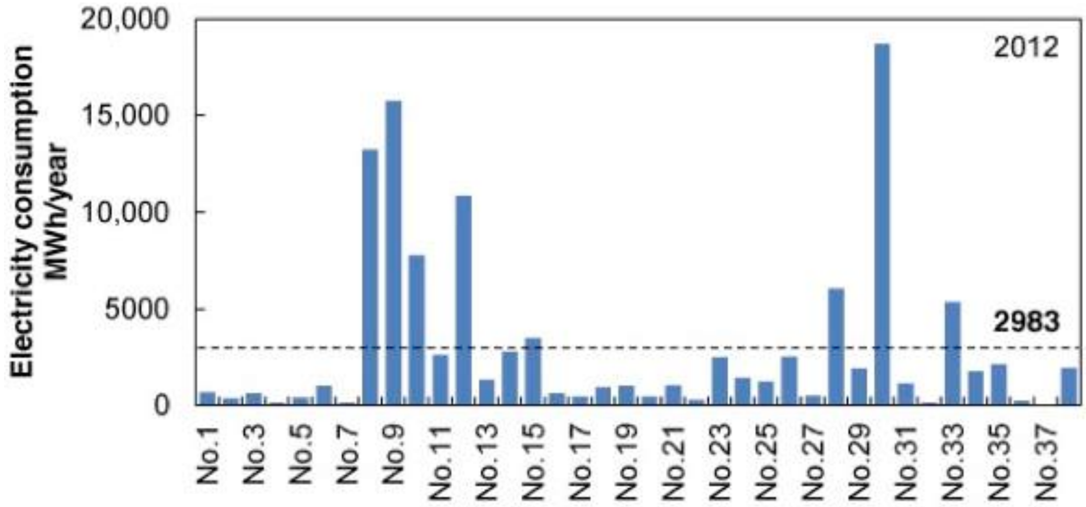


Fig. 7. Annual electricity consumption breakdown for different departments (The comprehensive list of department and their associated number is shown in Appendix D) in HOKUDAI during 2012.

Further research on the typologies of functions that display homogeneous ranges of energy consumption has to be carried out. In HOKUDAI, in 2012, electricity consumption for all the 38 departments was 2983 MWh/year on average; the top five "energivorous" buildings were the University Hospital, and the Engineering, Science, Medicine, and Agriculture departments. From 2008 to 2012, these departments accounted for 60% of the total campus electricity energy consumption.

Clusters accounting for these differences may allow a fair comparison among campuses having similar functions, and may help in setting average thresholds of energy consumption for each department. In the case of peaks due to experiments on behalf of third parties (*i.e.*, when universities are commissioned by industry to do some test requiring intensive energy consumption, like resistances trials on new materials), it can be suggested that each department pay for extra energy consumption. "Nominal" energy bills could also allow a fairer distribution of economic resources among departments and less energy wastage.

1.5.4 Beyond Current Energy Efficiency Indicators

The distance between quantitative (Green Metric ranking) and qualitative (ISCN reports) campus assessments is unavoidable. As already mentioned from the beginning of the chapter, if from one side, ISCN reports do not guarantee commitments in setting targets, from the other side the final list, and ranking, of specific indicators from the Green Metric could result in a black box of actual problems, being not necessarily linked to a virtuous sustainability strategy and, therefore, allowing for some kind of market (green branding) oriented green washing practice. This section presents some perspectives on how the willingness to set targets and indicators and overcoming the limits of voluntary qualitative sustainability reports could be framed, but with a broad view of sustainability, beyond eco-efficiency. Eco-efficiency has become perhaps the most popular concept and tool in corporate environmental and sustainability management, and also the most criticized (Chappells & Shove, 2005). Just ticking off the presence/absence of energy efficient appliances (indicator “2.1a”), or an Energy Conservation Program (indicator “2.4”) or a Smart Building program (indicator “2.1b”), does not guard us against prebound/rebound effects (Sunikka-Blank & Galvin, 2013), and incorrect maintenance of appliances, or account for occupant behavioural patterns in the actual use of energy (De Wilde, 2014; Korhonen, 2008). However, taking into consideration the importance of energy-related issues in the totality of the analysed CSAs (in Table 2, the frequency of adopted macro-criteria across the five most used CSAs), it seems crucial to find more appropriate indicators that bring us closer to the reality of energy use.

Tab. 2. The frequency of indicators related to physical elements in five CSAs frameworks. Squared in red, the indicators retrieved in all of the five CSAs. Source: author elaboration from [41].

Evaluation Category	**Area**	**Indicator**	**STARS**	**Uni-Metrics**	**UI GreenMetric**	**College Sustainability Report Card**	**Green League**
Physical Elements	Air and Climate	Greenhouse Gas Emission Reduction	*	*	*	*	*
	Buildings	Design and Construction	*	*	*	*	*
		Operation and Maintenance	*	*		*	
		Campus Density		*			
		Architecture Quality		*			
	Energy	Building Energy Consumption	*	*	*	*	*

	Renewable Energy Usage	*	*	*	*	*
Soil and ecosystem	Green Areas Preservation		*	*		
	Biodiversity					*
	Preserved Existing Areas		*			
	Connected Green Areas		*			
	Community's Memories		*			
	Open Space Areas		*	*		
Transportation	Commute Modal Split	*	*	*	*	*
	Bicycle Program	*	*	*	*	*
	Accessibility to the Public Transport		*		*	*
Waste	Waste Minimization, Recycling	*	*	*	*	*
Water	Water Conservation	*	*	*	*	*
Food & Recycling	Organic, local food		*		*	*

From looking at the most pressing elements to fixing prebound/rebound effects, such as incorrect maintenance of appliances, or occupant behavioural patterns, it seems more effort needs to be directed towards checking and testing the occupant satisfaction of universities and behavioural patterns in relation to sustainability. The tailoring of user behaviours can be in turn evaluated by *ex-ante* and ex-post evaluations of proposed actions, crossing-checking data with that from similar institutions and public buildings of similar cultures. Setting "personal" and room-based thresholds for thermo-hygrometric comfort according to the actual building occupants would serve also to point out other factors influencing occupants having a higher level of tolerance to discomfort; for instance, those related to having a higher degree of personal control over indoor temperature, being located in a historical building, or to be socially awarded among colleagues for virtuous energy use. For instance, a higher acceptance of discomfort means that users are more willing to collaborate with the University on energy reduction initiatives and to wear extra layers when the temperature drops below 20°C.

Further research on the social aspects of energy use may also involve cross-checking these cultural and attitudinal profiles with smart sensor and smart meter data charts, in order to tune the institutional strategies according to the changing (daily and yearly) population of this complex portion of the city.

1.6 Conclusions

The chapter reviews the most common and international Campus Sustainability Assessments (CSAs), outlining their limits in (i) not providing mechanisms for comparison (nationally and internationally); (ii) emphasising mainly Eco-Efficiency (EE) borne indicators, over a range of long-term social and built-environment sustainability measures; and, finally, (iii) because some of them are too narrow and qualitative without normative targets.

The case of Politecnico di Torino (POLITO), Italy, has been used to analyse its sustainability performance according to the "Green Metric" and "ISCN report" (two of the most adopted and diffused CSAs), and are then compared with the performance of Hokkaido University HOKUDAI, Japan. Results emphasize the gaps among virtuous sustainability actions (in the case of POLITO) and the Green Metric rankings. Therefore, on the bases of the analyses and results of both cases, and accounting for their structural and functional differences (POLITO is campus sprawled through the city centre, while HOKUDAI is a campus outside the city), a new CSA approach is suggested, proposing "clusters of different university typologies". In order to build a meaningful comparison among different cases, the cluster approach introduces the need to consider and classify cases according to the following macro-features: (i) spatial structure (scattered throughout the city or compact campuses outside the city); (ii) climatic zone and (iii) hosted functions for each case. At the micro-scale, the need for revising and substituting current eco-efficiency-driven indicators with more life cycle and user-centric related metrics is also proposed, with some examples regarding the energy issue. The adoption of annual user satisfaction surveys can offer great opportunities to track the post-occupancy effect of strategies for energy reduction, to profile the levers and the cultural attitudes of the university community, and to tailor internal temperature thresholds according to single margins of acceptance. Such a new approach—attentive to local constraints and long-term tracking of outcomes rather than an absolute record of taken actions—can help build homogenous university case studies, framed accordingly within clusters, to find similar and scalable successful practices, and also in self-monitoring progress toward achieving a truly sustainable university campus.

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Appendix A

The ISCN criteria and three principles held by POLITO.

The *Politecnico di Torino* has opted to divide the activities it carried out in the field of sustainability into five dimensions which highlight the most specific points of interest and which represent it in the most appropriate light possible.

Energy and Buildings: towards energy efficiency

This dimension highlights POLITO's focus on the reuse of sections of the city and pre-existing buildings, in continuing restoration and modernization for sustainability, and economic and energy efficiency.

Urban Outreach: towards integration in the city

This dimension was conceived to represent the sustainability of POLITO, in view of the urban/ metropolitan range of action (urban outreach), subtending a mature awareness of the need to offer a widespread and multi-polar system of services, which are highly interconnected, and permeable with the local resources (public and private companies and institutions at various levels)

Mobility and Metropolitan Area: towards a widespread and multi-polar campus

This dimension instead represents the relationship and the connection that the university builds with the outside; but above all, it represents the viewpoint of mobility and the transfers that the staff and users (of whom there are many) undertake every day, making the POLITO a centre of activity for the city of Turin.

People and Food: towards better quality of life

This dimension represents the POLITO focus on the wellness of those who live there daily (administrative technicians, teaching staff, students) supporting all activities undertaken in terms of security and quality of life, paying particular attention to food, education and research.

Purchasing and Waste: towards complete closure of products' lifecycles

Finally, the last dimension aims to highlight all the sustainable activities connected to the products' lifecycle theme, from purchase to disposal, trying to spread the recycle-reuse-decrease culture, which should be the fundamental approach.

These five dimensions are then crossed to three ISCN principles as described in Table A1.

Namely, the three basic principles of the ISCN network are:

Principle 1: Buildings and their sustainability impact. To show respect for nature and society, sustainability considerations should be an integral part in the planning, construction, renovation, and operation of buildings on campus.

Principle 2: Campus wide planning and target setting. To ensure long-term sustainable campus development, campus-wide master planning and target setting should include environmental and social goals.

Principle 3: The integration of research, teaching, facilities and outreach. To align the organization's core mission with sustainable development, facilities, research, and education should be linked to create a "living laboratory" for sustainability.

Table A1. The five dimensions (in bold) crossed to three ISCN principles (in italic) as described in the POLITO ISCN report.

ISCN Charter	**Energy and Building**	**Purchasing and Waste**	**Urban Outreach**	**Mobility and Metropolitan area**	**People and Food**
Principle 1	Resource Use				
	Building Design Aspects	Waste, recycling, local emission			
Principle 2	Institution-wide carbon targets		Master Planning	Transportation	Food
					Social Protection and Safety
Principle 3	Social Integration				
	Commitments and resources dedicated to campus sustainability				
					Integrated Communication

Appendix B

Table A2. The Green Metric 2014 report for HOKUDAI and POLITO.

No.	UI Green Metric World University Ranking	*HOKUDAI*	*POLITO*
1	**Setting and Infrastructure**	***score***	***score***
1.1	Campus Setting _ [1]rural [2]Suburban [3]Urban [4]Other	2	3
1.2	Number of campus sites _ Provide number	2	9
1.3	Total campus area (meter square) _ Provide number	1,866,400	267,586
1.4	Total Floor area of building (meter square) _ Provide number	733,934	116,372
1.5	Electricity usage per year (for lighting, heating, cooling, etc) (Total KWH) _ Provide number	114,762,489	16,685,358
1.6	Number of vehicles owned by your institution (buses and cars) _ Provide number	83	26
1.7	Number of cars entering the university daily (average based on balanced sample, e.g. considering term and holiday periods) _ Provide number	3720	800
1.8	Number of bicycles that are found on campus on an average day(include both those owned by the university and privately owned bikes) _ Provide number	5216	1000
1.9	Number of students (include both part-time and full time students) _ Provide number	18,165	33,356
1.10	Number of academic and administrative staff _ Provide number	4266	1629
1.11	Number of courses related to environment and sustainability offered _ Provide number	569	90
1.12	Total number of course offered	10,548	1926

	_ Provide number		
1.13	Number of study programs related to environment and sustainability offered		13
1.14	Total number of study programs offered	1177	
1.15	Total research funds dedicated to environmental and sustainability research (in US dollars, average per annum over the last 3 years)		6,527,578.71
1.16	Number of scholarly publications on environment and sustainability published (average number published annually over the last 3 years)		318
1.17	Number of scholarly events related to environment and sustainability (conferences etc)(average per annum over the last 3 years)	65	21
1.18	Number of student organizations related to environment and sustainability	8	5
1.19	Policy to reduce the use of paper and plastic in campus _ [1]No policy [2]Policy preparation [3]Policy implemented	3	2
1.20	Policy for a smoke-free and drug-free campus environment _ [1]No policy [2]Policy preparation [3]Policy implemented	3	3
1.21	Existence of a university-run sustainability website _ [1]Not available [2]in progress [3]Available	3	3
2	**Energy and Climate Change**		
2.1	Energy efficient appliances usage (extent to which energy efficient appliances/lighting fixtures, e.g. low watt light bulbs, are replacing conventional appliances) _ [1]conventional [2]Partly replaced [3]Fully employed [4]Smart building	2	3
2.2	Renewable energy usage policy (select one or more of the given energy sources used on your campus) _ [1]None [2]Bio diesel [3]Clean biomass [4]Solar power [5]Geothermal [6]Wind power	3, 4	5
2.3	Energy conservation program (formalized effort in encouraging members of the campus community to reduce energy use) _ [1]No policy [2]Policy preparation [3]Policy implemented	2	4

2.4	Green building (elements of green building implementation as reflected in all construction and renovation policy)(select one or more that apply) _ [1]None [2]Natural ventilation [3]Full Daylighting [4]Building effiency: less than 35% for circulation	3, 4	2
2.5	Climate change adaptation and mitigation program (current stage of institutional effort) _ [1]No program [2]Policy preparation [3]Policy implemented	3	3
2.6	Greenhouse gas emission reductions policy _ [1]No program [2]Policy preparation [3]Policy implemented	3	5
2.7	Area on campus covered in vegetation in the form of forest (provide as %age of total site area) _ %age	16	0
2.8	Area on campus covered in planted vegetation (include lawns, gardens, green roofs, internal planting)(provide as %age of total site area) _ %age	44	18
3	**Waste**		
3.1	Recycling program for university waste (policy led effort to encourage staff and students to recycle waste) _[1]None [2]Partial [3]Extensive	2	3
3.2	Toxic waste recycling (whether toxic waste is dealt with separately, for example by classifying and recycling it) _[1]Not treated [2]Partly treated in some places [3]Fully treated	3	1
3.3	Organic waste treatment (garbage, discarded vegetable and plant matter) (select the option that best describes your overall treatment of the bulk of your organic waste) _[1]Taken off campus to dump site [2]Dumped in open [3]Composted [4]Recycled	3	1
3.4	Inorganic waste treatment (rubbish, trash, discarded paper, plastic, metal, etc)(select the option that best describes your overall treatment of the bulk of your inorganic waste) _[1]Burned in open [2]Taken off campus to a dump site [3]Partially reused [4]Fully recycled	4	2
3.5	Sewerage disposal (primary method of treatment of sewerage) (select the option that best describes how the bulk of your sewerage is disposed of) _[1]Flows into river or waterway [2]Piped to septic tank	3	1

	[3]Treated before disposal [4]Treated for reuse		
4	**Water**		
4.1	Water conservation program (systematic, formalized program) _ [1]No program [2]Program preparation [3]Program implemented	3	3
4.2	Retention: non-retentive surfaces on campus as percentage of total area (where non-retentive surfaces incl. earth, grass, con-block etc, and retentive surfaces incl. concrete, tarmac) _ %age	40	20
4.3	Piped water (water consumed from utility or piped system as a percentage of all sources of water including, e.g. ground or well water) _ %age	9	0
5	**Transportation**		
5.1	Transportation policy designed to limit the number of motor vehicles used on campus (expressed as stage of implementation of that policy) _ [1]None [2]In preparation [3]Fully implemented	3	3
5.2	Campus buses (the availability of buses for journeys within the campus whether free or paid) _ [1]Not available [2]Available (paying service) [3]Available (free service)	3	1
5.3	Bicycle and pedestrian policy on campus (reflects the extent to which bicycle use or walking is supported) (select one or more options that apply to your campus) _ [1] Bicycle use not possible or practical [2]No policy but use not discouraged [3]Bicycles provided by university [4]Bicycle way [5]Pedestrian way	4, 5	5

Appendix C

<u>List of interviewed stakeholders</u>

Key stakeholders in the sustainability management at POLITO:

(1) Prof. R. Borchiellini (Vice Rector, Facility Manager)

(2) Prof. B. Dalla Chiara (Mobility Manager)

(3) Prof. D. Fino (Waste Manager)

(4) Prof. G.V. Fracastoro (Energy Manager)

(5) Prof. P. Lombardi

(6) Prof. P. Tamborrini

(7) Prof. S. Corgnati

(8) Prof. M. Bottero

Interviewed in the POLITO sub-groups managers:

(1) Living LAB—Gianni Carioni, manager

(2) EDILOG Office—Construction and Logistics Area, Valeria Giovanardi, Manager

(3) IT Office—Information Technology Area, Piero Bozza, Manager

(4) AQUI Office—Goods and Services Provision Area

(5) GESD Office—Teaching Direction Area

(6) CORE Office—Communication, Events and Public Relations Services

(7) SiTI—Higher Institute on Territorial Systems for Innovation, Valentina Ferretti, Marco Valle, Stefano Fraire, Luisa Ingaramo, Stefania Sabatino, Francesca Bodano, researchers

Key stakeholders in the sustainability management at HOKUDAI:

(1) Prof. Masahiko Fuji, Associate professor at the Graduate School of Environmental Science, Member of the Sustainable Low-Carbon Society Project 2010

(2) Prof. Takao Ozasa, Associate Professor, Laboratory of Urban Design, Division of Architectural Design, Faculty of Engineering, Director of the Office for Sustainable Campus

(3) Dr. Maki Komatsu, Coordinator, Office for a Sustainable Campus

(4) Mr. Tomohiro Morimoto, Unit chief, Facilities Department, Sustainable Campus Promotion Division, Office for Sustainable Campus

(5) Mr. Takashi Yokoyama, Project Manager, Office for a Sustainable Campus

(6) Prof. Takeo Ozawa, Faculty of Engineering, Architectural and Structural Design, Human Settlement Design

Students of attending the Candle Night 2013 event, members of Art Challenge "Takikawa" and the Environmental Promotion Section, master students at the Public Policy School, and international students at the Graduate School of Environmental Science.

Appendix D

Table A3. The HOKUDAI buildings analysed for their electricity consumption.

No	Department (38)
1	Letters
2	Education
3	Law
4	Slavic Research Center
5	Economics and Business Administration
6	Institute for the Advancement of Higher Education
7	Media and Communication
8	Science
9	Engineering
10	Agriculture
11	Environmental Earth Science
12	Medicine
13	Dental Medicine
14	Pharmaceutical Sciences and Pharmacy
15	Veterinary Medicine
16	Health Sciences
17	Central Institute of Isotope Science

18	Field Science Center for Northern Biosphere
19	Research Center for Integrated Quantum Electronics
20	Meme Media Laboratory
21	Center for Advanced Research of Energy and Materials
22	Creative Research Institution (Northern campus No.3)
23	Frontier Research Center for Post-genome Science and Technology (Northern campus No.2)
24	Research Center for Zoonosis Control (Northern Campus No.4)
25	Research Institute for Electronic Science (Northern Campus No.5)
26	Institute of Low Temperature Science
27	Research Institute for Electronic Science (Central Campus)
28	Creative Research Institution (Catalysis Research Center etc.)
29	Center for Promotion of Platform for Research on Biofunctional Molecules (Northern Campus No.6)
30	University Hospital
31	University Hospital (Center for Dental Clinics)
32	Information Initiative Center (South)
33	Information Initiative Center (North)
34	Bureau
35	Academic Affairs
36	Clark Memorial Student Center
37	Sports Training Center
38	Library

2 Trimmed Weapons for Energy Data Analysis in Universities' Living Labs: Current Gaps and Improvement Proposals

Abstract: Notwithstanding last thirty years of policies and discourses around the pivotal role played by education in driving sustainability transitions, few universities' initiatives have produced effective reductions in resource use or energy consumption. One of the main gaps lies on practices, and the challenges of elaborating sounding policies out from the available dataset. This chapter goes through the complexity of campuses energy policies, examining current gaps in energy data collection and processing in order to provide insights and guidelines for setting up sustainability transition strategies. Two universities from different countries are presented as case study (namely Turin Polytechnic University in Italy, and the Japanese Hokkaido University). By crossing data and comparing consumptions trends with other key variables (outside temperature, opening times, function hosted, number of students) a more appropriate methodology for energy data queries, pivot and displays is presented, addressing improvements in both self-assessments and external reporting purposes. Hints form the added value of an integrated and human controlled monitoring structure and inferential statistics methods use are highlighted in the conclusion, to help the change toward a holistic sustainability assessment and energy data management in university campuses.

Keywords: *Living Lab; Energy Data Management; Sustainability Assessment and Reporting; Campus Operation; Higher Education for Sustainability.*

Highlights:

- There is a gap in translating universities' energy data into meaningful sustainability policies

- Buildings energy consumption analysis was based on clusters of academic groups to find main factors affecting each type of group

- Results highlight the need of new assessment frameworks for universities energy policies

- Energy policies should be framed within homogeneous clusters of academic groups, function hosted and climate conditions

- Further research is needed on data processing algorithms using the exergy concept and inferential statistics methods

2.1 Introduction

During the last thirty years, several international initiatives have highlighted the pivotal role played by education to drive the transition toward a more sustainable society (Barth & Rieckmann, 2012). The urge to be a credible leader in this transition made university adopt sustainability protocols, actions and metrics from various fields, including diverse teaching methods (Cortese, 2003), environmental impacts displays (Lozano, Carpenter, & Huisingh, 2014) campus operation (Lozano, Ceulemans, & Seatter, 2014), energy management (Robinson, Kemp, & Williams, 2014), urban outreach (Trencher, Yarime, & Kharrazi, 2013), green branding and community building (Ramos et al., 2015). Of course exogenous regulations (i.e. from city councils, regional funds and national rules for sustainable resources management) play a crucial role in setting the background for enabling smaller scales sustainability transition (J. Evans, Jones, Karvonen, Millard, & Wendler, 2015), enlightening the leadership of higher education institutions (Lozano et al., 2015). However, the old-fashion functionalist paradigm promotes the "tick the box" philosophy, based on "sustainable" measures labelling campuses greening (Alexander & Colomy, 1990). Often, the resulting image obtained by complying with such rules put universities in the dangerous edge of apparent and green-washing actions, with no effective reductions in resource use or energy consumption (Caeiro, Leal Filho, Jabbour, & Azeiteiro, 2013; Robinson et al., 2014).

Beyond the ineffective "labelling the greening", recent studies round up some key challenges for educators toward a low-carbon society. The emphasis is placed on a better integration of environmental awareness into curricula and researches (especially those related to energy, as seen in (Desha, Robinson, & Sproul, 2014; Mälkki, Alanne, & Hirsto, 2014)) and most important, holistically into the management of the campuses as little but valuable sub-system of the city and citizens (Verhulst & Lambrechts, 2014), involving all level stakeholders (Disterheft, Caeiro, Azeiteiro, & Filho, 2014) in theory and in practices in particular within energy-related issues (Larrán Jorge, Herrera Madueño, Calzado Cejas, & Andrades Peña, 2014). Innovative solutions for these challenges can be tested within the campus itself as a valuable portion of city, collaborating also with others outside of academia. Utilising local environs as 'living laboratories' can be seen as a translation of the triple helix model (university, industry and government) that operates in a complex urban environment (Trencher et al., 2013). Market demand, governance, civic involvement plus a new helix, i.e. citizens' characteristics, seems to be the perfect condition to start guiding the transition from the cultural and social capital endowments that make university a unique portion of the city. In other words, the concept of "Living Lab" scales the length of the urban border condition to the campus' one, and takes students, teachers and administrative staff as "citizens" of this portion of the city. The "plus", differently from other urban heterotopies, is that this portion has more easily observable variables (energy consumption, occupational hours, users profiles) and may shape the development of the entire city generating intellectual capital, wealth and regulators of standards, as well social learning and knowledge-transfer of sustainability attitudes shifts (Deakin, Curwell & Lombardi, 2002).

The educational sector per se, is not only a societal challenge for behavioural change, but its built environment represents a testing laboratory for sustainability practices. It accounts indeed for the 17% of the overall non-residential building stock in the EU (BPIE, 2011). From the environmental impact point of view, since buildings are responsible for about 40% of total final energy requirements in Europe, the educational sector accounts for the 6,8% of the total EU energy consumption. In China, the largest energy consumer and CO_2 emitter in the world, it contributes approximately 40% of the total public sector energy consumption (SBCI, 2009). Therefore it appears crucial to develop a common strategy and appropriate assessment methods for energy reduction and sustainability practices in these particular kinds of public buildings.

In a previous paper, the authors already addressed a critic review about the inadequacy of the current Campus Sustainability Assessment Frameworks, proposing an emerging cluster approach enabling meaningful and beyond green-washing labelling of university campuses (Sonetti, Lombardi, & Chelleri, 2016). Dahle shares such a view, stating that although universities are not at ground zero with respect to greening, their poor overall environmental quality is to be justifying by budgetary constraints (Dahle & Neumayer, 2001). However, Dahle also emphasizes how these are partly due to institutional reluctances to change, in general, but mainly because of the lack of specialized knowledge accounting for how greening initiatives can finally save costs in the longer run, being economically sustainable. The complexity of the variables to be taken into account is also an important barrier for changing current environmental management in universities, as concluded by a survey on (Alshuwaikhat & Abubakar, 2008). In view of the heterogeneous structure, most campuses host numerous and complex laboratory experiments, agricultural practical, workshop operations, social and educational activities, medium-large scale energy supply and usage, transport and interaction, sports and recreation, thus needing more systematic and integrated approaches.

The gap that appears clear is that most universities concerned with sustainability do have already interesting data set available for energy analysis. However, the complexity of a campus, mostly for the various stakeholders engaged, the uncertain variables affecting energy consumptions and the lack of references for effective policies and thresholds, makes difficult to set appropriate tools to give sense and quality to the big quantity of data.

By presenting energy monitoring processes and relative methodology critique developed as at the Politecnico di Torino (POLITO) and comparing its energy trends with the Hokkaido University (HOKUDAI), this chapter seeks to examine current gaps in energy data collection in Universities. In par. 2.3, the POLITO case study is described along the IT facilities collecting all energy-related data. The par. 2.5 describes instead the energy management at HOKUDAI. Appendix A contain all the figures telling the trends and the comparison of single building performance along four years (2008-2012) or entire campus energy consumption trends. Appendix B relates to the University of Turin (UNITO) preliminary data collection, that will be used in a forthcoming works to cover the entire departments stocks retraceable in a University, to let meaningfully compare the POLITO+UNITO performance VS the HOKUDAI one. Appropriate methodology for energy data queries, pivot and display are shown both for self-assessment and for external reporting purposes. Hints form the added value of an integrated and human controlled monitoring structure of energy data collection is highlighted. In the conclusions, further steps on this direction, less IT levered and more human-centric, can help in enlarging the lens observing a wider range of phenomenon affecting energy consumption in public building. Different universities' data set can be a panel for inferential statistics methods (including the t-test, Analysis of Variance (ANOVA), Analysis of Covariance (ANCOVA), regression analysis, and many of the multivariate methods) to make inferences from our data to more general conditions, thus driving the change toward holistic sustainability assessment in Universities, beyond current functionalist practices and mere energy efficiency indicators.

2.2 Methodology

This study was carried out in order to provide data management examples that fit a wiser energy management model for university buildings, with the aim of reducing squanders and energy consumption, improving environmental and economic performances in universities. All energy-related information for the two universities have been collected in 2012 from surveys, focus groups, interviews and data mining from the living labs, surveys and official documents, maps, Archibus facility management data set available both in POLITO and HOKUDAI. Interviewees were selected mainly based on their level of involvement with sustainability initiatives. Four main themes were covered during the interview: sustainable campus initiatives (according to the area of expertise and knowledge of the interviewed), *in fieri* activities, governance of the decision-making process and management control systems (and more particularly about data collection and use). After having described the campus setting through maps observation and relevant stakeholders indications, the methodology used for energy monitoring and energy data collection in each university has been distinct the two universities. While POLITO has got a wide infrastructure and a dedicated officer for data analysis, gathering info both from smart metering and bills and from facilities interventions log, HOKUDAI data access is reserved only for research purposes, and derives info from the facility manager located in the sustainability office. This justifies why the chapter dedicated to POLITO data management systems (par. 2.4) is larger than the HOKUDAI one (par. 2.5.1). In order to allow a meaningful comparison among the campuses, the hypothesis of cluster of energy consumptions' thresholds (net of weather condition or occupational path) has been demonstrated. Analysing electric energy consumption per square meter and per function in HOKUDAI has been possible thanks to the exact match between the building floor areas and the department's functions hosted. Such spatial and functional symmetry is completely missing in the current (city) setting of POLITO campus, which allows different mixed functions in the same building. However, results from this methodology have been extended for scalable and transferrable results in the current campus sustainability assessment frameworks.

2.3 The POLITO case study

2.3.1 Campus setting

The Politecnico di Torino campus 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 POLITO setting (Fig. 1) counts indeed five campuses scattered throughout the city, in buildings dated from the 17th-century (the Castle of Valentino, with an area of about 40000 m^2) to late 50s (the main extended complex in Corso Duca degli Abruzzi, 187,000 m^2) and to 2000 (Cittadella Politecnica, 89,000 m^2 of student residences, research activities, technological transfers and services buildings). Farer form the centre, two former industrial sites were also refurbished and used for teaching activities (Mirafiori and Lingotto, ex-FIAT sites). In total, in 2012 the whole campus accounted for 33600 users (students and staff), and a yearly primary energy (PE) consumption of 225,475 kWh/m^2. All data related to energy consumption are collected by the living lab infrastructure and revised by the Energy Manager, an internal professor of POLITO who is in charge to communicate to the Italian Federation for energy efficiency the annual energy consumption.

Fig. 1 The Turin geographical position (top left), the Cittadella Politecnica site and the Castello del Valentino one (bottom left) and the characterization of surfaces broken down for different POLITO sites according to the ARCHIBUS softwares dataset (right) (source: www.polito.it)

2.3.2 Living lab data acquisition

Since 2008, thanks to a research project co-funded by Regione Piemonte called "WiFI4Energy", the Living Lab has being monitoring and providing data in a unified and integrated delivery mode. The on-site acquisition system is mainly based on 485 network segments on which are installed MODBUS devices, for a total length of more than 7 km. This wiring is used to monitor water consumption, PV panels, thermal energy production and consumption. The heart of the monitoring system is the "Living Lab", arranged inside the campus to be both a control room and a demonstrator. In 2012, the "Living Lab" began a fruitful collaboration with departments and faculties on various research projects and teaching initiatives with a focus on energy and sustainability, allowing to share common infrastructure acquisitions, technological resources, expertise and, most important, dataset. The "Smart and Green Building Services Management" provided by the "Living Lab" is the result of the close cooperation between different entities and divisions (energy manager office, energy department, Information Technology Area, Construction and Logistics). In the "Living Lab", all data streams are collected from on-site sensors and then processed and analysed. The main aim is to provide a decision support for the energy management, but there are also regular requests for research support and various educational initiatives. The monitoring system is based on the acquisition of data from different plants and flows equipped with meters, smart meters and heterogeneous data logger. Every 15 minutes all the devices send their data to a central repository (mainly via ftp but also through transactions via relational databases). Check-scanning in the acquisition chain run all the time to trigger alert in case of anomalies, both in terms of acquisition failures or outliers. This function (shown in Fig. 8 in the Appendix as ETL - Extract, Transform, Load) is written in *Perl*, an open source code, fast and flexible, particularly suitable to manipulate text files. The detail is then enriched with all possible categorizations that may be useful in following reporting, analytics and data mining activities. For example, timestamp is accompanied by tags related to date of measurement, date (year, month, day, hour, minute), day of week, weekday or holiday, energy band (F1, F2, F3), late evening or special working time, etc. Capabilities of ETL and data processing feed the Data Warehouse (DW) in Microsoft SqlServer 2012 environment. The DW layer can be easily migrated to open source applications such as MySQL or Postgres. Another important set of tags comes from mapping the electricity meter on locals. The "ARCHIBUS" software facility enables the collection of data on rooms according to area, volume, intended use, and number of occupants, closest cost centre and other features. This information allows calculating a room specific consumption either per m^2 or per person in a certain range, allowing performance comparisons, benchmarking, summary report or details.

2.4 Analysed Quantities at POLITO living lab

2.4.1 Electricity

The system for the acquisition of electricity consumption's data is measuring both active energy and reactive energy at the distributor outlet of 22 kV and of transformation cabins at internal 400V. Going down the shaft of the plant, detailed meters measure main office blocks or specific laboratories with high consumption. In total there are about 150 measurement stations in the entire "Cittadella Politecnica" site. Consumption related to a certain block is used to calculate the average consumption (kWh/m^2), and then it is multiplied to the surface of a single room. It is therefore a mixed model (on-site plus analytical measures), but since functions are the same inside all offices, errors may be negligible. Of course, laboratories with high consumption appliances (e.g. the wind tunnel) represent the exception. This type of allocation is possible thanks to the facility management system (IT management and support services) in combination with the space management system based on the ARCHIBUS frameworks. Its data loggers allow dissecting network segments and connecting each data logger to the Ethernet. Every log provides the energy consumption of the immediately previous score (one per minute), and downstream software aggregates those details to a quarter of hour. Quick transitory phenomena such as blackouts are registered by minute's detail.

The data in Fig. 9 were obtained from the living lab data set for 2012, were the Corso Duca site shows the highest electric energy consumption and also the highest variance along the year. The Mirafiori, Lingotto and Valentino sites show the lower consumption and the lowest variance. This can be due to the fact that both in Mirafiori and Lingotto sites are opened and frequented just for lectures and exams, thus showing an inflection during summer months and an increase during spring and winter terms. It is interesting to notice how the Valentino site responds just to the peaks of the outside temperature variation, namely February and July (in August the site is closed for holiday). This is mainly due to the thermal mass of the 1m thick walls of the Valentino Castle, that assure an almost constant internal comfort for the passive architecture's features of a 4 centuries old building. The varied consumption profile of the Corso Duca site replies to the higher external temperature in summer due to the lack of thermal insulation in the concrete walls and single-glazed windows in most of the buildings. Also, peaks of electric energy consumption may follow the occupational path of students lecturing in the winter and spring term, and the laboratories experiments running all over the year. At current time, a huge re-design of the entire site is taking place to substitute the most energy-leaking parts of the external envelope with thermal insulation coating and double glazed window. As shown in Fig. 10, there is a similar irregular path of consumption for the POLITO main site of Corso Duca over the years 2008/2012. The peaks in summer periods remained at the same value of about 1600 MWh, slightly decreasing in 2008 and 2011. In 2012, the curve of electric energy consumption rarely went behind the others, meaning that a higher consumption trend has to be considered in the following years.

2.4.2 Thermal energy

At current stage, thermal energy monitoring is less refined than the electricity one, although there are several gas meters for special plants and single buildings. The Cittadella Politecnica building is connected to the district-heating network, while the historic offices in the Castello del Valentino (Architecture Department) and the new headquarters of Mirafiori (Industrial Design, Visual Communication and Automotive Engineering departments) are served by natural gas boilers. The heterogeneity of systems must therefore be regarded as a design constraint that cannot be removed. The connection to the city district heating let the POLITO gas consumption be zero for several years. There are still some minor uses in other locations, but they affect the overall bill by approximately the 6%.

In Fig. 11, thermal energy consumption trends are showed for the POLITO Corso Duca main site over the years 2008/2012. The shape of load curves for the all 5 years is almost similar, being zero from May to September and starting increasing when the outside temperature starts decreasing, reaching peaks in January and February. It can be noticed that, generally, there is a slight increase of thermal energy consumption although the minima over the same years of the external temperature trends are slightly increasing (Fig. 18). Yet, 2012 presents a drop of consumption in January, October and November, making discharge the hypothesis of electrical equipment use during wintertime that may have overloaded the anomalous curve in Fig. 9.

Fig. 12 shows an interesting comparison of thermal energy consumption expressed in kWh/m^2 over the Valentino site and the two main sites of Corso Duca and Cittadella in 2012. The possibility of individual controlling the fan coil units, the high percentage of glass surface, east and north exposed, coupled with the use of natural gas supply, made the consumption of Valentino castle be higher than the two newer sites, were the district heating provides centralised and strictly controlled thermal energy flows following the occupational path of the buildings.

2.4.3 Drinking water

Water is a very cheap entry in the total university bill, but this should not prevent monitoring this resource and most responsible use of it. Furthermore, anomalies registered by the system can give information about leakages in the pipes or misuses. Currently there is only one measuring point per site, but sub-meters will be installed at each building entry-point in the next years. Fig. 13 shows water consumption trends in the main site of POLITO Corso Duca of 2016. A considerable fixed rate of water consumed by night can be observed in a typical weekday of 2011 (1/5 out of the total, more than 100 m^3 over the 24 hours), with peaks at mid-morning and mid-evening (probably at the first break of the morning lectures and at the end of the last evening lecture). Few days later, on a Sunday of the same month, the meter registered a fixed flow rate of about 6 m^3/h, with a total of about 180 m^3 on the 24 hours, of which almost the half by night. This anomalous consumption, both during night time and on holidays, led the facility manager to investigate about possible pipe failures, infrastructure's problems, or forgotten valves during experiments with cooling-plant phases. The audit carried out along the departments and the facilities of POLITO main sites led to the curve at the bottom of Fig. 13, hold on a typical week day in January 2016 with a cumulated flow of 200 m^3 during the while day (less than the half of a typical weekday of 2011), of which 1/6 consumed by night. The reasons of a fixed rate, although 1/5 lower than a comparable weekday of 2011, can be due to the de-icer circulation over night, to avoid pipe bursts.

2.4.4 Renewable Energy

A photovoltaic plant of 35 kWp has been installed in 2011 in the Cittadella Politecnica site. The panels have a total surface of 1625 m^2 and polycristallyine silicon cells (panel type EG 36 HE, 36 Xgroups cells, 6 inches each, extrabright superstate glass with 6 mm thickness, total voltage up to 1000Vdc). The monitored quantities range from direct solar radiation on roof pitches to hourly voltages and efficiency of the panels. In Fig. 14, yearly solar radiance registered from 2012 to 2015 on horizontal surface by the POLITO weather station shows a general slight increase of the total Wh/m^2 per year. Except for 2014, the peak of radiance was reached in July, designing a typical bell curve from 180kW/m^2 in summer to the winter minima of 35 kWh/m^2. 2012 marked the higher values in January, February and March, while 2014 marked the lower values in November, December and January.

Fig. 15 shows the total energy in kWh cumulated along the 24 hours (in red) and total power in kW (in blue) on the 15th of July 2015. The power load curve goes beyond the 4000 kW from 10 am to 5 pm, with a few of clouds that in early morning prevented a more linear rise of the total energy cumulated along the 24 hours, which reached almost the threshold of 70000 kWh. The production on the whole year accounted for the 15% of the total electric energy requested by the underlying building.

2.4.5 Air quality

The classroom n.1 served as sample for studies on real condition ventilation flows and energy consumption, and therefore equipped with gases tracers and air treatment units (ATUs). The goal is to characterize the behaviour of plants in terms of energy consumption by constantly monitoring pressure falls on filters, flow rates in branches, energy consumed by fans, filters efficiency, inlet and outlet CO_2 concentration: about 80 measures in total. The test, still underway at the department of energy located in the same POLITO site, aims to determine a maintenance schedule with a fixed minimum level of airflow (and thus of quality of the environment), to minimize energy and maintenance costs. The analysis of pressure drops due to the presence of air filter in classroom 1 (Fig. 16) shows that for most of the time the HVAC plant works drafting all outdoor air, even when it is reasonable to expect a partial occupancy of the classroom (for example at 8.15 am). The plant control system is a Demand Controlled Ventilation (DCV) type, so that it automatically opens louvers for air change if the CO_2 concentration inside the classroom results more than 600 ppm. If a positive drift affects the measurement over time, due, for instance, to the dirtiness of the air filter, over the years we can observe that, given a same CO_2 concentration inside the classroom, the number of hours in which outdoor air is drafting in is increasing, and the probe become not reliable already after 300 days from the air filter installation.

2.4.6 Meteorological data

The weather station at the Cittadella Politecnica is synchronised with the consumption databases as reference for temperature, humidity, wind speed and solar radiation, aside for air quality measurements regarding CO_2 and PM^{10} concentration. In Fig. 17 are shown the trends over the 24 hours of some of these quantities. $C0_2$ is neglected since data showed incoherence between days and a malfunction of the probe has been advised. The outside temperature doesn't show significant swings from daytime (26°C) to night-time (18°C) on the 21st of June 2015, day of paths in Fig. 17.

It is important to notice in Fig. 18 that a constant measuring of outside temperature can be talkative of global phenomena taking place, such the raising of the minima from 2010 to 2015 of about 5°C. The measurement regarding wind speed shows a quite scattered plot ranging from 0,7 m/s around 10 pm to peaks of 4.4 m/s (not enough as a start-up speed of a micro wind turbine) around 12:30 am. While rain was absent the whole day, relative humidity was above the 60% for almost 7 hours, and dropped around the 40% from 1 pm to 10 pm.

2.4.7 Active IP

PCs represent a non-secondary contribution for the total electric energy bill, being over 5000 in the all campus. In many cases, they remain switched on also during night hours, either to make elaborations or to make the computer available for remote use. It has also been tested how much this portion could save from by raising user awareness, for example by media-sponsored campaign and by programming software for remote shutdown or switch-on. The Living Lab has developed a system to monitor every 15 minutes, which PCs are on, and where. Since the system is based on questioning routers, it is possible to know the IP address, compare it to the DNS system and finally localize the user referred to it. The department of electronics had enriched those functions by establishing a weekly schedule[10] for PCs or an on-demand switching on/off. Network routers maintain internal lists with the association IP address of the device facing the network. Analysed every 15 minutes, these lists can identify individual IP assets, in a totally non-invasive than the same computer (no software installed).

It is possible to count, even by geographic location, the number of active IP, net of phones, users connected via Wi-Fi, VOIP phones. One part is definitely determined by the server plus various network equipment, but still a significant of active PCs remains. It's important to notice (Fig. 19) that there is a strong night / day swing, but the number of IP devices active at night (almost 4000) is hardly explicable if not assuming that owners forgot (or deliberately chose) to switch them off.

2.5 The HOKUDAI case study

2.5.1 Campus setting and Sustainability Office Data Management

The Hokkaido University (HOKUDAI) was founded in 1876 and it is located in the centre of the city of Sapporo (Fig. 2) on the northern Japanese island of Hokkaido. At the time of the survey (2012) it counted over 18.000 students. The campus is situated in downtown Sapporo and covers an area of 1.776.249 m^2 including the entire park in which buildings are located. Hokkaido University follows a series of sustainability initiatives in order to reduce its environmental impact and act as a ‘showcase’ for sustainable campuses. The university runs periodical stakeholder meetings in order to bring expertise from outside the university regarding the implemented programs and feedback on areas requiring improvement. To this end, Hokkaido University established the Office for a Sustainable Campus as the institution's core organization tasked with promoting campus sustainability actions and that provided the data at the base of this study.

[10] http://www.polisave.polito.it/

Fig. 2 The HOKUDAI campus site. Source: Google Maps

2.5.2 Energy performance according to university buildings clusters

Due to the cluster shape of the campus, and the perfect correspondence between building and department, the HOKUDAI buildings have been analysed according to their primary energy consumption per square meter per year (namely the 2012), the levelling rate and the electrification rate (Fig. 3). The levelling rate for electricity consumption in all departments was calculated multiplying by 12 the minimum electricity consumption per month and dividing the result by the annual electricity consumption. If the levelling rate is low, the seasonal fluctuation in electricity consumption is wide; when the rate reaches 1, the fluctuation is small. The relationship between annual electricity consumption per floor area and levelling rate is shown in Fig. 4. The high consumption - low fluctuation region includes Sciences, Medicines, and Research Centre groups. A major improvement in the efficiency of large experimental equipment used all year round may reduce this amount of costs. The low consumption-high fluctuation region includes mostly Arts and Humanities groups of faculties. The Data Centre electricity consumption per floor area was far higher than the others, followed by the Research Centre and Hospital groups (beyond 200 kWh/m^2/year) followed Data Centre. Comparing the levelling rate of each group, the rate was very high for Sciences Group and Medicines Group (about 0.9) and low for Arts Group and Others Group (about 0.7). To understand the proportion of electricity consumption in the total Primary Energy (PE) consumption, the electrification rate was calculated as the ratio between the yearly electricity consumption and the total PE consumption in the same year. As shown in Fig. 3, Data Centre displays a very high dependence on electricity. The rates for Medicines, Sciences and Research Centre were close to 0.5, which is relatively high. When the Hospital group relies also on gas for heating purposes, the electrification rate was the lowest (0.27).

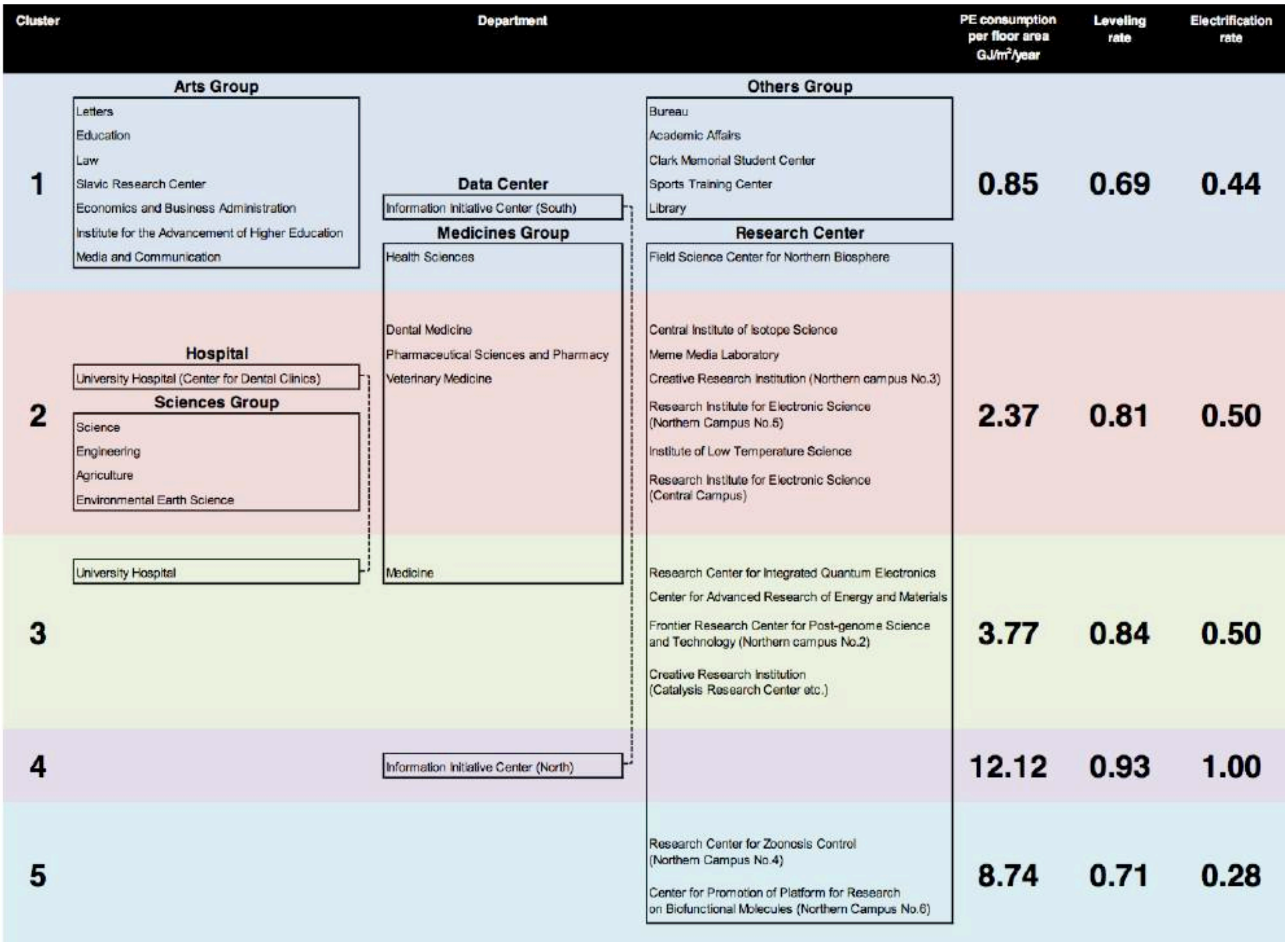

Fig. 3 Electrification rate per clusters of department at the Hokkaido University. Source: (Sonetti & Kikuta, 2013)

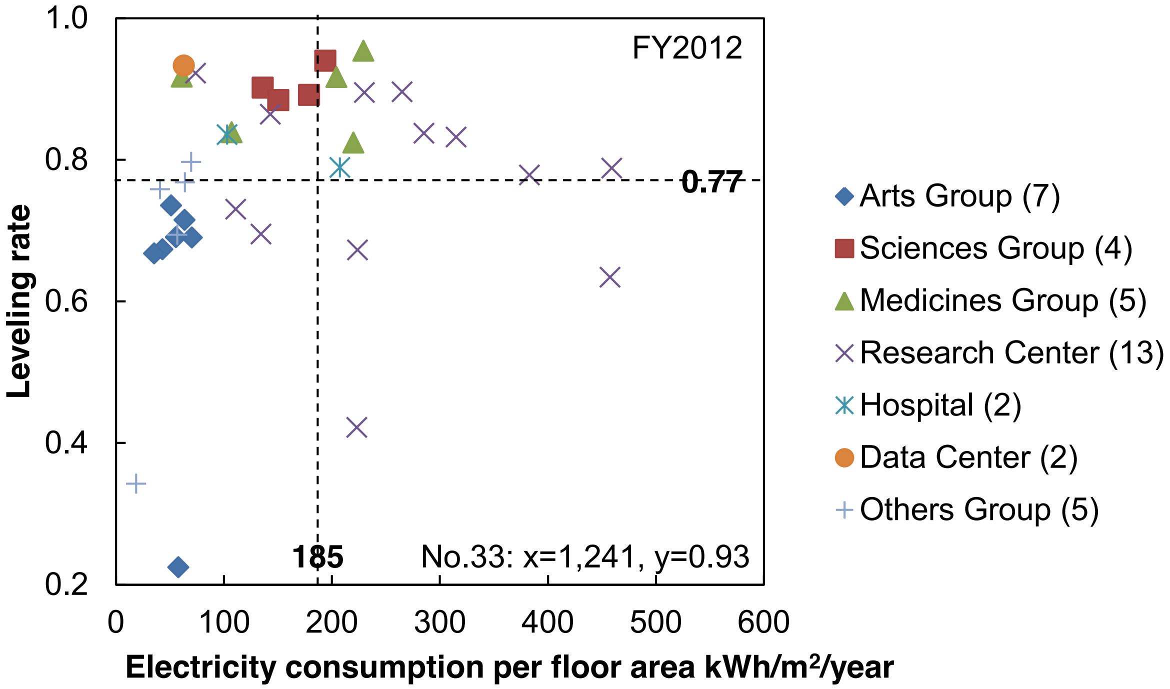

Fig. 4 Relationship between electricity consumption per floor area and levelling rate in different cluster of building in 2012. Source: (Sonetti & Kikuta, 2013)

A hierarchical cluster analysis by agglomerative method with PE consumption per floor area used the mean Euclidean distance and Ward method to produce the clusters in different colours in Fig. 3 and Fig. 5. The mean fluctuation characteristics for each cluster vary from Cluster 1 (a total of 15 departments, around 1 GJ/m^2/month), Cluster 2 (a total of 14 departments, around 2 GJ/m^2/month) and Cluster 3 (a total of 6 departments, around 3 GJ/m^2/month). Cluster 4 included the Data Centre, and Cluster 5 the biology Research Centre.

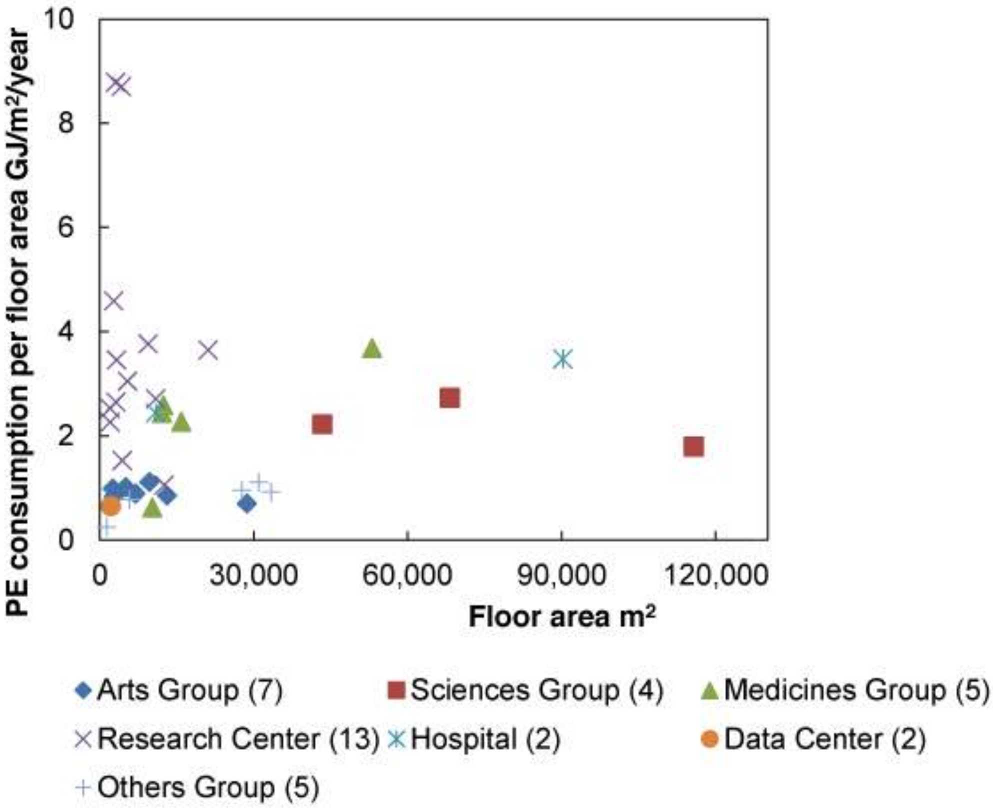

Fig. 5 Relationship between floor area and PE consumption per floor area in different cluster of building in 2012. Source: (Sonetti & Kikuta, 2013)

2.6 Discussions

2.6.1 POLITO- HOKUDAI Energy Data Management

From the wide numbers of features analysed across the two cases, it emerges that data monitoring does produces energy and money savings, both in short and in long terms. In POLITO, for instance, the monitoring of anomalous yearly trends of CO_2 concentrations in Room 1 has suggested a periodic calibration of CO_2 probes for 60 air treatment plants. In current management practice, this is almost never scheduled, thus neglecting the energy sounders (and unnecessary HVAC activation) deriving from mistaken CO_2 measurements. Also, thanks to historical data set, it could be possible to assess the effect of retrofit interventions over the POLITO sites, making appropriate both ex-ante and ex-post evaluations of saved resources, both in terms of electric and thermal energy consumption and of pay-back calculation of saved energy after the retrofit. As for the IP monitoring, even assuming an average absorption of 30 W by 2000 PC, a squander of 60 kWh per hour can be estimated. Considering night hours and day-breaks, a policy for automated PC switch-off could lead to lower the consumption of 1 MWh per working day, about the 2% out of the total. The inclusion in the POLITO weather data set of NO_2, CO_2, CO, SO_2, VOC, and PM^{10} concentrations can contribute to a local impact assessment. On-site air quality conditions potentially affecting other quantities observed could be characterised, such us the total solar radiation after a new waste management policy. Moreover, the water consumption audit at POLITO made campus users aware of possible controls / punishment, so that the squanders in revealed in 2011 automatically disappeared without any intervention on pipes or valves. However, in HOKUDAI the data access is not easy and open, producing barriers for external researcher's insights and mutual learning from other universities. An open data set of energy data may also put bases of interoperability among different sources. The HOKUDAI case is a perfect test bed for data management methods according to different faculties thanks to the default matching along consumption sites and supplier delivery points, as result of the cluster setting inside Sapporo. The need of a human supervision on trends, targets setting and failures energy performance appears crucial in both cases. Moreover, simplified information dashboards, alert and control panels that can be accessed via web or smartphones, tablets, monitors and information kiosks settled in the campus set interesting doors for bottom up collaboration and stakeholder engagement in campus sustainability initiatives. Final contents can be defined according to the target (public, students, employees, technicians, professors, and energy managers) and can be used to compare university's own data management with similar institutions.

2.6.2 POLITO- HOKUDAI Energy Performance

HOKUDAI's 516,509 m^2 of university campus area is 40% less in respect to Turin. But 16,418 users (51% less than POLITO) consume 1,731,798 GJ of PE (668% more than POLITO, in 2012). Just to give a most meaningful number to this dimension, while PE consumption per capita in Turin is 6,71 GJ, in Sapporo is 105 GJ (1471% more); the cost of it is 117 € per capita in Turin and 2779 € in Sapporo (2275% more) for 2014. This evident discrepancy led the study to deepen the analysis on data unifying the POLITO campus buildings for engineering, comparing the sum of the two electrical consumptions with the HOKUDAI one (see Tab. 1 Data set used for the two case studies related to 2012 in Appendix).

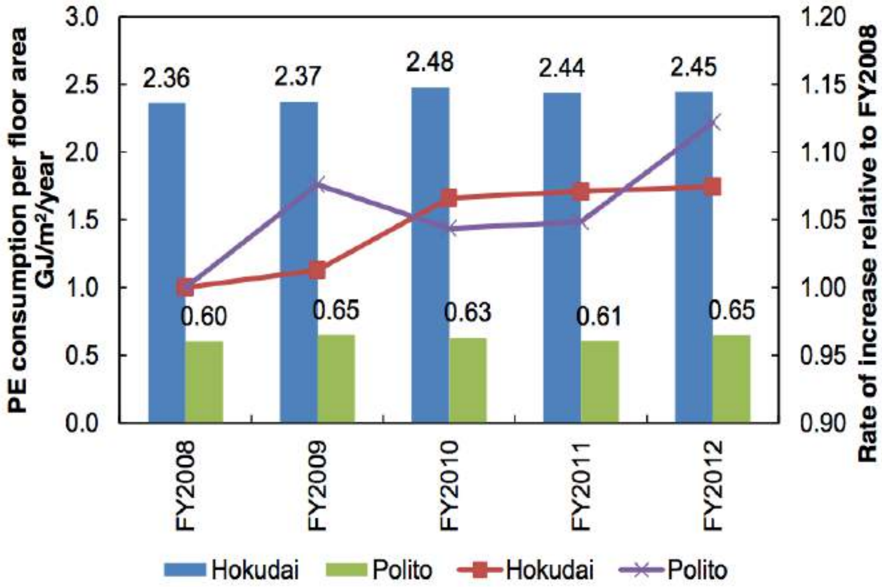

Fig. 6 PE consumption per floor area from 2008 to 2012 for POLITO and HOKUDAI campuses. Source: (Sonetti & Kikuta, 2013).

A cross comparison among the PE per floor area for the two universities has been not possible due to the lack of conciliated data between thermal energy consumption and building site. First, a comparison among the weather data of Torino and Sapporo has been carried out (Fig. 20). Comparing the two cities over the previous three years, the average outside air temperature was 9.4^{o} C for Sapporo and 14.7^{o} C for Torino, when the yearly span for Sapporo was wider than for Torino. The average global solar radiation was 3,377 Wh/m^{2}/day (1,234 kWh/m^{2}/year) for Sapporo and 3473 Wh/m^{2}/day (1271 kWh/m^{2}/year) for Torino. During summer time, the solar radiation for Torino tended to be much higher than for Sapporo, where the outside temperature tends to not follow the increase rate of global solar radiation. It can mean that Turin has got a faster response to the incident radiation thanks to other elements (relative humidity, heat island effects, wind speed, pressure, ozone concentration).

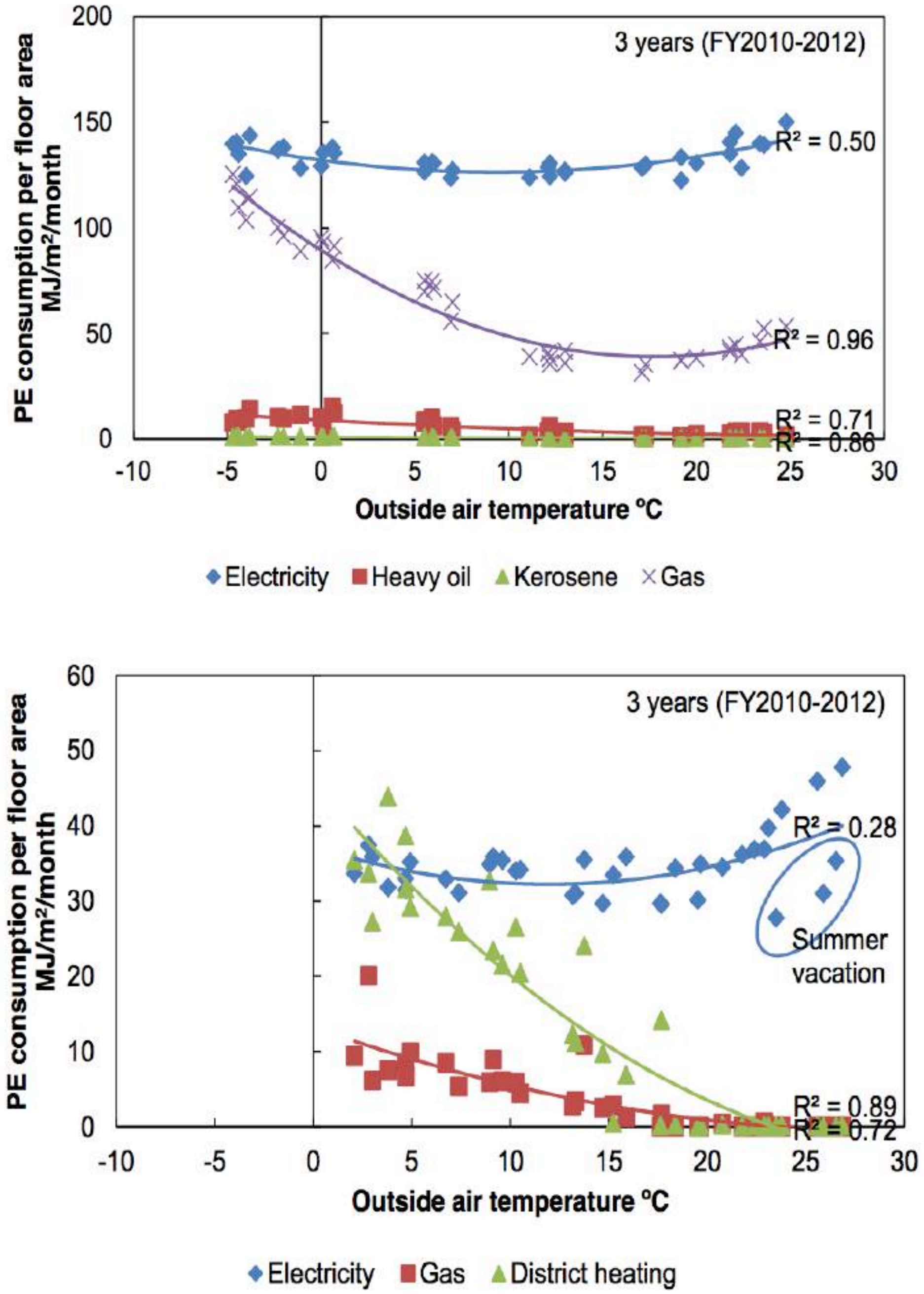

Fig. 7 Relationship between outside air temperature and PE consumption per floor area over three years (2010-2012) for HOKUDAI (left) and POLITO (right). Source: (Sonetti & Kikuta, 2013).

Fig. 6 shows the annual PE consumption per floor area POLITO was four times lower than HOKUDAI. Analysing the relation of outside air temperature and consumption of different energy type (Fig. 7), the seasonal correlations for gas in HOKUDAI ($R^2 = 0.96$) and district heating at POLITO ($R^2 = 0.89$) were obviously high; also, due to the effect of summer vacation the electricity path in August for POLITO) was below the trend line. For the two campuses, the seasonal correlation was quite low for electricity consumption. A multiple linear regression analysis with electricity consumption per floor area and capita for four departments (Engineering, Science, Medicine, and Agriculture) was performed. The explanatory variables were the outside air temperature, number of lecture days and proportion of students. The results on multiple linear regression analysis are presented in Tab. 2 in Appendix. In order to understand the effects of the explanatory variables, the standardised partial regression coefficient taking multicollinearity into account was verified. Larger absolute values of the standardised partial regression coefficient are associated with a stronger relation of the explained variable and explanatory variables. The adjusted R^2 was all 0.5 or higher, and as a result, the outside air temperature results to be the strongest factor for agriculture, while the proportion of students is the strongest factor for the other departments. In particular, from November to April the influence of the outside air temperature was largely different for individual departments. We can infer that the thermal performance of buildings and how to operate the heating are both significant factors. In addition, the number of lecture days for Engineering was a more important factor than for the other departments.

2.7 Conclusions

Current energy data collection methods and management have been analysed in two different case studies. Two universities are represented (the Politecnico di Torino in Italy and the Japanese Hokkaido University in Sapporo) crossing energy data and comparing mutual trends with other key variables (outside temperature, opening times, function hosted and number of students). Appropriate queries, pivot and graphic displays addresses improvements both for self-assessments indicators and for external reporting purposes. From the wide numbers of features analysed across the two cases it emerged that data monitoring does produces energy and money saving, both in short and in long terms. However, when data access is not easy and open (via a web site or a living lab facility), it can constitute a barrier for external insights and mutual learning from other universities. Conversely, a human (non-automatized) supervision on data trends, targets achievements and failures in energy trends appears crucial in both cases. A gathered campus, like the Japanese one, runs as a perfect test bed for data management methods according to different faculties, thanks to the matching between consumption sites and supplier delivery points.

Finally, clusters of homogeneous energy consumption are proposed according to the academic functions hosted in the analysed buildings, allowing comparison of university campuses similar for energy use intensity and *modus operandi*. Evidences of links between energy use intensity and surface, weather data and presence of big energy consumer functions (like hospitals, labs, data centre and canteens) can set internal improvement thresholds and warning values currently lacking in university campus sustainability frameworks (Sonetti et al., 2016).

Yet, the lack of coherent criteria should not stop campus rankings in dealing with important issues. This controversial step in the development of cross-institutional campus sustainability assessment tools will have far reaching implications for theory and practices. Further prompts could be to gather a wider universities open data set disclosing the same amount and quality of energy data, to apply inferential statistics methods (t-test, analysis of variance (ANOVA) and covariance (ANCOVA), regression analysis, and many of the multivariate methods like factor analysis, multidimensional scaling, cluster analysis, discriminant function analysis) to overcome the limits highlighted within this chapter. Of course, more cooperation on data disclosure (and quality of collected data) is a necessary step to frame base-lining university building energy and exergy characteristics.

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Appendix A

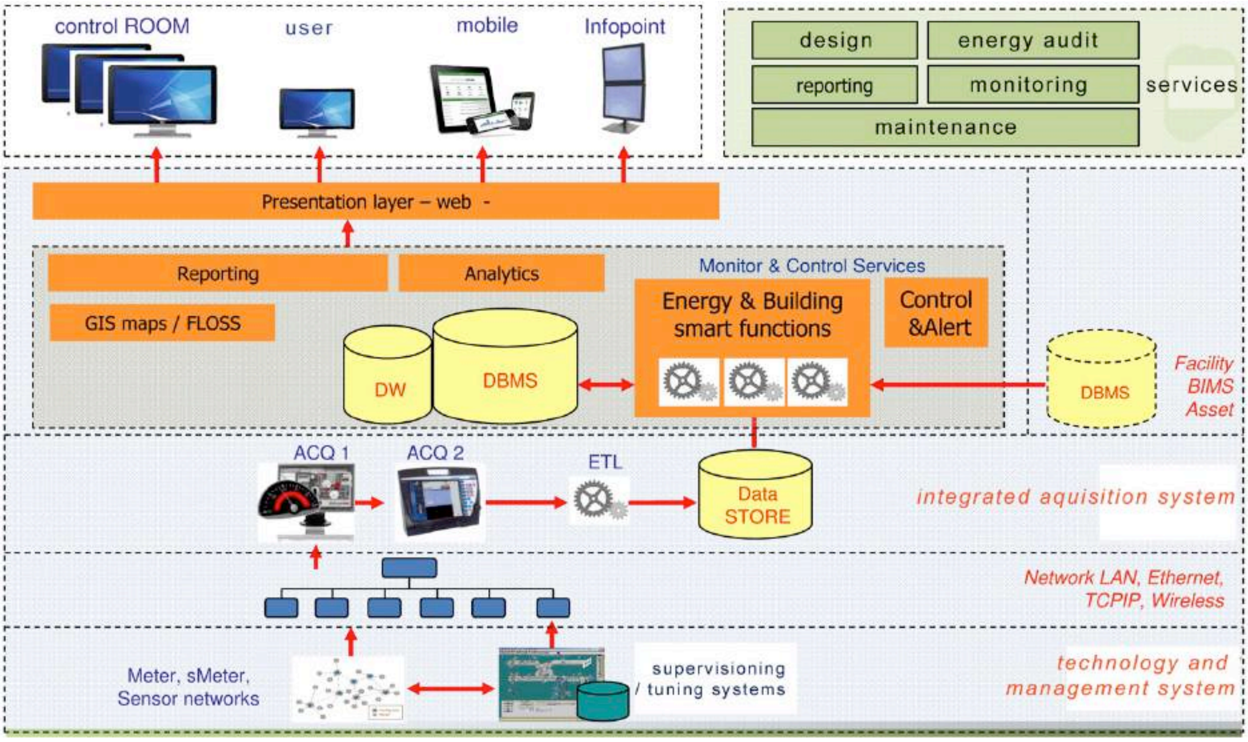


Fig. 8 The Living Lab IT architecture. Source: author elaboration on a scheme found at http://www.fierabolzano.it/klimaenergy/mod_moduli_files/Bozza%20new.pdf

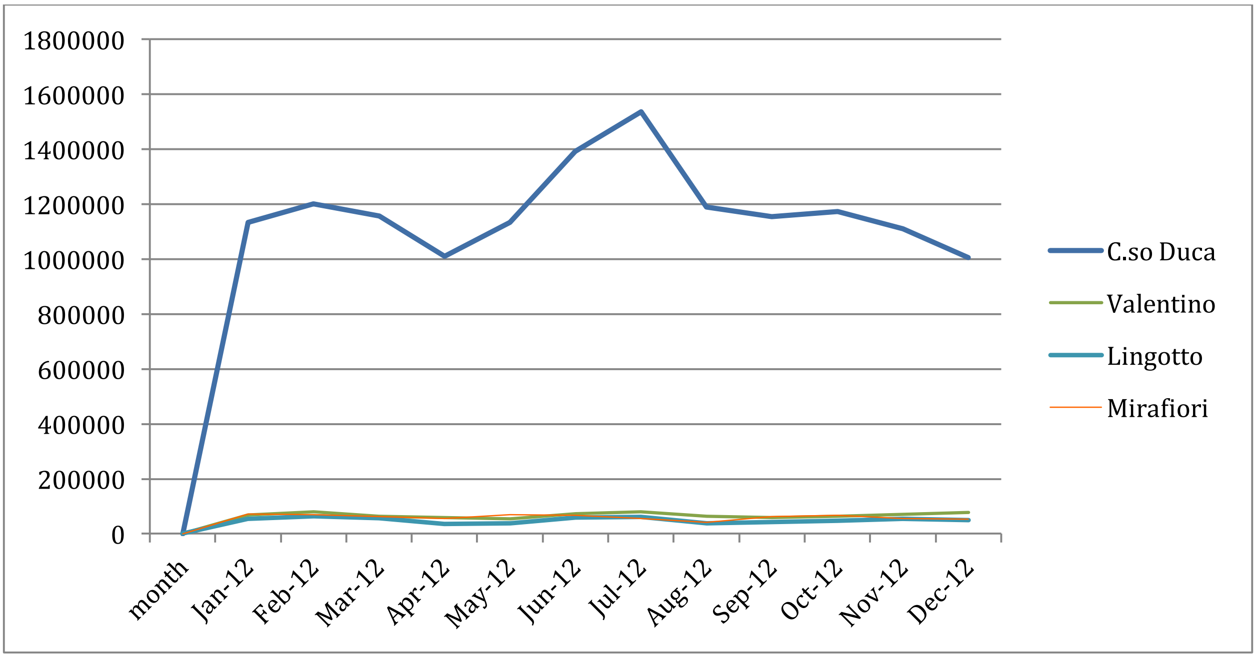


Fig. 9 Electric energy consumption (kWh) in the four main sites of POLITO in 2012

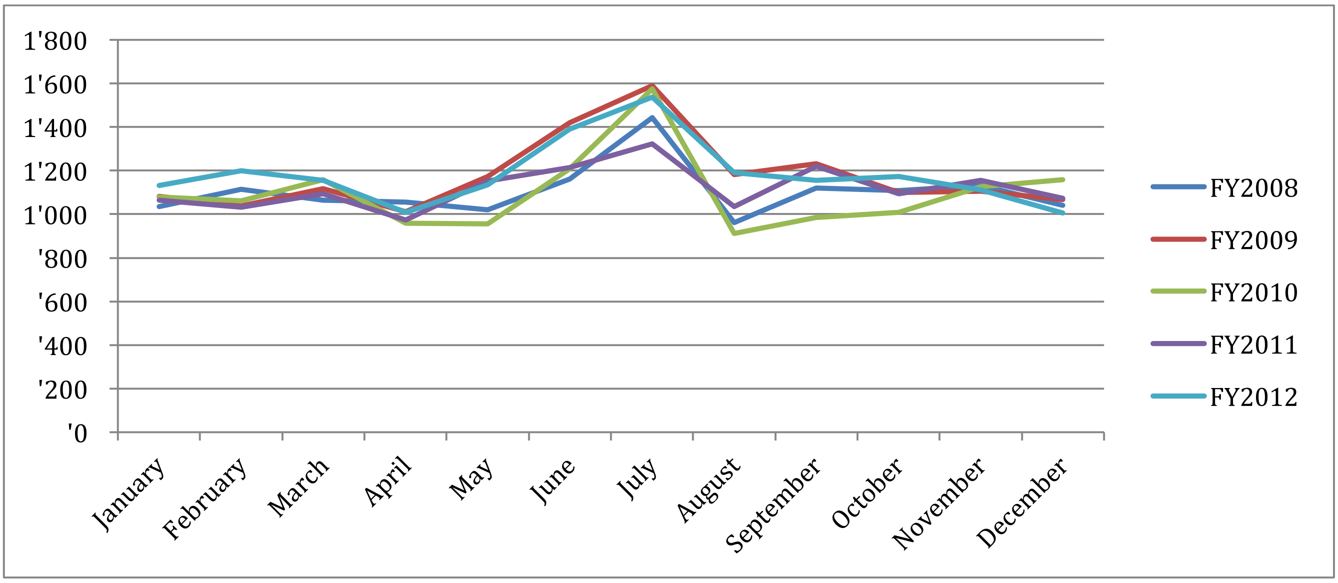


Fig. 10 Monthly Electricity Consumption (MWh) in the POLITO main site of Corso Duca from 2008 to 2012

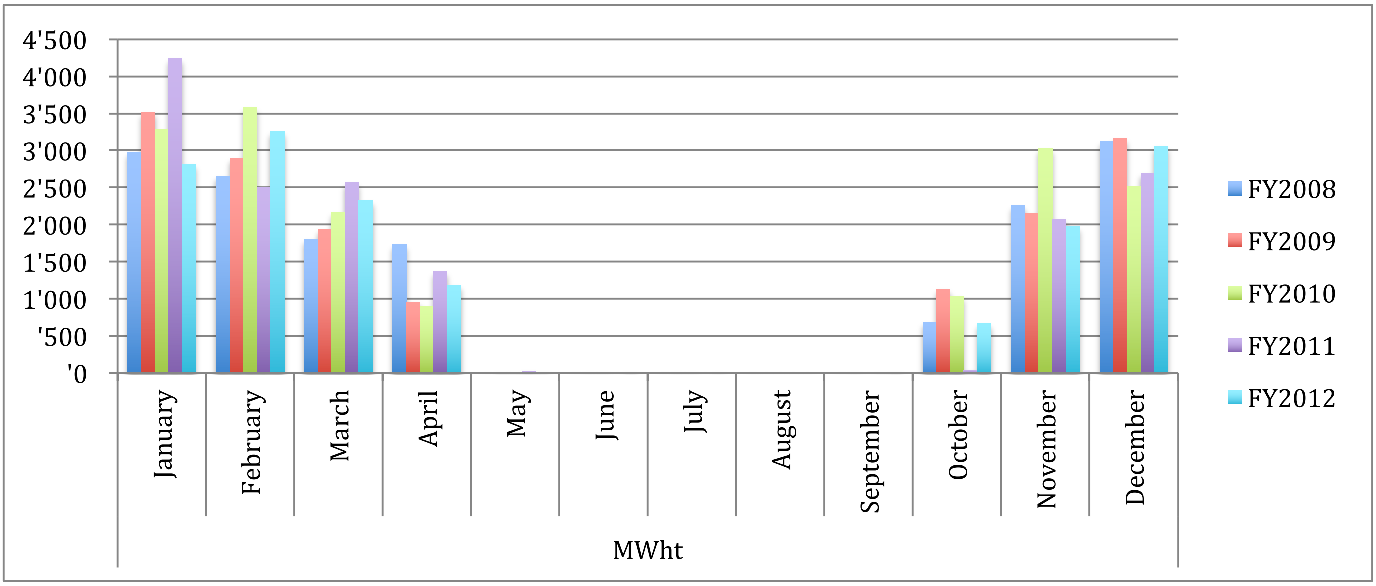


Fig. 11 Thermal energy consumptions trends for POLITO Corso Duca main site from 2008 to 2012

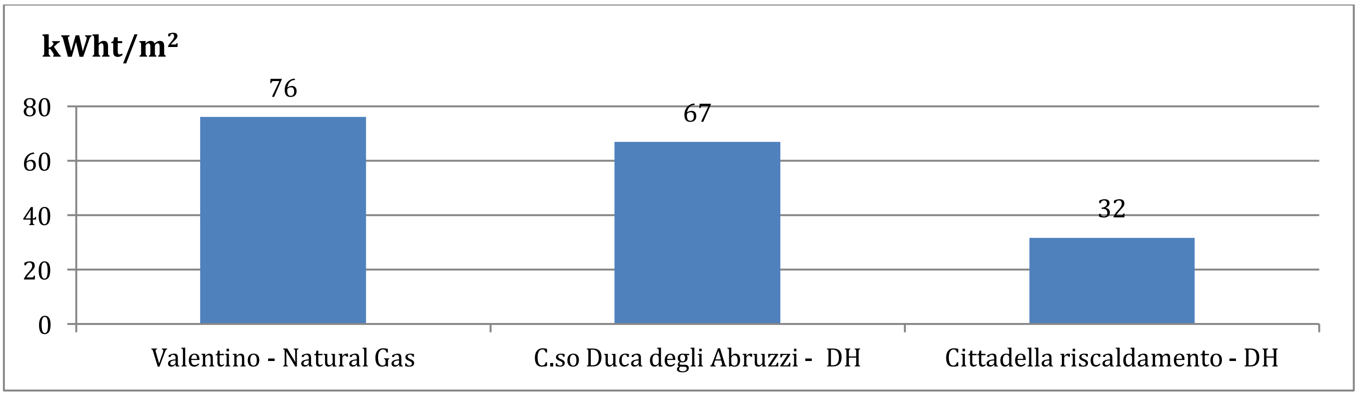


Fig. 12 Thermal energy consumption in 2012 weighted per floor area in the Valentino (natural gas) and Corso Duca and Cittadella main POLITO sites (supplied by district heating).

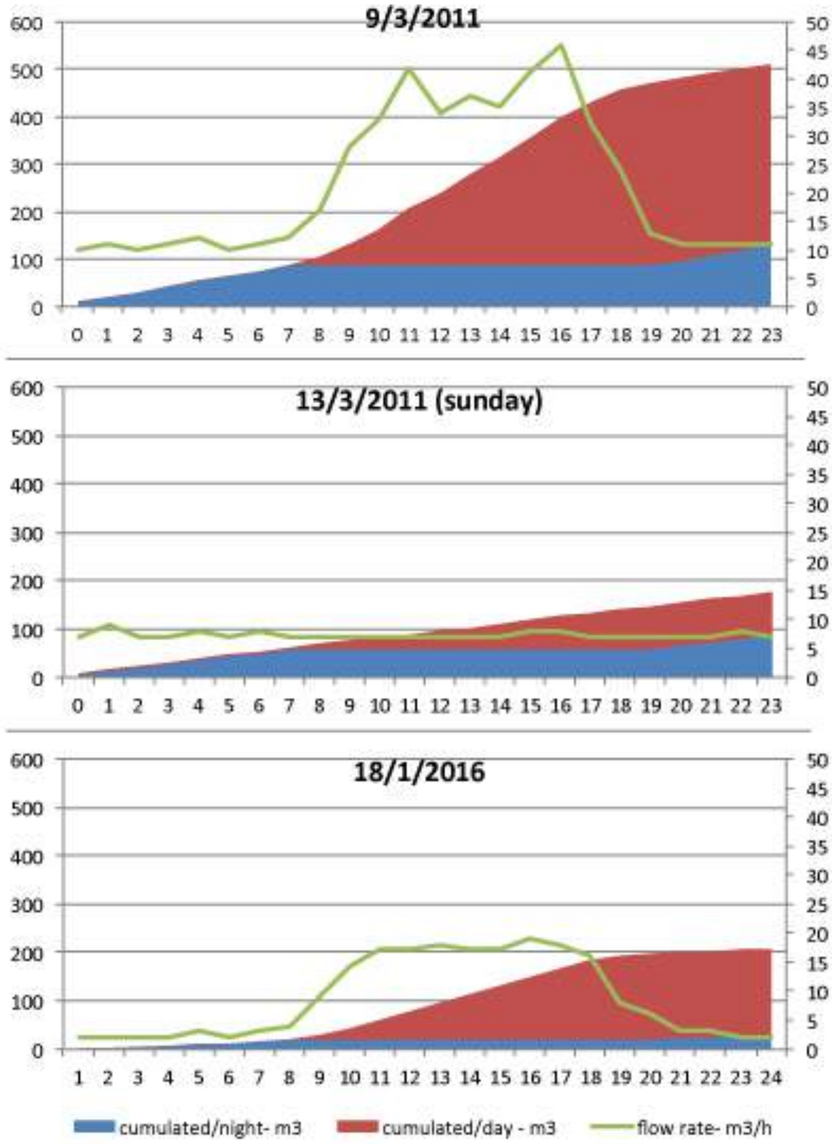


Fig. 13 Water consumption trends for the main site of POLITO Corso Duca on a typical week day in 2011 (top), on a Sunday of the same year (middle) and on a typical week day (bottom) of 2016. Primary axis in m3, secondary axis in m^3/h.

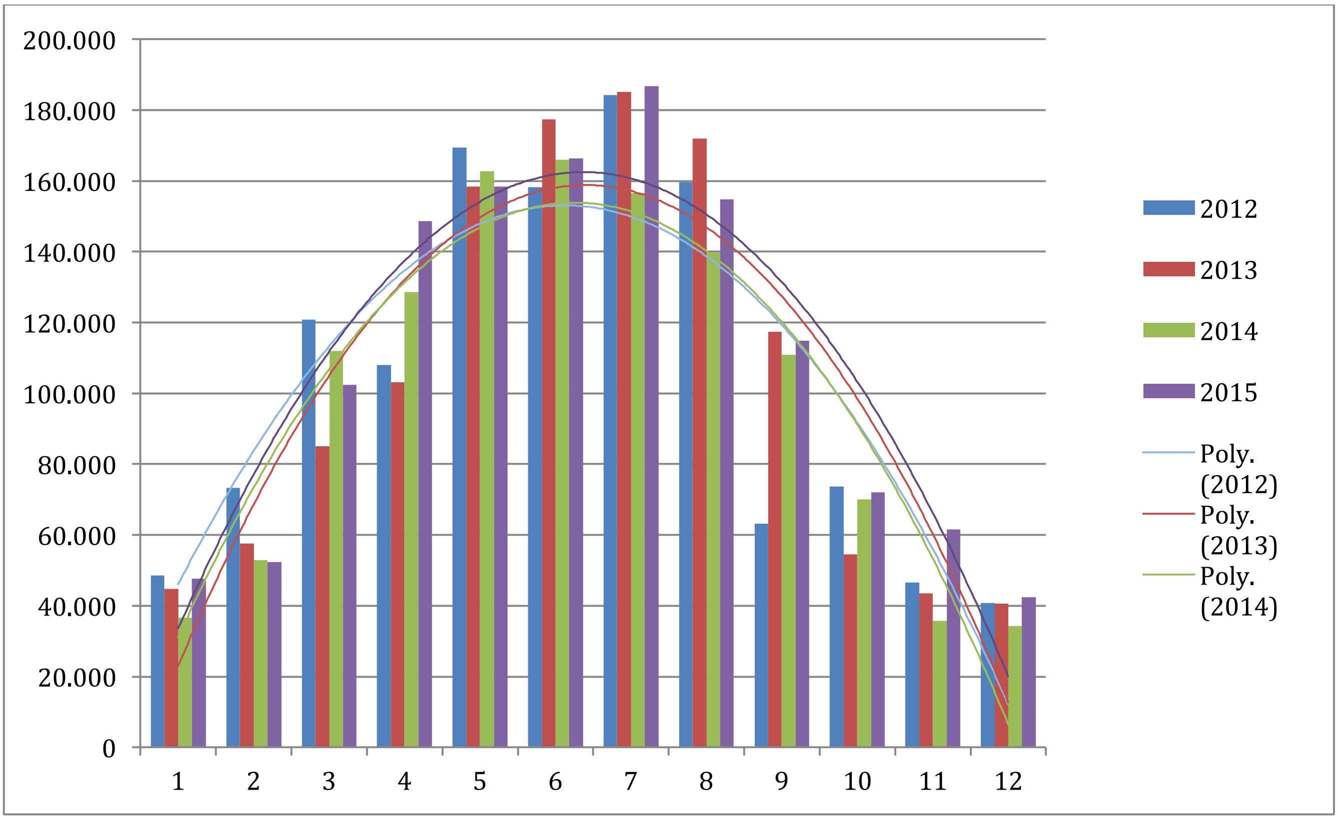


Fig. 14 Yearly solar radiance (Wh/m²) registered from 2012 to 2015 on horizontal surface at POLITO

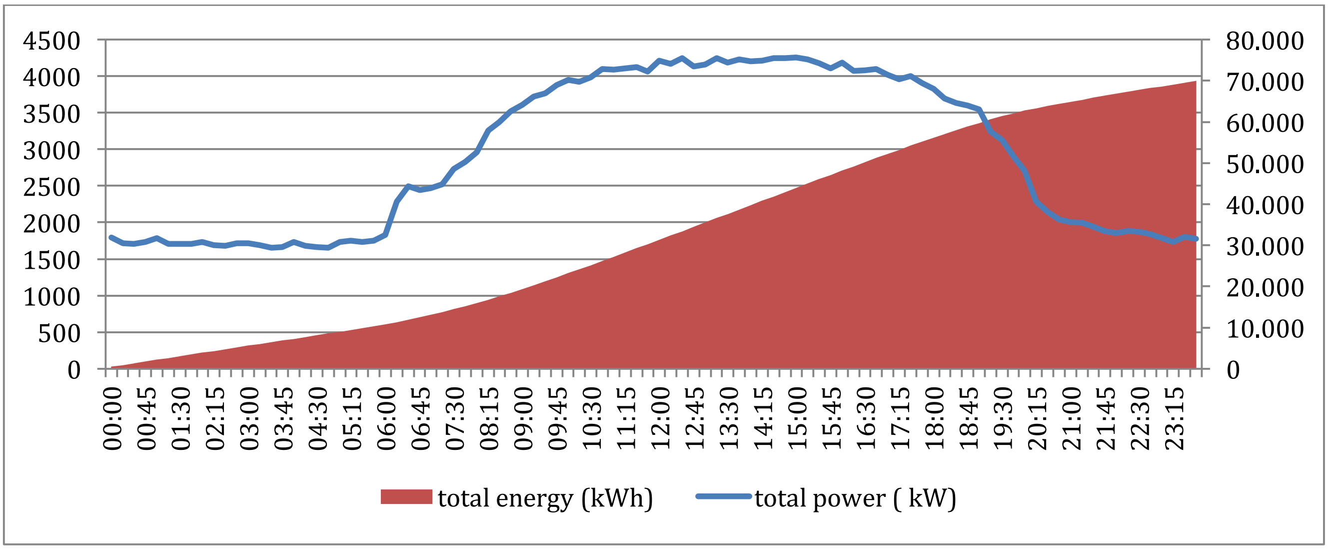


Fig. 15 Total energy cumulated along the 24 hours (in red) and total power load curve (in blue) in a typical summer day of 2015.

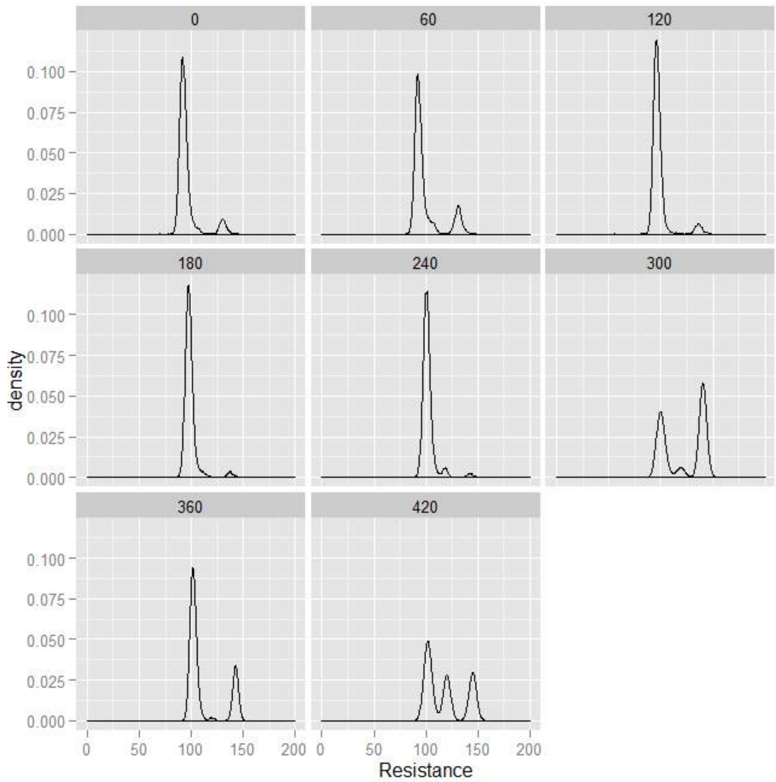


Fig. 16 CO_2 concentration registered after 0, 60, 120, 180, 240, 300, 360 and 420 days in classroom 1 after the installation of an air filter in the ATU.

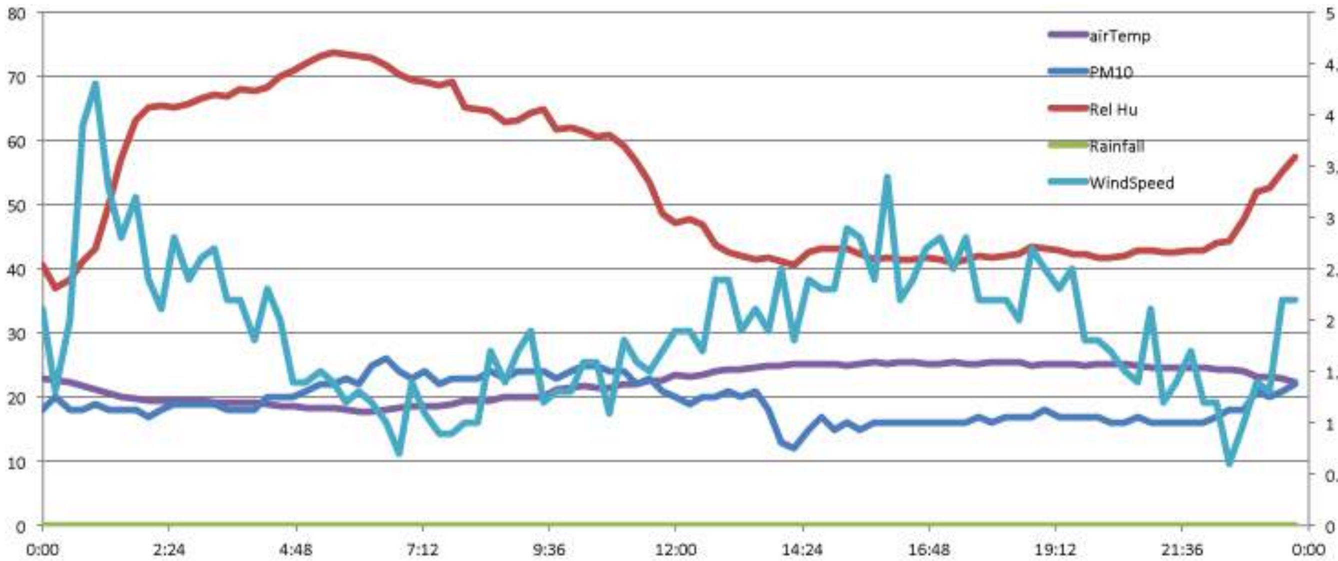


Fig. 17 Meteorological data from the weather station on the roof top of POLITO main site building, 21/06/2015

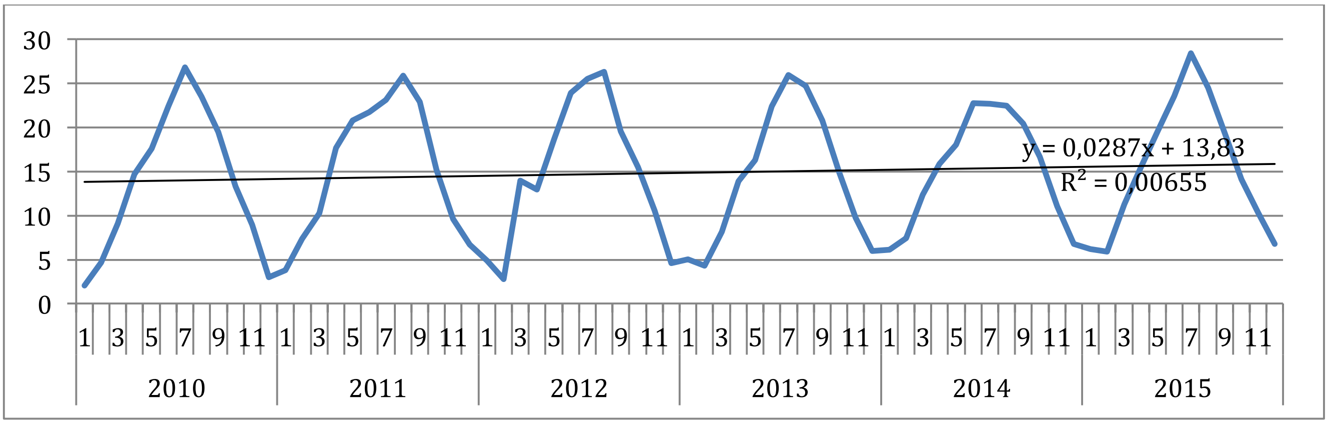


Fig. 18 External temperature averages trend as registered by the POLITO weather station from 2010 to 2015

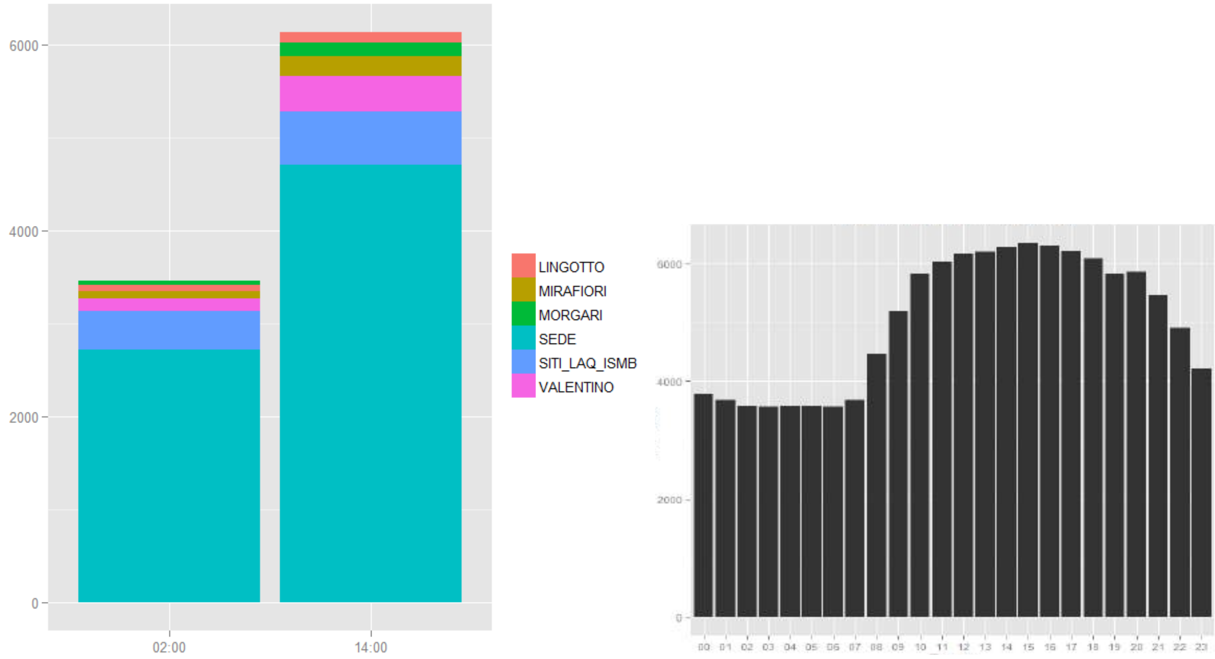
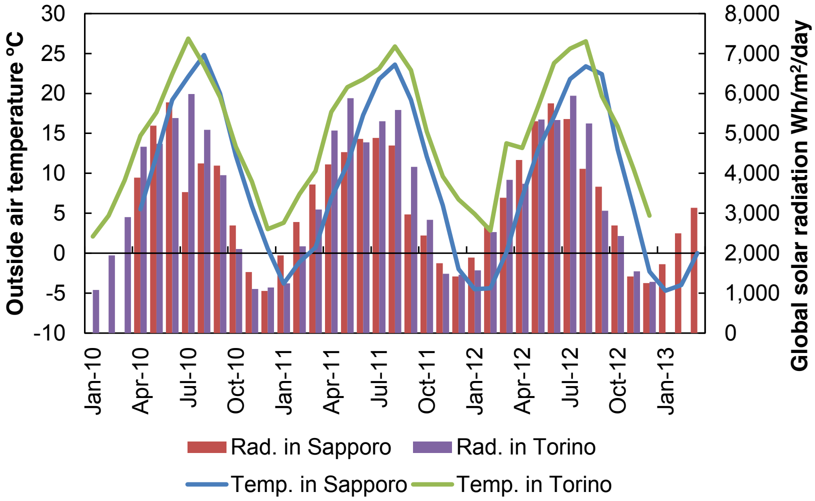


Fig. 19 Number of active IPs on 2am and 2 pm in a typical day in all POLITO sites (left) and trends on the 24hs of the total active IPs (right).



	Outside air temperature °C		Global solar radiation Wh/m^2/day	
	Sapporo	Torino	Sapporo	Torino
Average	9.4	14.7	3,377	3,473
Maximum	24.8	26.9	5,778	5,985
Minimum	-4.7	2.1	1,056	1,082
Standard deviation	9.9	7.9	1,397	1,702

Fig. 20 Meteorological data for Sapporo and Torino. Source: (Sonetti & Kikuta, 2013).

Campus data (2012)	**Area**	**Floor area - m^2**	**Electricity - MWh**	**Gas -m^3**	**DH - MWht**	**DH - MWh/m^2**	**Gas - m^3/m^2**
HOKUDAI*	Sapporo	707969	115656	12278786	0	115656	12278786
POLITO**	Unified	347756	16354	381834	15383	16354	381834
*	Hakodate Campus is not listed in the target.						
**	Corso Duca, Cittadella Politecnica, Castello Valentino, Politecnico, Lingotto, Mirafiori						

Tab. 1 Data set used for the two case studies related to 2012

Electricity consumption per floor area and capita		Standardized partial regression coefficient						Adjusted R^2
		Outside air temperature		Number of lecture days		Proportion of students***		
Wh/m^2/person/month		ºC		days/month		person/person		
Engineering	Nov-Apr	-0.56	**	0.44	**	-0.67	**	0.91
	May-Oct	0.53	**	0.46	**	-0.73	**	0.79
Science	Nov-Apr	-0.23	**	0.14	*	-0.92	**	0.94
	May-Oct	0.39	**	0.15	*	-0.87	**	0.91
Medicine	Nov-Apr	-0.12				-0.88	**	0.81
	May-Oct	0.58	**	0.24	**	-0.79	**	0.89
Agriculture	Nov-Apr	-0.90	**	0.48	**	-0.38	**	0.88
	May-Oct	0.67	**	0.29		-0.55	**	0.59
*		Statistical significance: P < 0.05						
**		Statistical significance: P < 0.01						
***		=B/(A+B) A=Teachers+Staffs B=Undergraduate students+Graduate students						

Tab. 2 Results of the standardised partial regression coefficient in HOKUDAI for three main explanatory variables, namely outside air temperature, number of lecture days, proportion of students out of the total department users. Data referred to 2012. Source: (Sonetti & Kikuta, 2013).

Appendix B

The UNITO case study

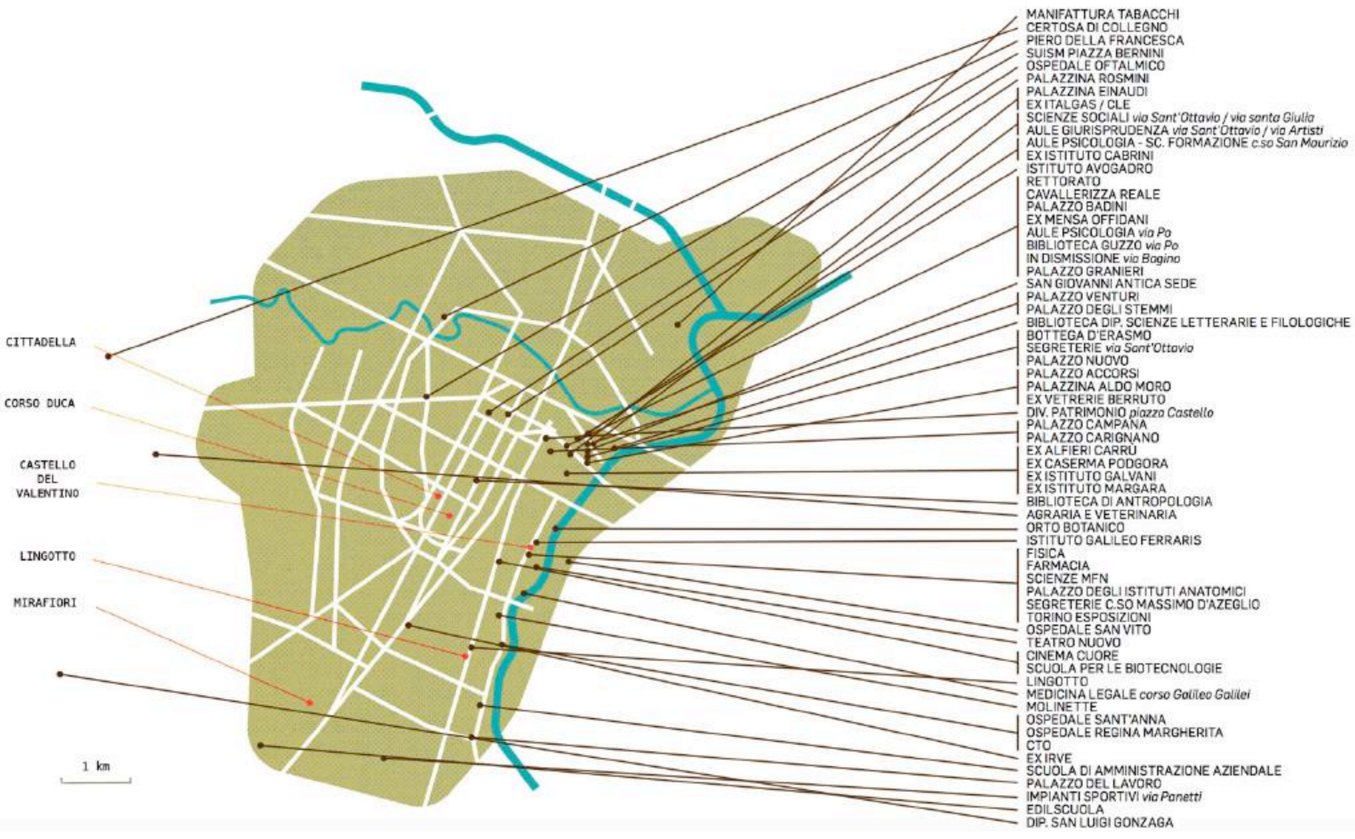


Fig. 21 The POLITO sites (in red, written on the left) and the UNITO sites (in brown, written on the right) scattered in the city. Source: modified by authors from (Initiative, 2015)

Campus setting and Sustainability Office Data Management

The University of Turin (UNITO) is one of the oldest Italian Universities. Hosting about 70.000 students, 4.000 academic, administrative and technical staff (2014 data), 1800 post-graduate and post-doctoral students and with 120 buildings (Fig. 21) in more than 500000 m^2 in Turin and in key places in Piedmont, the University of Turin can be considered as “city-within-a-city”. It carries out scientific research and organizes courses in all disciplines, except for Engineering and Architecture. The attention to energy conservation is recent, but started strongly in front of a large impact of energy consumption (340 GJ in 2013) (Initiative, 2015) with initiatives to renovate of the oldest university sites. Interventions are planned in order to reduce greenhouse gas emissions (104t of CO_2 equivalent in 2013) by increasing the efficiency of some plants (i.e. strengthening of cogeneration) and the purchase of electricity from renewable sources. The Green Procurement will also help the reduction of environmental impacts in the supply chain. The environmental management has not got a proper office up to now, but different stakeholders inside the university take care of the management of the following data: Energy, Water, Biodiversity, Emissions, Effluents and Waste, Transport, Supplier Environmental Assessment, Environmental Grievance Mechanisms. In particular, the Energy Manager of UNITO, similarly to the one in POLITO in compliance of the law 10/91, identifies actions, operations and procedures to promote the rational use of energy and to plot data against economic parameters and end uses.

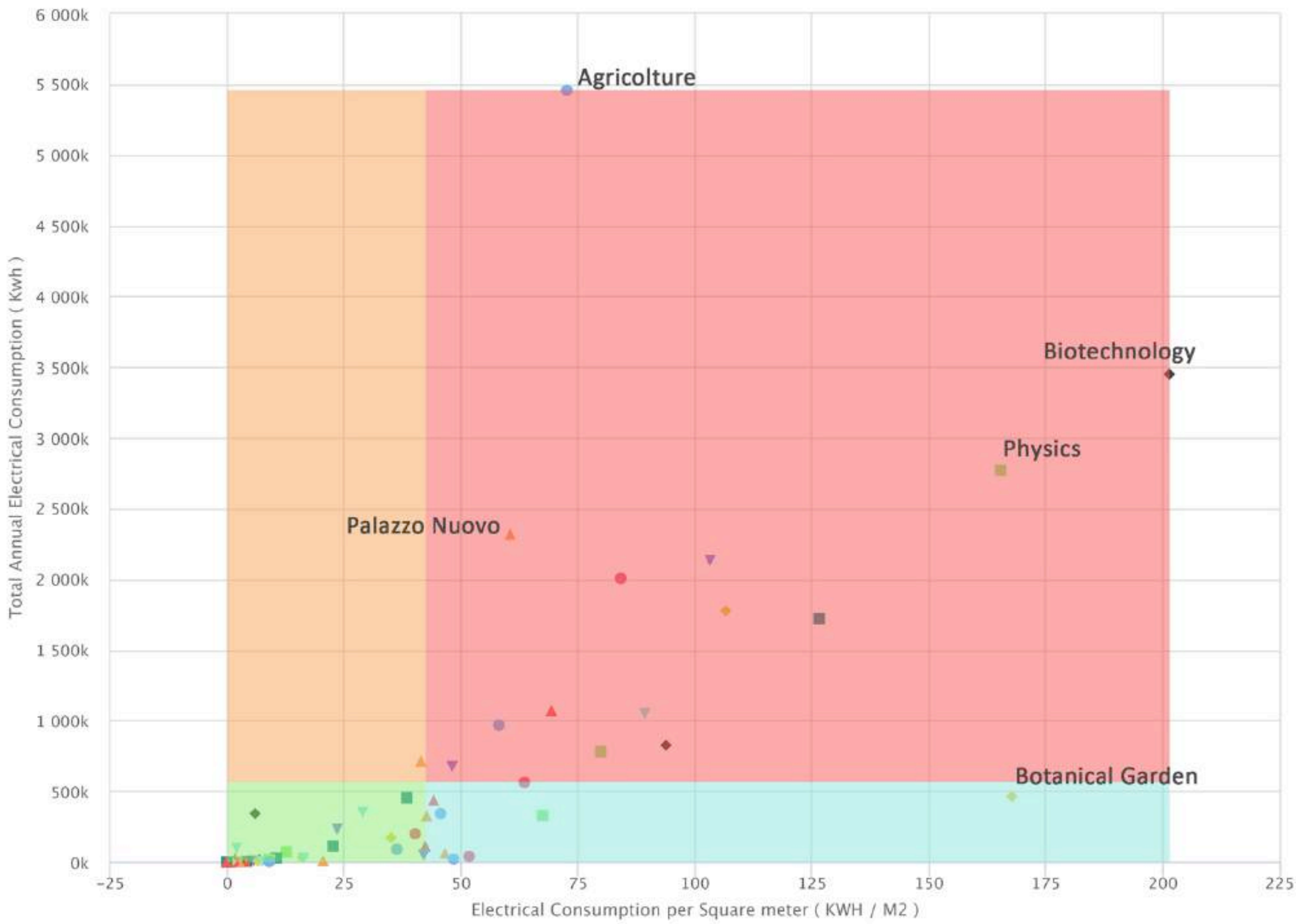


Fig. 22 Global electric energy consumption for 2012 at UNITO. Source: (UNITO, 2015)

Charts from the following figures comes from an open web site where energy consumption data (UNITO, 2015) can be browsed per year, per building and per month, with an interactive graphic interface that allow inter-comparison between different years, buildings, and day-bands of electrical consumption. Fig. 22 shows a scattered plot of the total 120 sites belonging to the UNITO building stock. The total annual electrical consumption per floor area is on the x-axis, while the total absolute annual electrical consumption is on the y-axis. We can point out some outliers in the chart: first of all, the botanical garden has got the highest electric energy consumption per square meter, but it is probably due to the wide green surface of the botanical garden (and therefore the high electric energy request from irrigation plants and green houses facilities) and the small floor area of the offices inside. For the same reason, the department of agriculture has got the highest electric energy consumption compared to the same quantity weighted per floor area, reasonably for the green house facilities and the equipment used for lab experiments. Homogeneous clusters of consumption both per square meters and absolute MWh/year can be traced in the green quarter of Fig. 22, grouping all the humanities and libraries of the main UNITO sites. The trend curve of linear correlation between surface and consumption shows an offset of 45 KWh/m^2 on the x-axis, after which the consumption increases up to 200 KWh/m^2 for the biotechnology department, mainly for the experiment running 24 hours per day and energivorous equipment. It can be noticed that the red quarter displays the typical consumption path of science faculties. Quite far from the trend line, "Palazzo Nuovo" requires more electric energy than a similar office facility per square meter because of the bad thermal insulation of walls and windows, dated in late '50s. Fig. 23 and Fig. 24 show the montlhy total electricity consumption broken down for hourly usage bands[11] for four UNITO's buildings: the Campus Luigi Einaudi VS the Department of Economics (Fig. 23) and the department of Psycology VS the San Luigi Hospital (Fig. 24). In the first comparison, the Campus Luigi Einaudi, recently build by a famous international firm, shows the highest consumption curve and the wider span in summer electricity reuirement for air conditioning. The excessive glass surface and the difficult in controlling lovers and windows opening make this building consume far more than predicted, as confirmed by numeours studies on this topic (see, for instance, De Wilde, 2014). Conversely, the electricy consumption of Economics is 2,7 less than the Campus Luigi Einaudi following the same trend, with drop in August for summer holidays and september peaks for examination and lecturing start. In July, the Campus Einaudi consumed 3,6 total KWh more than Economics, mainly in daytime. The F2 and F3 bands show similar consumptions for Economics, while the span results wider between the same bands registered in the Campus Einaudi, showing an anomalous consumption even on night, holidays and Sunday hours. Fig. 24 shows a similar comparison between the San Luigi Hospital and the Department of Psycology. Here, the consumption of the first is on average 30 times more than the second. The contribution in the F2 and F3 bands demonstrate how the hospital runs 24hours per day / 365 days per year with no interruptions and with the higher consumption values from May to September, with peak on July. Conversely, the department of Psycology does not follow any seasonal variation of outside temperature and registers peaks for the occupational path following lectures and exams days in winter and spring terms.

[11] F1- week-day hours: from Monday to Friday (8:00-19:00); F2- breakfast/dinner time and Saturday: from Monday to Friday (7:00-8:00 e 19:00-23:00) - Saturday (7:00-23:00); F3 - Night, holidays and Sunday hours: from Monday to Friday (23:00-7:00) - Sunday/holidays (0:00-24:00)

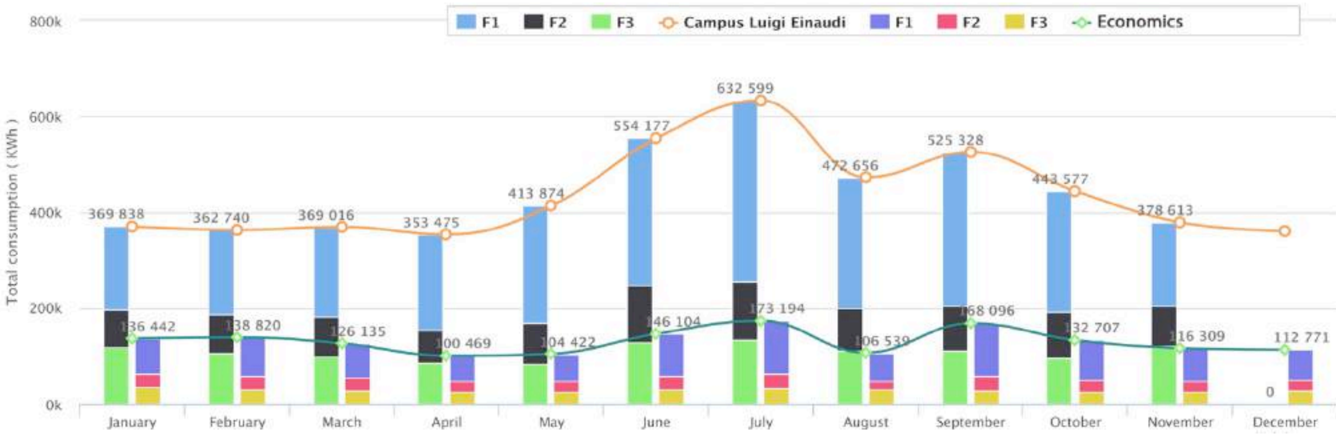


Fig. 23 Montlhy total electricity consumption broken down for hourly usage bands for two UNITO's buildings: the Campus Luigi Einaudi and the Department of Economics. Source: (UNITO, 2015).

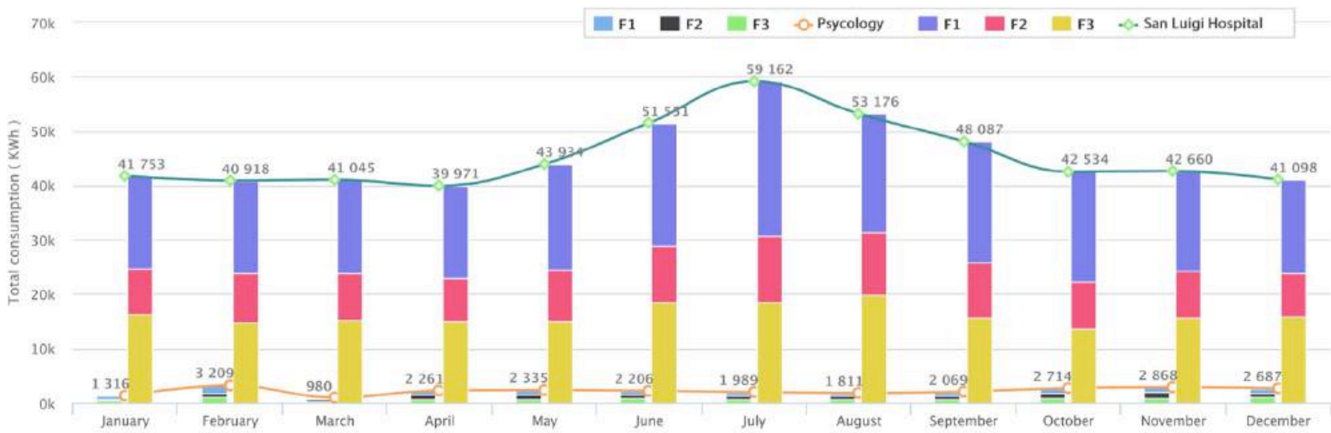


Fig. 24 Montlhy total electricity consumption broken down for hourly usage bands for two UNITO's buildings: the Department of Psycology and the San Luigi Hospital. Source: (UNITO, 2015).

Preliminary cross comparison among UNITO-POLITO-HOKUDAI campuses energy performance

Fig. 25 shows pie charts of total electric energy consumption (KWh) and thermal energy consumption (GJ) per floor area (m^2) and capita (p) in 2012 in HOKUDAI, POLITO and UNITO. Tab. 1 in Appendix shows data sum up for these charts. As appears clearly, the sum of UNITO and POLITO electrical consumption from all kinds of departments and functions, comprehending hospitals and data centers, is still almost the half of HOKUDAI's same amount per square meter. The variance becomes higher (9 times less) when KWhs are weighted on campus users. The same proportion are revealed by the charts displaying thermal energy consumption: the sum of UNITO and POLITO GJ per square meter is the half of HOKUDAI's number, while GJ per person are almost 10 times more in HOKUDAI than in UNITO and POLITO, revealing an higher need of energy for heating (yet inferable by the weather data in Fig. 20, where the minima of Sapporo are far below zero than Turin's ones.) This incomplete appendix demonstrates that further research on the exergy performance of the three campuses in needed to outline meaningful sustainability evaluations of different university campuses.

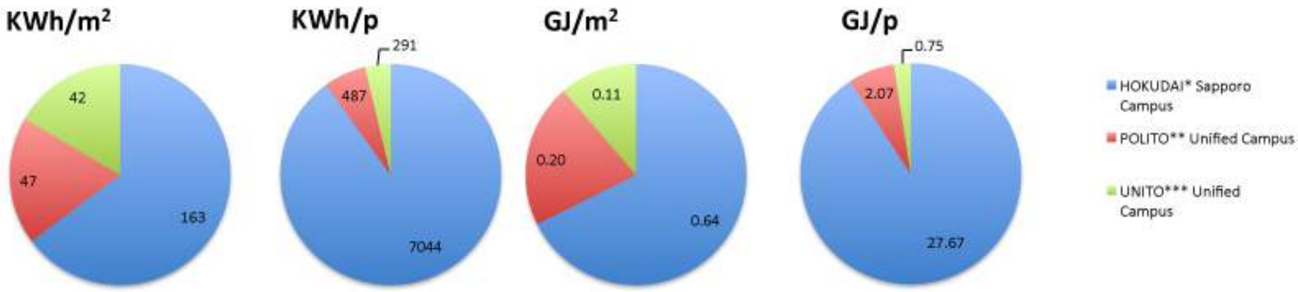


Fig. 25 Total electric energy consumption (KWh) and thermal energy consumption (GJ) per floor area (m^2) and capita (p) in 2012 in HOKUDAI (blue), POLITO (red) and UNITO (green).

3 Sustainability Management in University Campuses: The Road from Scattered Good Practices to Systemic Transformations

Abstract: This chapter aims to contribute to the emerging dialogue about how to accelerate the progress towards an institutionalised commitment to campus environmental sustainability. It will analyse three cases of good practices made to date in the field of "green universities" management, looking deeply into these experiences, interviewing their main stakeholders and revealing the main sustainability activators and barriers to transfer and widespread similar institutional transformation. A range of data is presented, from reports and interviews about lessons learned and approaches emerging from different environmental strategies to quantitative indicators analysis from the green metric reporters. One Italian, English and Mexican University are taken as success cases for different sustainability topics. The subject matter is wide ranging as it is intended as a starting point for the reader to pick and choose ideas that may warrant further investigation in their own university context. Even though many of the ideas presented need further exploration and development, in their current state they may prove of some value to the reader as a catalyst for a different level of institutional analysis.

Key-words: *Sustainability Management, Higher Education, Public Engagement*

3.1 Introduction

Half of the world's inhabitants now live in cities. In the next twenty years, the number of urban dwellers will swell to an estimated five billion people. NIMBY (Not In My Backyard) and BANANA (Build Absolutely Nothing, Anywhere, Near Anybody) city users' motto (Wester-Herber, 2004) seem to be very far from the KEFA - (Knowledge Everywhere For Anybody) and B-GOT (Beyond GDP, Beyond Oil, Beyond Tangibles) goals of european policies and enlightened researchers (Arrow et al., 1995). Plus, cities still consume enormous quantities of fossil fuels and emit high levels of greenhouse gases, but our planet is rapidly running out of the carbon-based fuels that have powered urban growth for centuries, and the eco-efficiency approach found in previous European policies seem to have failed in make us curb our greenhouse gas emissions (Chapman, 2012). What we surely know is that the city is the playground for tackling this issue. The requested change must come from the cities, with its citizens and its planners, as privileged sites of knowledge production and innovation, as well as strategic management hot spots. In this work, university campuses are identified as privileged sites in the city to observe, in a delimitated border, which resilience activators, community responses and flexible governance dynamics could take place for energy reduction (J. Evans et al., 2015).

There has been tremendous growth in the sustainability movement in higher education over the past 15 years. This growth has shown the need for stronger methods to measure progress toward achieving the sustainability that many claim. The Association for the Advancement of Sustainability in Higher Education or "AASHE" has a standard method for monitoring the sustainable progress for universities mainly from the United States and Canada. Launched in 2009, STARS is a transparent self-reporting tool and analysis available to universities. The system works by measuring the sustainable performance in academia, operations and administration using default settings. Since STARS was launched in 2009 have been more than 300 institutions evaluated by 2014 and more than 400 participants in 8 countries, the updated STARS 2.0 version allows institutions outside the United States and Canada participate and be evaluated from 2014 (Lidstone, Wright, & Sherren, 2015). The world University Ranking GreenMetric was established in April 2010 in order to provide a profile that could be used to compare the commitment of universities to a greener future and to promote their sustainable operation. The Ranking expects to promote awareness of the institutions of higher education and the value of policies and systems that will have a positive impact on global warming and climate change, particularly those that help reduce carbon emissions promote energy efficiency, alternative forms of transport, campus reforestation and waste recycling. Therefore, campus sustainability has become an issue of global concern for university policymakers and urban planners, as result of the living lab model that bring at cluster scale the impacts of campuses activities and operations. The issue has also been intensified by the pressure from government environmental protection agencies, sustainability movements, university stakeholders as well as the momentum of other forces including student activism and NGOs (Caeiro et al., 2013).

A sustainable university is defined by Velazquez (Velazquez, Munguia, Platt, & Taddei, 2006) as ‘‘a higher educational institution, as a whole or as a part, that addresses, involves and promotes, on a regional or a global level, the minimisation of negative environmental, economic, societal, and health effects generated in the use of their resources in order to fulfil its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable lifestyles.’’ Cole (Cole, 2003) also defines a sustainable campus community as ‘‘the one that acts upon its local and global responsibilities to protect and enhance the health and well being of humans and ecosystems. It actively engages the knowledge of the university community to address the ecological and social challenges that we face now and in the future”. A sustainable university campus also connotes a clean and enjoyable campus environment that promotes equity and social justice having a prosperous economy through energy and resource conservation, waste reduction and efficient environmental management that benefits the present and future university community.

There is a common understanding in the literature that a sustainable university campus implies a better balance between economic, social and environmental goals in policy formulation as well as a long-term perspective about the consequences of today’s campus activities. As sustainability is characterised by economic growth based on social justness and efficiency in the use of natural resources, it should includes the recognition that all stake holders’ co-operation and participation is required to effectively achieve sustainability goals. However, as Lang (Lang, 2015) warns, there are very limited correlations between institutional environmental performance and adoption of campus sustainability initiatives, be they targeted operational or coordination and planning best practices, or curricular, co-curricular or research activities. Conversely, there are strong correlations between environmental performance and campus characteristics, namely, institution type and climate zone. The traditional practices and regulations of addressing environmental issues, project and ad hoc manner have become highly inefficient and cannot guarantee sustainability. Environmental issues are becoming more complex, multidimensional and interconnected and environmental sustainability by its very nature requires an integrated and systematic approach to decisions making, investments and management (Disterheft et al., 2014). Therefore, there is need for a professional and systematic environmental management approach to reducing the consumption of resources and negative impacts of the various campus operations and promoting campus sustainability. Unfortunately, this approach is generally lacking in most universities, and achieving sustainability is not easy (Alshuwaikhat & Abubakar, 2008).

This is why the present study tries to understand what good practices are able to build a sustainable community within the University, to set a fertile ground for long-term sustainability practice roots. After having explained why the sustainability concept is being embedded in today's higher education institutions, the introduction shows the limits of the current scattered and spontaneous approach toward a systematic sustainability management through a literature review of management cases and best practices. Then, three case studies are taken to demonstrate very different ways to achieve sustainable communities, although not included in standard key performance indicator of sustainability.

Data from the Politecnico di Torino, in Italy (par. 3.2), the Universidad Autonoma de Tamaulipas, in Mexico (par. 3.3), and the University of Cambridge, in United Kingdom (par. 3.4), have been collected from the living lab via one-to-one interviews with local officers, surveys, field-work qualitative documentations and on-line websites. Ex ante and ex post energy trends after sustainability actions have been tested though historical data set of energy consumption both from smart meter data log and from bills. A relevant source of information to complement the interviews came from internal and external documents available in a very peculiar and restricted-access University like Cambridge. Public and private documents consist in annual reports, websites, activity reports, campus assessments, internal mail, PowerPoint presentations, news media articles and the Archibus data-base. Most of these documents were obtained on the Internet, although the interviewees provided some reports and memos, too.

In the conclusions (par. 3.7), a framework for an integrated approach is presented, as well as some policy suggestions for the scalability and transferability of the good practices emerged toward a systemic transformation of the sustainability management in contemporary universities.

3.2 The Politecnico di Torino Green Team

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. In 2012, the Polytechnic accounted for 32000 students in 60 courses (undergraduate and postgraduate), more than 30 masters and 24 PhDs; 18 departments; 20700 m^2 of classrooms; 850000 m^2 for research activity; 1600 employees, including 800 teachers. The distribution for headquarters shows that over the 85% is consumed on the *Cittadella Politecnica*, and this is why monitoring activities are mainly concentrated there. The status quo sees the Politecnico in a very low position according to the national and international Green Metric Ranging, although: the 100% of the electric energy consumed in the campus comes from renewables, and a consistent part of the thermal energy comes from district heating; a new PV plant of 400 kWp has recently been approved, new double-framed and low-e windows substituted all the old windows, thermal insulation has been provided for all the most dissipative walls of the main building; Car-ride, car-pooling, electric vehicles charge stations, public transport reduced seasonal tickets and closed bike parking are some of the mobility manager recent achievements; 0-km food, green product procurement, paper-less communications, campus differentiated waste collection points, water dispensers are other tangible and visible effort in the direction of sustainability education, as well as the introduction of night open lectures, sustainability-dedicated courses and several international project on campus sustainability management. In the 2014 Green Metric Report, POLITO's total ranking was 4103 vs. 6094 (University of Bologna, ranked first in Italy) e 6057 (University of Turin, ranked second). The 2000 points that put away POLITO form the top have been lost mainly in the Waste and Transportation categories. Nevertheless, in the Energy and Environment category POLITO ranked well among the others thanks to the monitoring system and the IT large use in the Living Lab.

The first embryo of the Living Lab experimental infrastructure was realized between 2008 - 2010 thanks to a research project co-funded by the Piedmont region called "WiFI4Energy". The monitoring system supported and complemented different technologies and devices, providing data in a unified and integrated delivery mode. The heart of the monitoring system was the "Living Lab" as it can be visible now, arranged inside the campus to be both a control room and a demonstrator.

In 2012, the "Living Lab" began a fruitful collaboration with departments and faculties on various research projects and teaching initiatives with a focus on energy and sustainability, allowing to share common infrastructure acquisitions, technological resources, expertise and, most important, dataset. The "Smart and Green Building Services Management" provided by the "Living Lab" is the result of the close cooperation between different entities and divisions (energy manager office, energy department, Information Technology Area, Construction and Logistics). In the "Living Lab", all data streams are collected from on-site sensors and then processed and analysed. The main aim is to provide a decision support for the energy management, but there are also regular requests for research support and various educational initiatives.

In 2015, the Politecnico di Torino, in collaboration with the Higher Institute on Territorial Systems for Innovation (SiTI), has being carrying out a project, namely "Sustainable Path", aiming at tracking down all the sustainability initiatives. The first outcome is a report compiled for the ISCN – International Sustainable Campus Network - that serves as a basis for the strategic plan further directions.

In the light of what emerged along the scouting of the different, hidden but yet virtuous sustainability actions in the energy, waste, mobility, communication and urban management fields, the report eventually proposes to set a long-term group work, a "green team", which will be in charge of the overall sustainability strategy of the Athenaeum. Current internal managers of the aforementioned fields could make up the core, and be supported by the existing Living Lab. The idea is that this precious structure will be used and supported by a sustainability coordinator, in charge of in-out communication with the dean's office and the board of directors, and flanked by an administrative office for estate and infrastructures maintenance, logistic, external communications and every initiative falling into the POLITO sustainability framework. The so composed "Green Team" will interrelate with the National and International network of sustainable campuses, alumni, students, general public, city council and interested companies and start-ups.

Green Team	Role
Energy Manager	Energy efficiency compliances, improvements in consumption reductions and infrastructure maintenance
Mobility Manager	Optimisation of Mobility flows related to university employees and indirect users, city council compliances and dialogues for an integrated strategy to reduce pollutants emission in atmosphere
Urban Manager	Impact assessment of the five sites owned by POLITO within the city context, integrated strategy for student residences and user facilities in synergy with regional and city plans
Waste Manager	Management of optimal waste collection and reduction; initiatives for users and employees awareness regarding reuse recycling of materials they use or buy.
Communication Manager	Internal and external communication regarding the sustainable branding of the institution
Student Rep	Bottom-up approach to collect ideas and feedback from the majority of users in POLITO

Tab. 3 The green team scheme at the Politecnico di Torino. Source: author's data elaboration from internal documents preparation for the ISCN sustainability report.

The main points of interest that stand out from this diagram are the following:

- The Green Team is made up of members from within the department but reunited with a proper budget just for sustainability action planning, where positions have already been established/formalised (see tab. 1); a coordinator has to be named to work close to the Rector and with the internal offices, with the role of acquisition, or new figures might be defined in the future according to actual needs

- The Green Team will collaborate with external corporations (services providers, city councils, private sponsors, etc.) leveraging on the data from Living Lab, which also acts as a centre for the monitoring and collection of data compliant with the mission.

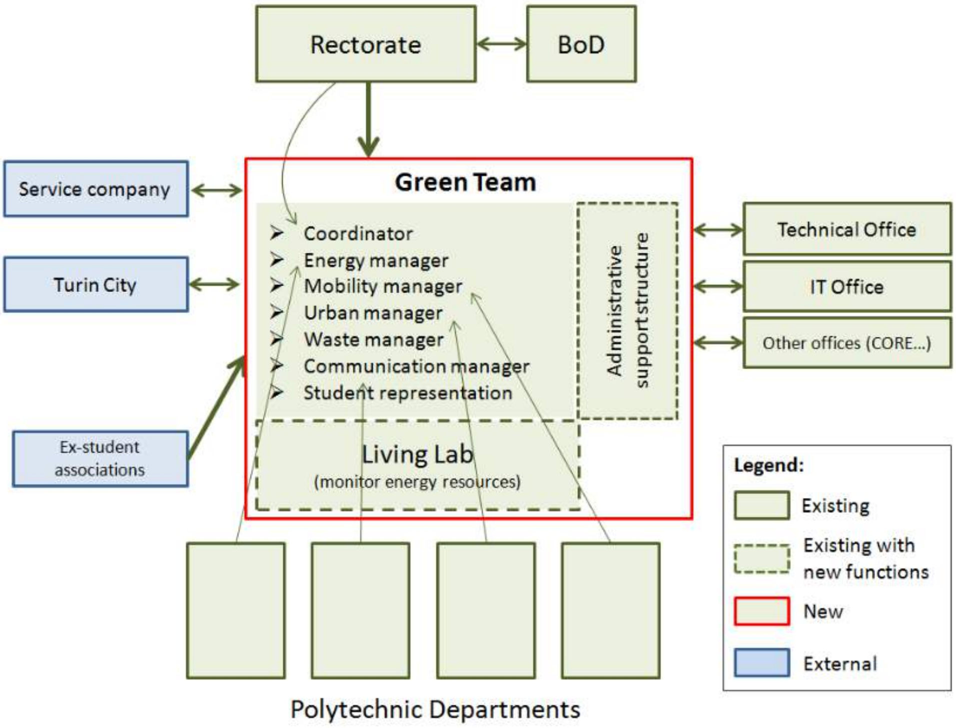


Fig. 26 The sustainability management scheme at the Politecnico di Torino. Source: author's data elaboration from internal documents preparation for the ISCN sustainability report

3.3 The Universidad Autónoma de Tamaulipas and the 'social factor'

The Universidad Autónoma de Tamaulipas (UAT) is located in the state of Tamaulipas, an area of Mexico with warm semi-humid climate, which reaches high temperatures in summer. It is an institution with degree studies ranging from high school to doctorate. It has approximately 41,000 students and about 7,300 employees, has a length of 40 years and is the largest in the region. It's commitment with sustainability started in 2014 with the integration of its own sustainability committee and their participation with GREENMETRIC as well as AASHE. As a result of this university keen in sustainability evaluations it has obtained a place in 2014 GREENMETRICS Ranking and a bronze medal during 2015 from AASHE STARS. The General Coordination of Sustainability emerges as cross-office inside the research department. It is responsible for coordinating the efforts of sustainability, generate strategies for the institution accreditation as well as projects to communicate and disseminate the results to the university community and society. The start of its sustainability effort was on July 2014 with the creation of the sustainability development committee. This committee responsible for the creation of a sustainable development plan, sustainability evaluations of the institution and any project related with sustainability in order to lead the University through a sustainable path. It is also in charge of assessing the president to identify and prioritize institutional efforts. It is officially integrated by: an institutional president; secretaries for Linking and extension, Research, Management, Academic, Finances; General Institutional Lawyer; Institutional Controller; Internal Assessor; Executive Secretary. Any sustainability-related project has to be approved by the committee. The executive Secretary has its own office the Sustainability Coordination, in charge of the sustainability report and all the projects proposed to the committee.

3.3.1 Best Social Practices at UAT

According to STARS, the two main impact sections for social factor are the Campus engagement and Public engagement criteria (see tab. 2).

STARS Social Impact Criteria (21%/tot)	STARS Coordination, Planning & Governance Criteria (8,47%/tot)
Students educators program	Governance
Student orientation	Sustainability Planning
Student life	Diversity and equity coordination
Outreach materials and publications	Support for Underrepresented groups
Outreach campaign	Affordability and access
Employee educators	Employee compensation
Employee orientation	Wellness program
Staff Professional development	Workplace health and safety
Community partnerships	
Inter- campus collaboration	
Continuing education	
Community service	

Community stakeholder engagement	
Participation in public policy	
Trademark licensing	
Hospital network.	

Tab. 4 The STARS social impact criteria and the Coordination, Planning & Governance Criteria. Source: https://stars.aashe.org

It is important to notice that the credits with higher social impact are those with higher points achieved for UAT besides the Academics. Both of these groups of credits represent the 30% of all available points in STARS, the same points available for their highest category. However, those are the less considered, as being naturally part of the institution branding activity. One of the reasons for this, is that the University has since always a great keen on student and staff wellbeing, and part of all developing plans always includes the students, the staff and the community. In order to analyse STARS social impact credits relationships an interaction mapping has been done. With this map it is possible to observe the main credit categories related to the social impact. As it is possible to observe Campus Engagement category has a relationship with all the other categories in the system. Therefore, the impact of the social factor in the campus sustainability is evident. Even though Campus Engagement and Public Engagement categories are directly working with social impact, they are related with the other categories such as investment, health, wellbeing and work, diversity and affordability, coordination, planning and governance among others. One of the most important things to reflect on is that all strategies and programs analysed for the STARS ranking were already applied, designed and put in place well before a sustainability plan even existed. For an institution where sustainability has not been even mentioned in the strategic plan but actually been practiced throughout its recent years, a BRONZE medal by the STARS committee is a very important signal. It means that probably not all the efforts made in the management rooms are necessary or assure the good result in terms of user awareness and mentality shift, while leveraging on "physiological" and usual environmental behaviours just "celebrate" the activities realised by the staff, faculty and students by their own initiative. Some examples of exemplary performances that allowed great accreditation for the University are in bold in

Tab. 4. For the "Outreach materials and publications" credit, UAT gained score thanks to a radio broadcast called "Universidad Sustentable" (Sustainable University) transmitted by the University Radio Station "Radio UAT". The program includes invited researchers, faculty members or staff friendly communicating all sustainable issues in our University, city, state, country and all around the world. In the "Community Partnership" credit two exemplary practices got the score. The first one is called "COMASS" (Operational Center of Multidisciplinary Attention and Social Services), and it is a center created in 2004 with the purpose to link students to vulnerable communities. Intended to impact the community in the short, medium and long term through free delegations by public institutions, it provides free services regarding health, nursing, social work, law, informatics and statistics to the community. By 2014 it has served 6 neighbourhoods and has benefited 12522 people. Another community partnership program is the "Laying Hens Program". It consists in the distribution of laying hens to families in rural communities for self consumption and for trade. It takes place annually, but it has the constant participation of students which are in charge of monitoring the growth process of the hens during the first weeks of the project. It is designed for families in rural area in order to get them additional income, providing better nutrition to their families and encourage roots in their communities. It is carried on in collaboration with the city council and the veterinary school. About tenthousand laying hens are distributed annually; during the first year, the 94% of the survived birds produced between 60 and 70 eggs per week. This managed to revive the economy in this sector. The "Community Service" credit acquisition in Mexico is very different compared to other universities. Since community service is an indispensable requirement to obtain a professional degree, every student must contribute in no less than 6 months and no more than 2 years with 480 hours of community service. The result is a contribution of 4,926,720 hours in a year thank to the participation of 25,072 students.

The "Wellness Program" credit is another exemplary performance for UAT. All enrolled students have an insurance that covers health problems related with University activities. This insurance covers preventive courses in birth control, stress control, weight control, diabetes, cholesterol prevention, and many others. All the Union members of the university benefits of an annual salary increase, attend free courses and workshops in order to increase their salary or their working category, receive a 100% scholarship for their children studying at UAT, apart from free medical devices such as needed glasses, orthopaedic appliances, hearing, prosthesis, etc. Lastly, the “Affordability and Access” credit has being achieved as a result of the low cost of studying in Mexico. Being UAT a public institution, the average cost per semester is about $220 USD for any careers offered by the University. Low-income students could apply to scholarships covering the study cost as well as personal needs.

3.4 The University of Cambridge and the urban outreach

The University of Cambridge (UNICAM) is one of the world's oldest universities and leading academic centres, and a self-governed community of scholars. Its reputation for outstanding academic achievement is known world-wide and reflects the intellectual achievement of its students, as well as the world-class original research carried out by the staff of the University and the Colleges. With more than 18,000 students from all walks of life and all corners of the world, nearly 9,000 staff, 31 Colleges and 150 Departments, Faculties, Schools and other institutions, at the heart of this confederation is a central administration team. It is small because the Colleges are self-governing and teaching staff carries out much of the daily administration at Cambridge, but they are integral to the make-up of the University of Cambridge. Students live, eat and socialise in one of the University’s 31 autonomous Colleges. Each College has its own internal procedures. The University has a central senior administrative team, responsible for the management of the University.

3.4.1 The Sustainability Management

With an estate portfolio valued at over £1.7bn, a planned capital building programme worth £412m, and energy costs of £15m a year (three times more than the Politecnico di Torino’s one), the University has a high environmental impact and large carbon footprint. The University is committed to continual environmental improvement, including an absolute reduction of its overall carbon footprint by 2020. However, seen the peculiar configuration of the University Board, the management of the complex issue of sustainability performance is faced by separated commission in charge of controlling the Energy, the Estate and the Public Engagement Initiatives held among the 32 independent colleges. While the University of Cambridge is committed to reduce its environmental impact with a dedicated Environment and Energy Section, not every college can or want to set specific target for energy reduction, both for the historical building heritage (insanely energy leaking) and for staff and students who just don’t support these efforts. A new building energy manager has been appointed recently: a brief interview with Xiang Cheng put lights on the weaknesses and the opportunities that still have to be fixed and deployed in the overall sustainability strategy of the University.

Firstly, looking at the timeline of the Sustainability Office set up, we can observe it was born quite recently. Before 2008, there were two separate environmental office and energy team. In 2008, the first Environmental Policy was adopted, preceding the 2010 Carbon Management Plan (up to 2020) and the 2010 Energy and Carbon reduction plan. In 2011 an existing travel plan has been adopted, and in 2013 a review of the Environmental policy set up a proper environment and energy section. Whereas the University of Cambridge is a first class institution in undergraduate education and research on sustainability issues, it awkwardly fails when trying to reach its environmental targets and performances.

3.5 Energy Use in Buildings

The *Energy@Cambridge* initiative was established in 2010 as a University-wide initiative and is sponsored by Professor Lynn Gladden, the Pro-Vice-Chancellor for Research at the University of Cambridge. It brings together the activities of over 300 academics working in energy-related research. The *Energy@Cambridge* initiative aims to leverage the University of Cambridge's expertise to tackle grand technical and intellectual challenges in energy which require the integration of science, technology and policy research, and work with industry, funding agencies, UK and foreign governments and other sponsors and benefactors to secure funding for research in energy.

The Environment and Energy Section is responsible for promoting sound policies and practices throughout the University to protect and enhance the local and global environment.

A lot of experiments have already taken place under this flag, involving social practice theory for changing attitudes, in-depth interview with focus groups, personal billing in some departments, the equipment of multi-functional meters and thermometer for custom rooms (that resulted to be too complicated and therefore claimed for a better transparency and visual communication for greening offices), test-building close study (the Sainsbury Lab for GSHP plants), and many others. On a public website[12] there are energy consumptions trends of different buildings shown as daily charts, where the hourly peaks are clickable and they can

[12] http://www.environment.admin.cam.ac.uk/what-are-we-doing/energy/energy-dashboards

prompt the average power use. Monitored data – such as environmental conditions within the buildings and the operational status of HVAC plant – are viewable on easy to understand graphics pages. Both live and historic values can be displayed. Password protection of the supervisor database prevents unauthorised adjustment of the controls.

3.6 Public Engagement Initiatives

There are many examples of departments, research groups, individual researchers and students getting involved with public engagement initiatives from the University of Cambridge. In addition, the University's nine museums and collections are open year-round reaching hundreds of thousands of visitors, and the Institute of Continuing Education provides lifelong learning opportunities. The University of Cambridge has set up a proper public engagement team, in order to provide co-ordination of major events, practical support, community contacts and advice to nurture charitable, educational and voluntary partnerships between the University and its communities. The programmes co-ordinated by this office include the Cambridge Science Festival, the Festival of Ideas, Open Cambridge, Bridge the Gap charity walk and the Cambridge Community Knowledge Exchange. Each initiative has its own public website with a lot of lectures, video, photo and audio file to share the events globally. They also provide public engagement advice, training and networks for University staff and students, working closely with many voluntary organisations and statutory bodies, and we provide a central information point for members of the public. It is worth here mentioning a few lines about these major public events, that really put Cambridge at the forefront of the public engagement strategies for University and research centres institutions.

The Cambridge Science Festival gives the public the opportunity to explore Cambridge Science. Thanks to the generosity of the University, sponsors and partners, most of the events are free. The Science Festival provides the public with opportunities to explore and discuss issues of scientific interest and concern and to raise aspirations by encouraging young people to consider a career in science, technology, engineering or mathematics. Each year, the Festival welcomes over 40,000 visitors to over 280 events and receives extensive national and local media coverage. Over 170 event coordinators organise talks, interactive demonstrations, hands-on activities, film showings and debates with the assistance of around 1,000 staff and students from departments and organisations across the University and research institutions, charities and industry in the eastern region. In addition, over 150 people volunteer their time to act as stewards to ensure visitors have a safe and enjoyable Festival experience.

2015 marked the eighth year of the Festival of Ideas. The Festival includes debates, workshops, talks, exhibitions, and performances, celebrating the arts, humanities, and social sciences. Featuring researchers from the University of Cambridge, local public figures, and renowned guests, the Festival is guaranteed to have something for everyone in the city. The *Cambridge Festival of Ideas* was established in 2008 with the aim of encouraging the public to explore the arts, humanities and social sciences, meet academics and students, and engage with the University via a thought-provoking and creative series of mostly free events.The inspiration for the launch of the Festival of Ideas was the widespread popularity of the annual Cambridge Science Festival, and the valuable communication experience that staff and students gain through engaging with the public. The Festival of Ideas focuses on fuelling the public's interest in and involvement with the arts, humanities and social sciences in a unique and inspiring way. It aims to gauge the similarities and differences in the approaches to public engagement required for science, technology, engineering and maths, and for the arts, humanities and social sciences

Open Cambridge is part of the national Heritage Open Days scheme. Designed to offer special access to places that are normally closed to the public or charge admission, the initiative provides an annual opportunity for people to discover the local history and heritage of their community. Many Colleges and museums across the City allow public access throughout the year with a variety of opening hours and charges.

Bridge The Gap is a unique way to raise vital funds for two extremely worthwhile causes with every penny raised through registration and participant sponsorship going direct to the charities. It is a walk that takes place every year on a September Sunday and that starts from Parker's Piece for raising money for Arthur Rank Hospice and the News' community fund Press Relief, and it includes the route and interviews with some of the Porters at the colleges to visit as well as information about the day and the charities supported by taking part. Another initiative is the *Cambridge Community Knowledge Exchange*, a research matchmaking programme, brokering partnerships between community organisations with research questions and students carrying out research in fulfilment of their degree programmes. Organisations gain the opportunity to initiate and benefit from research projects, while students gain the opportunity to contribute to valuable causes in the Cambridge community. Students could work on many different issues including health and social issues in the community, environmental questions, local history, management and strategic planning, policy and legal research, information technology and more. The Community Knowledge Exchange also supports transnational research as a partner in PEARES (Public Engagement with Research and Research Engagement with Society), a four-year project funded through the European Commission's 7th Framework Programme. There is also the possibility to book a speaker to deliver a talk or hands on activity for state school or voluntary/community organisation. The 2007 Connecting with Communities survey found that:

- 8,250 staff and students were involved in outreach or voluntary activities
- These staff and students invested 370,000 hours their time, worth approximately £4,000,000 to the community
- More than 1 million people benefited from voluntary activities undertaken by University staff and students
- Around £1 million was raised and donated to charity by University staff and students

In the University of Cambridge series at *Hay Festival*, more than 20 Cambridge academics will be speaking on subjects ranging from hate speech, morality and torture and the battle of Waterloo to global health innovation and pandemic flu research. *The Cambridge Series* has been running for seven years at the prestigious Festival and is part of the University's commitment to public engagement. On the website of the event, audio file of each professor's speech are available for free. Moreover, free events and lectures are open to the public all year through, and they can be easily spotted on the website[13].

It has to be outlined here that the availability and the easiness-to reach of all this information are also facilitated by a dedicated website to go through each of them. *The Outreach Directory* is intended to help members of the public, schools/colleges, and voluntary and community organisations find out more about activities run by the University.

There are also researcher association devoted to the sustainability cause: one example is the *GreenBRIDGE*, an interdisciplinary group of graduate researchers at the University of Cambridge interested in the sustainability of the built environment. The aim is to provide a

[13] http://www.admin.cam.ac.uk/whatson/

platform for discussion of ecological, social, cultural, technological and economic issues which affect the built environment. Research topics within the group include: Green building and green retrofitting, High-density housing, the roles of heritage and conservation in cities, Sustainable design and eco-innovation, Low-carbon energy (energy decarbonisation).

Last but not the least, created in 2001, the *Centre for Research in the Arts, Social Sciences and Humanities (CRASSH)* supports, promotes and conducts interdisciplinary research of the highest order. Located at the heart of the humanities campus, the Centre's managed research programme produces annually over 250 events a year, with 25 conferences, 14 graduate and faculty research groups, Humanitas Visiting Professors, and longer term interdisciplinary research projects. The regular work-in-progress seminar for fellows – external and internal visiting fellows - contributes to the lively atmosphere of intellectual exchange.

There is also a private engagement regarding the energy issue as seen in the *Cambridge Retrofit project*, that aims indeed at creating a process by which the major organisations take leadership roles to unlock their internal resources and expertise, and by which registrants in the system and guided into clusters of projects created around themes that match their interests and needs. These "Communities of action" are made up by lead organisation, sponsors and property owners to help and realise events, projects and media coverage.

3.7 Discussion and Conclusions

The Politecnico di Torino adopted a centralised policy that leverages all the energy consumption upon a fine data monitoring system and centralised decisions. Its relatively low position in the UI Green Metrics world university ranking does not reflect a quite virtuous energy consumption and resources management, both compared to similar institutions and to its previous years' performance.

Conversely, the Universidad Autonoma de Tamaulipas does not collect any quantitative information regarding energy/water consumption. However, to comply with the Green Metrics report it had to scout all best practices related to sustainability via on-site surveys, interviews and the dissemination effort of the entire sustainability office. The result has been a university Most of the sustainable good practices have been carried on without any emphasis or community branding; yet, UAT's high position in international ranking demonstrates how important can be qualitative data collection and analysis even outside specific indicators accomplishment.

Finally, the University of Cambridge represented the extreme case of town-and-gown campus, therefore providing no exact, wide or transparent quantities of monitored energy for every building, nor its sustainability organisation is a proper body inside the quite complex academic structure of colleges and historical hierarchies. Nevertheless, several buildings analysis and voluntary initiatives born by individual colleges, private grants and student works granted an outstanding performance in the urban outreach category and in the public engagement activities.

Perhaps most importantly, a common weakness within the three cases is the absence of a long-term follow-up of the promoted activities. All projects tend to be carried out over the short term (six months to a year) but no indicator to measure the efficacy of building renovation initiatives, sustainable farming educational activities or public lectures affluence is registered. This may not be sufficient to adequately evaluate the persistence of the energy savings benefits, social impacts or environmental education results, if the goal is to assure long-term changes in consumer behaviour and practices. It also makes difficult to assess the actual size of the direct rebound effect with a high level of confidence. Therefore, a general need is to call for appropriate indicators and mandatory track for sustainability initiatives inside each university. Moreover, in all the three cases, an interactive sustainability web site is lacking. A rich web-platform could be the place where opportunities and problems will become visible and proposals will be collected and shared. Of course, the prerequisite for the success of the initiative is the creation of a strong awareness on the topic of sustainability within the community, something that at present state is still missing. The governance of the process is fundamental for supporting and feeding a complex and long-term project like the one we are proposing, and to manage a large amount of ideas and proposals by the community.

Eventually, above all in the energy efficiency and renewable energies field, there is no % of energy to be saved in one year, from now to 2020 (reduction of fuel consumption and dispersion), or % of saved money by widespread use of renewable sources, or %reduction of waste water management, and so on). Aiming at no specific target leads to vague researches and monitoring activities with no useful outcome nor action to be suggested, and no specific request of more equipment by the living lab to become more competitive, as well as a consequent lack of results in terms of money saving and image improvement. As good scalable example, the UAT "sustainability office" could be the solution to take care and supervise first of all four main themes or areas of interest, namely "People, Energy, Environment and Social Impact", deliberately broad in order to encourage an interdisciplinary approach. A crucial factor to drive policies and funding schemes is certainly the adoption of a common framework to make the economic board of university dialogue with the environmental and social activist and managers. Even in the case of UNICAM, where placing a brand onto a topical area associated with the University of Cambridge is world-wide recognised as a confirmation of value, the financial forecasts for the coming five years show a small surplus planned on the Chest each year, well below the level needed for long-term sustainability. To assist in longer term strategic planning, a set of sustainability metrics has to be developed covering the full range of the university's operations. This is indeed the main barrier highlighted in the study of Wright (Lidstone et al., 2015) regarding facilities management directors' conceptualizations of sustainability in higher education. Since the financial barrier was the most often reported when asked what the major hurdles are to achieving institutional sustainability, and many participants also reported they do not expect this barrier to disappear in the future, much work has to be done in order to enlarge the conceptualizations of sustainable development mostly focused on environmental sustainability, specifically energy, resource management, and waste reduction. This is consistent with the findings of (Wright, 2010), where university presidents and vice-presidents also favoured the environment over social and economic factors when discussing sustainability. These thoughts are echoed by the respondents' ideas of a sustainable university, with environmental sustainability being the most popular response. This focus on the physical impacts relating to sustainability is not surprising, as the facilities management stakeholders largely deal with the physical aspects of the campus, and have the most control over the environmental factors of the institution. An holistic metrics for social and economic assessment of environmental management practice will allow financial boards to track performance over time and make comparisons with peer institutions where comparable data are available (Sonetti et al., 2016). Metrics consistent with the proposals for a new annual sustainability assurance report have to be further developed.

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4 Human Factors and Energy Consumption: Insights from Social Practice Theory and User's Comfort Definitions for Effective Energy Policies in University Campuses

Abstract: The key assumption from which this study start is that tackle global climate change is not simply, or not only, a matter of finding more efficient ways (mostly technological or relying on urban teleconnections) of meeting untouchable human quests. While the concept of sustainable development was born having mainly production-oriented policies as institutional outcomes, the co-responsibility of consumers resulted later on in more demand-side policies. The active involvement of the users by means of purchase choices and the adoption of more sustainable lifestyles gave new sense to apparently consolidated concepts about the energy transition and the role of the society aside the one of technology. Therefore, adopting a socio-technical approach this chapter investigates the changing definitions regarding comfort and the decision-making mechanism of consumption practices, believed to be pivotal for energy reduction policies in public buildings. The co-design of an app for HVAC control via users' real-time feedbacks was the opportunity to explore people perception about "energy consumption" and "comfort" in university campuses. The Design Studio Methodology allowed inserting other energy-related items than the ones suggested by current literature (i.e. thermo-hygrometric, air quality, brightness, crowding and noise discomfort data). Such quantitative measures have been anyhow collected in the equipped classrooms in the university campus taken as case study to further match the objective comfort levels and the subjective time-aligned user feedbacks on rooms' conditions. This chapter demonstrates how taking advantage of users' expressed needs may be shift the attention of policy makers to several neglected aspect impacting the workplace comfort, like cosy sofas or colourful interiors, possibly cheaper and more controllable than the main stream ones, like greener energy supply, smart appliances and centralised controlling systems. A wider audience crossed with real-time quantitative parameters can provide evidences for the effectiveness of this approach in reducing energy consumption in public building. Acting wisely and surgically on certain human factors and collective thresholds of discomfort acceptances can un-lock the social potential for the change. Current technical trajectories are becoming ultimately

unsustainable, but in parallel user awareness of impacts can make comfort "just" a highly negotiable socio-cultural construct.

Keywords: *Energy Consumption; Human Factor; Social Practice Theory*.

4.1 Introduction

The idea that human activities have caused deleterious and irreversible effects on Earth's ecosystem is finding growing support. However, from the political and institutional points of view, a concrete attention toward environmental issues only began to develop in the aftermath of the first energy crises of the 1970s, mainly as a consequence of their effects on economic development (Robèrt et al., 2002).

In that climate of "concern" for the environment accompanied by a strong desire for progress, the concept of "sustainable development" was born having as institutional outcomes production-oriented policies. The responsibility for the management of the environmental resources was then attributed to the actors of the productive sectors. The objective of the reduction of the environmental impacts was attributed to the direct intervention of corporate actors (Wallner, 1999).

Lately, this paradigm expanded till reaching a progressive adherence to the attribution of co-responsibility to consumers. They have been recognized to have the power to influence production and supply by means of their purchase choices and the adoption of environmental-concerned lifestyles. As a result of this conceptual improvement, demand-side policies were elaborated, with the aim of spreading awareness among citizens, to become more actively involved in the transition toward sustainable consumption choices (Chappells † & Shove ‡, 2005).

These socio-technical transitions to sustainability are not easy to be put in practice, since current energy, transport, and food supply systems are stabilized by lock-in mechanisms (involving complex financial cycles, self-induced behavioural patterns, unveiled interests, inertial infrastructures, political subsidies and global regulations) (Geels, 2004).

However, radical innovations can disrupt these consumption mechanism breaking in certain niches, where dedicated actors nurture alignment and development on multiple dimensions to create new fit-on- purpose configurations (Rip & Kemp, 1998).

The key assumption from which this study starts is that tackle global climate change is not simply, or not only, a matter of finding more efficient ways (mostly technological or relying on urban teleconnections (Seto et al., 2012)**) of meeting untouchable human quests.**

It is instead urgent and effective to challenge the current passive adoption of energy consumption practices, comfort quests and the apparently implacable trajectory of increased resources depletion implementing very local social practice of sustainability.

Possible local niche-innovators are pointed out in this study as university campuses, where the living lab paradigm transforms them into test bed for social experiments and good practices toward wider urban sustainability. In particular, the quest for comfort is explored as one of the main responsible for increasing energy and resources consumption. In public building, this quest is usually not accompanied by user awareness about environmental impacts and societal consequences of high comfort levels requiring high energy consumption.

This study describes an exploratory research that aims to:

- Frame socio-technical research approaches into the study of energy consumption practice

- Give insights for tailoring energy policy in university campus starting from the socio-technical analysis of users and context

- Suggest effective user engagement methodology for comfort quest interceptions in university campuses.

Therefore, the structure of the chapter is the following:

- In par. 4.2, relevant literature on comfort quest and its relation to consumption practice is discussed; - Par. 4.4 presents the case study, its socio-technical context of and the methodology used for a Afterwards, in the par.2, the case study of co-design workshop (par. 4.4.2). Preliminary results about “energy” and “comfort” users’ perceptions (par. 4.4.3) are presented. Although part of a project for the design of an HVAC management software which responds to user feedbacks about comfort, these results gave chances to explore a new emerging definition of comfort by campus users in light of the literature and research goals is presented, as well as a reflection on the limitations of this research (par. 4.5). Final conclusions (par. 4.6) are shared leading up to recommendations for follow-up researches on energy reduction policies in university campuses.

4.2 Practices and infrastructures of consumption

4.2.1 The right to the comfort

In the definition of new solutions for climate change, energy efficiency and sustainability paths, the social component is gaining an increasingly fundamental a role. The practical use of energy can be described both as socially organized and technologically structured (Lutzenhiser, 1994). As said, throughout history, the connection between society and nature is considerably changed, principally for the incredibly growing technological progress and the intensive exploitation of different energy resources. Transformation involved the comfort dimension as well. During the last century, comfort levels became standardized around certain parameters, the quest for higher comfort has become more and more relevant in the energy consumption factors array (Shove, 2010). Once considered a luxury, an elitist privilege, it became a primary good and seen as something that people have a right to expect (Shove, 2007). Nowadays the majority of global population, who lives and works principally in urbanized areas, performs the everyday life activities inside microclimatic regimes, or rather buildings (or building systems) that are at least partially climatically and intensively controlled. To maintain the standardized comfort levels, these buildings - both domestic and public - use a big amount of energy and produce a high impact on the environment. Therefore, it is necessary to keep in consideration the comfort dimension in its interaction with the technical system (architectonic specificities, HVAC features) and the social one (people habits and behaviours, choices, gripes) (Shove, Pantzar, & Watson, 2012).

Also if the socio-technical dimension of comfort definition is quite clear, "comfort levels are typically defined as the result of a feeling of psycho-physical well-being experienced by a person; it results from a combination of environmental factors - such as humidity, temperature, brightness - and individual perception (Chappells † & Shove ‡, 2005).. Focusing on those psychological and physical parameters, research on comfort has been often linked to technical and behavioural sciences; for this reason, social factors have been usually excluded from the analysis (Höppe, 2002). Recently, social research improved this definition

(Hargreaves, 2011; Shove & Walker, 2014; Strengers, 2012): comfort is not just a feeling, but it may be intended as a dimension that is shaped within a culturally collective frame, more or less shared, and then takes place in a context of experiential sensory perception by individual subjects.

The quest for comfort plays indeed a crucial role in our daily life, but also in our global impact on the environment. Comfort is closely related to progress, mass consumption and throwaway-lifestyles. In the 'homo comfort' society (Boni, 2014) technology mediates daily activities, making possible to achieve the desired levels of well being with technical development and electronic devices. The totality of human existence in developed countries is grounded to patterns of consumption hardly avoidable at current pace. This is why criticizing the current quest for comfort and calling for more sustainable lifestyle often results in sterile polemics or unheard voices (Devine-Wright, 2014). Cases of people completely turning their lifestyle toward a model of self-sufficiency are still rare and not scalable to actual urban sets (Princen, 2003). Nevertheless, recognizing comfort as an integral part of daily life seems essential to address the issue of path-dependency maintaining both an artificial condition of normal achievability of it (claimed and expected) and the locking-in mechanism of the complex energy systems.

4.2.2 Information about Energy, the invisible (especially in public buildings)

Aside the right to the comfort, another barrier for the transition toward a low carbon society lays in the configuration of energy itself: not a tangible good, neither visible (and after that assumption, the plethora of projects for making energy visible (Gustafsson & Gyllenswärd, 2005; Pierce, Odom, & Blevis, 2008)). Furthermore, human actions are not generally aimed at consuming energy: energy is what allows the deployment of common daily practices, defined as inconspicuous consumptions (Shove, 2010). People wash, clean, write, have fun, cook, warm up, or use t-shirts, packaging, furniture, food, without considering – or without knowing – the environmental or social consequences of their consumer choices. In this sense, energy consumption is embedded in everyday activity, although unconsciously. For sure, Environmental policies have thus been evolving toward a participatory dimension, from the early oriented output till latest demand-side policies.

To this extend, the study of consumption practices conducted within existing buildings consider both the complexity of physical structures (historical period, architectural features, different materials) and their equally complex infrastructures, both human and virtual. As Janda (Janda, 2011) warns, "buildings do not use energy: people do": physical considerations, technical and economic analysis of the construction is useless if not supported by consumer actors in the scene they are playing in.

Consumption practices are typically studied through economic, psychological and sociological approaches (Hargreaves, 2011) in order to identify behaviours, practices and choices implemented in indoor environments (public or private, individually or collectively). Consumption practice as an entity is configured by a series of interrelated elements that make it recognizable, understandable and describable. These elements are declined in different ways (Tab. 5) after Schatzki definition of practice as an entity "unfolding in temporally and spatially dispersed nexus of doings and sayings" (Schatzki, 1996, p.89) ; to be produced and reproduced, practice must be understood, organized according to rules and principles and loaded with meaning by the plaintiff through "teleoaffective structure". Applying the practice theory to energy consumption appears crucial for redefining the relationship between individual and society, usually understood as opposing concepts. To overcome this dichotomy catching the deeper relationships between structure and individuals, Giddens conceives social practices as "mediating concept between action and structure" (Røpke, 2009, p. 2491). Society is here conceived as the result of social practices produced and reproduced in time and in space. Within the practice lies the site of the social (Spaargaren & Oosterveer, 2010), realized in the network of relationships that actors huddle while playing such practices. Different contributions to social practices according to different authors are shown in Tab. 5**.**

Schatzki	**Warde**	**Shove-Pantazar**	**Reckwitz**
Practical understanding	*Understandings*	*Competences*	*Body*
			Mind
			The Agent
			Structure/Process
Rules	*Procedures*		*Knowledge* *Discourse/Language*

Teleo-affective structures	*Engagement*	*Meanings*	
	Items of consumption	*Products*	*Things*

Tab. 5 Key-elements for the definition of the practice-as-entity according to different authors. Source: (Gram-Hanssen, 2008).

Practical theory applied to the field of consumption "reconstitutes the actor's role in social processes without losing sight of the broader structures, which influence social action" and at the same time they allow the realization (Cellamare, Ferretti, Pisano, & Postiglione, 2011, p.36). It also highlights the skills that actors have staked in conducting some practice, thus revealing possibilities of intervention for change. At the same time, this system can be contextualized in a daily repetition, i.e. “routinized behaviours” identifiable collectively, but reproduced on an individual level (Evans, McMeekin, & Southerton, 2012, p.116).

In this sense, the *locus* of consumption practice is identified in a daily complex socio-technical system. The materiality of energy becomes meaningless following the increasing technical and technological mediation intervention in the relationship between energy and practitioners. The recursive activities of production and reproduction of everyday practices help to reinforce the invisibility of energy, mainly because of a lack of awareness about the environmental impact of routine practices (Røpke, 2009), especially in public buildings.

The introduction of ICT solutions for the energy monitoring and user awareness is based on the information deficit model. Accordingly, information delivered via apps or home displays should increase user awareness in relation to energy consumption, carrying out cost-effectiveness analysis and implement friendly info graphics. However, his type of solution presents many limitations especially in the case of public buildings (Darby, 2006). First of all, users do not appear to be stimulated by any economic advantage after their choices. Then, the possibility of tuning comfort levels in public building, with high number of heterogeneous users, is usually very limited. The impacts after individual choices always appear poor, if compared to the repercussion of what it is produced collectively. Third, a collective environment requires a stronger, and sometime difficult mediation of behaviours and wide-range choices compared to a domestic one.

4.2.3 Information about energy users in university building

More specifically, in the context of a university campus, single students are certainly given the possibility to act over lighting equipment, and sometimes on HVAC systems, too. But if a planned, collective action could record a significant reduction of the energy consumed by all the campus, it has been quite difficult to highlight best cases in this respect in current literature reviews (Di Stefano, 2000; Venetoulis, 2001). In contexts where the structural system is configured in a rigid form - like most of the public and, among these, university buildings - adaptation appears as the only solution that can be undertaken by users, along with the complaint. Since making complaints is not always possible or convenient, as top-down answers are not always feasible in buildings with low flexibility of use and management, adaptation represent the most applied remedy.

This actual unsatisfactory situation regarding energy user engagement can be labelled as the classical hirschmaninian "forced loyalty", (Hirschman, 1970) where individuals (or groups of individuals, or institutions) facing dissatisfaction react in three ways: exiting (abandoning the source of dissatisfaction), raising the voice (to communicate their disappointment), and being loyal (keeping the relation with the object anyway). In the case of energy feedbacks in university buildings, the possibilities of raising the voice are discouraged, being the energy manager often unreachable, or the building too old for allowing any sort of intervention; the exit strategy is often significantly expensive in terms of both time and efforts, if not impossible. What remains to users is to be loyal to the system, and deal with its dissatisfactory conditions, sometimes autonomously fixed by single devices (fans, electric heaters, humidifier, dryers, etc.) that make bills raise up but reach desiderate comfort levels (Sunikka-Blank & Galvin, 2012).

Factors affecting comfort conditions in the workplace are not only very important for physiological and psychological reasons, but also play a significant economical role. It has been demonstrated that they strongly influence the occupants' productivity, above all in University, whose knowledge transfer mission is fostered above all in the informal moments of sharing the same physical space (Leaman & Bordass, 1999). However, comfort issues do not yet play a major role in the day-to-day operation of university buildings, mostly due to a lack of understanding of human comfort and its in situ assessment.

In fact, while several scientific studies put important findings as the basis of national and international standards, they only focused on correlations for thermal comfort criteria or on health issues. Fewer publications can be found on the interrelationships between different indoor environmental parameters and the impact of individual satisfaction parameters on the overall satisfaction with workplaces (De Dear & Brager, 2002; Nicol & Humphreys, 2002; Wagner, Gossauer, Moosmann, Gropp, & Leonhart, 2007).

4.3 Conclusions from literature and resulting research goals

From the literature review it emerged that by engaging beneficiaries, energy reduction is within reach. Evidences from various authors support both ‘push’ methods as well as participatory and creativity stimulating approaches. Therefore, the following points are used to design an appropriate methodology to engage campus users in energy reduction policies:

- Use community empowerment framework to support proposed actions avoiding feeling of helplessness or not usefulness
- Choose a friendly language, youngster syntax and only meaningful information, i.e., those people may use as basis for action
- Make use of social media (i.e. twitter and other mobile apps) to influence decision-making
- Make use of interaction between peers to support the process of adopting new measures and/or changing behaviours.
- Favour diversity over expertise amongst participants to foster creative solutions and nurture empowerment.

In 2015, the Campus Luigi Einaudi (CLE), one of the 120 buildings of the University of Turin (UNITO), Italy, has been used as test bed for a one-year project named Comfortsense (CS). That project was the test bed for applying the methodological approach drawn from the literature review.

A co-design workshop has been chosen to make people aware of their own position in a change process through. If the exact contents and results of the workshop are less relevant, this awareness is a first step to increasing their willingness to change, since creativity and collaboration oriented approaches can stimulate new trains of thought and new connections. With the focus on campus users, these consideration lead to new ideas in terms of contents (e.g., IT products for real time feed backs on comfort levels) and empowerment (active realisation of the individual's power to invoke changes). Based on these items, the following research goals (RG) for the CS project were derived:

- RG1: Explore new comfort definitions by actual campus users as a kick-start for appropriate energy policy in university buildings;

- RG2: Explore the effect of co-design[15] approaches on the level of engagement of direct beneficiaries

- RG3: Ex-post evaluation on energy consumption after having given the user the possibility to act over innovative comfort parameters through mobile apps and remote controlling on temperatures.

This study related only to the RG1. However, it constitutes the necessary base for RG2 and RG3 achievement in the forthcoming years.

4.4 The co-design of an energy monitoring software at Campus Luigi Einaudi in Turin, IT

Participatory design is a useful method to tailor ICT solutions on actors' need, since it screens the characteristics increasing the usability of the final product through the joined efforts of participants. In fact, an energy feedback system can be considered effective only if understood and used for final changes in energy consumption (both in terms of quantity and quality). Therefore, for the CS project a preliminary analysis of the socio-technical context has been carried out to overcome barriers after the introduction of new feedback systems into "forced loyalty" situations.

Users sample took into account the following features:

- Familiarity with the places of consumption (i.e. the case study);
- Competencies users have, what they are able to understand;
- Socio-demographics data;
- Motivations;
- Information that could be considered important given their level of knowledge of the technical systems;

[15] For both research goals, "design" does not just focus on product features but on an entire process that uses design tools and techniques.

- Ways information is interpreted;
- Most appropriate timing for data transmission and reception.

4.4.1 *The case study*

The CLE building has been selected because its extremely higher energy consumption in comparison with other UNITO buildings (Fig. 29). The aim of the project was to develop an ICT infrastructure to implement information flows regarding the socio-technical of buildings and users. The solution provided was a mobile app revealing both subjective comfort levels of users (through their own feedbacks), and environment objective parameters (through smart sensors in equipped rooms). This study focuses on the outcomes of the co-design activity of this app, which provided evidences on:

- How a specific context can influence the development of an ICT solution;
- How the concept of comfort is declined inside university campuses;
- How considering psychophysical feedbacks is not always the best option for achieving energy efficiency in public buildings.

The sociotechnical system considered in this study is represented schematically in Fig. 27: the black arrow represents input, the white one output. Dotted lines are practices immerged in the object we are considering as part of social components influenced and influencing technical infrastructures. Outside the borders, a feedback loop (dashed line) goes in and out the CS goal of decoupling comfort and energy consumptions information flows.

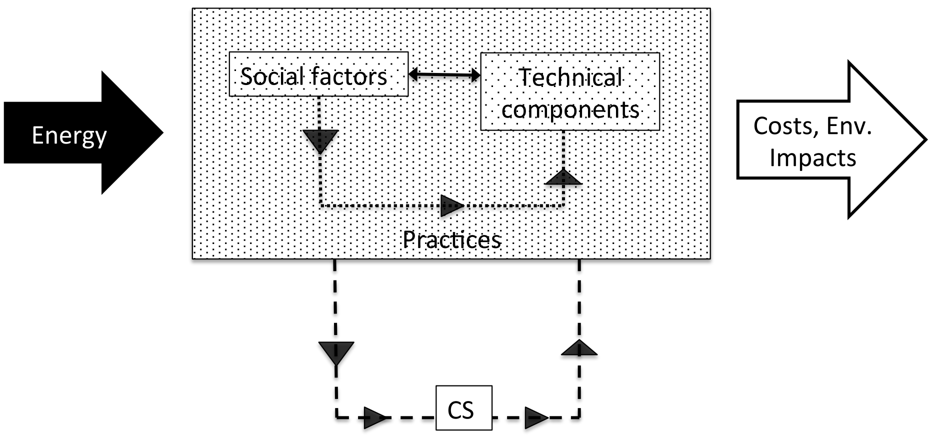

Fig. 27 The socio-technical system of the CLE case study context.

The CLE unit belongs in turn to a bigger university campus, which can be understood as a broad socio-technical system divided into partially independent subsystems. Analyses can be carried out in individual structures, but they cannot be separated from a macro consideration of the system they are inserted in. The social component includes students, administrative staff, teachers and temporary visitors. The CLE was opened in September 2012 and in the course of two years achieved a very high energy consumption for the type of activities carried out in framework; this consumption was produced by the intensive work of the HVAC especially in summer (Fig. 30). The paradox that led to choose this case study was that despite the elevated energy consumption, CLE's users complaint about internal discomfort increased overtime. The CS project had the task of implementing the information flows between social component and system technology at CLE, trying to fix discomfort problems while reducing energy use and costs.

4.4.2 Methodology

The co-design activity of software for energy control according to users' comfort feedbacks consisted of three phases:

- socio-technical system framing and selection of participants
- questionnaires
- co-design workshop

The first phase lasted three months, and produces internal reports regarding the socio-technical system of UNITO and CLE in terms of energy consumption practices.

Then, a sample of 33 representative campus users was selected to take into account the most influent target of campus energy consumers, according to the features listed in par. 4.4. The focus has been on students who constitute the most numerous part of University's building users and account for collective action, more effective on wider audience of people. Eventually, a questionnaire about energy and comfort perceptions was distributed and gave the kick for the workshop activity. The co-design has been conducted with the of the industrial partner of CS using the Design Studio Methodology, based on the ideas generation process of working teams through fast steps. The purpose was to develop five prototypes of ICT solution concerning the comfort of users in the Campus environment. This methodology provided different opportunities for individual and group works, spread on time but organized at fast pace. The intention at the base is to generate many ideas and solutions quickly through sketching, iteration and critique. Ideas may come from anyone, allowing for divergence and then convergences, bringing the whole team together and finally creating a shared understanding and knowledge of the problem. At the beginning and at the end of the co-design activity, a compact questionnaire was distributed to the sample of students. This was to track their entrance and outgoing mind-sets about the core topics of the CS project.

Categories from feedbacks socio-technical analysis are drawn from the relevant literature review (Bonino, Corno, & De Russis, 2012; Darby, 2006; Hargreaves, Nye, & Burgess, 2010; Kramers & Svane, 2011) and then they have been reinterpreted and adapted to the CS project extents (Tab. 6). They have been used to compare the prototypes and highlight the main differences and similarities in light of student's redefinition of comfort. Deeper description of these categories can be found in Appendix B.

Aside this qualitative data collection, further steps of CS envisage a quantitative analysis of temperature, humidity, crowding and CO_2 levels inside the monitored study-rooms thanks to sensors provided by the industrial partner of the project. These equipment (Fig. 31 and Fig. 32 in Appendix A) consisted in indoor sensors of temperature, humidity, CO_2, crowding, and wearable sensors of temperature, humidity, brightness, location and CO_2. An Android app given to users merge all the previous data with geo-localised and time-referred feedbacks about hydrothermal comfort perceptions, light comfort, crowding sensations, global subjective comfort, weight, sex, age, clothing and physical activity. Although these steps are not part of the present study, a brief overview of possible outcomes from qualitative-quantitative data matching is shown in the discussion.

Original categories	**Reinterpretation**	**Description**
Time reference	Time reference	Frequency and timing of received/sent data
Granularity	Spatial granularity	Spatial details of the context from data

Medium	ICT infrastructure	Elements composing the system
	Socio-technical interaction	Interactions in the system
Captology level	Engagement methods	Methods to involve users in ICT use
/	End users	Targets of ICT solutions
/	Topics	ICT fields of application

Tab. 6 Categories for user feedback analysis readapted from (Bonino et al., 2012; Darby, 2006; Hargreaves et al., 2010; Kramers & Svane, 2011)

4.4.3 Results

The energy practices of CLE

The relationship between technical and social component within the CLE resulted mainly as a one-way information flow between the technical system and the users. The observed consumption practices can be described as unconscious and indirect. To explore in mayor depth, the meaning that the actors attribute energy consumption in public buildings, a questionnaire was handed out to the workshop participants. Despite answers have not statistical value and are not yet coupled with a quantitative analysis, interesting insights emerged.

According to our sample, elements influencing the CLE energy consumption are: electric appliances, night time costs, and daily activities (Fig. 33). Less regarded elements were all correlated to occasional events or less massive practices. This could highlight a general idea of energy consumption as due to both technical and social components. Moreover, the idea of energy consumption deploys in "continuity" (everyday, daytime and nighttime). This means that workshop attendees were pretty conscious of the energy behavior of this specific socio-technical system.

Down line the first observations and questionnaire's answers, practices conducted at CLE can be distinguished as in Tab. 7.

Formal	Macro practices closely related to the functions running at CLE (like studying in

	the library, attending lectures or working in the office);
Informal	Macro practices conducted in the context but not directly related to the function of the context (like talking with friends, relax between classes, drinking together in the bar after work, and so on);
Derived	Micro practices implemented only to be physically present in the environment or to pursue formal / informal practices (take the bus, use the toilet, eat, photocopy, and so on);
Unaware	Micro practices affecting the framework without the actor realizes it, such as energy consumption to maintain a certain comfort standard.

Tab. 7 Energy consumption practices observed at CLE, University of Turin, along the *Comfortsense* Project.

These practices, identified as disaggregated for analytical purposes, are in fact related to each other in a very complex and nested frame. Also, the distinction between macro and micro practices is a simplification allowed from the special kind of context we are analyzing. Indeed, in university campuses can occur that some users spend time in the buildings with different purposes. For example, occupying a place library can certainly be linked to the practice of study, but it is not uncommon to see actors who benefit from the library to consult mates or have a place to connect their laptop for purposes other than study.

Thus, identified practices in Tab. 7 can be configured both as collectively and as entities; they are then reproduced with different modes in individual performance. The power consumption in a university can be defined as the unwitting product of daily practices intended primarily as demands on the energy supply of the socio-technical system. The practice systems there inserted is the set of activities for which the energy is delivered in specific space-time coordinates.

The comfort definition at CLE

During the workshop, held in Italian, participants were asked to write down three concepts or elements immediately associated to the word of "comfort". After that, they were asked to point out the most relevant elements affecting the perception of comfort, out of some terms in a given list. As shown in Fig. 34, the majority wrote the word "comfort", which in Italian means “material” comfort, doing something in an easy way of. "Easiness", "well-being ", "safety" "ease" "relax" were relevant terms as well. Not so relevant, but still interesting, terms like "hydro massage and couch", "silence", "health" "personal spaces" "quality" and so on, revealed a not-shared position around the concept definition. When asked about comfort perceptions, terms like temperature, brightness, crowding and air quality gained significant success, followed by harmony, on-going activity, emotional state, noise, Wi-Fi network and so on (Fig. 34, Appendix A).

shows the five ICT solutions proposed by the workshop attendee students downstream the three phases in par. 4.4.2, all relating the concept of comfort to specific discomfort conditions. Two out of five regard the recycling, since CLE was lacking of a proper recycling system at the time of the questionnaires. The remaining three solutions are related to the concept of usability of spaces and places. “Places 5B” was thought to solve the problem of the improper use of the campus library and its consequent overcrowding; “CLEbus” took care of the mobility inside and outside the CLE, organize schedules and transfers logistic; “Smart CLE” did the same but adding news and hints about lessons, seminars, university life events and so on. Energy monitoring is explicitly inserted in just one solution, the “Green is Free”, where the app displays the amount of water, oil and CO_2 saved after each recycling action.

Tab. 8 The five ICT solution proposed downstream the co-design studio in the CS project

	Time reference	Spatial granularity	ICT infrastructure	Engagement methods	Socio-technical interaction	End-users	Topics
5B Places	Real time	Single area of the building (library)	Mobile app + Sensors (temperature and crowd)	Simple real time data report	Oneway: from technical components to users	Students	Crowding, livable spaces, living comfort
CLEbus	Real time and simulation	Urban area and single building	Mobile app + Sensors (GPS and crowd)	Real time data, simulations, social network, map and news	Threeway: from technical components to users; from users to users; users feedback to the technical components	Students and people working in the building	Mobility, time organization, community, ORIENTEERING
Green is free	Real time and historical records	Single area + green facilities	Mobile app + green facilities + Smart card	Real time data display, historical data visualization, gaming	One way: from technical components to users	Students, General University public	Recycling, good practices

CLEan	Real time data, Historical records	Building	Mobile app + hardware	Real time data + notifications/information + gaming + map	One way: from technical components to users	Students	Recycling
Smart CLE	Real time data, Historical records	Building	Mobile app	Map, news, lessons list, utilities, users experience	Two ways: from technical components to users; users feedback for other users	Students, but different targets	Usability of the place/space

4.5 Discussion

Comparing the two set of answers related to energy and comfort perceptions and beliefs can give meaningful insights for the discussion. A general perception of comfort in continuity to psychophysical studies inserted new elements, and excluded others that were considered relevant from the literature review (like humidity, weather conditions, appetite, clothing, air pressure, air velocity). Enlarging the meaning of "perception", in the brainstorming phase the comfort dimension assumed a wider range of definitions, quite in line with the cultural context of the workshops attendees. In fact, major accordance has been given to psychophysical parameters quite different from those considered relevant by the CS project. A strong influence seems to come from the material realm (like “softness” or “accessories possession”) and from a general perception of facility and ease. Unexpectedly, energy utilities or physical parameters received less attention. However, these considerations have to be weighted along the limits of this case study. The very limited sample of students (33) has been left free to interpret the idea of comfort and decline this into concrete ICT solutions for its achievement. No hints about electric energy or specific sensors were given. These outputs highlight three main issues:

- Energy consumption in public buildings is felt like something produced collectively and in continuity
- Comfort concept has several possible declinations rather that a simple perception
- Comfort perception seems to strongly depend on the physical usability of places

These considerations open further and wider research trajectories: if a greater, and more representative sample of campus users may confirm these insights, an innovative focus for energy reduction policies in campus design and operation management can be set. Rather than acting on temperature and air quality, equipping rooms with sensors, and processing big data on energy analysis, maybe could be meaningful to operate on comfortable facilities, like comfortable chairs, cozy interiors, chromo-therapy led lights design and others architectural features not normally applied in public building.

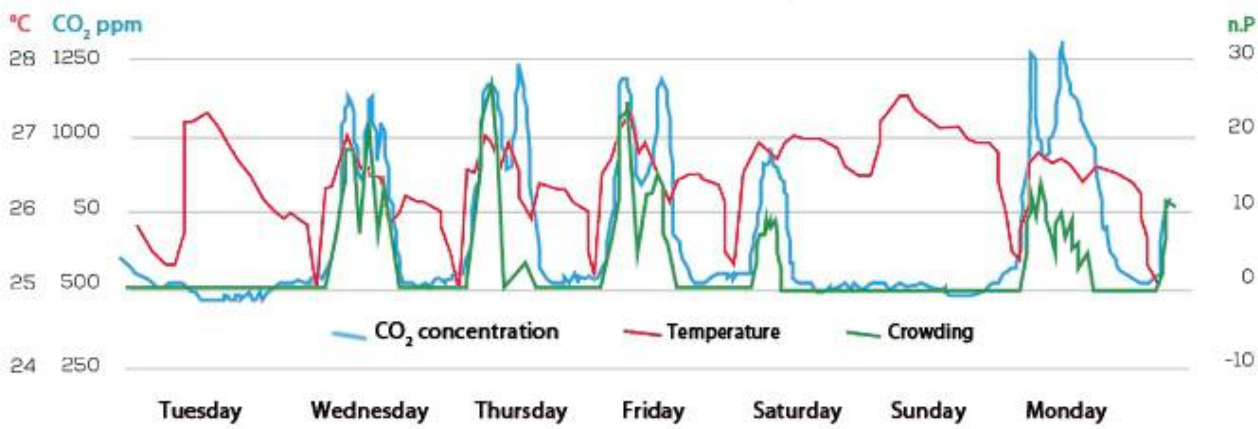

Fig. 28 CO_2, temperature and crowding values as registered in the out-aloud study room at CLE, Turin, from 2 to 8 June 2015.

Empirical evidences may reinforce these hypotheses, after having synchronized user feedback on comforts and quantitative data analysis in the monitored room. As shown in Fig. 28, the inside temperature does not seem to follow any crowding or CO_2 path (Wednesday, Thursday and Friday present similar paths, except for temperature drops in late evenings presumably for the empty rooms on Thursday). From findings in par. 4.4.3 it can be expected that the CO_2 concentration can affect comfort perception less than crowding (especially on Monday, the two paths seems quite mismatched). If the real time feedback confirms so, active policy on space optimization and controlled access to the study room can create greater comfort condition and cheaper energy reduction results than expensive and complicated automated window openings (for air change and set point temperature re-gaining) or new chillers.

4.6 Conclusions

The key assumption from which this study starts is that tackling global climate change is not simply, or not only, a matter of finding more efficient ways (mostly technological or urban teleconnected) of meeting untouchable human quests. While the concept of sustainable development was born having mainly production-oriented policies as institutional outcomes, the co-responsibility of consumers resulted later on in more demand-side policies. The active involvement of the users by means of purchase choices and the adoption of more sustainable lifestyles gave new sense to apparently consolidated concepts about the energy transition and the role of the society aside the one of technology.

Therefore, adopting a socio-technical approach, this chapter investigates the changing definitions regarding comfort and the decision-making mechanism in consumption practices, believed to be pivotal for energy reduction policies in public buildings.

The adoption of a socio-technical approach arises from the literature review outlined in par.1. The concept of comfort has been indeed usually related to physical and psychological parameters, trying to analyse individual votes around standardized termo-hygrometric levels. However, as seen in par. 4.2.2, the social practice theory allow enlarging the comfort dimension to a wider range of factors combined in complex landscapes, from social interaction to collective perceptions, daily practices and cultural environments.

Current strategy for comfort achievement in public building mixes two apparently opposite orientations: product-oriented and demand-sided policies. In the latter, ICT is gaining prominence, as they are seen by the neo-functionalist narrative as tools to match energy demand and offer, enhancing the efficiency of the distribution systems and nurturing the market of smart appliances and current lifestyles.

However, social practice theories on energy consumption outlined relevant human factors that constitute the ground for acting on comfort parameters. Consolidated practices, barriers, opinions and cultural backgrounds could invalidate or facilitate the whole energy transition management. In this perspective, the energy consumption is considered as the product, more or less conscious or desired, generated in the recursive systems of practices of everyday life.

To detect and analyse the material component of the daily reproduction of consumption practices in a university campus, a case study located in Turin has been taken. The co-design of an app with students for HVAC controls via users' real-time feedbacks involved a sample of participants in the Campus Luigi Einaudi at the University of Turin, IT. The Design Studio Methodology was used to identify technical and social barriers to change, structural lock-ins and path dependencies. The questionnaires and open brainstorming sessions about "energy" and "comfort" perceptions constituted the opportunity to explore users' inconspicuous consumption practices inside the and outside the campus buildings. Three main issues came out:

- Energy consumption in public buildings is felt like something produced collectively and in continuity, thus offering margin of intervention on communities like university campuses, where education for sustainability is an urgent call;
- Comfort concept has several possible declinations rather that a simple perception; as a primary good, if not as a right, it is considered easily achievable thanks to the progress of technology that satisfy almost every need quickly and effortless;
- Comfort perception seems to strongly depend on the physical usability of places: comfortable and cosy environments, with nice sofas and interior design care, relax areas and late-night cafes for community building are part of the comfort even more than humidity or temperatures.

Eventually, this study brings two main results in the motivational comfort research field:

1) Practice theory applied to energy consumption allows identifying the practices of consumption engaging users in the place they are pursued. This is of outmost importance in in public buildings, were inconspicuous consumption practices are prevalent and there is little possibility of direct intervention from the users.

2) Co-design workshops showed how comfort can have several facets according to the level of engagement and expectation of users: considering the local human factor when designing policy for public building energy management may outline unexpected (and cheaper and easier to achieve) variables relevant to actual users.

Further research on the factors that make users more flexible in accept lower internal comfort levels' is needed, by coupling the qualitative data coming from the socio-technical approach and a quantitative analysis from smart sensors both fixed and wearable. In fact, if rebound and prebound effects put uncertainties on the efficacy of current energy policies, innovative EU research directives push to tune certain comfort parameters – like indoor temperature – around users' activities, to increase threshold of lower temperature acceptances and therefore reduce the energy consumption especially in public buildings.

To address the issue, an interdisciplinary perspective with sociologist, urban planners, architects and IT engineer seems to be the elective strategy to fill the cognitive and spatial gap between the places of production and the places of consumption. Of course, a remarkable rearrangement of both economic systems and of logistic infrastructures is required, as well as a political pledge by all big countries to increase people's awareness in the short and in the long term.

Acknowledgement
This study was born after the preliminary result of *Comfortsense*, an interdisciplinary project coordinated by the University of Turin in collaboration with several private enterprise and startup in the city of Turin. *Comfortsense* is funded by the "Programma Operativo Regionale" 2007/2013 (POR), the regional tool regulating the European "Fondo Europeo di Sviluppo Regionale (FESR)"

It aims to take advantage of the "Internet of Thing" and the "Smart Cities Technology" in order to improve building energy efficiency and people's comfort. More info on http://www.green.unito.it/?q=node/87.

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Appendix A

Fig. 29 The CLE, University of Turin, IT. Photo courtesy of www.futura.unito.it

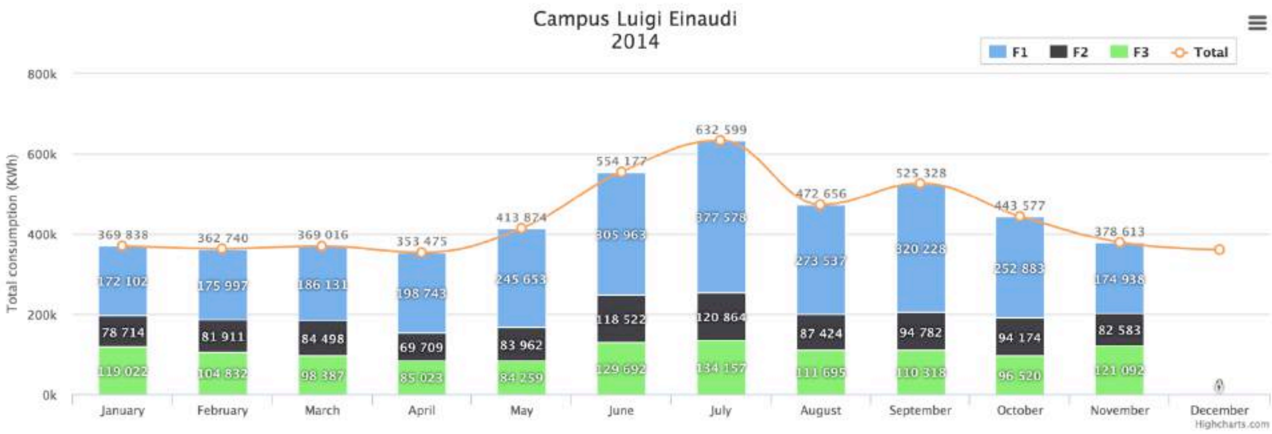

Fig. 30 The CLE electric energy consumption in 2014. Source: http://www.green.unito.it/graphs-consumption/single_building_page.php

Fig. 31 Crowd-sensor (left) and temperature, humidity and CO_2 sensor (right) installed in the out-loud study room at CLE

Fig. 32 Thermostat for temperature regulation (left) and wearable smart sensor (right) for temperature and humidity measurements used in the Comfrotsense Project

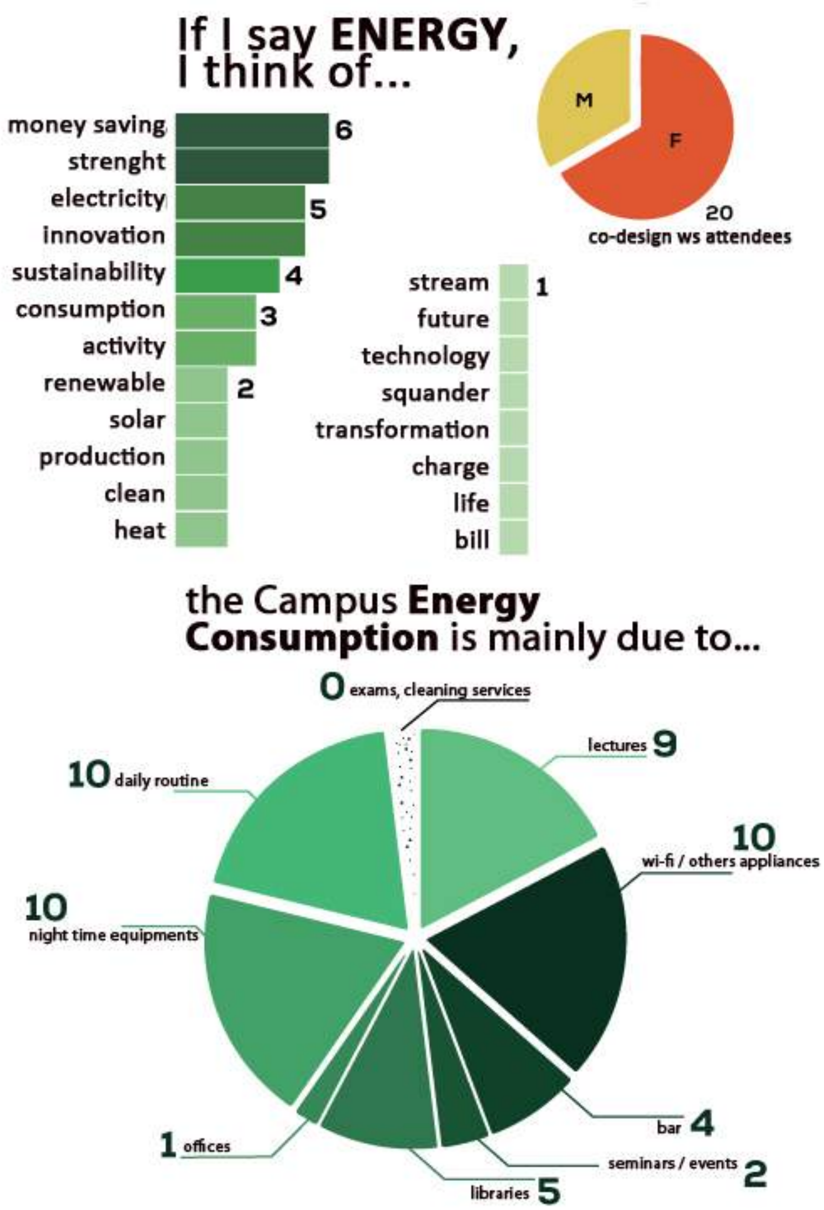

Fig. 33 Answers related to energy-issues brainstorming in the co-design workshop held at CLE, June 2015

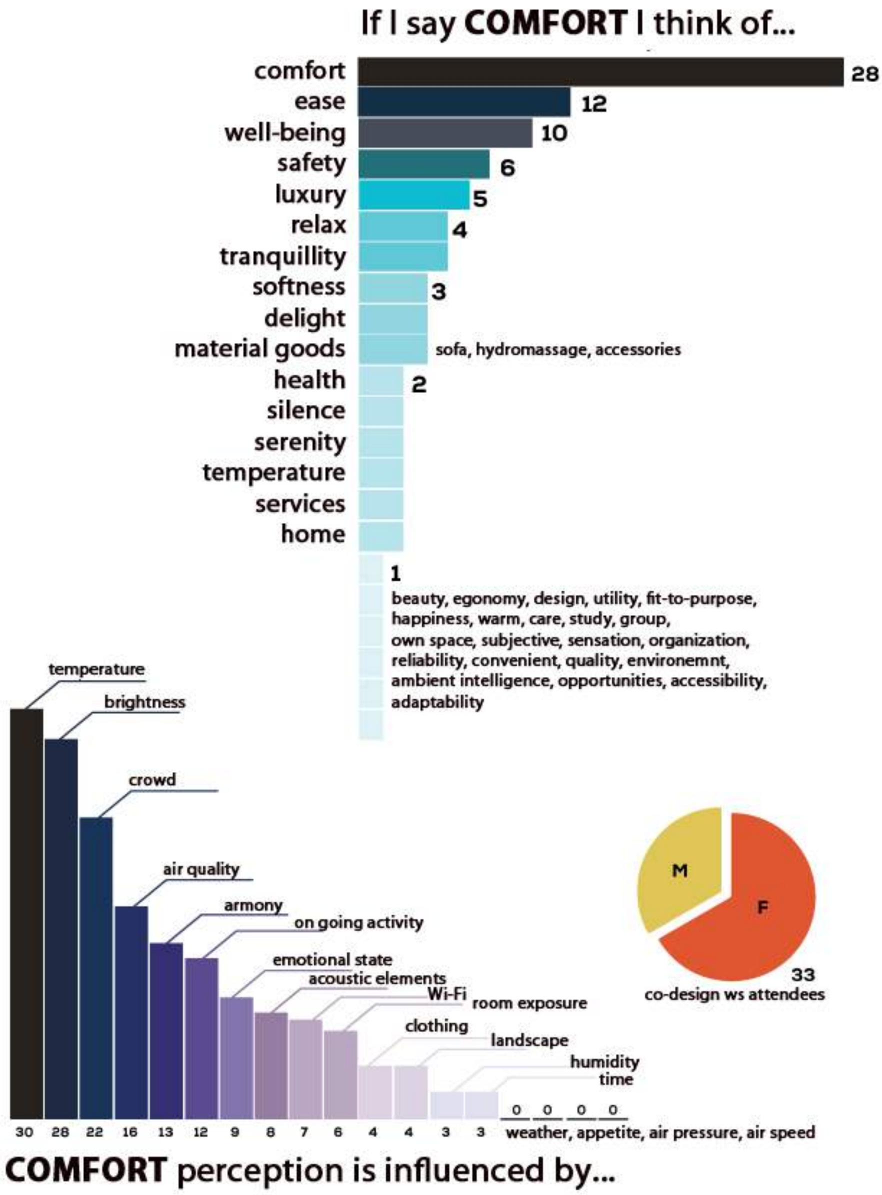

Fig. 34 Answers related to comfort-issues brainstorming in the co-design workshop held at CLE, June 2015

Appendix B

Strategies

Strategies withstanding final products can be of two types: antecedent or consequent (tab.9). In the first case, the aim is to foster possible changes in user's consumption style; in the second case, the aim is to update the user about his/her consumption profile.

Antecedent	Information: suggestions and information provided to the user prior consumption and/or purchase choices
	Goal setting: prior set for a certain energy target
	Commitment: higher effort requires users evaluating and modifying sensitively their own behaviour concerning energy consumption
Consequent	Feedback: show the user the amount of consumed energy
	Reward: economic or social rewards after user's virtuous behaviours
	Criticism: display of comparative analysis between users' consumption profiles

Tab. 9 Type of strategies for user ICT mediated feedbacks analysis

It is not possible to identify the best strategy before an evaluation of the context and user's peculiarities. Furthermore, these strategies could be mixed to be more effective in the path through awareness increase of energy savings.

Time reference

The main difference in temporal terms in existing products consists in the reception of information in real time or having access to historic data. One solution clearly does not exclude the other, as the two settings can be used in mixed way to make comparisons. While long-term data are easier to obtain - as seen in the case of monthly bill - real time data are available only if there are specific technical settings; for example, these data in home consumption are available just if devices are provided with sensors allowing real time survey. The evaluation about which time reference is pertinent for a certain product is to be done depending on the context needs; for example, if in a collective-use environment - as an university campus - a real time data could even result contrasting, in a domestic context could be possible to obtain more significant outcome. In fact, in the first case, consumption is created by the mix of a lot of people actions and therefore is not changeable immediately; on the contrary, in a domestic context, actors are less and a consumption real time visualisation could highlight behaviours with negative consequences on energy consumption, facilitating the user's comprehension and acknowledgment.

Spatial granularity

Similar to temporal reference, granularity indicates the spatial detail level hypothetically reached by a final product. However, desired data could not be available depending on that context; in this sense, it must be considered that some kind of energy can be more easily monitored rather than others and that the level of simplicity to trace and use some specific data could change from a context to another.

Medium

The medium is composed by two elements: the kind of software and the kind of device that support the preferred software. The first one is about representation and interaction on a digital level between the users and the available information; the second one is about the physical device on which the information is received. Two different examples - thought for different aims - can be a 3D visualisation solution on a public display in an office or a smartphone application with an energy game; it is clear how the two factors can be combined to produce final solutions which are diametrically different. Each setting will have a different impact on final user, which is a fundamental consideration as to adapt the tool to the context. 3D solution can provide an environment visualisation much more similar to the reality, demanding a minimal abstraction skill to the user.

Advanced features

Besides receiving information about consumption and visualising used energy, user could be engaged in a more complete way, by sending suggestions and alerts to the users or by interacting in the very middle of virtual communities through social media.

Captology level

The level of persuasiveness of the solution is strictly linked to these choices; more than a reasoned choice, captology declares mainly an aim, a list of desiderata to motivate the user in an effective way. Captology evaluation can be faced both a priori, as an aim in the solution construction, and *a posteriori,* in the evaluation of the effects produced by the solution use.

5 Conclusions and further research

We are moving into a world that differs in fundamental ways from the one we have been familiar with during most of modern human history. This thesis is about the current and the immediate role of university campuses to contribute in a fair and more sustainable transition towards the new low-carbon society. The fundamental argument is that there is a serious gap between the aspiration related to sustainability by higher education institutions and their real performances. Whilst formally moving towards sustainability within their curricula and resources management, universities are still immersed in all the complexity, the uncertainty, the scarcity of resources and the leading green-washing paradigm of the cities they are in. This is why this thesis aimed at updating the debate on current sustainability assessment frameworks for Universities and their role in dodging the functionalist rhetoric and the eco-efficiency paradigm towards truly sustainable university campuses.

The introduction framed this discourse within the current climate change debate and the role of cities, outlining the importance of a clear definition of urban sustainability indicators and criteria for making the economic, environmental and social spheres dialogue on the unavoidable trade-offs of a low-carbon society. There is little doubt in the scientific community that anthropogenic greenhouse gases directly influence the climate system. Nevertheless, current reports on the state of the world and the levels of consumption show that very little progress has been done in the field of sustainable development in cities. Cities are responsible of the 75% of natural resources depletion and about the 70% of the global energy consumption. Sustainable, smart and green paradigms embedded into urban policies in recent years did not produce the expected results in managing the energy transition of such complex and dynamic entities, intrinsically unstable entities: cities suffer downturns, face unexpected events, and take some time to recover from crises (if that). They are large, open and dispersed; they gather life but also distribute it. They are full of variety, latency and multiplicity. They are territories but also nodes in multiple networks. They are constantly evolving, often in unpredictable ways and in new directions. Much of this change brings turbulence, uncertainty and insecurity. Yet, in the normal course of events, this instability does not cause cities to fall apart or descend into uncontrolled decline, and when things do go off course, recovery and readjustment swiftly follow. In the course of time, cities have endured all manner of difficulty, hedging against risk and bouncing back from adversity, small and large. Therefore, if cities are unstable, they can be also called, in some ways, resilient. While some cities have declined after suffering adversity, many others have managed to recover or stave off the worst, albeit by paying a price. However, resilience, as many other watch-words in the current debate on the most appropriate urban policies for climate change, gained intermitted consensus. In this frame, the basic assumption of this thesis is that an operative, global sustainability transition against climate change should be kick-started at a very local level. Citizens, especially the one who will be enabled to twist the current business models of productions streams and market levers, could be educated and re-educated with sustainability principles. Academic institutions are of course the fast track to this extend, to start the educational process in the very centre of urban and community environments. However, we can't exclude the fact that the economic growth from the 1980s until 2008 transformed academia itself into a commodity system, in which not only education but also our social and cultural reality became "schooled". Yet before this period, in 1971 the philosopher, social critic and priest Ivan Illich published a book called "Deschooling Society", in which he referred to the revolutionary potential of *deschooling*, and outlined the possible use of technology to create institutions serving personal, creative, and autonomous interaction. Illich's concept of *deschooling* is clearly relevant today, given the contemporary relationship between digital tools and learning, free access to information, and new economic models. If sustainability education should start from the university curricula and top-down (slow) country-ministry decisions, numerous non-site-specific environmental initiatives have sprung up, from open-air classes to on-line courses. Practices of giving talks or teaching whole courses remotely and in real-time began a few years ago with wikis, blogs and podcasts, and have now evolved on a broad scale. One of the best-known formats currently in use is the MOOC (Massive Online Open Course), in which professors offer courses or talks for an unlimited number online students to follow. #webinar[s], now found on Twitter, are invitations to a "web seminar" open for anyone interested in whatever topic is at hand. Still, the most interesting developments in education may have yet to take place. From this perspective, it could therefore be the case of a critical evaluation of the radical innovation and the strategic rethinking needed by universities, to play their parts in the urgent call for action against climate change.

That part has to be played at first by students, teachers and administrative staff seen as citizens of the special portion of the city after the re-known living lab model, that is University its physical dimension taken as test bed for sustainability solutions. The support of private industries and governmental task forces often foster the role of University in the co-creation of sustainable life conditions and the partnerships with its environment are constantly growing, thanks to European funded project for advanced education schemes, collaborative researches, consultations with local government for urban reforms or real estate developments, as well as industry and NGOs sources of human capital. This led many universities to assume a highly ambitious role of collaborating with diverse social actors to create the needed societal transformations towards sustainable lifestyles. The so-called "third mission" refers indeed to a further goal: to engage with societal demands and link the university with its socio-economic context, pivoting on the feature that make University a unique urban stakeholder: there, a tangible sustainable community has the strength to become a reliable source of attitude shift toward a more sustainable lifestyle at individual and bigger level.

Of course, this scale-up is not costless: decision making at urban level requires complex methods to evaluate different features and guarantee the sustainability and the resilience for a large number of stakeholders. That, in the case of University, is far from homogeneous: short staying students (from one month or one year) or long-staying ones (5 years or more), permanent staff and daily visitors constitute a community pretty difficult to target in term of differentiated strategies and social practice studies. As outlined in the triple helix model, the simultaneous satisfaction of all the stakeholders interfering with the university sphere is almost impossible: place of knowledge transfer, economic node and platform for the interplay of different social actors: decision makers, urban planners, investors, developers, construction companies, designers (engineers, architects), grant managers, building owners, SMEs, IT solutions providers, citizens, and finally students, professor, peer universities, research centres, not to mention the legislative (regional and ministerial) compliances depict a very complex scenario to be managed.

Yet, the opportunity of engraving sustainability principles in university campus users, seen as future society makers and community builders more than any other citizens sample, is believed to be pivotal now, both in the abstract level of curricula and practically in all campus operations by means of university green-pledges.

As concluded in the first chapter, campus greening is often the first step universities take towards sustainability. However, the diffusion of sustainability reporting methodologies and rankings is still at an early stage. It is biased in mainly measuring energy efficiency indicators while omitting basic features enabling meaningful comparisons among centres (for instance addressing social aspects related to long term sustainability transition). A critical perspective on sustainability university frameworks is introduced at the end of the first chapter through a review of current Campus Sustainability Assessments (CSAs) and a comparison of two case studies, finally proposing a new CSA approach that encompasses clusters of homogeneous campus typologies for meaningful comparisons and university rankings. Most of current CSAs appeared limited for (i) not providing mechanisms for comparison (nationally and internationally); (ii) emphasising mainly Eco-Efficiency (EE) borne indicators, over a range of long-term social and built-environment sustainability measures; and, finally, (iii) because some of them are too narrow and qualitative without normative targets. The case of Politecnico di Torino (POLITO), Italy, has been used to analyse its sustainability performance according to the "Green Metric" and ISCN report initiative (two of the most adopted and diffused CSAs), and are then compared with the performance of Hokkaido University (HOKUDAI), Japan. Results emphasise the gaps among virtuous sustainability actions (in the case of POLITO) and the Green Metric rankings. Therefore, on the bases of the analyses and results of both cases, and accounting for their structural and functional differences (POLITO is a campus sprawled through the city centre, while HOKUDAI is a campus outside the city), a new CSA approach is suggested, proposing clusters of different university typologies. In order to build a meaningful comparison among different cases, the cluster approach introduces the need to consider and classify cases according to the following macro-features: (i) spatial structure (scattered throughout the city or compact campuses outside the city); (ii) climatic zone and (iii) hosted functions. At the micro-scale, the need for revising and substituting current eco-efficiency-driven indicators with more life cycle and user-centric related metrics is also proposed, with some examples regarding the energy issue. The adoption of annual user satisfaction surveys can offer great opportunities to track the post-occupancy effect of adopted strategies for energy reduction, to profile the levers and the cultural attitudes of the university community, and to tailor internal temperature thresholds according to single margins of acceptance. Such a new approach—attentive to local constraints and long-term tracking of outcomes rather than an absolute record of taken actions—can help build homogenous university case studies, framed accordingly within clusters, to find similar and scalable successful practices, and also in self-monitoring progress toward achieving a truly sustainable university campus.

Notwithstanding last thirty years of policies and discourses around the pivotal role played by education in driving sustainability transitions, few universities' initiatives have produced effective reductions in resource use or energy consumption. One of the main gaps lies on practices, and the challenges of elaborating sounding policies out from the available dataset. The second chapter goes through the complexity of campuses energy policies, examining current gaps in energy data collection and processing in order to provide insights and guidelines for setting up sustainability transition strategies. Two universities from different countries are presented as case study (POLITO and HOKUDAI again), crossing energy data and comparing mutual trends with other key variables (outside temperature, opening times, function hosted and number of students). Appropriate queries, pivot and user-friendly graphic addresses improvements both for self-assessments indicators and for external reporting purposes. From the wide numbers of features analysed across the two cases it emerged that data monitoring does produces energy and money saving, both in short and in long terms. However, when data access is not easy and open (via a web site or a living lab facility), it can constitute a barrier for external insights and mutual learning from other universities. Conversely, a human (i.e. non-automatised) supervision on data trends, targets achievements and failures in energy trends appears crucial in both cases. A gathered campus, like the Japanese one, runs as a perfect test bed for data management methods according to different faculties, thanks to the matching between consumption sites and supplier delivery points. This feature let HOKUDAI's buildings be analysed according to their primary energy consumption per square meter per year (2012), their levelling rate and their electrification rate. The high consumption - low fluctuations region included Sciences, Medicines, and Research Centre groups. A major improvement in the efficiency of large experimental equipment used all year round has been found to reduce costs. The low consumption-high fluctuation region included mostly Arts and Humanities groups of faculties. The Data Centre electricity consumption per floor area was far higher than the others, followed by the Research Centre and Hospital groups (beyond 200 kWh/m^2/year) followed Data Centre. Comparing the levelling rate of each group, the rate was very high for Sciences Group and Medicines Group (about 0.9) and low for Arts Group and Others Group (about 0.7). To understand the proportion of electricity consumption in the total Primary Energy (PE) consumption, the electrification rate was calculated as the ratio between the yearly electricity consumption and the total PE consumption in the same year. Data Centre displays a very high dependence on electricity, while rates for Medicines, Sciences and Research Centre were close to 0.5, which is relatively high. When the Hospital group relies also on gas for heating purposes, the electrification rate was the lowest (0.27). A hierarchical cluster analysis by agglomerative method with PE consumption per floor area used the mean Euclidean distance and Ward method to produce the clusters of homogeneous consumption in different colours in Fig. 3 and Fig. 5 in page 91. The mean fluctuation characteristics for each cluster vary from Cluster 1 (a total of 15 departments, around 1 GJ/m2/month), Cluster 2 (a total of 14 departments, around 2 GJ/m2/month) and Cluster 3 (a total of 6 departments, around 3 GJ/m2/month). Cluster 4 included the Data Centre, and Cluster 5 the biology research centre. Clusters of homogeneous energy consumption were proposed according to the academic functions hosted in the analysed buildings are believed to allow a more meaningful comparison of university campuses similar for energy use intensity and *modus operandi*. Evidences of links between energy use intensity and surface, weather data and presence of big energy consumer functions (like hospitals, labs, data centre and canteens) can set internal improvement thresholds and warning values currently lacking in university campus sustainability frameworks. To this extent, a multiple linear regression analysis with electricity consumption per floor area and capita for four departments (Engineering, Science, Medicine, and Agriculture) was performed. The explanatory variables were the outside air temperature, number of lecture days and proportion of students. In order to understand the effects of the explanatory variables, the standardised partial regression coefficient (R^2) taking multicollinearity into account was verified. Larger absolute values of the standardised partial regression coefficient are associated with a stronger relation of the explained variable and explanatory variables. The adjusted R^2 was all 0.5 or higher, and as a result, the outside air temperature results to be the strongest factor for agriculture, while the proportion of students is the strongest factor for the other departments. In particular, from November to

April the influence of the outside air temperature was largely different for individual departments. We can infer that the thermal performance of buildings and how to operate the heating are both significant factors. In addition, the number of lecture days for Engineering was a more important factor than for the other departments. This study demonstrated that applying inferential statistics methods (t-test, analysis of variance (ANOVA) and covariance (ANCOVA), regression analysis, and many of the multivariate methods like factor analysis, multidimensional scaling, cluster analysis, discriminant function analysis) may overcome the limits of current eco-efficiency metrics also highlighted within the first chapter. This controversial step in the development of cross-institutional campus sustainability assessment tools will have far reaching implications for theory and practices.

Further prompts gather a wider universities open data set disclosing the same amount and quality of energy data. Of course, more cooperation on data disclosure (and quality of collected data) is a necessary step to frame base-lining university building energy and exergy characteristics. In this direction, the third chapter aimed at contributing to the emerging dialogue about how to accelerate the progress towards an institutionalised commitment to campus environmental sustainability. Three cases of good practices made to date in the field of "green universities" data management and data disclosure have been analysed, looking deeply into these experiences, interviewing their main stakeholders and revealing the main sustainability activators and barriers to transfer and widespread similar institutional transformation. A range of data is presented, from reports and interviews about lessons learned and approaches emerging from different environmental strategies to quantitative indicators analysis from the green metric reporters. One Italian, English and Mexican University are taken as success cases in different sustainability topics. The topics are wide ranging as they are intended as a starting point for readers interested in university sustainability management, to pick and choose ideas that may warrant further investigation in their own university context. Even though many of the ideas presented need further exploration and development, in their current state they may prove of some value to the reader as a catalyst for a different level of institutional analysis. POLITO adopted a centralised policy that leverages all the energy consumption upon a fine data monitoring system and centralised decisions. Its relatively low position in the Green Metrics CSA world university ranking does not reflect a quite virtuous energy consumption and resources management, both compared to similar institutions and to its previous years' performance. Conversely, the Universidad Autonoma de Tamaulipas (UAT) does not collect any quantitative information regarding energy/water consumption. However, to comply with the Green Metrics report, it had to scout all best practices related to sustainability via on-site surveys, interviews and the dissemination effort of the entire sustainability office. Most of the sustainable good practices have been carried on without any emphasis or community branding; yet, UAT's high position in international ranking demonstrates how important can be qualitative data collection and analysis even outside specific indicators accomplishment. Finally, the University of Cambridge (UNICAM) represented the extreme case of town-and-gown campus, therefore providing no exact, wide or transparent quantities of monitored energy for every building. Its sustainability organisation is not represented by a proper body inside the quite complex academic structure of colleges and historical hierarchies. Nevertheless, several buildings analysis and voluntary initiatives born by individual colleges, private grants and student works granted an outstanding performance in the urban outreach category and in the public engagement activities. Perhaps most importantly, a common weakness within the three cases is the absence of a long-term follow-up of the promoted activities. All the projects tended to be carried out over the short term (six months to a year), but no indicator is able to measure the efficacy of building renovation initiatives, sustainable farming educational activities or public lectures affluence. This is not sufficient to adequately evaluate the persistence of the energy savings benefits, their further social impacts or environmental education results. If the goal is to assure long-term changes in consumer behaviour and practices, the lack of appropriate metrics makes difficult to assess the actual size of the direct rebound effect with a high level of confidence. Therefore, results call for appropriate indicators and mandatory tracking systems of sustainability initiatives inside each university. Moreover, since in all the three cases an interactive sustainability web site is lacking, a rich web-platform could be the place where opportunities and problems could easily become visible, and proposals be collected and shared. Of course, the prerequisite for the success of such initiatives is the creation of a strong awareness on the topic of sustainability within the community, something that at present state is still missing all around. The governance of the process is fundamental for supporting and feeding a complex and long-term project like the one we are proposing, and also to manage a large amount of ideas and proposals by the community. Above all, in the energy efficiency evaluation area of most CSAs, there is not any percentage of energy to be saved in one year, or of saved money by widespread use of renewable sources, or by the reduction of waste and water consumption, and so on). Aiming at no specific target leads to vague researches and monitoring activities with no useful outcome nor action to be suggested, as well as a consequent lack of results in terms of money saving. A crucial factor to drive policies and funding schemes seems to be the adoption of a common framework to make the economic board of university dialogue with the environmental and social activist and managers. Even in the case of Cambridge, where placing the UNICAM brand onto a topic is world-wide recognised as a confirmation of value, the financial forecasts for the coming five years show a small surplus planned for sustainability actions. To assist universities in long-term strategic planning, a set of sustainability metrics should be developed, covering the full range of the university's operations, a bit like the biggest companies do with internal audit to check their process quality. This is indeed the main barrier highlighted in many studies regarding sustainability management in higher education institutions. This is also consistent with the findings of the most relevant stakeholder's interviews made in the UK, Mexico, Japan and Italy, where university presidents and vice-presidents also favoured the environment over social and economic factors when discussing sustainability. This focus on the physical impacts relating to sustainability is not surprising, as the facilities management stakeholders largely deal with the physical aspects of the campus, and have the most control over the environmental factors of the institution. However, none of the interviewed was actually knowing how to put in practice these priorities and how to track related performances. Holistic metrics for social and economic assessment of environmental management practice will allow financial boards to track performance over time and make comparisons with peer institutions where comparable data are available. As a good scalable example, a structure like the UAT's sustainability office seemed a good starting point supervise themes falling in the People, Energy, Environment and Social Impact spheres, deliberately left broad in order to encourage an interdisciplinary approach and user engagement in them. The academics realms and management strategies intercepted along these studies demonstrated that user engagement can be the very fisrt lever to rely on for long term sustainability results.

The fourth, last chapter starts from the key assumption that tackle global climate change is not simply, or not only, a matter of finding more efficient ways (mostly technological or relying on urban teleconnections) of meeting untouchable human quests. While the concept of sustainable development was born having mainly production-oriented policies as institutional outcomes, the co-responsibility of consumers resulted later on in more demand-side policies. The active involvement of the users by means of purchase choices and the adoption of more sustainable lifestyles gave new sense to apparently consolidated concepts about the energy transition and the role of the society aside the one of technology. Therefore, adopting a socio-technical approach, this chapter investigates the changing definitions regarding comfort and the decision-making mechanism in consumption practices, believed to be pivotal for energy reduction policies in public buildings. The adoption of a socio-technical approach arises from the literature review outlined in the first chapter. The concept of comfort has been indeed usually related to physical and psychological parameters, trying to analyse individual votes around standardised termo-hygrometric levels. However, social practice theory allows enlarging the comfort dimension to a wider range of factors combined in complex landscapes, from social interaction to collective perceptions, daily practices and cultural environments. Current strategy for comfort achievement in public building mixes two apparently opposite orientations: product-oriented and demand-sided policies. In the latter, ICT is gaining prominence, as they are seen by the neo-functionalist narrative as tools to match energy demand and offer, enhancing the efficiency of the distribution systems and nurturing the market of smart appliances and current lifestyles. Social practice theories on energy consumption outlined relevant human factors that constitute the ground for acting on comfort parameters. Consolidated practices, barriers, opinions and cultural backgrounds could invalidate or facilitate the whole energy transition management. In this perspective, the energy consumption is considered as the product, more or less conscious or desired, generated in the recursive systems of practices of everyday life. To detect and analyse the material component of the daily reproduction of consumption practices in a university campus, a case study located in Italy has been taken. The co-design of an app with students for HVAC controls via users' real-time feedbacks involved a sample of participants in the Campus Luigi Einaudi at the University of Turin. The Design Studio Methodology was used to identify technical and social barriers to change, structural lock-ins and path dependencies. The questionnaires and open brainstorming sessions about "energy" and "comfort" perceptions constituted the opportunity to explore users' inconspicuous consumption practices inside the and outside the campus buildings. Three main issues came out:

- Energy consumption in public buildings is felt like something produced collectively and in continuity, thus offering margin of intervention on communities like university campuses, where education for sustainability is an urgent call;
- Comfort concept has several possible declinations rather that a simple perception; as a primary good, if not as a right, it is considered easily achievable thanks to the progress of technology that satisfy almost every need quickly and effortless;
- Comfort perception seems to strongly depend on the physical usability of places: comfortable and cosy environments, with nice sofas and interior design care, relax areas and late-night cafes for community building are part of the comfort even more than humidity or temperatures.

Eventually, this last chapter brought two main results in the motivational comfort research field:

1) Practice theory applied to energy consumption allows identifying the practices of consumption engaging users in the place they are pursued. This is of outmost importance in in public buildings, were inconspicuous consumption practices are prevalent and there is little possibility of direct intervention from the users.

2) Co-design workshops showed how comfort can have several facets according to the level of engagement and expectation of users: considering the local human factor when designing policy for public building energy management may outline unexpected (and cheaper and easier to achieve) variables relevant to actual users.

Further research on the factors that make users more flexible in accept lower internal comfort levels' is needed, by coupling the qualitative data coming from the socio-technical approach and a quantitative analysis from smart sensors. In fact, if rebound and prebound effects put uncertainties on the efficacy of current energy policies, innovative EU research directives already push to tune certain comfort parameters – like indoor temperature – around user's activities, to increase threshold of lower temperature acceptances and therefore reduce the energy consumption especially in public buildings. To address the issue, an interdisciplinary perspective with sociologist, urban planners, architects and IT engineer seems to be the elective strategy to fill the cognitive and spatial gap between the places of production and the places of consumption. Of course, a remarkable rearrangement of both economic systems and of logistic infrastructures is required, as well as a political pledge by all big countries to increase people's awareness in the short and in the long term.

Bouncing off the title of this thesis, we can conclude that even if the implementation of sustainability standards in university campuses is a global trend, yet very few institutions are leading long term transitions through systemic perspectives of campuses sustainability. To answer the two questions stated in the abstract, we can say that the majority of university are still remaining stuck on technocratic targets set around energy reductions, while improvements on resources efficiency is left to single and isolated initiatives or funding opportunities. Indeed, in a world increasingly dominated by cities and urban systems the role of university campuses in contributing to a fair and more sustainable and low carbon society transition is becoming more and more urgent. However, this still seems far from being really on the go. There is a serious gap between the aspiration related to sustainability by higher education institutions and their real performances (Zsóka, Szerényi, Széchy, & Kocsis, 2013). Whilst formally moving towards sustainability within their curricula and resources management, universities are still leading green-washing strategies related mainly to enhance their scores within international universities or green rankings (Green, 2013). Current sustainability assessment frameworks for universities play a crucial role in dodging the functionalist rhetoric and the eco-efficiency paradigm towards truly sustainable university campuses (Caeiro, Leal Filho, Jabbour, & Azeiteiro, 2013). Campus greening is indeed the first step universities take towards sustainability (Filho, 2000), but the diffusion of sustainability reporting methodologies and rankings is still at an early stage (Alonso-Almeida, Marimon, Casani, & Rodriguez-Pomeda, 2015; Lozano et al., 2015). It is biased in mainly measuring energy efficiency indicators while omitting basic features enabling meaningful comparisons among centre, for instance addressing social aspects related to long term sustainability transition (Arroyo, 2015). Most of current CSAs appeared limited since: (i) not providing mechanisms for comparison (nationally and internationally), (ii) emphasising mainly Eco-Efficiency (EE) borne indicators, over a range of long-term social and built-environment sustainability measures, and finally (iii) because some of them are too narrow and qualitative without normative targets (Shriberg, 2002). A critical perspective on sustainability university frameworks is introduced by Sonetti et al. (Sonetti, Lombardi, & Chelleri, 2016) through a review of current Campus Sustainability Assessments (CSAs). The authors propose a new CSA approach that encompasses clusters of homogeneous campus typologies for meaningful comparisons and university rankings building. Such new approach—attentive to local constraints and long-term tracking of outcomes rather than an absolute record of taken actions—can help build homogenous case studies for relevant comparison and mutual learning. This conclusion's main concern is in line with the previous critical literature, addressing the issue of how generic concepts (i.e. sustainability) are operationalized in different and sometime not effective nor consistent ways. Because of the emergence of the resilience paradigm applied to city studies by environmental scientists (Elmqvist 2014), planners (Eraydin and Tasan-Kok 2012, Coaffee 2013), and policy makers (Satterthwaite and Dodman 2013, Wagenaar and Wilkinson 2013), the paper aims to un-pack different coexisting (although potentially conflicting) approaches in operationalizing resilience, and to propose a set of principles and indicators that integrate resilience within universities sustainability strategies. As recently proposed by the United Nation urban sustainable development goal (USDG 11, 2015) resilience is going to become an attribute of sustainability. Responding to this framing and its operationalization challenge, this final chapter presents some reflections on how to integrate these two concepts relying on different university campuses taken as study cases.

5.1 Gaps in universities sustainability management: proposing propeller blades for sustainability transition

As stated in the previous chapters, notwithstanding last thirty years of policies and discourses around the pivotal role played by education in driving sustainability transitions, few universities' initiatives have produced effective reductions in resource use or energy consumption. One of the main gaps lies on practices, and the challenges of elaborating sounding policies out from the available dataset. Current failures in transitioning toward such an integrated sustainability goal could constitute the basis for integrating some principle from resilience thinking in building more adaptive capacities in university campuses, in order to face change and related challenges (Brandon & Lombardi, 2010). This indeed could introduce some socio (behavioural) and economic aspects of the campuses system into account when addressing sustainability strategies. The most relevant stakeholder's interviews made in the UK, Mexico, Japan and Italy, confirmed the current trend in focusing mainly on environmental, over social and economic, factors when discussing about sustainability targets. The focus on physical impacts of campuses is not surprising, since the facilities management stakeholders largely deal with the physical aspects of the campus, and have the most control over the environmental factors of the institution. However, none of the interviewed knew how to put in practice these priorities and how to address socio-economic issues and track related performances. Drawing from the qualitative outcomes of our interviews, we can say that universities' sustainability transitions are effective and integrated when the management perspective synergistically work on the three 'propeller' blades boosting sustainability transition (see). Their representation as a screw emphasizes the need of addressing not only the university campuses sphere of action (working within universities), but three more systems to synergistically consider both industry partners, public institutions and the civil society.

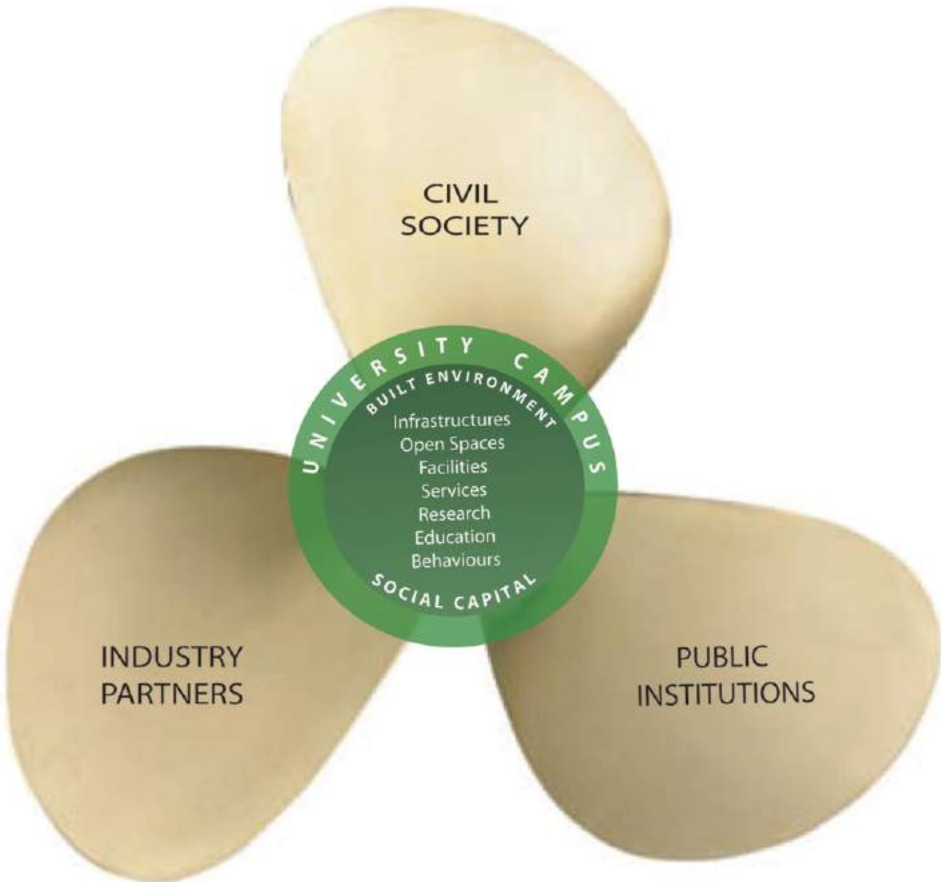

Fig. 35 The screw enabling urban sustainability transitions for universities campuses and its three blades of actions.

The screw in Fig. 35 explains the sustainability management focus of this study through synergies among:

1) University Campus: in the central campus sphere (in green), the built environment (with its infrastructures, facilities, open spaces, services) coexists within the university' social capital (made of behaviours, education targets and research plans). Each of the elements falling in the university sphere plays a role in the community building and influences the campuses metabolism after users' awareness on resources consumption, behavioural changes, energy savings educational activities, etc. Aside this so called "endogenous" work, those elements also bridge the university' sphere to other three exogenous actors:

2) Civil Society: the influence of universities on civil society can significantly contribute to social innovation, boosting interactions among generations, different urban stakeholders, NGOs and associations driving societal transitions;

3) Public Institutions: the relationship between universities and public institutions is definitely a jeopardized issue, socio-cultural and economic contests dependent. However, university's dependency after public funding does not always reflect effective bilateral collaborations between universities and public institutions. Results after joint research projects are often forgotten after the completion, or never applied to real world needs. Bridges between the public and research education activities should be fostered by letting academics be more influential on the policy level and in turn bringing academics out of their *turris eburnea* - the ivory tower that host specialists who are so deeply drawn into their fields of study often can't actively search for a solution, or simply accepting that even educated people can't understand them;

4) Industry Partners: if from one side public-private partnerships have been the engines of all most relevant urban transformations, universities collaborations with industry partners can contribute to operationalize sustainability innovations products and markets equilibria. Whether research should not pursue only private interests is a long lasting discussion in different academic fields. However, university have the power to twist this partnership through the simultaneous hybrid of the other blades, to protect and ensure democratic, participative and integrated approaches.

5.2 Sustainability and resilience: approaches beyond mis-used urban metaphors

The problem of the sustainability management at university campus level could be seen as a particular case of a more complex problem of a sustainability management at district or, more, at urban scale. As a particular part of the city, although peculiar for its dimension and intersection with others mutual affected urban spheres, the university campus presents all the impacts that predominant paradigms from public and private money trends have on physical spaces. So far, to promote sustainable development, urban (and university') stakeholders have reduced problems into parts that fit functional sectors, organisational mandates and academic disciplines. This has been pointed out to be the major weakness for future self-claimed smart and sustainable cities as it clouds the bigger picture of the dynamic nature of our urban environment. A resilience-thinking approach may make some urban strategies poor in terms of eco efficiency, but supportive of a systemic and wide sustainability overview, being related to the degree to which the system can build capacity for learning and adaptation. Management is a key measure, capable to destroy or build resilience, depending on how the socio-ecological system organises itself in response to management actions (Ernstson et al., 2010).

We believe that introducing resilience thinking into the sustainability paradigm may help to reframe the governance of a campus (and a city) since it allows to:

- reconceptualise: since mapping all possible interdependencies among system element is too difficult, because many of them are hidden, to approach the design problem at higher level allows for anticipation, as well as for change from simple reconfiguration to more complex expansion and adaptation;

- study what goes right: contrary to traditional safety thinking, breadth is more important than depth. Instead of focusing on failures, resilience emphasises the importance on focusing on what works (Hollnagel, Woods, & Leveson, 2006);

- cultivate requisite as imagination, i.e. the measure of an organisation in the ability to anticipate changes in risk before failure and loss occur, to create foresight, enhancing creativity, allow bottom- up inputs, etc.;

- develop new tools to maintain and operate the system, so create ways for a system to monitor its own adaptive capacity so that it can make change in anticipation of future opportunities or disruption;

- provide feedbacks, and cultivate ways to visualise and foresee side effects.

Indeed, we could look at the phenomenon of urbanisation as a way of life following the stabilisation of the climate, when primordial human settlements chose permanent agriculture as a primary way of living, and therefore a permanent way to set up their first communities. From that moment on, human settlements (cave, *domus, urbs*, town and city) have witnessed a scale up in the manipulation of nature, rather than build adaptive capacities to live according to environmental changes. In the later century, incredibly rapid technology advancement made human settlement incredibly resistant, but here comes the paradox put on the table by urban resilience: cities have been designed to remove or minimise environmental disturbances, but that led to the ineffectiveness of this approach in addressing issues of social equity and environmental protection. On this soil, the resilience narrative is the VIP in the pageant of the coolest, newest urban mantras. Building resilience and adapting to climate change is increasingly a high priority for cities. Besides mitigation, on which efforts have largely focused in the past, cities should today play a larger role in adaptation. The World Bank and various other public and private institutions (UNEP, ARUP, Cities Alliance to cite some) are working to strengthen their capacity to assess vulnerability to climate change impacts and to identify corresponding plans and investments to increase their resilience.

The metaphor of resilience has been stretched and adapted to almost any field and political discourse, until the point to which it is at risk of becoming meaningless (Christopherson, Michie, & Tyler, 2010). "To be capable to adapt to changes" is the metaphor that has slowly conquered the global development policy agenda (GSP, 2012). Multidisciplinary literature recently highly criticized the links from the metaphorical meaning of resilience and "business as usual practices", dealing with policy making (MacKinnon & Derickson, 2012), planning (Davoudi et al., 2012), disaster recovery (Creech & Steele, 2005), climate change (Pelling, O'Brien, & Matyas, 2014) and in general questioning the sustainability of resilience-related practices (Lorenzo Chelleri & Olazabal, 2012). Recent calls for integrating transformative capacities within the spectrum of resilience features (Folke, 2006; Elmqvist et al., 2003) have launched the challenge of operationalizing and managing different (sometime potentially conflicting) facets of resilience. Indeed, resilience could be related to long-term goals (supporting learning, transformative changes, transition in technology, etc.) or short term goals (building robustness for critical infrastructures, enhancing monitoring and on-time management of services, etc.). Choosing between a) enhancing the resilience of energy net, or b) investing in its diversity by fostering renewable energy resources, it is all but a policy choice, since both option contributes equally to building a more resilient system. Therefore, the concept of "managing" resilience, better than build it, is indirectly emerging from critical literature (Beilin, Reichelt, & Sysak, 2013; Friend & Jessop, 1969; Meerow, Newell, & Stults, 2016). Indeed, "resilience trade-offs" emphasized such synergistic or potentially conflicting aspects of resilience operationalization (Schuetze & Chelleri, 2011; Waters, 2012) and refers to one of the first and main challenges in positioning (universities) resilience: how to unpacking resilience metaphorical meanings into coherent approaches avoiding trade-offs among different objectives related to sustainability (related to economy or environmental or societal or political aspects of campuses)? In the classic three resilience approaches are taken as a basis for reasoning over the main schools of thought, translating the metaphor of resilience within different (potentially conflicting) management approaches (Pearson & Pearson, 2012).

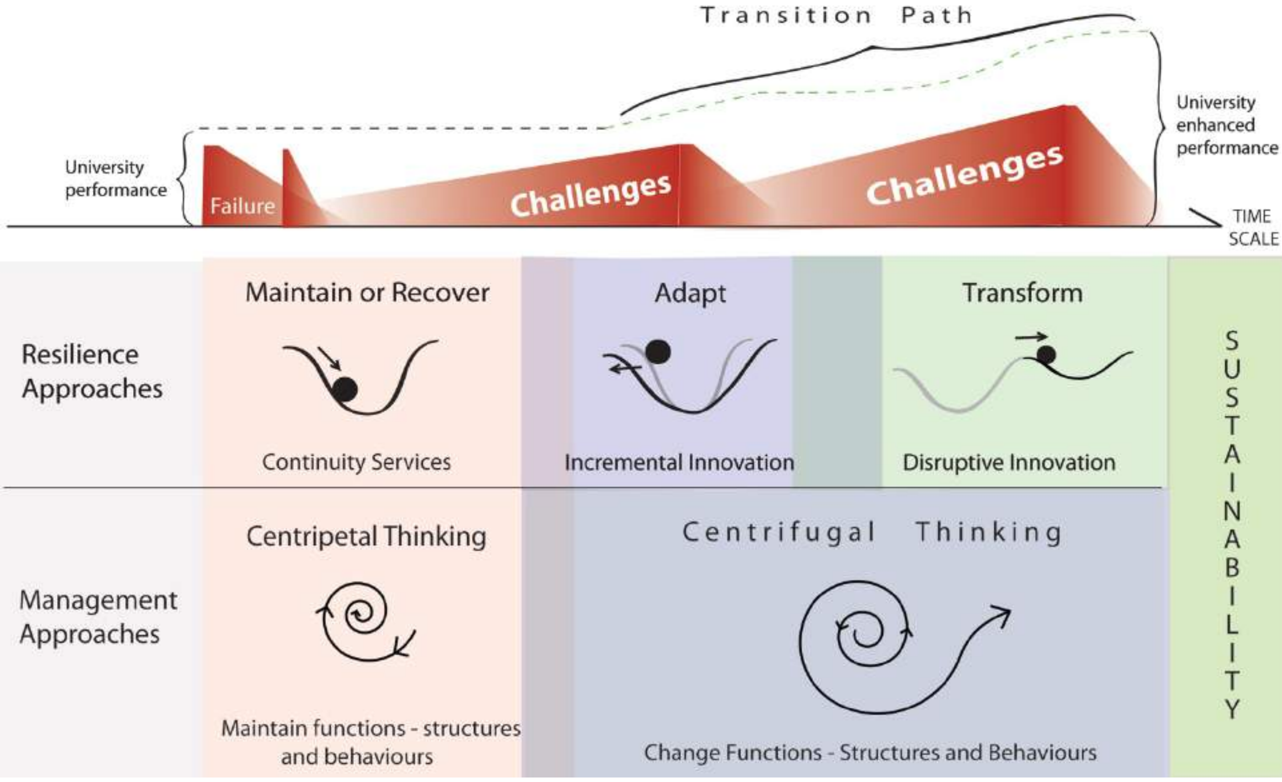

Fig. 36 Resilience and management approaches in a timeline toward a sustainable university

In the upper part of Fig. 36, the transition path of university performance is envisaged in respect to external or internal shocks (i.e. a technical failure) and long term sustainability challenges (i.e. decreasing number of students, or the need of flexible spaces to welcome new ways of studying and learning through social media). Respond to short versus long term challenges is a very complex prioritization and management strategy. Indeed, if from one side it is necessary to respond and be prepared to the short term needs for guarantee the services continuity like on-time monitoring, increasing redundancy, modularity of ICT and physical infrastructures (left part of Fig. 36), it is also necessary to think about the ability of gradually change functions and structures for the long term challenges (right part of Fig. 36). The policy and management implications and tensions emerging when choosing and balancing between different management approaches, addressing short or longer term challenges, are represented in the bottom of Fig. 36. Here, the "centripetal" versus "centrifugal" thinking draws different attitudes toward the management practices operationalizing the metaphor of resilience: the first seeking to maintain functions (so structures and behaviours of the system), the other pointing out the need of upgrading through incremental innovations or changing functions, structures and behaviours with disruptive innovations. Of course, there is still not a clear cut-line among these different approaches reflecting attitudes to accept and manage change over time. At the same time, these tensions have been attributed as conceptual differences between resilience and sustainability, conceived from the practices as different and sometime conflicting notions, being related to risk reduction (emergency and recovery, in the case of resilience) and future scenarios (planning a more sustainable path for our planet, in the case of sustainability). However, as illustrated in the first part of this section, the two concepts are increasingly seen in synergy, and this frame tends to build and enhance over such a synergistic proposition. Because of this, the challenge in framing resilience within sustainability university campuses management strategies appears more related to how to manage it (which approaches, and which perspectives?), rather than build it, or integrating it within current sustainability guidelines.

5.3 New indicators from an energy resilience perspective

There is a very fragmented and multidisciplinary literature proposing resilience principles with a variety of examples, referring to ecosystems (Biggs, Schlater et al. 2012), social-ecological systems (Carpenter, Walker et al. 2001), urban systems (Leichenko 2011), economies (Lang 2012), social systems etc. Rather than finding top-down ways to deduce appropriate energy resilience indicators from such vast literature, we adopt a bottom-up approach review in order to propose a set of determinants and normative principles enabling resilience. Conversely, relying on urban resilience literature and common definitions, we propose to find these resilience principles within the already existing practices related to sustainability strategies in university campuses. Case studies analyses are from Japan (the Hokkaido University Campus), Mexico (the Universidad Autonoma de Tamaulipas), the UK (the University of Cambridge) and Italy (the Politecnico di Torino and the University of Turin). In particular, referring to the proposed table 1, we are interested in providing some food for the mind, and coherently to the approaches and un-packing of resilience provided in the previous section, each resilience principle that we found in the existing case study practice, has been referred to i) the university itself and its sustainability propeller blades (see Fig 1, being the blades the industry partners, public institutions and civil society) and ii) its relation to the different resilience approaches (these have been schematically reported as Business Continuity Resilience (R_{bc}), Resilience for Adaptation (R_a) or supporting Transformation (R_t)). The resilience principles that we found were namely: Self-sufficiency, Diversity, Redundancy, Adaptation, Exposure to Disturbances, Learning and Knowledge Transfer. With different degrees of engagement, annotated in the table with the (+) symbols, these determinants intercept the core sphere of university campus, with its physical and intangible structure (campus' infrastructure, open spaces, facilities, services, plus campus' research organization, education methodologies and sustainable behaviours display) and work synergistically with the others three knots (civil society, public institutions, industry) belonging to the urban context. Resilience principles from case studies related to energy resilience in university campuses are prompted in Tab. 10:

Resilience Determinants	**Case Studies (Energy Focus)**	**Urban Propellers Blades**	**Resilience Type (R_{bc}, R_a, R_t)**
Self-sufficiency	At UAT (MEX), a large investment plan for energy from photovoltaic was done to guarantee self-sufficiency in case of energy Failures/Blackouts/Political uncertainties over the supplier.	Industry +++ Governmental Institution +	$\mathbf{R_{bc}}$
Diversity	At HOKUDAI (JP), the Fukushima disaster put lights on the risk of single-supplier and make university choose for energy source diversity, at least to guarantee the short-term continuity of services.	Industry + Governmental Institution +++	$\mathbf{R_{bc}}$
Redundancy	UPS (Uninterrupted Power Supply) guarantee a short term resilience, plus monitoring and controlling facilities like livings labs, are present mostly in POLITO and UNITO (IT) cases.	Campus Infrastructure +++	$\mathbf{R_{bc}}$
Adaptation	UNITO (IT) pushes user engagement via projects for energy saving measures. Exploring users' perceptions and discomfort tolerance thresholds put the education at the very centre of the toward a contagious social practices shift. This enhances the	Civil Society + Education +++	$\mathbf{R_a}$

	adaptive aspect of resilience working on socio-technical systems incremental shaping.		
Exposure to Disturbances	The UAT (MEX) case shows how scarcity of resources can be of outmost importance for ringing the change toward a more sustainable campus. Products from local farming are merchandised as "proudly made in UAT" and external suppliers are minimum. At HOKUDAI (JP), woods after crops is given free to campus users for domestic heat production.	Civil Society +++ Campus Infrastructure +	$\mathbf{R_a}$
Learning	HOKUDAI's users education for behavioural change is between incremental and disruptive innovation toward new lifestyle to disseminate in everyday life.	Education ++ Civil Society +++	$\mathbf{R_t}$
Knowledge Transfer	UNICAM (UK) has a millenary tradition for self-learning and knowledge production to foster innovative energy supply systems or saving mechanism or greener materials. Potential disruptive innovations coming from active research on energy topics make university structure resilient in welcoming these changes maintaining the same identity and function since centuries.	Research +++ Campus Infrastructure +	$\mathbf{R_t}$

Tab. 10 Energy resilience determinants from case university's studies related to urban knots (Civil Society, Industry, Governmental Institution with different levels of engagement (+)) and inner campus sphere (both with its physical infrastructure and social capital features).

As can be seen in Tab. 10, UAT demonstrated the highest degree of self-sufficiency in the energy management of the campus, since a large investment plan for energy from photovoltaic was done following the new rector's willingness of branding "green" the relatively young university of the district of Tamaulipas, in northern Mexico. To guarantee self-sufficiency in case of political uncertainties over the supplier, this decision is strongly connected with the urban surrounding, with emphasis on the action undertaken at top level by governmental institution and of course the availability of efficient and up-to-date energy engineering industries, plants and technicians of renewable energy sources. Avoiding black-outs and failures in the short term may seems actions falling in the R_{bc} type, even if a prolonged strategy of total energy independence could be a disruptive innovation in the energy markets. Although in POLITO the 100% of the electric energy consumed in the campus is certified to be produced from renewables and a consistent part of the thermal energy comes from district heating, the existing PV plant of 400 kWp is not sufficient to cover neither the 0,1% of the total electricity request. After the Fukushima disaster, Japan at country level put lights on the risk of a single energy supplier. HOKUDAI choose for an energy diversity plan, to guarantee the short-term continuity of services and be able to deliver energy from nuclear and hydroelectric/thermic plants as well. Redundancy is assured by UPS (Uninterrupted Power Supply) in most of the cases to guarantee a short term resilience. Monitoring and controlling facilities like livings labs, are present mostly in POLITO and UNITO (IT) cases. This is retraceable in most Italian cases, where the lack of external funding makes Living Lab facilities bloom from the collaboration with departments and faculties on various research projects and teaching initiatives. This allow to share common infrastructure acquisitions, technological resources, expertise and, most important, dataset. Its management is the result of the close cooperation between different entities and divisions (energy manager office, energy department, information technology area, construction and logistics). In the Living Lab, all data streams are collected from on-site sensors and then processed and analysed. The main aim is to provide a decision support for the energy management, but there are also regular requests for research support and various educational initiatives, making the effect of this initiatives falling in the resilience building for adaptation purposive and educational shift toward a tangible sustainability attitude. Drawing results from that infrastructure, UNITO pushes user engagement via projects for energy saving measures coming from regional and European funding. Exploring users' perceptions and discomfort tolerance thresholds put the education at the very centre of the toward a contagious social practices shift. This enhances the adaptive aspect of resilience working on socio-technical systems incremental shaping. To detect and analyse the material component of the daily reproduction of consumption practices in a university campus, UNITO profited of the co-design of an app with students for HVAC controls via users' real-time feedbacks. The Design Studio Methodology was used to identify technical and social barriers to change, structural lock-ins and path dependencies. The questionnaires and open brainstorming sessions about "energy" and "comfort" perceptions constituted the opportunity to explore users' inconspicuous consumption practices inside the and outside the campus buildings, showing that comfort perception seems to strongly depend on the physical usability of places: comfortable and cosy environments, with nice sofas and interior design care, relax areas and late-night cafes for community building are part of the comfort even more than humidity or temperatures. Civil society comes to play also because of the need of other comfort levels found outside the campus wall, in the nearest city cafes, libraries, readers club or co-working spaces. The UAT case shows how scarcity of resources can be of outmost importance for ringing the change toward a more sustainable campus. Products from local farming are merchandised as "proudly made in UAT" considerably reduce the external supplier's orders. The exposure to disturbances (in this case very related to the urban unsafety and the need to create a "protected" environment) worked in the same way at HOKUDAI (JP), were for educating people to be resilient to natural disaster and eventually energy failures, woods is given free to campus users after crops for domestic heat production. HOKUDAI's user education for behavioural change can be framed between incremental and disruptive innovation toward new lifestyle to disseminate in everyday life. Through its frequent programme for sustainability communication and bottom-up suggestions in campus operations management, HOKUDAI aims to extend the sustainability paradigm very out from the campus bubble following a series of sustainability initiatives in order to reduce its environmental impact and fulfil its goal for the creation of a 'showcase' sustainable campus. These initiatives could be categorized in four key groups consisting of the sustainable campus core schemes, sustainability programs, human resource development and education, leading Sustainability Networks and campus sustainability assessment schemes. The university runs periodical stakeholder meetings in order to bring expertise from outside the university regarding the implemented programs and feedback on areas requiring improvement. A series of voluntary student activities to enhance campus sustainability (e.g. *Hokudai Genki* project, Sustainable Campus Contest, Candle Night and Sustainable Campus tour, Hokkaido University Campus Visit Projects, and so forth) are held by different university departments and groups. Efforts are being made as well to cultivate human resources by fostering a series of sustainability programs among the student body. The knowledge transfer determinant has been of outmost importance in the sustainability management of UNICAM (UK). Cambridge has a millenary tradition for self-learning and knowledge production to foster innovative energy supply systems or saving mechanism or greener materials. Potential disruptive innovations coming from active research on energy topics make university structure resilient in welcoming these changes maintaining the same identity and function since centuries.

Depending on the application context, resilience thinking may force policy makers to consider issues such as the users' socio-demographic features, the level of available awareness (professional, technological, energy, environmental), the degree and the kind of motivation, an information tailoring ad-hoc for different targets, and so forth.

In all the cases, the relative sustainability managers stated that the most interesting approach to put in top-down needs and bottom-up demand is believed to be the participatory design, which is much more useful if the participants involved are carriers not only of interest, but also of skills and differentiated experiences and active contribution for scoring the common goal.

Indeed, a collective response was lacking when modern buildings and high-tech equipment in the university campus unloaded the self-consciousness of the sustainability duty to third parties (e.g. in Japan and Italy with external contractor of services, monitoring devices, database, administrative bodies paying the bills, global evaluative boards, national disaggregated policies, and so forth). However, both in Italy and Japan the campus users presented self-motivation drivers along with the effect from the existing energy reduction campaigns as causes of behavioral change. The limited participation in sustainable activities in POLITO and UNITO is outweighed by a great interest in future participation by the University's decision board, indicating the potential of sustainability initiatives. The *conditio sine qua non* is of course the tailored communication tools and strategies, profiting of the university-made prototypes to monitor and collect data, allowing comparisons and self-evaluations by students and staff, and above all nurturing a strong sense of community and self-responsibility to be spread, hopefully, also outdoor.

5.4 Conclusions and further research

As further research trajectory, this thesis believe the resilience thinking could help to reframe sustainability evaluation issues, putting attention the the persistence, adaptability and transformation capacity of (urban) systems. It would mean to assume change and uncertainties in our evaluation, nurturing conditions for recovery and renewal after disturbances, combining different type of knowledge for self-learning, creating opportunities for self-organization of future, truly smart cities. Far from romanticizing "the past", or "the slow", the conclusion of this contribution is useful to outline that the "immunity" from environmental disturbances offered by the most common idea about living lab and smart city can blind us from our critical dependences on nature, reduce our resilience capacity and shape unsustainable futures. Of course, more research is needed to evaluate these long term effect, and which kind of indicators may be suitable to track our progress toward a city that include resilience and humanism in its governance, rights and values (Lombardi, 2011). Even if there is still no agreement about a common definition for urban resilience, what we wanted to explore here is the process of translating the theoretical concept of resilience into practice by using recent experiences from our ongoing evaluation on sustainability management in university campuses. The use of those resilience indicators coupled other university's sphere interaction (waste, mobility, human resources education, etc.) could help to understand differences between university communities and to shape future community energy resilience interventions and, when scalable, further urban governance directions. Although such work has not just entered the mainstream but tried to transform at least research understanding in university sustainability management, it has some limitations: It relies on just few cases, and it lacks of much more discrete treatement on the notion of sustainability, climate change and resilience. A larger literature reviews on the urban translation of these arguments could fill this gap, as well as the inclusion of a wider sample of university can explore if this approach needs tuning tools to adapt to more complex and scattered campus scenarios. More sophisticated analysis tools (neural network analysis, multiple linear regressions, urban metabolism methods (Carpaneto, Chicco, Mancarella, & Russo, 2011)) can help to put together different variables (energy use behavior, demographic characteristics, traditional values, type of available appliances and energy sources) and their interaction with socio-ecological systems, resilience capacity, community building and cultural identity preservation (Cannarella & Piccioni, 2011).

To conclude, the scheme in Tab. 10 just aims at introducing food for thoughts in the current academic brainstorming about urban resilience determinant. The focus among the different case studies used as opportunities to explore urban resilience indicators rappelled down the university campus has been energy. After that, other relevant and intersecting factors (water, ICT, waste, food) contributing to the function and the input-output model of a university campus could be analyses via the same framework. Although the monitoring via livings labs seems a shared step for a sustainable university management, none of the universities explored via literature reviews and fieldworks undertaken for this study presented any long-term resilience/sustainability plan of targets. However, signals of hope came from the many stakeholders met on this challenging and mind-feeder path, creating the condition to pledge for the first Italian network of Sustainable University Campuses, to be presented at the ISCN world congress to be held in Siena, in July 2016. The Italian Network of Sustainable Universities (RUS as the acronym comes from the Italian language) frames current sustainability management models in a country specific context by setting a shared framework for sustainability metrics, data collection quality and quantity, mapping of transferrable sustainable practices, using strategic management tools, and periodic meetings among the participants. The final purposes of RUS are the dissemination of the sustainability culture and best practices among Italian universities and the active engagement of all urban stakeholders gravitating around sustainability management issues. The power of such network is to increase the positive impact of single actions into a gradual national commitment towards green growth, contaminating the surrounding urban stakeholders in terms of added values and saved resources.

The many signatories of RUS, the several shining, good willing and wise university' sustainability managers, plus all the single volunteers for sustainability enhancement met along my research path, made worthy the aim of this work: contributing to enrich the critical perspectives on how to operationalize and un-pack the resilience and sustainability paradigms synergistically, far from proposing mere metaphorical labels fitting on business as usual campuses agendas, but paving the way toward truly sustainable university campuses.

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I want to dedicate this dissertation
to the memory of my beloved grandma,
and to all the persons I find always,
and unconditionally,
close to me in this continuous
and never-dying love stream.