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Being the energy manager in a technical university

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ABSTRACT

Politecnico di Torino has 33,000 students enrolled and a yearly budget above 250 M€, with an overall energy consumption of around 5,000 toe.
The author of this paper, Energy Manager of Politecnico from 2006 until 2018, describes the continuous efforts for reducing energy demand carried on during these years. These efforts regarded – following an inverse path respect to the energy flow - the building envelope, thermal and electric installations (heating, air conditioning, lighting, etc.), and finally concerned energy supplies, and the criteria to make a choice among the different vectors and sources, considering economic and environmental issues.
These actions were not necessarily undertaken by the Energy Manager decision alone, as they rather depend on other factors such as availability of financial resources, as well as logistical and "academic" priorities. However, the Energy Manager was the reference person for promoting actions which make the Campus life more sustainable, and also for receiving complaints about malfunctioning installations, energy waste or discomfort. Recently, within the activity of Politecnico "Green Team" (http://www.campus-sostenibile.polito.it/it/green_team), the Energy Manager contributed to disseminate good practices concerning energy (and waste, mobility, water…) among students and staff, and gradually the Campus itself became the target of studies and experiments involving a wide range of educational activities (field experiments, final projects, internships…).

1. INTRODUCTION

With an overall primary energy use around 5000 toe (tons of oil equivalent), Politecnico di Torino (PoliTo), according to Law 10/91, must nominate an Energy Manager. Traditionally, at Politecnico this role is held by a professor, even if there are highly qualified engineers and architects working at the Technical Office of the Campus. As previously stated in a paper on the same subject [1], this is a sort of anomaly having advantages and disadvantages. On one side it allows to quickly transfer competences and innovative solutions to the real world, and to create a strong link between these practices and education through thesis projects and scholarships. On the other hand, the institutional (education, research, academic) engagements of the energy manager do not leave him the time needed to constantly tackle the daily challenges concerning energy supply, use and management. Finding the right balance between these tasks in reciprocal respect with all stakeholders is not always easy.

2. THE PRESENT SITUATION

The main general data concerning Politecnico and those concerning its energy use are reported in Table 1. They both refer to year 2016. Data for 2017 are very close to the previous year, with 5028 toe overall primary energy use.

About 70% volume of PoliTo premises dates back to the '50s (1958) with typical wall U-values ranging between 1 and 1.2 W/(m^{2}K). Among the other premises, we have to mention the XVII century Valentino Castle (10% in volume), while most of the remaining buildings (the so-called "Cittadella Politecnica") have been built in recent years and comply with the new energy saving regulations. Last year the Energy Centre, a new important premise, has been inaugurated within Politecnico. It is a building containing many innovative solutions: high performance envelope, photovoltaic installations, groundwater heat pumps, and district heating-supplied adsorption cooling. However, this innovative building has not been analyzed in this article. Specific heating energy use is around 11 kWh/m^3, a rather low value and a globally good performance which may be explained by the compactness and large size of the main seat fabric.

Table 1. PoliTo general data and energy data (2016)

Number of BSc and MSc students	33 000	Budget (M€)	257
Permanent staff	1725	Heated volume (m^3)	1 430 000
Electricity (MWh)	16 665	Specific heating energy (kWh/m^3)	10.74
District heating (MWh)	12 434	Energy/budget (toe/M€)	19.40
Natural gas (m^3)	306 457	Energy/student (toe/stud)	0.151
Overall primary energy (toe)	4 987	Energy/staff (toe/pers)	2.89

In order to respond to the obligations with FIRE (the Italian Federation of Energy Managers) and to keep under control the overall energy situation at PoliTo, a total energy figure has to be yearly calculated, summing up all the different energy vectors. Prior to this, electricity, heat (mainly deriving from the urban district heating system), and natural gas, have to be converted into primary energy, conventionally measured in toe, using a specific primary energy factor (f_{EP}) for each vector.

According to present Standards and regulations, the values of primary energy factors should be calculated as follows:

- Electricity: $f_{EP,el} = 1/\eta_{Ies}$ where η_{Ies} is the average efficiency of the Italian electrical system (0.413). Therefore $f_{EP,el} = 2.42$ (see [2]).
- District Heat: primary energy factor of district heat has to be calculated according to UNI EN 15316:2008 "Buildings heating systems - Method for calculating energy requirements and system efficiency" [3]. Whether the District Heating company does not declare any value, $f_{EP,h}$ is assumed to be 1.5. The company supplying Torino district heating system has certified for years 2016-2018 $f_{EP} = 0.626$ [4], an astonishing low value (<1!), obtained thanks to the high efficiency Combined Heat and Power (CHP) plants.
- Natural Gas: considering extraction and transport losses fEP,NG = 1.05 [2].

Primary energy factors are changing year by year. However, for the sake of comparing the different years, a constant f_{EP} value has been adopted for each energy vector, adopting the values suggested by FIRE (see Table [2]).

Table 2. Energy conversion factors and f_{EP}

	Electricity	Heat	Natural gas*
1toe =	4 545 kWh	11 630 kWh	1 220 m^3, or 11 630 kWh
f_{EP} (std)	2.42	0.626	1.05
f_{EP} (FIRE)	2.56	1	1

*Lower calorific value 9.54 kWh/m^3

As a result, a reasonable time history of energy uses can be produced, as it is shown in Figure 1.

From this Figure it may be noticed that, after reaching a peak value close to 6000 toe in 2012, overall primary energy consumption slowly decreased until it came back to values below 5000 toe, as ten years ago.

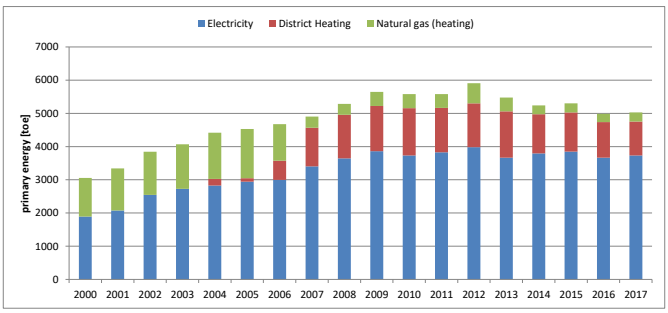

Figure 1. Time history of primary energy use at PoliTo (2000-2017)

It should be pointed out that this decrease has taken place in spite of the fact that all main activities (number of students, economic balance, publications, patents,…) carried on at PoliTo have been constantly growing. By normalizing total primary energy consumption with respect to the number of staff personnel and students (a sort of energy intensity value), it can be clearly seen in Figure 2 that these two indicators have been steadily decreasing in the last years.

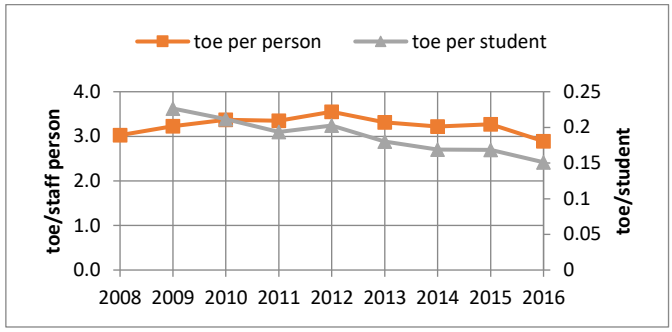

Figure 2. Time history of energy intensity referred to personnel and students at PoliTo (2008-2016)

This achievement may be explained with the numerous energies saving actions which have been undertaken. They will be briefly described in the following paragraphs.

3. ENERGY actions UNDERTAKEN

3.1 Energy efficiency

In the last ten years more than half of the 17 000 m^2 of the 1958 old single-glazed iron-on-iron frame windows have been replaced with high efficiency ones, with low-emissive glass coating, argon filled gap and thermal break frame (thermal transmittance U-value around 1.2-1.4 W/m^{2}K).

Replacing 1 m^2 of window will reduce heat losses by more than 200 kWh/year, without considering the reduction of air infiltration, which may lead to similar savings and dramatically improve local (cold draught and radiative asymmetry) comfort conditions. Furthermore, on East/West orientations glazed surfaces were replaced by low solar factor ones, and on South orientations motorized outdoor venetian blinds were adopted.

Along with replacement of windows, the old oversized radiators under the windows were replaced by fan-coils, which my accomplish a dual winter-heating and summer-cooling function. Whenever radiators have been replaced, an insulated drywall has been added to the thin and low thermal resistance under-window wall, thus achieving a further reduction of wall heat losses and radiator emission losses.

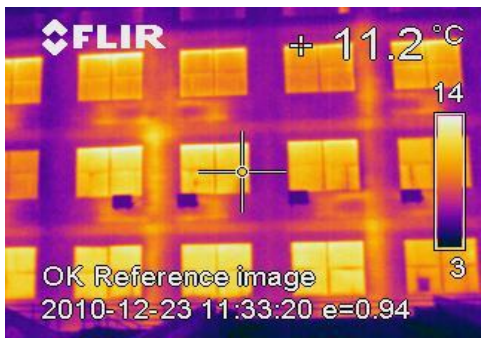

Figure 3. IR image of a façade before retrofit. Notice the hot spots due to radiators and external room A/C units

Finally, on all terminals (both radiators and fan-coils)

thermostatic valves have been applied.

A more recent intervention concerns fluorescent lamps, which have gradually been replaced by high efficiency LED ones. About 850 (6% of total) of these lamps have been installed during 2016.

Finally, variable speed pumps have replaced the oversized on-off pumps of the heating/cooling circuits, with an impressive reduction of pumping energy consumption.

3.2 Renewable energy

The activities in this area mainly concern photovoltaic installations, but the use of ground water as a heat sink for chillers has also been included under this paragraph.

(1) *Photovoltaics*. About 30.000 kWh are yearly produced by the 35 kW PV installed at the "*Fucine*" skylight eight years ago. On April 10, 2017 the new 600 kW Photovoltaic (PV) system has been installed on one of the industrial sheds at the Cittadella premises (see Figure 4). In its first year it produced about 750.000 kWh (1250 full-load hours), or 4.5% of PoliTo electrical consumption.

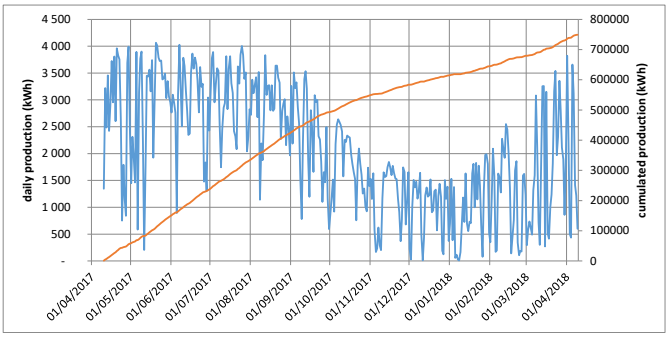

Figure 4. Daily and cumulated energy production by the new 600 kW "Cittadella" PV installation (2017-2018)

(2) *Ground water condensed chillers*. The first centralized chiller was realized in the '90s at the service of the air conditioning system of the Rectorate, and was already condensed by groundwater. With the gradual extension of centralized air conditioning to all Politecnico, three new refrigeration plants have been realized, and ground-water cooled chillers have now reached a global frigorific power of 5700 kW. By using magnetic levitation compressors and ground water condensation they reach average seasonal EER in the order of 5÷6. These chillers have replaced hundreds of old, noisy, inefficient, and unaesthetic split Room Air Conditioners (RAC). Unfortunately, the evaluation of energy savings is made uncertain by an undesired change of attitudes of the users. Whereas switching off the RAC before leaving the office was considered normal like switching off the lights, with centralized A/C systems users do not take care of switching off the fan-coil before leaving their offices. This misbehavior substantially reduces, but does not entirely wipe out, the expected savings.

3.3 IP devices

The use of IP devices (that is, information devices connected to the Politecnico network: PC, routers, printers, and other peripheral devices), in a public research institution like Politecnico, is of growing importance, and also accounts for a large use of electricity (about ¼ of total electricity use). Part of this huge energy consumption could however be substantially reduced if we consider that many PCs.

(1) are unnecessarily active 24/7, and

(2) are often idling even during working hours.

A typical example of point a) is shown in Figure 5, where the number of IPs making Ethernet traffic (IP-MET) at Politecnico has been recorded during a normal working day (Monday, 19 March 2018). It can be noticed that during the night between Sunday and Monday about 3500 IP-MET were detected, corresponding to more than half the number of IP-MET in peak working hours (about 6000). This means that more than half the IPs were connected during the whole weekend, most of them without accomplishing any useful task.

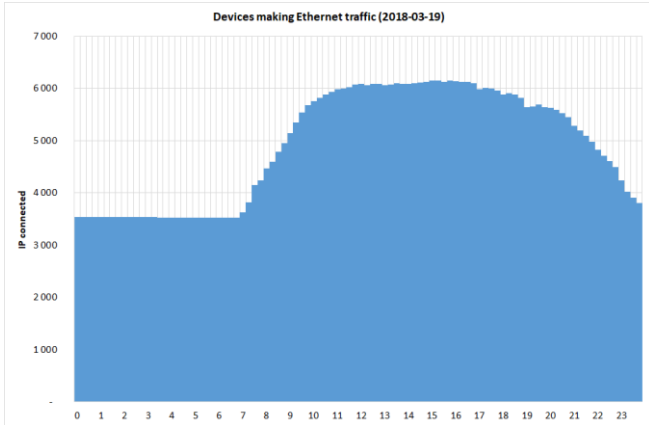

Figure 5. Number of IPs making Ethernet traffic during a working day at Politecnico

Let us now concentrate on PCs, which have a share of about 2000 out of 3500 IP: they make Ethernet traffic both when they are switched on and regularly operating, and when they are in stand-by conditions (with screen off), while they do not make Ethernet traffic when they are hibernated or switched off.

In Table 3 the typical ranges of absorbed power are reported for a normal PC in different operation modes.

Table 3. Typical values of absorbed power by a PC in different operation modes

	Operation mode	Absorbed power (W)
PC making Ethernet traffic	Regular (*level 1 activity*)	40÷50
	Stand-by (*level 2 activity*)	20÷25
PC <u>not</u> making Ethernet traffic	Hibernation (inactive)	2÷3
	Switched-off	0

Apart from a few PCs with scientific software (typically CFD) running day and night, the overwhelming majority of the PCs detected as IP-MET during off time were actually in stand-by mode (level 2 activity). As such, they absorbed around 2000 x 0.025 = 50 kW in total, while in hibernation state they would have absorbed only 6÷8 kW.

It has to be considered that the total number of standby hours may amount to more than 6000 hours/ year (week-ends, holidays and vacations days give around 125x24 = 3000 hours, and night-time hours of week-days are at least another 240x14 = 3360 hours).

A software application able to move all PCs from stand-by to hibernation state at PoliTo would therefore allow yearly energy savings amounting to (50-8)*6000 ≈ 250,000 kWh, with money savings above 40,000 € per year.

Such software applications do exist, and might be used also to tackle point b) situations: that is, they may hibernate PCs during phone calls, meetings, coffee or lunch breaks, etc., when they would be normally operating at level 2 activity, without reducing in no way their functionality. For example, Figure 6 shows the utilization profile of the 30 PCs hosted in one of the students Computer Labs (LAIB) of Politecnico, from September 28, 2015 to January 24, 2016.

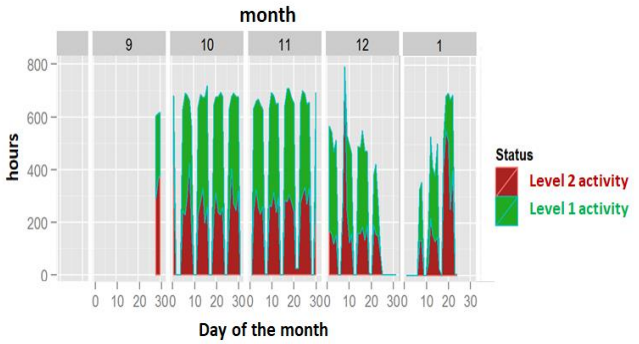

Figure 6. PC utilization profile in a students' computer lab

Hours during which PCs are operating at level 1 activity are shown in green, while those during which PCs are in level 2 activity are shown in red. Until November 30, on each weekday the total is around 700 hours: 400-460 hours/day in activity 1 (green) and about 240-300 in activity 2 (red).

On December 1st, a software application reducing parasite consumption during stand-by was tested. Its effect is clearly visible by the fact that, whereas the regular activity hours (in green) remained the same, the total area was reduced (with the exception of December 8 holiday, due to a wrong closure operation carried on the day before), thanks to a decrease of stand-by hours (in red) to about 150.

Analysis of daily consumption before and after the application of the software has shown a reduced energy consumption of 5÷6 kWh/day for that Lab.

In order to extend this application to all PCs of the central administration offices, and eventually to all PCs in the Campus, some evident issues concerning privacy have first to be solved. A conservative estimate of the application to 2000 PCs with hibernation during non-working and idling times leads to more than 750,000 kWh saved each year.

3.4 Green procurement of energy

Besides the "concrete" actions described above, Politecnico decided already some years ago to purchase a certification (GO – Guarantee of Origin) which guarantees that all the electricity originates from renewable energy sources. This is obviously just a virtual certification, as in a strongly interconnected electrical network like the Italian one, it's impossible to distinguish electricity by the source and installation which produced it. However, this symbolic certificate, with a price well below 1 €/MWh, is an evidence of the engagement of Politecnico in reducing Greenhouse Gas emissions and supports us in claiming the use of totally "green" electricity in our Campus.

A more practical and effective action concerns the choice of heat supplies. Since 2007 most of our Campus is connected to the Torino district heating system: only the Valentino Castle and a few smaller premises are still heated by gas boilers. This choice is only partially related to minor economic and practical advantages, the main advantage being the virtuous origin of the heat distributed through Torino district heating system. As previously mentioned, this heat mainly derives from combined heat and power (CHP) plants with high efficiency combined cycle gas turbines (CCGT), ensuring a primary energy factor far less than 1.

4. THE GREEN TEAM

The so-called "Green Team" (http://www.campus-sostenibile.polito.it/it/green_team) was created in 2015 under the auspices of the Vice Rector for Logistics, Organization and Infrastructures Romano Borchiellini, on the occasion of Politecnico application to the ISCN (International Sustainable Campus Network). It was an important step forward in the activity of the Energy Manager, because for the first time the energy issue was made a system together with waste, mobility, green procurement, and "sustainability" really became a strategic priority at Politecnico. The Green Team is coordinated by Patrizia Lombardi, nominated deputy Rector of Politecnico by the recently appointed new Rector Guido Saracco (March 2018). Since 2015 the Green Team produces a yearly "Sustainable Campus Charter Sustainability Report" in which the activities carried on by Politecnico by the following WPs are described:

(1) Energy and buildings
(2) Mobility and transport
(3) Communication
(4) Food, water, and waste cycle
(5) Green procurement

The Green Team WP on energy and buildings takes advantage of the fundamental support of the so-called Living Lab (http://smartgreenbuilding.polito.it/), which gathers, monitors and elaborates the energy data of Politecnico.

The Green Team activities are shared with other Italian Universities through a Network of Universities for Sustainable Development (RUS). In particular, RUS\Energy is coordinated by the present Politecnico Energy Manager, Alberto Poggio.

Politecnico also participates to a special international ranking, GreenMetric, launched in 2010 by Universitas Indonesia (http://greenmetric.ui.ac.id/overall-ranking-2017/), which grades universities according to the efforts made to implement environmentally friendly and sustainable policies and programs in their Campuses.

Since 2015 PoliTo has rapidly climbed the ranking: in 2015 it was at the 333rd place in the world out of 406 participating universities; just one year after it jumped to place 142 out of 516 universities, and last year (2017) reached a finally gratifying 114th place out of 619 universities (and 5th place in Italy). The explanation for this rapid improvement is unfortunately not only related to the actual interventions previously described. This kind of rankings is based on a self-filled up questionnaire, and as such we have learned from experience how to (correctly) describe and enhance the activities which have been carried on.

5. CONCLUSIONS

Being the Energy Manager at Politecnico di Torino for twelve years (2006-2018) has not been a simple business, especially whereas due attention has to be paid also to other institutional priorities like teaching, research and coordination of the Energy Engineering Program.

However, maintaining a precarious equilibrium among tasks and people pertaining to very different contexts, this activity provided to the author of this paper many gratifications, especially since when PoliTO started to embrace sustainability policies with sincere conviction.

Thanks to this coordinated effort we achieved the goal to provide a good quality of life and comfort to a growing number of personnel and students, while reducing energy consumption, environmental impact and costs.

Last but not least, in a technical university like Politecnico di Torino, we have more and more involved our students in the sustainable activities going on in the Campus. We have shown them, and to our stakeholders at large, that research and education on sustainability are not only on scientific papers and lecture notes: day after day they become concrete measures which will hopefully make our Campus a sort of collection of good practices that may be seen, touched and imitated.

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