An Evidence Based Online Design Platform: Challenges and Limitations

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Abstract

Historically, the problems associated with feedback in building energy consumption are threefold: a) a lack of information, b) a lack of effective use of the existing data, c) a lack of knowledge how to engage more than the interested few to understand and act on building performance. Whilst introduction of Display Energy Certificates (DECs) created a framework for information generation, their intended role is to place the subject building within the context of similar type of buildings but this data can provide little or no insight into the root causes of the energy performance. To go beyond the headline benchmarking of energy performance of buildings and to provide evidence based design advice to various stakeholders such as building designers, clients/investors, facility managers, and users on how their buildings are performing with regard to their architectural, engineering and occupancy characteristics we need an intelligent and rapid feedback tools/protocols.

It is well known that the useful feedback should contain extensive building design and performance data, benchmarked against similar type of buildings, and accompanied with 'do and do not' reflections from all key stakeholders involved especially the design team and facilities managers. In order to facilitate the need for more comprehensive feedback in the UK, a consortium of researchers from industry and academia has created an online Evidence Based Design platform called CarbonBuzz.

Having this in mind this paper describes the development of an Italian Evidence Based Design online platform using the UK based CarbonBuzz as an example. The paper is set out in 3 sections: a) a framework for platform development, analysing the source of data and completeness of records currently in CarbonBuzz in order to inform the development of the Italian platform and b) a data structure review, identifying potential challenges in translating

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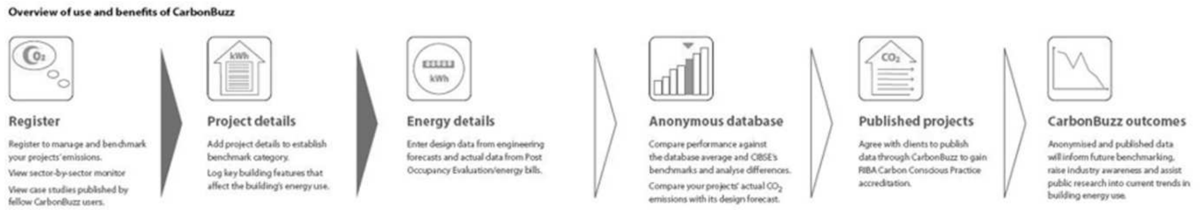
the UK data structure in the context of Italian regulatory requirements, and c) developing prototype, describing the data collection protocol used to inform the development of the Italian platform which follows Evidence Based Design principles with an aim to provide advice on how choices related to design, construction and management of a building impact its carbon emission. The paper concludes by reflecting on these limitations of this development programme and describes some additional features employed by the Italian platform in order to overcome some of these challenges.

Keywords: energy performance, low-carbon design, web platform, post-occupancy evaluation, occupant feedback

1. Introduction

Previous research studies clearly showed that ongoing efforts to deliver low carbon buildings while providing acceptable indoor environmental quality have had little success (Dasgupta et al 2011). The absence of readily available energy use data matched with descriptors for physical forms, indoor environment characteristics, occupant use of space and behaviour affects the accuracy of predicted energy consumption at the design stage and prevents the development of transparent and validated strategy for modelling energy use in buildings. (Prodromou et al 2009). This has been further substantiated by the opinion of 286 UK professionals regarding designing of low carbon buildings, which has clearly identified the inability to predict the actual consumption of buildings as one of the key risks (Dasgupta et al 2011). The discrepancies between operational versus designed performance of buildings have been additionally substantiated by Post Occupancy Evaluation studies (POEs) and as a result the designers and engineers are increasingly under pressure to provide more accurate estimates for energy consumption in buildings and supply guidance to achieve carbon reduction targets. Although essential, the detailed POEs are usually carried out by the interested few in academia and industry, on a small number of buildings involving expensive and time consuming monitoring campaigns, all of which is limiting the possibility to formulate robust Evidence Based Design guidance. Moreover, data collected is rarely collated in a single database and disseminated to inform further research.

To overcome these limitations a number of institutions have embarked on research programmes including: the Building Energy End-Use Study in New Zealand (www.branz.co.nz/BEES); the Energy Efficient Buildings Research programme by the Precourt Energy Efficiency Center at Stanford University in the USA



(http://peec.stanford.edu/buildings/); and a retrofit specific programme in Canada at the Institute for Building Efficiency (http://www.institutebe.com). In the UK, a consortium of partners led by Aedas R&D and supported by the Chartered Institute of Building Services Engineers (CIBSE), the Building Research Establishment (BRE), the Royal Institute of British Architects (RIBA), University College London (UCL) and AECOM, along with other industry partners, has developed an Evidence Based Design online platform – CarbonBuzz (www.carbonbuzz.org). Initially funded under University College London (UCL) UrbanBuzz Programme, CarbonBuzz is a free platform that collects anonymous energy building consumption data to highlight the performance gap between design figures and actual readings of recent projects (Figure 1).

Figure 1: Overview of CarbonBuzz

It is believed that this crowdsourcing data platform would enable researchers and building professionals to map and benchmark the annual energy consumption of a building from design to operation by fuel as well as by energy end uses. In doing so it highlights the gap between design stage predictions and operational energy use and draws attention to 'unregulated' energy use which have a significant impact on achieving expected energy performance (Figure 2).

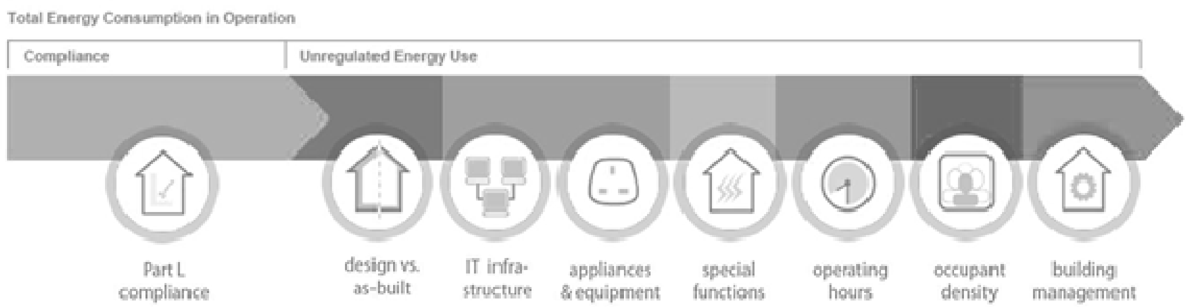


Figure 2: CarbonBuzz – mandatory compliance vs. actual performance

Unlike the UK Climate Change Act (2008) which has committed the UK Government to cut the CO_{2eq} emission by 80% by 2080, the Italian Government adopted lesser carbon reduction targets based on the revised EU Energy Performance of Buildings Directive (EU/31/2010) Strategy 20-20-20 which requires each Member State to reduce CO_{2eq} emissions and the consumption of primary energy by 20% (from 1990 level), and to increase the use of renewable energy supply by 20% by 2020. Within the European Action Plan for

Energy Efficiency, Italy requires benchmarking tools and methods that use actual consumption to verify theoretical estimations. Updating of the legislative framework in Italy (D.Lgs 2005/92, D.Lgs 2006/311, D.Lgs 2008/115, DPR 2009/59, D.Lgs 2011/28) as well as the technical norms (UNI-TS 11300) that introduced standards, methodologies and innovative tools for new construction and refurbishment of public buildings, further action is required to sustain the interventions in this sector. Having this in mind this paper aims to: a) analyse the source of data, completeness of records currently in CarbonBuzz in order to inform the development of Italian Evidence Based Design online platform and b) identify potential challenges in translating the UK data structure in the context of Italian regulatory requirements, and c) describe the data collection protocol used to inform the development of the Italian platform which follows Evidence Based Design principles with an aim to provide advice on how choices related to design, construction and management of a building impact its carbon emission.

2. Framework for Platform Development

To define a framework for the development of Italian platform, a simple statistical analysis was carried out to identify a) type of registered organisations, b) type of registered organisations uploading the energy data, c) type of registered organisations uploading design and actual data, d) number of projects with energy data by building type, and e) completeness of data records. This analysis provides an insight who might be the most interested stakeholders and potential supporters of the Italian platform.

Analysis of CarbonBuzz database shows that the platform had 575 registered users in July 2012, an increase of 42% from 2011 (July 2011- July 2012), across 17 company categories. [Since the time of this analysis the number of registered organisations increased to 674 to November 2012]. The major groups registered: architects (141 architectural practices registered; 23% increase), engineers (82 engineering practices registered; 21% increase) and consultants (59 consultancies registered; 51% increase). An 80% increase in University registrations has to be noted (74 universities registered) which means that 25% of all UK Higher Education Institutions (universities, colleges of higher education and further education colleges that offer HE courses) have been registered with CarbonBuzz (includes university estates as well as research groups). Other organisations include: business management (43), central government (7), computing companies (16), construction (23), local government (14), manufacturers (12), media (2), property management companies (22), quasi-governmental (19) and surveyors (3).

Table 1: Registered organisations contributing energy data

Company Categories	Number of Organisations Contributing Energy Data 2011	Number of Organisations Contributing Energy Data 2012	% Change
Quasi-governmental	8	23	188
Architects	82	100	22
Engineers	18	11	-39
University	2	2	0
Consultants	1	1	0
Business management	4	16	300
Local government	3	1	-67
Total	121	159	31

The overall number of organisation contributing design and actual data has not increased to the same degree as the total number of organisations registered with CarbonBuzz (Table 2). There has been an overall increase of 7%. Consistent with the makeup of the registered organisations and the 2011 data, architects still contribute the highest number of energy records (18 new projects). Table 1 shows large percentage increases in contributions from quasi-Governmental organisations (15 new projects) and Business Management (12 new projects) organisations albeit from a very low base. Note that the reduction in numbers is due to project deletions throughout the analysis period.

Table 2: Organisations contributing design and actual data

Company Categories	Number of Projects 2011	Number of Projects 2012	% Change
Architects	25	16	-36
Engineers	6	6	0
Business management	4	7	75
University	0	1	100
Quasi-governmental	8	15	88
Property	2	0	-100
Total	43	46	7

Table 3 shows that the number of projects with energy data in the database has increased from 299 in 2011 to 381 in 2012, this decreases to 319 if those marked as test are not included in the count. Education is the largest category contributing 42% of the total non-test buildings. 243 (76% of the total) of non-test projects have any energy data (either design or actual electricity or heat consumption data) of these 49 (15% of the non-test projects) have design and actual electricity data and 44 (14%) have design and actual heat consumption data. In total 40 non-test projects (12.5%) have design and actual electricity and heat consumption data for comparison in the database.

Table 3. Projects with energy data by CarbonBuzz sector

Sector	Number of Projects	Number of Projects (not including those marked 'Test')	Percentage of total (non-Test)
Civic & Community	11	11	3
Office	110	85	27
Education	151	135	42
Health	16	12	4
Residential	37	28	9
Retail	21	18	6
Sport & Leisure	20	19	6
Hospitality	6	5	2
Industrial	4	3	1
Other	5	3	1
Total	381	319	100

Of all the projects 96% (306 projects) have a gross floor area figure and 82% (262 projects) have project value associated with the project. However basic building geometry factors are less well represented; circa 15% of projects have a data entry for actual number of storeys and less than 10% have a figure for actual floor to floor height. Less than 50% of projects have figures for actual numbers of occupants and operating hours and almost no projects have detail on facility management arrangements.

Analysis of the data base has identified five types of data entry error: a) format errors, b) unit errors, c) boundary errors, d) category errors, and e) errors with a drop down classification. Most of the above errors can be omitted in the Italian platform through user guidance, adjustment to drop down menus or relational checks being built into the database.

3. Data-structure Review

CarbonBuzz is based on the data structure of the Display Energy Certification (DEC) system, set up as part of the UK's implementation of the EU Energy Performance of Building Directive (EPBD) since 2006. This certification rates operational performance – and the CarbonBuzz tool takes lessons learned from benchmarking actual energy use and applies them to inform design phase predictions. The procedures for a National Calculation Methodology (NCM) for the purposes of production of Energy Performance Certificates (EPC – asset rating) and Display Energy Certificates (DECs – operational rating) are incorporated in software tools developed by the UK Government (SBEM – non domestic and SAP – domestic buildings), however other approved Dynamic Simulation Models (DSM) can be used (IES, TAS, Design Builder). This approach is used for demonstrating compliance with Part L2a of the UK Building Regulations (HM Government 2010). CIBSE TM22 Energy Assessment and Reporting Methodology (CIBSE 2012) data structure represents the foundation of the DEC system and allows for the collection of building information in very general terms from the 'top down', or for users to build up very detailed illustrations of data use from individual loads from the 'bottom up'. The aim of using TM22 as a basis for collection is in order to provide cross industry coordination and take advantage of data that may already be collected elsewhere.

The current published CarbonBuzz database is split into two subsets: ‘Project Details and ‘Energy Records’. For a detailed structure of this complex database please register as the CarbonBuzz user. Project Details describe the characteristics of the building and are in turn broken down into:

- Project Details (per project) detailing: building location, building use, number of zones, building ownership and tenancy, design/management teams;

- Project Details (per energy record) detailing: data collection dates, if data comes from a particular data set (i.e. TSB BPE or DEC data), benchmark targets/rating system used, which edition of building regulations applied, embodied energy, any uploaded drawings or images, cost;

- Project Details (per zone) detailing: servicing strategies (lighting, heating, ac, nat. vent etc.), low and zero carbon technologies employed, building fabric details (proportions of glazing, U-values etc.), air tightness, building dimensions, separable or special energy uses, occupancy rates, facilities management strategies.

Energy Records describe the energy consumption associated with the building and are split into Design and Actual data. Each contains:

- Source of data (software if prediction, meter type/frequency if actual);

- Total Electrical Energy use broken down into: Low and zero carbon uses/sources, Building loads (services, lighting), Occupational loads (small power, ICT, catering transport, special or separable functions);

- Total Non-Electrical Energy use broken down into: Low and zero carbon uses/sources, Building loads (services, heating, DHW), Occupant Loads (catering).

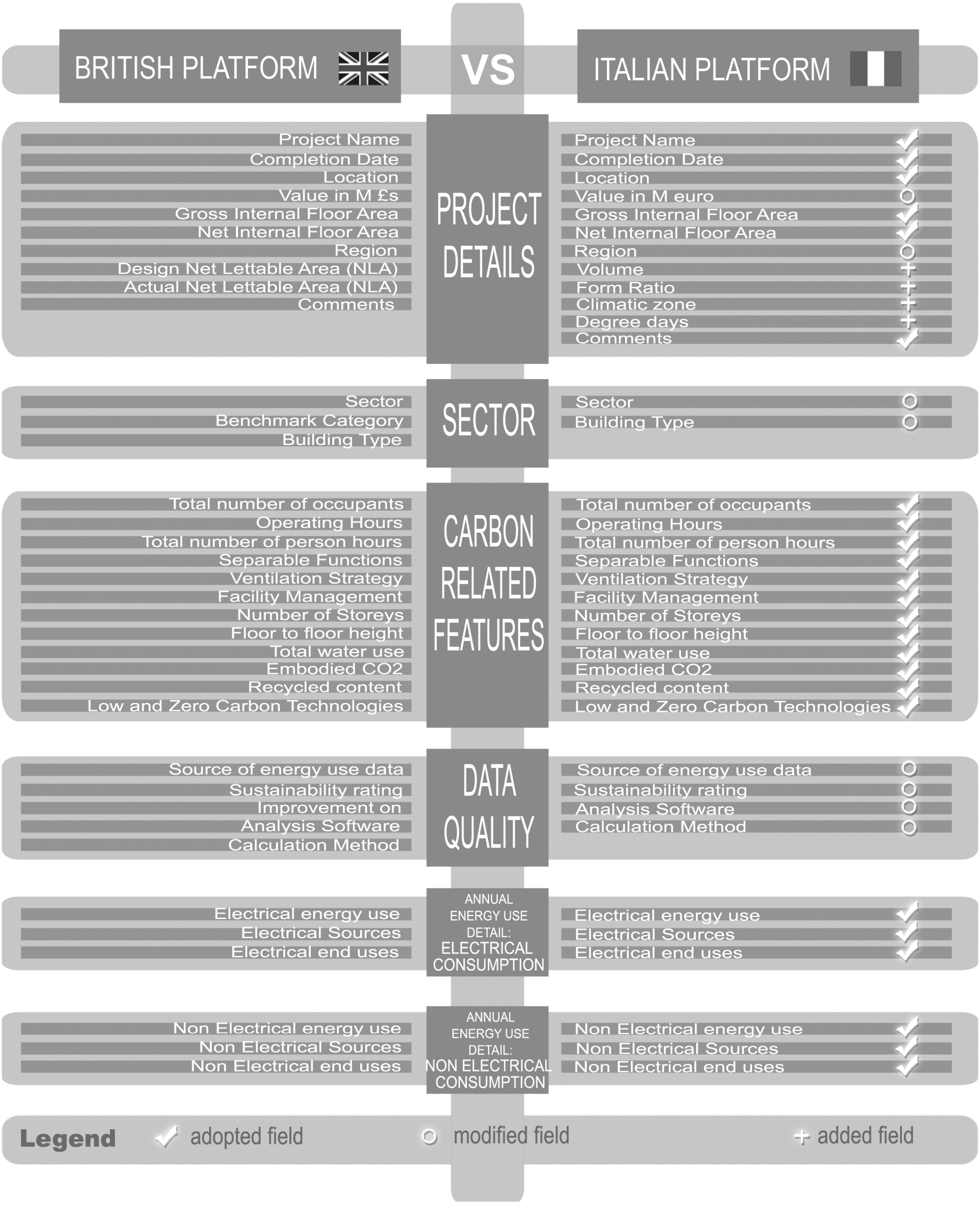
Unlike the UK where users can compare design stage carbon emissions, calculated during the planning and detail design phases against the DEC benchmarks, calculated in kg CO_2/m^2/year (kWh/m^2/year), in Italy the legal limits have been set based on an Energy Performance Index (EPi limit) that is evaluated in kWh/m^2/year (for residential buildings) and kWh/m^3/year (for non-residential buildings) which deals with winter heating performance only. The Italian Guidelines for Energy Classification of Buildings (D.M. 26/06/2009) prescribes that the energy class of a building, EPgl (index of global energy performance), is calculated using the following equation (Bianchi et al 2009):

EPgl= EPi + EPacs+ EPe + Epill,

where: EPi: index of energy performance for heating, EPacs: index of energy performance for the production of hot water, EPe: index of energy performance for cooling, and EPill: index of energy performance for artificial lighting. At the moment, the energy class for a building is still determined by the performance index for winter heating (EPi) and hot water production only (EPacs) (Romani et al 2011). For summer cooling, only a qualitative assessment of the building envelope characteristics is required (Boffa et al 2012). The EPi index has to be lower than the minimum fixed value defined by the following parameters; a) heating degree-days for selected climatic zone, and b) surface (external building envelope area) to volume (building volume heated) ratio (S/V). Some regions, in anticipation of the long delayed national guidelines, have developed their own procedures on minimum requirements and the certification of buildings. The Italian platform will incorporate the definition of the minimum requirements and methodologies for the assessment of the cooling energy performance (EPe), also for artificial lighting (EPill), and the regulations on the use of renewable energy technologies in buildings (EU 2008).

Furthermore, the following issues have led to a modification and development of new datafields in the Italian data structure: a) *modus costruendi* (heavy weight continuously supported structure vs. light weight wood/steel frame structure), b) lack of ‘cradle to gate’ embodied carbon data in Italy: some research has been carried out in this field including the so-called “Accordo di Programma” between the Region Marche and ITACA, l’ITC-CNR and the Polytechnic University of Marche which developed the first institutional database of building materials and products, which follow the CEN TC350 life-cycle analysis methodology developed by the EU, c) a large variety of the environmental sustainability protocols used which are used only in two Italian regions (ITACA Protocol, BREEAM, LEED Italia, CasaClima, Passivhaus), d) lack of regulatory requirements to develop a detailed submetering strategy to quantify energy end uses such as heating, cooling, lighting, small power loads, etc. Figure 3 compares the structure of both British and Italian online platforms.

Figure 3: British vs. Italian database structure



4. Developing Prototype: Data Collection Study

For energy performance feedback to be informative it needs to capture both building design and performance data. Buildings can then be benchmarked against similar typologies and ‘do and do not’ reflections can be added by key stakeholders involved especially the design team and facilities managers. A data collection study was carried out in Rome to identify potential problems in translating CarbonBuzz data structure to the Italian regulatory environment and practice. The work was structured around five key phases:

4.1 Selection of case study buildings

Six buildings were selected to cover a range of ages, building types and building systems. The buildings were listed in three major groups: a) buildings using non-electrical energy sources for heating with no cooling systems or mechanical ventilation (1 case study), b) buildings using non-electrical energy sources for heating with electrical cooling and mechanical ventilation (3 case studies), and c) buildings using electricity both for heating and for cooling (heat pump) or mechanical ventilation (2 case studies).

4.2 Data Collection

The data gathered from the Roma Tre University Estates included the following: a) architectural and morphological parameters (location, orientation, year of construction, heated building volume, usable floor area, building envelope area, S/V ratio, number of floors, floor to ceiling height), b) use of buildings (academic department, number of occupants, office hours, and system operating hours), c) building construction parameters (building envelope characteristics, glazing parameters, etc), d) building services data (heating, cooling, mechanical ventilation, etc.), e) facilities management (energy data, review of energy certificates, interviews with energy managers).

4.3 Inspection of the sample buildings

As part of the data collection the team carried out a series of site visits to verify the information obtained from the desktop study. At this stage further data was collected about mechanical systems via questionnaires aimed at facilities managers. These covered energy consumption patterns and contributing factors including the use of electrical devices, artificial and natural lighting, heating/cooling installations, natural and artificial ventilation.

4.4 Collection of electricity consumption data

Apart from the data obtained from the energy performance certificates the following data was acquired from the energy managers: a) monthly electricity bills and b) half-hourly electricity data for a full year for all the buildings in the pilot. Half hourly electricity data shown in Figure 4 were used in to highlight the limitations of the Italian EPi calculations which according to 2008 implementation of EPBD excluded both EPe: index of energy performance for cooling, and EPill: index of energy performance for artificial lighting.

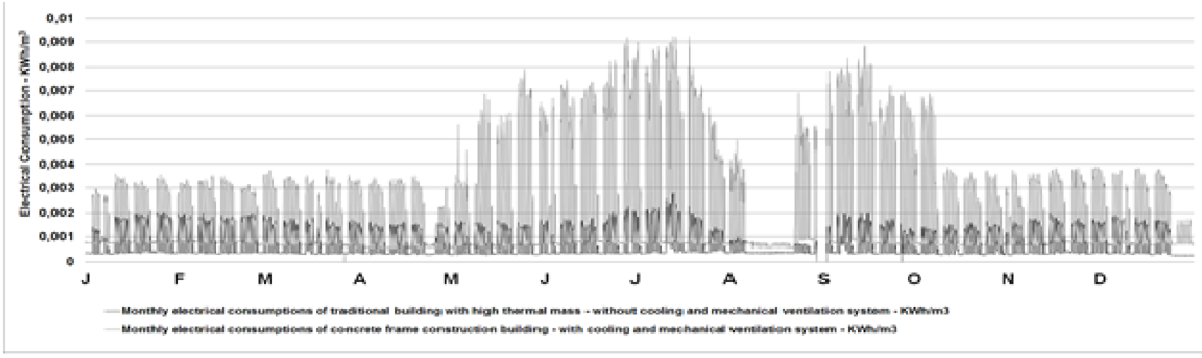


Figure 4: Electrical consumption – naturally ventilated heavyweight building vs. lightweight building with mechanical cooling (half hourly data)

4.5 Non-electric energy consumption

Figure 5 provides the headline energy consumption results obtained from the POEs carried out in 6 case studies. Energy end uses estimated in this way were uploaded into the platform, where it is possible to read either by project or by portfolio.

In this figure and for each case study, electrical and non-electric energy consumption refer to envelope's characteristics (form coefficient S/V represents the ratio between dispersing area and heated volume of the building), structural type (massive building/concrete frame), presence and types of plant systems (heating, cooling, mechanical ventilation).

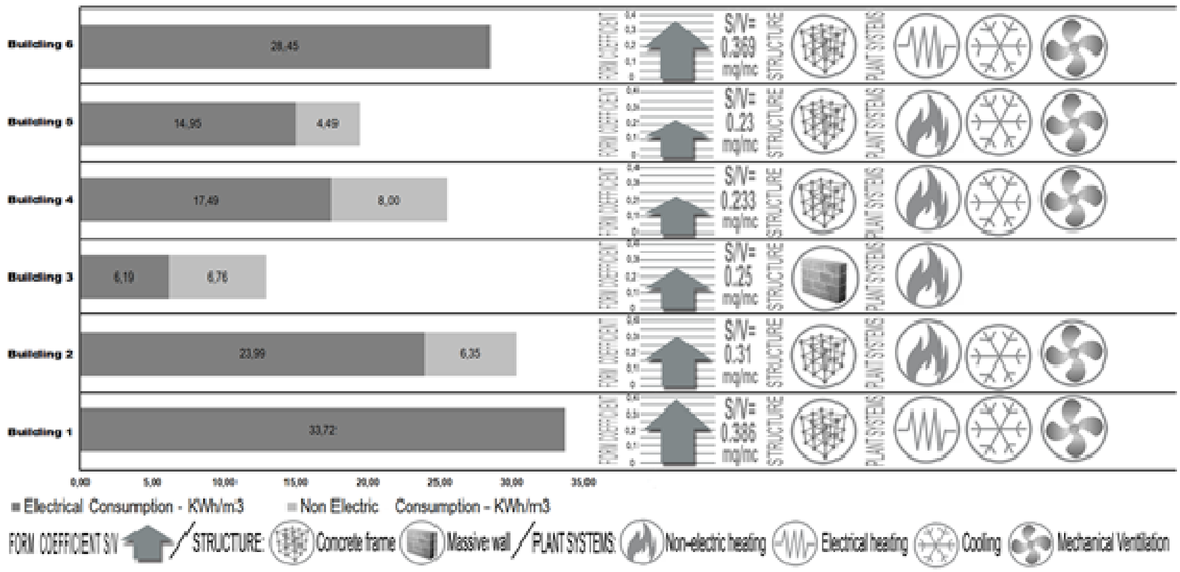


Figure 5 : Overview of energy consumption in 6 case study buildings

Table 4 compares EPi values, which were adjusted to take into account the equipment's intermittence, the building's structural inertia and the equipment's operating hours, with the actual energy consumption and EPi lim values.

For the buildings that have non-electric heating, table 4 compares Epi values (energy performance index) – which derive from energy certificates and were re-evaluated by considering a correction factor due to intermittency of the equipment (which is calculated on inertia of the building and operating hours) - with actual energy consumption derived from non-electric bills; both values were compared with the limit values of energy performance (Epi_{lim}), established by law: in almost all cases the real consumption and the consumptions in the energy certificates were higher than the limit value, but surely the real ones were closer.

Table 4: Actual vs. estimated energy consumption data for 4 case studies (with non-electric heating)

case study	EPi [kWh/m^3/y]	energy class	intermittent factor	revalued EPi [kWh/m^3/y]	non-electric consump. [kWh]	Heated volume [m^3]	non-electric consump. [kWh/m^3/y]	EPi lim [kWh/m^3/y]
2	30,89	G	0,6136	**18,95**	1073337	84476	**12,71**	**7,86**
3	31,03	G	0,7994	**24,81**	119203	17625	**6,76**	**6,89**
4	21,46	F	0,6136	**13,17**	625526	78169	**8,00**	**6,61**
5	35,50	G	0,6136	**21,79**	464198	51645	**8,99**	**6,56**

5. Conclusions

This Italian-UK collaborative research project has reinforced the need for more transparency in reporting energy consumption data to address the lack of evidence and clarity about building performance. It is clear from this study that this data is difficult to get hold of and compare ‘like for like’ even across a region where this is mandated.

Although the CarbonBuzz has been created to address this problem, a brief analysis of the source and quality of data currently in CarbonBuzz demonstrates that the data available in the public domain is still not sufficient to support the development of an alternative approach (Hawkins et al 2012) for understanding the impact of building design parameters on the energy use in buildings. This is reflected in the fact that only 8% of 575 registered users have contributed both design and actual data. However, the fact that there is a steady increase of architectural, engineering practices using the platform indicates that there is an appetite for this approach. Indeed, the next UK release of the platform has built on feedback from a broad range of stakeholders to incorporate additional functionality to manage and share such data transparently over time and to improve the capture of physical forms, indoor environment characteristics and occupant use of space and behaviour.

The Italian prototype has adopted what were perceived as the strong points of the CarbonBuzz approach including the following principles: a) data structure facilities creation of a database divided into categories where data about CO_2 emissions can be collected and compared like for like, b) facilitating comparison between energy certification and operational energy use (adapted to Italian regulatory context), c) analysis of end use energy consumption, and d) ease of use and accessibility for all users, online sharing of data relating to consumption. The data collection and processing pilot study carried out on 6 university buildings has highlighted how hard it was to get evidence and clarity about building performance even for new buildings. Capturing project and energy use data from Italian case studies has identified some potential limitations of using the UK CarbonBuzz platform on international projects. These limitations arose from the type of data available, differences in the implementation of EPBD regulations and Italian building types and construction systems. The data collection and processing study provided a very useful insight which has been used to develop a prototype for an Italian online platform which will be presented at the CIB 2013. Further data fields have been inserted into the platform with regard to the following: a) building envelope and its exposure and occupancy to enable implementation of Italian EPBD protocols.

This paper underlined some critical features, together with the necessity of future actions aiming on the one hand to the fine tuning of the system of systematic survey of data and of their informatics management, on the other to the environmental mitigation and infrastructural updating for the energy efficiency of the examined buildings.

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