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CAPTURING THE VIEWS OF ARCHITECTS ABOUT BUILDING PERFORMANCE SIMULATION TO BE USED DURING DESIGN PROCESSES

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ABSTRACT

In the past 30 years, much effort has been directed to make building performance simulation become inherent in architectural practice. Anecdotal evidence however shows that it still a long way for this goal to be achieved. This paper presents the outcome of a survey conducted in Australia, India, the US and the UK, to investigate difficulties that architects have to overcome in their day-to-day practices and identify the reasons why using building performance simulation, regardless how friendly the tools are, is still not and may never be in the mainstream of their practices. Based on the survey, the paper proposes a number of recommendations to overcome this challenge in line with IBPSA's vision on bridging the gap between research and practice

INTRODUCTION

It has been long argued that design decisions made by architects in early design stages will have long-term impact on the performance of the building once it is built and operated (Givoni 1988, Holm 1993, Hayter et al. 2001, Attia et al. 2012a). In response to this, and together with the developments that have been occurring in the building performance simulation (BPS) area, for almost 40 years there has been much work done to develop "architects-friendly" BPS tools. The intention of such development is to provide tools that can assist architects during early design processes in making decisions about the building design.

During the earlier years, a number of academia and researchers with some architectural background (or who had worked with architects) developed such tools. These included:

- Work by Milne and others at UCLA from the late 70's to early 90's with Solar-5, Daylit, Superlite and Climate Consultant (Milne and Yoshikawa 1979, Milne et al. 1983, Clayton et al. 1988),
- Work by Papamichael at LBNL in the 90's with Building Design Adviser (Papamichael et al. 1996) and by Balcomb at NREL with Energy-10 (Balcomb 1997),
- Work by Degelman at Texas A&M University with RENCON, EnerCAD, and EnerWin (Degelman and Kim 1990, Degelman and Soebarto 1995, Degelman 1997).
- Work by Marsh during the late 90's, who developed Ecotect while at the University of Western Australia (Marsh 1996, 2000). The software was later acquired by Autodesk in 2008.

Along with the above developments, both government institutions and commercial companies also developed graphical user-interface programs used as the front-ends for well-established simulation programs at the time, such as DOE-2, BLAST and TRNSYS, and later for EnergyPlus (Crawley et al 2001). These included:

- Work by Huang with DrawBDL (Huang 1994) and Hirsch with PowerDOE (Hirsch et al. 1998) to be used as the user-interface for DOE-2.
- Work by Christensen et al (2006) with BEOpt and Tindale and Potter (Design Builder 2015) with Design Builder, to be used as the front-ends for EnergyPlus.

In the meantime, others have continued to develop stand-alone BPS programs (with graphical user interface), including ESRU developing ESP-r (Sars, Pernot and Wit 1988, Clarke and Strachan 1988), EDSL (2015) developing Tas and Integrated Environmental Solution (2015) developing IES Virtual Environment.

While in theory the above tools are supposed to assist architects during the design process, anecdotal evidence shows that they are still not the mainstream tools used by architects to design buildings, hence they are not particularly popular among practising architects (with the exception of Ecotect). In order to bring BPS closer to architects and better inform the architects during the design process, recent attempts have focused on integrating existing 3D modelling with BPS tools. A number of BPS programs are now linked to, or can be performed by using, CAD software such as SketchUp, AutoCAD, Microstation and Rhinoceros. Apache thermal simulation of IESVE, for example, can be performed through SketchUp (with IESVE plugin). DIVA, which uses EnergyPlus as the engine, simulates 3D models generated in Rhinoceros/ Grasshopper. OpenStudio performs thermal simulation using EnergyPlus for 3D models created in Trimble SketchUp. Rhinoceros

and SketchUp can also be used to run Radiance-based daylighting simulation program DAYSIM.

Another type of model integration is by a central model method (Negendahl 2015, Mitchell 2011). This method is based on a centralized Building Information Modelling data framework known as BIM. In this method, various tools, one of which performs BPS, read and write to the same central building model. A BIM tool such as Revit or Microstation becomes the central design model, which provides the geometric detail for BPS, as well as to perform other purposes such as construction documentation and specification. One example of this is AECOsim Building Designer (ABD) built on the Microstation BIM platform (Bentley 2015). ABD is a full-featured architectural, structural, mechanical and electrical BIM platform that also integrates EnergyPlus and Radiance for early conceptual design. The challenge of this method, however, as pointed out by Negendahl (2015) is in defining a common exchange format. For example, for documentation and specification purposes, all of the building construction and components are modelled in detail; however, such detailed modelling is not necessary for an energy simulation. Anecdotal evidence also shows that the ones who are supposed to perform BPS by using a BIM model tends to rebuild the model using their own BPS tool, instead of using the BIM model provided, simply because the BIM model is too complicated for performing BPS (Malin 2007).

It is important to note that the use of BPS has significantly increased in the last 10 years due to the use of environmental performance rating tools to obtain green building certification or rating. A significant portion of assessments in LEED, BREEAM and Green Star, for example, is on the building's energy use, normally predicted by using BPS. It is however unclear who usually performs the simulation or conducts the assessments. Shi and Yang (2013) imply that currently architects do not perform such assessments.

The study presented in this paper investigated whether, after more than 30 years of trying to bring BPS closer to architects, or vice versa, such attempt has been successful. It was also questioned whether architects in practice do approve of BPS and use it in their day-to-day job. Researchers continue to claim that architects should play a major role in designing energy efficient and the so-called green, sustainable buildings, and offer the promise that BPS will help architects achieve that goal. Yet the take up rate of BPS by architects is reported to still be quite low (Horvat and Dubois 2012, Kanters et al. 2014, Lin and Gerber 2014).

Numerous studies on the relationship between BPS and architects tend to focus on two things. First is to find out the barriers in using BPS tools amongst architects, and second is to come up with the 'wish-list' of what architects need in BPS tools (for example, Hopfe et al. 2005, Hopfe et al. 2006, Attia et al. 2012b, Kanters et al. 2014, Son et al. 2015). Though having different foci, such studies are based on the same premise, that is, architects are expected to perform BPS, and if not, it is important to identify the problems and find out the solutions.

The work presented in this paper tries to take a step back from expecting that architects should perform BPS in order to achieve an energy efficient, green building. Instead of promoting this idea, the authors argue that it is necessary to present the above statement to architects as *a question* in order to gather a more realistic picture. The two main questions presented to the architects are (1) "Do you think it is a reasonable expectation that architects (must) do building performance simulation in order to produce well-performing buildings?" and (2) "How do you deal with this issue in your practice?" Thus, instead of focusing on the tools, the study focused on the practice or operation of the architects or architecture firms.

As the uptake of BPS in architectural practices is still not great, the study hypothesized that: (1) performing BPS is not part of the main responsibility of architects (regardless of user friendliness of the BPS tools), and (2) there are further issues (other than the tools) that prevent architects from using BPS.

By conducting this survey, it is expected that the barriers of using BPS current architecture practice can be better understood. In IBPSA's recently published position paper (Clarke 2015), Proposition 1 aims to establish requirements specification for future BPS tools. As many architects are members of the organization, we believe that this survey will contribute to achieve this aim by "establishing a vital bridge between research and practice" (Clarke 2015).

METHODS

The study was intended as pilot work that may lead to a larger study in the future should the results indicate the need for a more in-depth study. The study was conducted through on-line survey to practising architects in four countries: the US, Australia, India and the UK. The invitations to participate in the survey were distributed to the local institutes of architects as well as through direct contacts. Note that it was a requirement of the study for these architects to be registered architects (opposed to for example architectural technicians) who may or may not have been practising as "environmental" architects and who may or may not have been using BPS tools. The survey was open for one month from February to March 2015.

There were 25 questions in total. The questions were mostly multiple-choice or single answer from a list of choices; however, for every question the respondent could add an additional answer. The summary of the questions is shown in Table 1.

Table 1
Summary of questionnaire

	Demography
1	General information, optional (name and contact details)
2	Country
3	Size of firm (small: < 10; medium: 10 < size < 30; large: >30)
4	Years of experience (< 5; 5 < yrs < 10; 10 < yrs < 20; >20)
	Operational
5	Types of projects mostly deal with (e.g. residential, hotel, office, educational, health care)
6	The tasks spent with the most time (e.g. planning, meeting clients, meeting others, design)
7	Design and documentation tools used in the firm (e.g. hand drawing, physical model, AutoCAD)
8	Types of communication mostly used (e.g. phone, in-person, email, file exchanges)
	Building performance or design analysis
9	Types of specialized building performance or design analysis (e.g. shading, energy, daylighting)
10	Who conducts the analysis (e.g. project architect, in-house specialist, outside specialist)
11	How the analyses is mostly conducted (e.g. rule of thumb, design guideline, computer program)
12	If using computer program, what software is used (e.g. Design Builder, IESVE, Ecotect)
13	Reason for using those software programs
14	Level of satisfaction with the software (from very satisfied to very dissatisfied)
15	If not using computer simulation, what reason
16	If analysis is conducted outside, what are the reasons
17	If analysis is conducted outside, how the analyses is mostly conducted (e.g. rule of thumb, design guideline, computer program)
18	If using computer program, what software is used by outside firm (e.g. Design Builder, IESVE, Ecotect)
19	If analysis is conducted outside, how does the outside specialist attain the building model (e.g. use file provided, import relevant information only, create own model)
20	How are results communicated back (e.g. phone, in person, email)
21	How satisfied with results from specialist (from very satisfied to very dissatisfied)
	Expectations and Recommendations
22	If environmental analysis is perceived important by clients, what should happen within the firm (e.g. train specialist, invest in tools, develop guidelines)
23	If environmental analysis is perceived important by clients, what should happen within the architecture profession (e.g. train specialist within the firm, invest in tools, develop guidelines)
24	Suggest future ways to incorporate building performance assessments if you think important
25	Any other comment

RESULTS

General

In total, we received 118 responses with the majority from the US (67.5%), followed by India (19.7%), Australia (7.7%) and the UK (4.3%). The responses from Australia and the UK were below expectations but this may be due to the very short time frame and change of the office bearers of the architecture institute at the time of the survey.

Out of these 118 respondents, majority (53%) came from small firms (less than 10 employees), followed by large firms (more than 30 employees) at 32.5% and medium size (between 10 and 30 employees). In all the countries, the respondents included a number of world-renowned architecture firms. Majority of the firms or architects who responded had more than 20 years of experience (59%) while there were 21.4% of respondents with between 10 and 20 years of experience, and 12.8% between 5 and 10 years. Only a handful had less than 5 years of experience.

The types of projects that the respondents had worked on varied greatly, but most had worked with office building projects, educational buildings, and single dwellings. Other building types included civic buildings, retail buildings, hospitals, hotels, warehouses and short arenas.

We ask the respondents what tasks they spent most of their time in a project. They indicated that they spent most of their time for, in the following order, design development, planning, meeting with clients, communicating with other consultants, design exploration and documentation. Generally, they did not consider design analysis a high priority, together with design presentation and writing specification. The respondents spent the least amount of time doing surveying, cost estimation and on-site supervision.

During the design process, while using CAD programs is usually the norm in contemporary architecture practices, the survey shows that nearly 72% of the respondents still used, or at least started the project with, hand sketching/drawing. This was

followed by using the SketchUp program to develop the design (58%), and then using AutoCAD (56%) or Revit (42%) to document the design. Physical models were also used by around 23% of the respondents. See Figure 1.

Nearly 20% of the respondents also provided information about other tools that they used during the design process. These tools were Ecotect, Vectorworks, VisualDOE, DesignBuilder and eQuest (in that order). This indicates that some respondents did perform BPS during the design process and considered these tools as 'design tools'. Other tools mentioned were Green Star, Solibri, Onuma, REScheck, COMcheck and Naviswork.

To communicate with other consultants, majority of the respondents still relied on direct in-person meetings, phone conversations and sending or emailing drawings. Only 20% of the respondents implemented BIM approaches or used BIM tools and less than 10% used collaborative tools. See Figure 2.

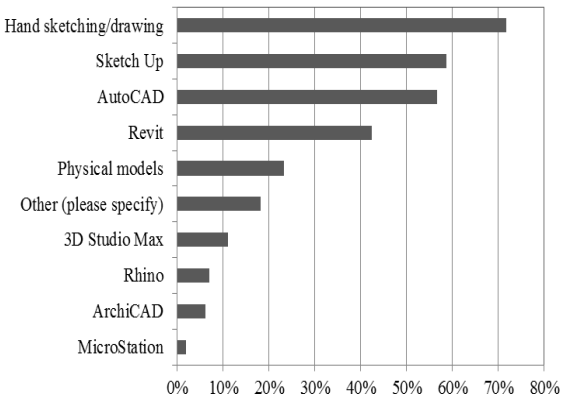


Figure 1

Tools used to design and document

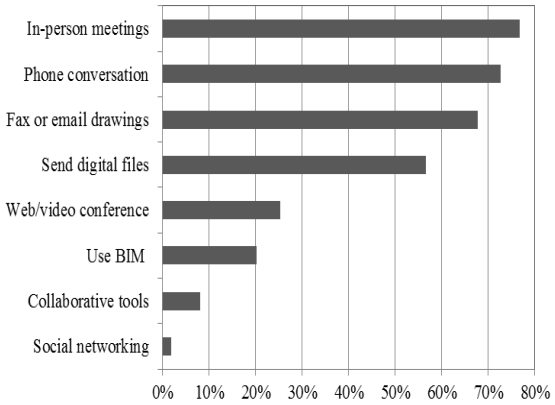


Figure 2

Forms of communication with other consultants

Building performance or design analysis

In-house versus outside experts

More than 80% of the respondents claimed that they or their firms performed building performance analysis, though not necessarily by using any BPS tools. Out of those who responded, more than 60% conducted solar access/shadow/shading analysis as well as energy analysis. Thermal comfort in a passive mode and daylight analyses were the next types of analyses conducted, followed by electric lighting and acoustical analyses. A few also mentioned that they performed some environmental analysis. However, when asked further about who conducted the analyses, nearly half responded that the analyses were conducted by a combination of in-house experts and outside consultants, and only 26% stated that the analyses were conducted by the project architect.

Interestingly, more than 65% of the respondents did not answer when asked about how the analyses were performed, whether by using rules of thumb, design guidelines or standards, or computer simulation. It is suspected that those who did not answer this question were those architects who did not perform the analyses (as only 26% of the architects did) and they were not sure how the analyses were done, be it conducted by specialists in their firms or by the outside consultants. Out of those who responded, 68% mentioned that they used BPS programs, while 32% used either rules of thumb or design guidelines.

For load and energy simulations, eQUEST was the mostly used tool by in-house specialists, followed by IESVE then DesignBuilder and EnergyPlus. Other tools used by the respondents included DOE-2, Ecotect, PHPP, SAP/SBEM/PHPP, CPHC, as well as HAP/Carrier and Trace/Trane. Ecotect, despite the fact that it is no longer part of AutoDesk suite, was the tool used the most by the architects, for solar shading and daylighting analysis, followed by SketchUp, then IESVE, Radiance through IESVE and Radiance through Design Builder. See Figure 3.

Most respondents (88%) did not provide the reason for choosing to use the above software. Of those who responded, ease of use, reasonable outputs and affordable cost were the three main reasons for choosing the software. They also mentioned integration with 3D modelling software they used for design as a reason.

In general, they were 'reasonably' to 'very satisfied' with the BPS software used and only less than 5% stated that they were not satisfied due to the cost and sometimes inaccuracy in the results, without referring to any particular software.

When consultants outside the architect office conducted the building performance analysis, there were several main reasons for doing so, including:

- There was no specialist within the firm (23%).
- The cost of the software was high (14%) and they did not have enough projects to justify the need to conduct building performance analysis (12%).
- More priority was given to the design process (13%)

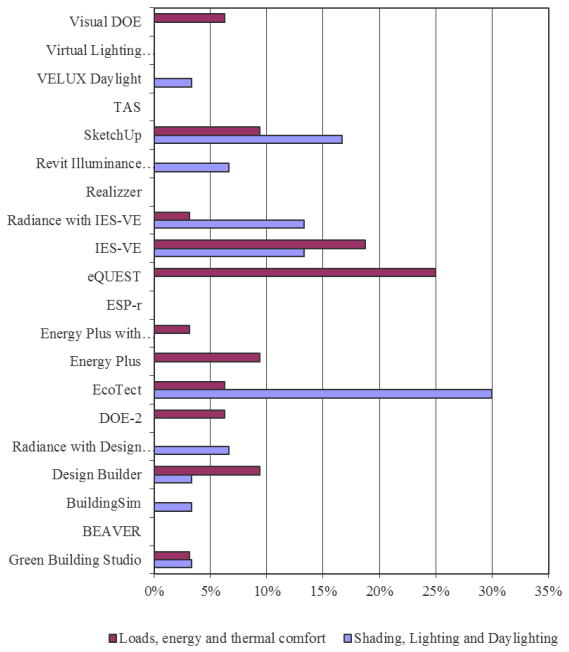


Figure 3

BPS tools used by the respondents

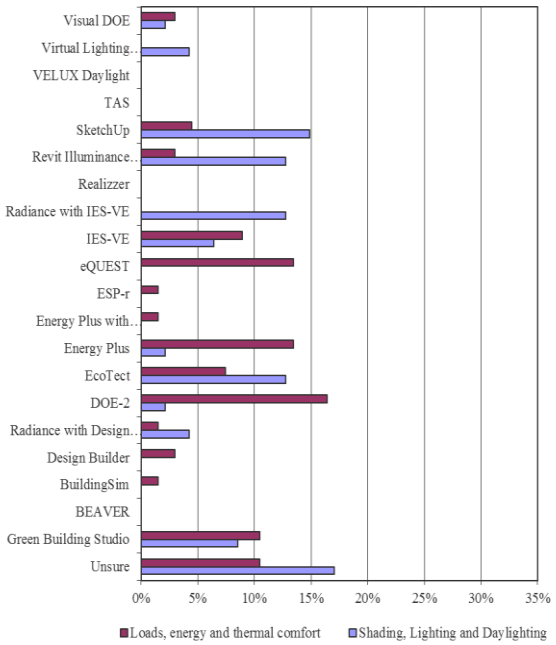


Figure 4

BPS tools used by the external specialists worked for the respondents

- Even if the specialists existed within the firm, they did not have the time to do the analysis (21%), and
- Such analysis was not included in the fee structure hence it was not feasible in terms of cost return (12%).

When external consultants conducted the building performance analysis, nearly 80% did the analysis using BPS tools while the rest used design guidelines. The external consultants mostly used DOE-2, eQUEST, Green Building Studio and IESVE for load and energy simulation whereas SketchUp, Revit Illuminance, Ecotect, Radiance with IESVE and IESVE were mentioned as the tools used for solar shading analysis. See Figure 4. It is important to note that more than 15% of the respondents did not know what tools their external consultants used.

Since more respondents used external consultants than conducted building performance analyses internally, it was important to know how they communicated the project to the external consultants and how the consultants communicated results to the architects. About 60% of the respondents stated that the external consultants used the drawing file (presumably 3D modelling or 2D drawing file) from the architect however modified the file and only used the relevant information to be used in the analysis. About 22% stated that the external consultants would create their own file for the analysis, while the rest (18%) stated that both the architects and the external consultants used the same BIM model.

Majority of the respondents stated that the external consultants communicated the results to the architects by providing a written summary (91%). They also communicated through in-person meetings (53%), by phone conversations (34%) and tele-conferencing (9%). Only 13% used BIM models to communicate the results to the architects. About 85% of the respondents stated that they were satisfied with the reports provided by the external consultants while the rest were rather dissatisfied. Of those who were dissatisfied, they mentioned that they wished that the analysis had been performed by in-house experts, but they faced the barriers, as mentioned earlier.

Expectations and recommendations

While 74% of the respondents admitted that they or their firms did not necessarily conduct building performance analysis, more than half acknowledged the important of such analysis and tools. However, in order for architects or architecture firms to perform such analysis or use such tools, the respondents recommended a number of issues to be first addressed, in the following order:

1. Incorporate performance assessment into the fee structure
2. Invest in tools or software
3. Train specialists within the firm
4. Develop or access procedural guidelines to prepare drawings to be used by external specialists, and
5. Have access to, or use software with, higher capability of interoperability.

Thus, there seems to be two different directions in the recommendations by the respondents. The first one is aiming at performing the analysis within own firms by investing in tools and training. These are

reflected in the first three recommendations above. The second seems to suggest 'business as usual', reflected in the last two recommendations, however they also suggested the need to develop some guidelines to prepare building drawings in such a way so that they will be easily used by the external specialists to perform building performance analysis. Some of the respondents, however, suggested no change at all to the current practice of architects.

Of those who perceived that increasing the use of BPS in architecture firms would be necessary, nearly 80% suggested that there should be on-going professional development in building performance. Half of the respondents also stated that building performance should be made compulsory at the tertiary education level while about the same number of the respondents urged that BPS should become part of the required skill for architecture registration. In other words, improving architect's knowledge about environmental issues and building performance, whether it is through tertiary education or continuous training in practice, is considered to be the first important step to take. Then to ensure that architects will perform building performance analysis or use BPS tools, the service to doing so has to be included in the architect's fee structure.

DISCUSSION

This study has shown that a large number of architects (74%) surveyed do not use BPS in their day-to-day practice. Design exploration and development, planning, meeting with clients, communicating with other consultants, and documentation are the main activities of an architect with far less time is spent on design analysis. For some of the architects surveyed (18%), however, design exploration and development also included using computer tools such as Ecotect and Visual DOE, indicating that for some, design analysis was conducted throughout the design process and not seen as a separate activity.

Despite the fact that in the US the General Services Administration (GSA) mandated that new buildings, through its Public Buildings Service (PBS), use BIM, and in the UK BIM Level 2 has been mandated for use on all government-funded projects from 2016, it is interesting to note that more than 70% of the respondents (still) used hand drawing. These hand drawings are often accompanied by using CAD tools such as SketchUp, AutoCAD and Revit which are the three most frequently used CAD tools by the respondents, in that order. It is also as interesting to note that the respondents mostly (still) adopted the traditional ways of communication, such as in-person meetings, phone conversation, and sending digital drawings to the other consultants rather than implementing BIM approaches and using collaborative tools.

Although the respondents did not spend much of their time to conduct design analysis, they or their firms did perform building performance analysis, particularly on solar access/shadows/ shading. This analysis, however, was not necessarily conducted in-house; 74% indicated that such analysis was usually conducted by a combination of in-house and external experts or consultants. In either case, more than half would use BPS to conduct the analysis.

The reasons for involving external experts or consultants varied from not having the relevant experts within the firm, high cost of the software giving more priority to design, to not having enough time to perform the analysis. A number of respondents also indicated that as long as performing BPS was not mandatory for any architecture services, it would be unlikely for architects to perform BPS because such work was usually not included in the existing fee service structure for the architects or the volume of projects that require such analysis was small.

CONCLUSIONS

This study intended to provide BPS researchers an insight of common practice and use of BPS in architectural offices in the US, Australia, India and the UK. Further, we attempted to demonstrate how architects perceive the role of BPS in their practice. We acknowledge that the total number of respondents in this study was very small, thus the use of the reported results must be done with caution. A larger study will be required to confirm the findings or otherwise, and to include other questions to investigate, for example, the impact of the regulatory contexts on architectural practices in different countries and the relationship between the age of the respondents and their willingness to adapt to changes and new practices.

Nevertheless, the results above confirm the hypotheses stated earlier. Most architects who responded to the survey did not see that performing BPS was their responsibility, while there were a number of issues other than the issues around the BPS tools themselves that prevented these architects from using them. In other words, despite the advancement in software developments including improved accuracy, usability or user-friendliness of the interface, and improved inter-operability between BPS, 3D modelling and other tools, these architects did not perceive such developments to be relevant to them, regardless of the expectation by BPS researchers and software developers that architects should perform BPS during a design process.

It is however encouraging that the majority of the architects surveyed (87%) expressed a desire to embrace building performance analysis and BPS as long as the fundamental issues above have been addressed. This is either by enhancing the capabilities of their own staff or by improving the communication with external specialists as well as having access to or using software with higher capability of interoperability.

Three main suggestions were proposed by the architects:

1. Making building performance analysis a compulsory subject in tertiary education of architecture,
2. On-going professional training in building performance and BPS, and
3. Making proficiency in BPS part of the required skills in architecture registration.

FINAL THOUGHTS

While many of the fundamental problems identified in the study can only be addressed by the architecture profession itself together with the relevant bodies such as the accrediting body of architecture schools and the architecture registration body, we suggest that IBPSA play a vital role in assisting the architecture profession to incorporate BPS in architecture education and practice. Through its members who work in academia or work with architects, for example, IBPSA can assist tertiary architectural education institutions as well as the architecture profession in developing course material and training packages relating to BPS. IBPSA can also assist architectural practitioners by developing guidelines on how to methodically work with common 3D modelling packages that have interoperability capability, such as SketchUp, Revit, and Rhinoceros, so that the 3D model can also be used to perform relevant building performance analysis (either by in-house or external specialists). This is in line with the vision of IBPSA and its first and further propositions (Clarke 2015):

- Proposition 14 on embedding BPS in practice
- Proposition 15 on education, training, and user accreditation.

The Energy Design Advice Scheme in Scotland in the late 90's (ETSU 1998) as well as the activity by the Scottish Energy Design Group (SESG 2005), which is an affiliate of IBPSA-Scotland, were some examples of the collaboration between the BPS community and the architecture profession (McElroy 2006). In the past few years, IBPSA-USA has also worked together with the architecture community to encourage the adoption of sustainable design practices and the use of BPS in early design process (IBPSA-USA 2015). Other IBPSA affiliates are encouraged to follow this path, even though the success of such effort is really on the architecture community itself to more actively engage and become a major player in the development of tools, the embedding of BPS in practice, and development of relevant training material.

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