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Adequacy of current design tools and methods for solar architecture – results of IEA-SHC Task 41's international survey

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ABSTRACT: The International Energy Agency's (IEA) Task 41: Solar Energy and Architecture gathers researchers, academics and practicing architects from 14 countries in a project pursuing the objectives to identify and address obstacles that architects are facing in solar design. Part of this three-year project is the development of an international survey -intended for practicing architects- addressing a broad range of issues from passive and active solar design to the availability and adequacy of existing digital tools. This paper presents parts of the results of this international survey related to Task 41 Subtask B: Tools and methods for solar design. The results show that there is still a need to improve tools and methods for architects such as increased support needed for decision-making and for solar design in CAAD tools. The results also state that architects' skills with regards to solar design in tools are 'poor' or 'very poor'. Furthermore, results indicate that decision-making for the integration of solar technologies in the conceptual phase is mainly handled by the architects alone. Finally, the results show that tools need to be simpler, that the interoperability between software needs to be improved, that tools should provide key data about solar energy aspects as well as explicit feedback to the architect, and that tools need a better visualisation especially for active solar energy systems.

Keywords: design methods, digital tools, CAAD, visualization, simulation, solar architecture, survey, early design phase

1. INTRODUCTION

The amount of solar energy reaching the surface of the Earth in one year is vast: it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined [1]. Also, more solar energy reaches the surface of the Earth in one hour than the total amount of energy used by humans in one year [2]. In many locations, the solar energy incident on the roof of a typical home exceeds by far its energy consumption; there is, therefore, the potential for a building to achieve net zero energy consumption if the utilization of solar energy to produce electricity, useful heat and daylight is optimized [3]. In spite of these facts, a large portion of the potential to utilize solar energy still remains unused [4]. According to the International Energy Agency, this is caused by several factors:

1) economic factors,
2) lack of technical knowledge,
3) reluctance to use "new" technologies, and
4) architectural (aesthetic) factors [5].

The integration of solar energy systems and technologies in existing and new buildings could be greatly facilitated in the future if architects are informed, aware and engaged in the development of solar energy in buildings. Architects should also be conscious of the potential, limitations and characteristics of solar energy systems. Architects have a significant role to play in the development of solar energy systems and technologies in buildings because they are primarily responsible for early design phase (EDP) decisions (such as orientation, shape, size of openings). EDP decisions have the greatest impact on the durability and performance of any building project [6].

1.1. Task 41: Solar Energy and Architecture

Task 41: Solar Energy and Architecture is gathering researchers and practitioners from 14 countries in a significant project, which will identify obstacles for solar design while providing recommendations and support for the implementation of solar technologies and strategies in buildings. The ultimate goal of Task 41 is to accelerate the development of high quality solar architecture. This task is focused mainly on the architectural profession, as a key factor in the future evolution and implementation of solar building design in existing and new buildings. The main objectives of Task 41 are:

1) to support the development of high quality architecture for buildings integrating solar energy systems and technologies, and
2) to improve the qualifications of architects, communications skills and interactions between building professionals, manufacturers and clients.

To achieve these objectives, the work plan of Task 41 is organised according to three main subtasks: A, B and C. Subtask A concentrates on architectural quality criteria; guidelines for architects and product developers by technology and application for new products. Subtask B focuses on guidelines for the development of methods and tools with emphasis on tools for EDP as well as tools for the evaluation of the integration quality of various solar technologies. Lastly, Subtask C concerns integration concepts and examples, and derived guidelines for architects.

This article presents some results of Subtask B, which pursues the following specific objectives:

3) to achieve an inventory (state-of-the-art) of existing methods and tools that architects currently use at EDP when designing buildings integrating active and/or passive solar components,
4) to identify current barriers preventing architects from using existing methods and tools for solar building design, and
5) to identify important needs and criteria for new or adapted methods and tools to support architectural design and integration of solar components at EDP.

The first objective (State-of-the-art) has already been reached and the results have been published as Report T.41.B.1 titled *State-of-the-Art of Digital Tools Used by Architects for Solar Design* [7].

2. LITERATURE REVIEW

A literature review showed that computer-aided architectural design software is adequate to support architects during the design process and c improve their skills [8]. Previous studies also indicate that design teams use available tools in different ways during the design process and a lack of tools for early design was identified [9]. It was shown that design team used computer tools for around 25% of their work in the early stages of the design. On the other hand, it showed that the design units indicated that 100% of their tasks were computerised. Therefore, it appears that currently, the software tools are primarily developed for advanced design stages.

3. METHOD

3.1. International survey

The web-based survey was conducted internationally including 14 countries (Australia, Austria, Belgium, Canada, Denmark, France, Germany, Italy, South Korea, Norway, Portugal, Spain, Sweden and Switzerland) and was translated into eight languages. The translations were made by the researchers and professionals involved in Task 41. The survey was generated with the program *Questionform* [10] and was launched on the Internet by each national coordinator of IEA Task 41. Data collection lasted from May 3rd, 2010 to October 25th, 2010.

The focus group of this survey consisted of practicing architects. Within Task 41, one national coordinator for the survey was appointed; all of them used a different approach for reaching the focus group. Examples include: creating national databases of contacts through professional associations and public directories, through publishing survey links in architectural publications, newsletters and on websites.

3.2. Questionnaire

The questions and layout of the survey were developed during the IEA Task 41 international meetings with the collaboration of all researchers and practitioners. The IEA Task 41 team created two surveys: one relative to Subtask A objectives, and the other relative to Subtask B objectives. Both surveys included the same first two questions which aimed to determine the knowledge and the awareness of respondents about solar architecture. The survey related to Subtask B consisted of 22 questions including three question types: multiple selections of specific categories, a single selection of a specific category, and free text. The multiple selection questions showed a list of the most expected answers. Some of them also allowed respondents to specify other answers.

3.3. Response rate

A total of 223 completed questionnaires were analysed out of 616 received for Subtask B survey. One limitation of this survey is the fact that respondents are most likely to be those who are interested in the issue of solar energy and who either have previous experience with integrating solar energy in architecture or willing to do so in the future. This, in itself, constitutes a bias of the research. Also, the low response rate for the survey generally shows that there is a low interest by architects for this topic, which bears consequences for the future development of solar energy in buildings. It may also indicate that architects have little availability for answering surveys. For example, around 1050 emails were sent in Canada, resulting in only 30 fully completed surveys. The response rate for Canada was thus only around 3%, which is rather low.

3.4. Data analysis

The data was collected and analysed by the Canadian Subtask B team.

Detailed data analysis of all responses will be presented in the Report T.41.B.2 titled *International survey about digital tools used by architects for solar design* which is part of Task 41 official publications, and will be available in March 2011 on the IEA Task 41 web site. The data analysis does not include a statistical analysis to test and proof the sample representation of the population. Therefore, the survey sample and findings are not statistically representative and were analysed statistically. However, the results outline patterns and tendencies among the design community of architects internationally.

4. SURVEY FINDINGS

4.1. Description of respondents

A series of questions at the end of the questionnaire aimed to establish the participant's profile. These questions included the following aspects: description and size of architectural firm, scope of architectural practice, type of building projects designed, project delivery method, year of birth, gender, profession (architect, engineer, physicist or other) and professional experience. Mostly, the results permitted to describe the general profile of respondents and indicated that most often, the respondents:

- worked in small firms;
- were active mainly nationally, but sometimes collaborated in international building projects;
- worked with newly-built projects and building renovations in similar proportions;
- worked on residential and commercial building projects rather than institutional, governmental or industrial buildings;
- used a traditional project delivery method where the owner has separate contracts with the architect and contractor;
- were males born between 1951 and 1980 with more than 10 years of professional experience.

4.2. General questions related to energy use

The first question aimed at determining the importance attributed to solar energy aspects in the architectural practice. The majority (79%, n=177) of respondents considered the use of solar energy in architecture as 'important'. A minority (17%, n=37) of respondents were 'neutral' about solar energy aspects and a few (4%, n=9) rated it as 'unimportant'. None of the respondents answered 'I don't know'.

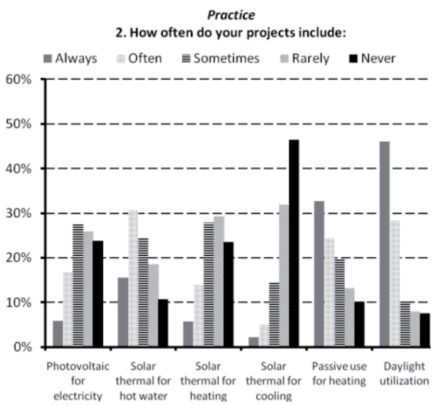

Figure 1: Distribution of answers for question 2 about occurence of solar energy systems or aspects in current architectural practice (n=223).

The next question (Figure 1) concerned the integration of solar design aspects in the actual architectural practice of respondents. This question concerned 'photovoltaic technologies for electricity', 'solar thermal systems for domestic hot water', 'solar thermal technologies for heating', 'solar thermal technologies for cooling', 'passive use of solar gains for heating', and 'daylight utilization strategies'. The results show that a large proportion of respondents answered that they always included 'passive use of solar gains for heating' (36%, n=79) and 'daylight utilization strategies' (49%, n=109). In contrast, respondents always included 'solar thermal for hot water' (17%, n=38), 'solar thermal technologies for heating' (5%, n=12), 'photovoltaic technologies for electricity' (5%, n=10) and 'solar thermal technologies for cooling' (2%, n=5).

4.3 Questions concerning methods

Question 3 (Figure 2) aimed at determining the moment during the design process, when the professionals first considered the integration of solar energy technologies. Results show that 69% (n=154) of the respondents would consider the integration of solar energy technologies during the 'conceptual phase'. About 26% (n=58) would consider it in the 'preliminary design', 4% (n=9) in at the 'detailed design' phase and 1% (n=2) during the 'construction drawings' phase.

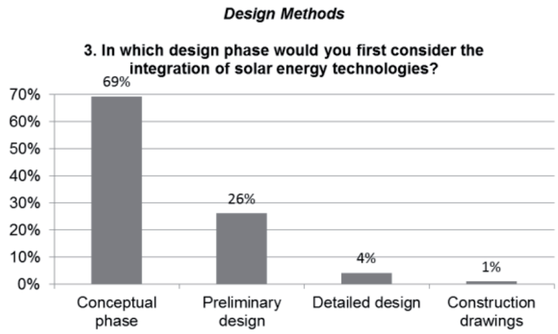

Figure 2: Distribution of answers for question 3 about the moment in the design process when solar energy technologies are first considered (n=223).

Question 4 (Figure 3) aimed at determining the methods used in the design process. Out of 693 selections, 21% (n=144) were marked as 'experiences', 17% (n=120) as 'interactions with the owner', 15% (n=103) as 'collaboration with others'. The next most popular choices were 'design guidelines' (12%, n=86), and 'computer simulations' (9%, n=63). Finally, the least popular selections were 'conception of several propositions' (8%, n=53), 'interactions with future users of the building (public participation)' (7%, n=46), 'rules of thumb' (6%, n=43) and 'expert systems architecture (concept research)' (5%, n=35).

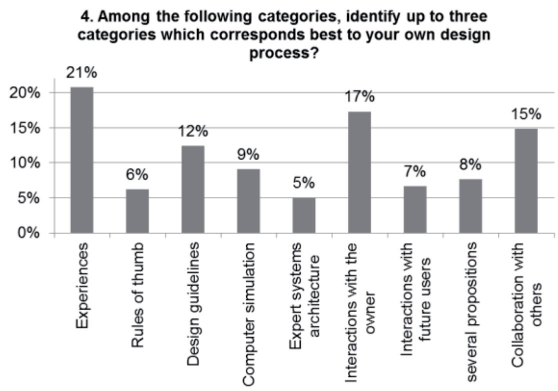

Figure 3: Distribution of answers for question 4 about design process (total number of selections=693).

Two questions aimed at determining how the integration of solar energy technologies was handled in the design process of 1) small projects and 2) large projects. The results show that for both projects sizes, most of the respondents handled the integration of solar energy by themselves. Concerning the EDP, results show that for the 'conceptual phase' and 'preliminary design phase', respondents selected more often 1) 'do it myself', 2) 'consult a colleague (architect) with specific experience', 3) 'involve a building physics/building science specialist', 4) 'involve an external solar energy consultant' and 5) 'involve an internal solar energy consultant'.

The following question was an open-ended question which aimed to identify the need of practitioner-related methods to support the integration of solar systems. Mainly, respondents answered that they would require simple, systematic and clear methods to use in the EDP. They also requested methods that would help take decisions, size technologies, evaluate technologies and involve relationship with contractors, better availability of building physics services, integration of architecture, training to improve knowledge and a catalogue of products available on the market.

The last question concerning methods (Figure 4) aimed at defining which methods were used in the design process. A total of 468 selections were made for this multiple-choice question. Figure 4 shows that a third (32%, n=151) of all selections was related to 'integrated design process-IDP' (collaboration with others professionals in multidisciplinary teams), 26% (n=122) was for 'intuitive design process' (i.e. intuitive decisions made without conscious thought and often refers to the architect's experience), 21% (n=97) for 'participatory design' (interaction between the future users of the building, (i.e. public participation), 18% (n=85) for 'energy-oriented design' (i.e. practicing sustainability with calculator and computer simulations) and 3% (n=13) was for 'other' methods.

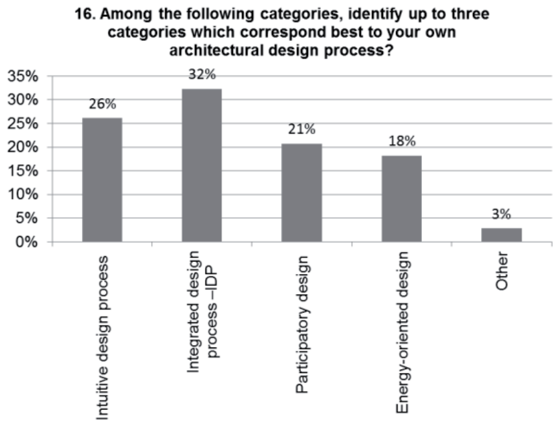

Figure 4: Distribution of answers for question 16 'Among the following categories, identify up to three categories which correspond best to your own architectural design process?' (n=223).

4.4 Questions concerning tools

Question 7 (Figure 5) aimed to identify the current skills of respondents with different tools for solar design. Respondents had to rate their skills concerning four types of tools: 'graphical solar design methods' (i.e. solar charts), 'CAAD (computer aided architectural design) programs', 'solar design tools included in the CAAD programs you currently use' and 'advanced solar or energy simulation tools'. Figure 5 shows that respondents had more skills (very advanced or advanced) with CAAD than all the other tools, but they did not really use solar design tools included in the CAAD programs (31%, n=69 considered their skills as 'poor' and 27%, n=60 as 'very poor').

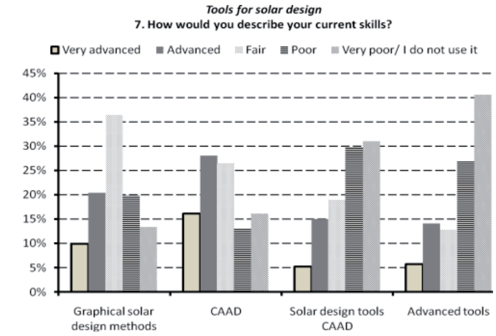

Figure 5: Distribution of answers for question 7 about the skills with the use of different tools (n=223).

Question 8 aimed to determine what software are used by respondents in their current architectural practice and at which phase of the design process these software are used. The software included in the choice of answers were selected among the ones inventoried in the Report T.41.B.1 *State-of-the-art of digital tools for solar design used by architects* [7]. These software were classified according to three categories: Computer-aided architectural design (CAAD), visualization and simulation tools. The results show that these three categories are used in all stages of building projects; 'conceptual phase', 'preliminary design phase', 'detailed design phase' and 'construction drawings phase'. Also, the results show that AutoCAD, Google SketchUp, Revit Architecture, ArchiCAD, Vectorworks and 3ds Max were the CAAD tools most often used by architects, all design phases combined. Concerning visualization tools, the most popular tools, all along the design process, were V-Ray, Artlantis, Renderworks, Maxwell Render and Mental Ray. For simulation tools, the most popular tools were Ecotect, RETScreen, Radiance, PV syst, Polysun, and eQUEST.

Question 9 aimed to determine which factors influence the choice of design tools for professionals. The answers indicated that 'user-friendly design interface', 'cost', 'simulation capacity' and 'interoperability with other software' were more important than 'availability of scripting feature', 'availability of plug-in(s)', 'quality of output (images)' and '3D interface'.

The next question aimed to evaluate the level of satisfaction of respondents concerning the computer tools they currently use. The software included in the choice of answers was the same as question 8. Out of 565 selections, most respondent were 'neutral' (40%, n=226) and 'satisfied' (31%, n=177) with the tools. Only 10% (n=58) were 'very satisfied', 12% (n=66) were 'dissatisfied', and 7% (n=38) 'very dissatisfied'.

The following question (Figure 6) aimed to identify the barriers to the use of solar design tools. A total of 558 selections were made for this multiple-choices question. Figure 6 shows that the most popular selections for this question were 'tools are too complex; high learning curve' (19%, n=105), 'tools are too expensive' (14%, n=80), 'using the tools takes too much time' (11%, n=62) and 'tools are not integrated in our CAAD software' (12%, n=66). Three choices were selected less often which are 'tools are not supporting the conceptual design', 'tools are too systemic', and 'tools are not integrated in our normal workflow'. Least selected were 'tools are too simplistic', 'I don't know/not applicable' and 'other' barriers.

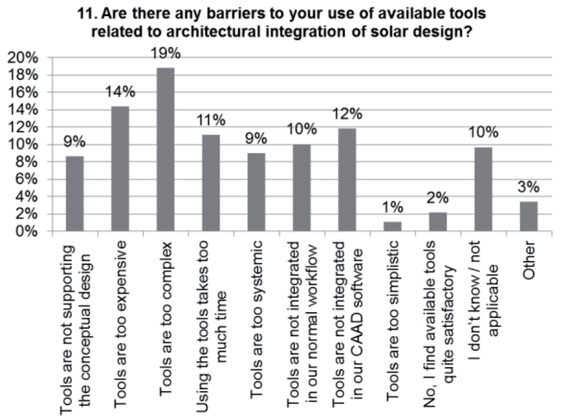

Figure 6: Distribution of answers for question 11 about barriers related to the use of the tools for the architectural integration of solar design (total number of selections=558).

Question 12 (Figure 7) aimed to identify the needs of practitioners related to tools to support the integration of solar architecture. For the 'conceptual phase' and 'preliminary phase', most of the selections were for 1) 'improved tools for preliminary sizing of solar energy systems', 2) 'improved tools for providing key data (number) about solar energy', 3) 'tools that provide explicit feedback' and 4) 'improved tools for visualization'. Concerning the 'detailed design phase' and 'construction phase', most selections concerned 'improved tools for preliminary sizing of solar energy systems' and 'improved tools for providing key data (number) about solar energy'.

The last question on tools was an open-ended question aiming to get the personal opinion of respondents about the availability of tools and their use. The results indicate that respondents requested simple, effective and intuitive tools to be available to use in the EDP. They want tools that:

- have more interoperability;
- are more general and easy to learn;
- calculate quantitative outputs;
- quickly assess optimum building specifications (orientation, thermal mass, thermal inertia, solar use, size panels, etc.);
- integrate shadows;
- perform insolation analysis and exterior temperature;
- combine solar energy with other sources of energy;
- involve 3D models;
- generate complete thermal analysis (hourly, monthly and annual);
- generate relevant outputs and
- involve economic analysis.

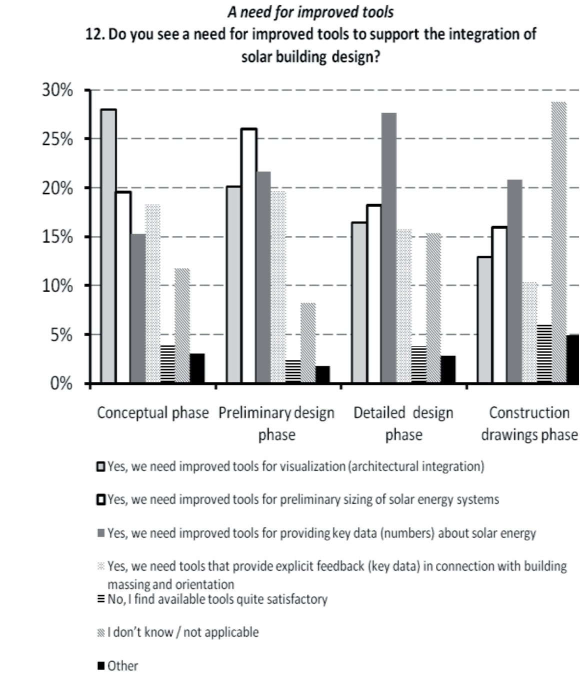

Figure 7: Distribution of answers for question 12 about needs for improved tools to support solar building design (total number of selections=1 221).

5. CONCLUSION

The results of this international survey show that methods and tools for solar architecture are not yet well-defined and suitable for architects. The importance to adapt methods and tools to support architectural design and integration of solar components -in order to accelerate the development of solar energy in architecture- is recognised without a doubt. Results of this survey identify important needs and criteria for methods and tools to support architectural design and integration of solar components at EDP (early design phase). The results also emphasize that the early design phase (EDP) is crucial for the integration of solar systems and strategies, both for passive and active solar energy systems.

The international survey shows that the issue of solar energy use in buildings was actually important for respondents. Most of them already used some technologies, especially passive strategies such as the use of solar gains for heating and daylight utilization. The results indicate that the traditional approach (project delivery method) was still used by architects and past research have shown that this is not providing the best results [11].

Concerning methods, results indicate that in the majority of cases, architects handled solar integration by themselves. In some cases, in the EDP, they consulted a colleague architect with specific experience, a building science specialist, or an external and internal solar energy consultant. In addition, results show that respondents used mostly 'integrated design process-IDP' which means that respondents are involved with other professionals, such as engineers and experts, in multidisciplinary teams. They also used 'intuitive design process' which refer to their own experiences. Lastly, 'energy-oriented design' method is used, which indicates that the interest about solar energy utilization is real. The respondents' design method was often based on experiences, interactions with the owner, collaboration with others, design guidelines and computer simulations. These design methods were more used than the utilization of several propositions to evaluate possibilities, interactions with future users of the building, rules of thumb and expert systems architecture. Current barriers were that methods were unsystematic, did not support decision-making process in satisfactory manner and did not improve much knowledge about solar technologies.

When considering tools for solar design, the results show that current obstacles architects are facing lay in additional skills needed for solar design in CAAD. As for the advanced tools, the obstacles were identified as: complexity, costs of programs, time needed to master advanced software and the lack of interoperability with other software commonly used. As a frequency of use, most of respondents used AutoCAD, Google SketchUp, Revit Architecture, ArchiCAD and 3ds Max as CAAD tools, V-Ray, Artlantis, Renderworks, Maxwell Render and LightWave as visualization tools and Ecotect, RETScreen, Radiance, PV syst, Polysun, bSol and PV SOL as simulation tools. For the EDP, respondents expressed the need for improved tools for preliminary sizing of solar energy systems, providing key data about solar energy output, providing explicit feedback and allow visualization of architectural integration quality. Since EDP is a highly intuitive, iterative process, an appropriate EDP tool should allow changes on the building overall volume, geometry, or orientation with only a mouse click, and provide direct feedback related to solar aspects to the architect.

The detailed results of the survey will be presented as IEA Task 41: Report T.41.B.2. From this report, clear guidelines for tool developers will be written. It is expected that this will initiate communication between tool developers and the architectural community in order to stimulate the development of adequate and improved digital tools.

5.1 Limitations

Although sent out through many channels, the response rate for this survey was low and can be seen as the main limitation of this survey. It shows that there is a low interest amongst architects for this topic. Also, there is a risk that the respondents are those who are interested in the issue of solar energy and this in itself constitutes an important bias of this research.

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