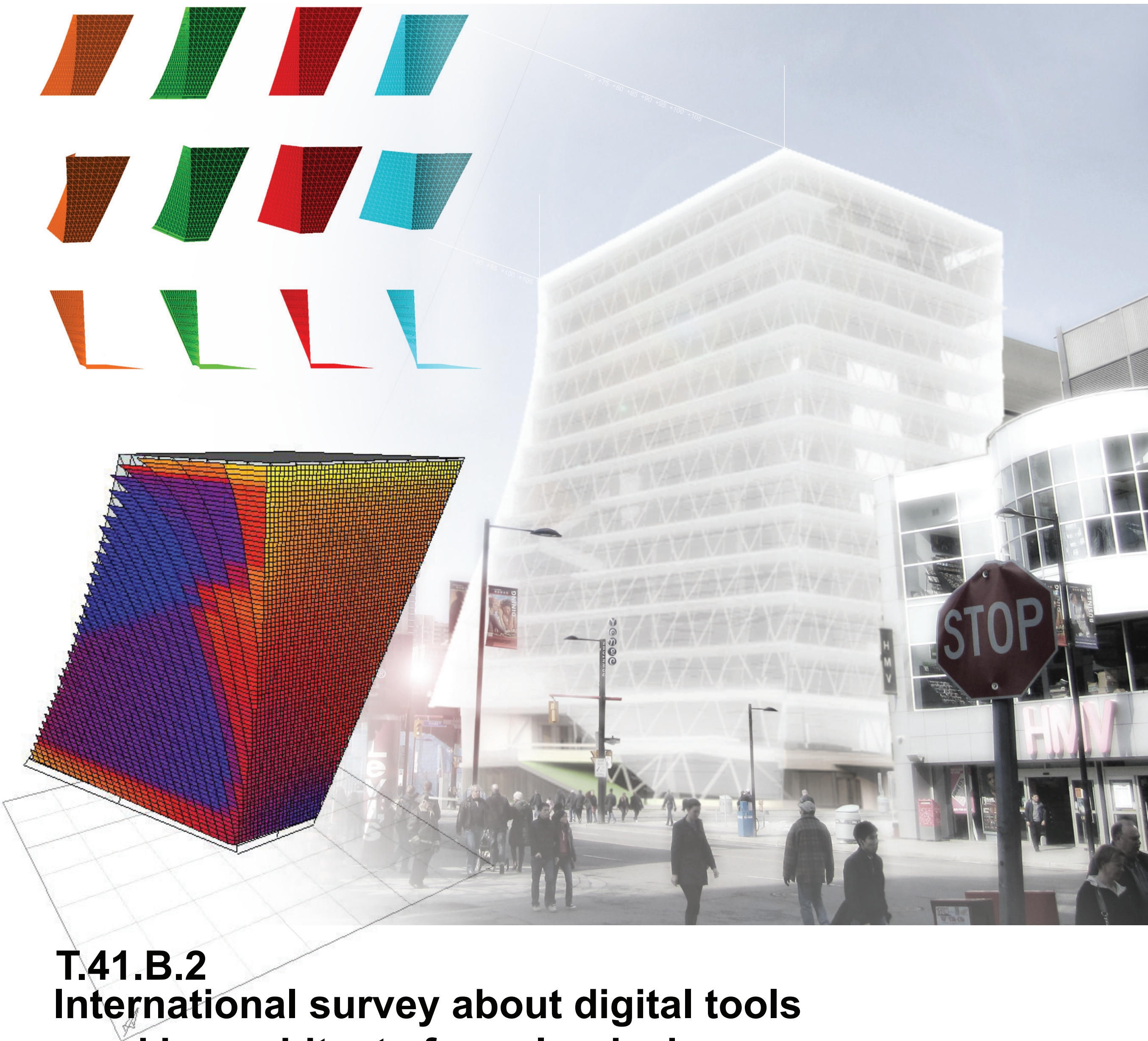
TASK 41 SOLAR ENERGY AND ARCHITECTURE



T.41.B.2
International survey about digital tools used by architects for solar design

Subtask B: Methods and Tools for Solar Design

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Task 41 - Solar Energy and Architecture
Subtask B - Methods and Tools for Solar Design

Report T.41.B.2
International survey about digital tools used by architects for solar design

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KEYWORDS

Solar energy, buildings, architecture, architects, tools, computer programs, simulation, energy, design process, design tools, design methods, early design phase, active solar systems, solar thermal collectors, photovoltaic (PV) panels, passive solar heating, daylight harvesting, daylighting, passive cooling.

ABSTRACT

This report forms part of IEA-SHC Task 41: Solar Energy and Architecture, specifically Subtask B: Methods and Tools for Solar Design. After a literature review of former studies made between 1993 and 2011, the international survey Design Process for Solar Architecture, conducted in 2010 within Task 41 is presented and analyzed. Professionals in 14 countries were contacted and questioned about their use of digital tools for solar design and related themes, such as, barriers for the use of digital tools or their design process. In addition, general data concerning the firm (size, type of buildings) and personal facts (age, experience, profession) was collected. The response rate was less than hoped; nevertheless, this report points out that there is a high awareness of the importance of solar energy use in buildings, but that there are still a number of barriers to the widespread application of digital tools during the design process. The survey affirms results of former investigations by others presented in literature review that widely accepted solar design software packages adequate for use by architects in the early design phase are still lacking. The identification of opportunities and obstacles, special requirements expressed by professionals and suggestions for improvements will help formulate the next program of work, which will involve the development of guidelines for both professionals and software tool developers in order to support design methods and enhance the use of solar energy in building projects.

EXECUTIVE SUMMARY

In the context of Subtask A and B of IEA-SHC Task 41 – Solar Energy and Architecture, an international survey was carried out which was separated in two parts, one for each Subtask. Subtask A survey was dealing with the obstacles architects are facing in relation to architectural integration of solar energy systems. Subtask B survey was dealing with the adequacy of existing tools and methods for solar design at the early design stage; results of which are presented in this report. Every participating country sent the survey to national professionals, focusing on architects but also including engineers, organizations, manufacturers and developers.

The objectives of the survey were:

1. To identify barriers of existing digital tools and design methods for solar design;
2. To identify the needs of architects for better or improved tools and methods.

The results of the survey will also be used to develop guidelines for software developers, which will be completed in the next phases of Subtask B.

Methodology

A literature review of similar studies done up to date was commenced in order to identify if and how these issues were approached before. Fifteen studies that extend over the period of 1993 to 2011 on use of predominantly simulation tools by professionals were reviewed.

As for the survey, in each participating country, one national coordinator involved in Task 41 was appointed for distribution. The coordinators used a variety of methods to reach practitioners: either by publishing links for surveys through national associations of architects, through professional newsletters and magazines or through specially built mailing lists developed for this purpose. This variety of survey distribution methods resulted in the difficulty of knowing precise response rates. A total of 350 surveys were completed, with a further 78 delivered incomplete. A survey was considered incomplete if at least one question was unanswered. This can be considered a low response rate. This may reflect limitation in distributing the survey, lack of time or a general low interest in solar design issues in some countries.

Results

Literature review

Even though the studies reviewed in literature survey span a period from 1993 to 2011, it was very interesting and surprising to observe that the needs expressed by users have remained relatively unchanged over time: from dissatisfaction with low operability between software tools, inadequate incorporation of tools' functions in the flow of architectural design stages, incomprehensible and/or poor representation of results, etc.

Results from the survey

The majority of respondents represented small or medium size firms (1-10 employees) and were mostly active nationally. The respondents' work encompassed a wide selection of project- and building types, with residential buildings being most common. Sixty seven per cent of respondents indicated that they use a conventional project delivery method, with Design-Build contracts and Construction Management being the second most common methods. The majority of respondents were between 31 and 50 years old; sixty six per cent of all respondents were male, and most were

architects or designers, with a few engineers and other professions also represented. Most (74%) had more than 10 years of professional experience.

Solar energy use

Eighty two per cent of respondents stated that solar aspects are important in their current architectural practice. The most common solar design strategy was daylight utilization, with 74% responding that this is always or often included in their projects. Passive solar for heating was the second most common strategy, with 58% of respondents always or often including this in their projects. Forty seven per cent always or often include solar thermal for domestic hot water use, while photovoltaics and solar thermal for heating are less common, at 23% and 20% respectively. The least common solar strategy was solar thermal for cooling, which is commonly utilized by only 7% of respondents.

Methods for solar design

The questions in this section focused on design processes and decision making. Respondents utilized a variety of design processes: 33% responded that the Integrated design process (IDP) best corresponds to their own practice, with the remainder divided between Intuitive design processes (25%), Participatory design (21%) and Energy-efficient design (18%).

Sixty nine per cent of respondents stated that solar energy technologies were first considered in the conceptual phase, underlining the need for well developed conceptual design tools. Most respondents base their design processes upon experiences, interaction with the project owner, and collaboration with others.

Responses describing decision making in small projects indicate that the conceptual phase is largely handled by the architect alone (53%). Specialists are more likely to be involved in later design phases and multidisciplinary workshops play a fairly small part, with a 6-10% response rate irrespective of design phase. On the other hand, decision making in large projects is more likely to involve specialists in the conceptual phase, but 32% of respondents still state that this phase of large projects is handled solely by the architect. External solar energy consultants and building science specialists are relatively common in the later phases of large projects. Multidisciplinary workshops also play a larger role than in smaller projects (10-12% depending on project phase).

Tools for solar design

The majority of respondents described their skills with graphical solar design methods as fair (37%) or poor (20%). With regards to solar design tools in CAAD, and for advanced solar or energy simulation tools, the majority responded that they considered their skills to be poor (30% and 27%) or very poor (31% and 41%). In comparison, most respondents described their skills with CAAD software, an integral part of architects practice, as advanced (28%) or fair (27%).

A question asking at which stage in the design process various software tools are used returned a number of results. The most commonly used CAAD tools were AutoCAD, Google SketchUp, Revit Architecture, ArchiCAD, Vectorworks and 3dsMax. The most common visualization tools were Artlantis, V-Ray, RenderWorks and Maxwell Render, while Ecotect, RETScreen, Radiance, Polysun and PVSol were the most common tools for simulation.

The most common CAAD, visualization and simulation tools are all used in all project phases, but the aptitude of different tools for different phases is reflected in the responses. CAAD tools prioritising a simple user interface and rapid modeling (e.g. Google SketchUp) are used extensively in the early design phase, while more complex tools (e.g. Revit Architecture, AutoCAD) are more common in the later project phases.

A similar trend is visible in simulation software, with some products being preferred in the early design stage (e.g. Ecotect, RETScreen, even Radiance) and others used more heavily in later stages (e.g. Polysun, PVsol). The most common visualization software packages are used fairly evenly across the design phases; however, the total number of respondents who indicate that they use visualisation tools is considerably less than those using CAD tools. The factor that most influenced the respondents' choice of software was a user-friendly design and interface (27%). The next most common factors were costs (20%), interoperability with other software (18%) and simulation capacity (13%). Quality of output (images), 3d interfaces, availability of plugins and availability of scripting features were considered less important.

Respondents reported varying degrees of satisfaction with their chosen software programs (CAAD, visualization and simulation tools) in terms of support for solar building design. For many programs, the response rate was so low that it is not possible to form meaningful conclusions.

The most common barrier to respondents' use of tools related to architectural integration of solar design was that tools are too complex (18%). Further common barriers were that tools are too expensive (14%), that tools are not integrated in CAAD software (12%) and that the use of the tools takes too much time (11%).

Respondents also stated that the tools do not adequately support conceptual design (9%), that they are too systemic (8%) and that they are not integrated in normal workflow (10%). Only 2% are satisfied with the existing tools.

When asked about the needs for improved tools in each design phase, the responses were as following: categories such as improved tools for visualization of solar systems, tools for preliminary sizing, tools that provide explicit feedback and tools for key data were in close proximity, with some difference in leadership among these between phases. However, the most common response for the construction drawings phase was 'I don't know/ not applicable' (29%), followed again by 'improved tools for key data' (21%) and 'preliminary sizing' (16%). This may indicate that architects do not feel confident with highly specialised solar design tools that are more suitable for the construction drawings phase/ advanced stage in the process.

Individual comments about improvements in tools were also proposed by some of the respondents; these have been collated in section 4.4.7 of this report.

Conclusions
Both the literature review and survey results strongly indicate the need for further development of software tools for solar architecture, focusing upon tools appropriate for architects: a visual tool that is easily interoperable between different modelling software packages, and which generates clear and meaningful results that are compatible with architectural design workflow.

The survey shows a strong awareness of the importance of solar aspects amongst the respondents. However, this, combined with a limited use of solar energy technologies, suggests the need for further skills development and tools to support implementation of these technologies. The survey has resulted in a number of concrete examples of the needs of practitioners and suggestions on what such tools should include.

The low participation rate in the survey limits the reliability and value of some of the results, especially the comparative analysis of the different software tools in use today. However, it can still provide sufficient indications of needs and trends.

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LIST OF ABBREVIATIONS

AIA	Australian Institute of Architects
BiPV	Building integrated photovoltaic
BPS	Building performance simulation
CAAD	Computer-assisted architectural design
CPUC	California Public Utility Commission
DHW	Domestic hot water
DOE	Department of energy
EDP	Early design phase
EPBD	Energy Performance Building Directive
EUP	European Union Parliament
GUI	Graphical user interface
NZEB	Net zero energy buildings
PV	Photovoltaic
SBRN	Solar Building Research Network (Canada)

LIST OF COMPUTER PROGRAMS COVERED

CAAD tools
Allplan
ArchiCAD
AutoCAD
Blender
Bricscad
Caddie
CATIA
CINEMA 4D
DDS-CAD
Digital Project
form•Z
Google SketchUp
Houdini
IntelliPlus Architecturals
Lightworks
Maya
MicroStation
Revit
Rhinoceros 3D
SolidWorks
Spirit
Vectorworks
3ds Max

Visualization tools
Artlantis
Flamingo
Kerkythea
LightWave
LuxRender
Maxwell Render
Mental Ray
POV-Ray
RenderMan
RenderWorks
RenderZone
V-Ray
YafaRay

Simulation tools
bSol
DAYSIM
DesignBuilder
Design Performance Viewer (DPV)
Ecotect
EDG II
EliteCAD
ENERGIEplaner
eQUEST
Green Building Studio
IDA ICE
IES VE
LESOSAI
Polysun
PVsyst
PV*SOL
Radiance
RETScreen
T*Sol
VisualDOE

1. INTRODUCTION

Climate change and the scarcity of energy resources are two of the big challenges the world will face in the near future [European Renewable Energy Council, 2010]. Two of the main conventional fuels which play central roles in our energy supply are oil and nuclear energy. Fossil fuel prices have drastically increased, especially in the last decade [Federal Institute for Geosciences and natural resources, 2009]. Also, some evidence suggests that the peak in the world's discovery of oil was during the 1960s; the world started using more oil than the amounts found in 1981 and the gap continues to widen [Gerling, 2007]. For nuclear energy, assuming that the future electricity consumption levels will be the same as those in 2005, and that nuclear power will continue to use the same type of technology, the available resources today would last at least 75 years [Solomon & Bedel, 2003]. However, radioactive waste, the treatment costs and related public health risks, as well as the risks of nuclear accidents are among the most serious issues to take into consideration when calculating the real costs of nuclear energy [Bernardo, 2011]. According to [Gerling, 2007], countries that begin to address the issues of energy resource scarcity and implement the necessary changes will find themselves enjoying huge advantages over those which continue to live in the past and have blind faith in unspecified technological solutions, or the ability of an open market to deliver.

The necessary development of renewable energy sources is further motivated by the urge to slow down climate change. The main conclusions of the latest report of the Intergovernmental Panel for Climate Change [IPCC, 2007] are that the 'warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level'. Moreover, an assessment currently under development indicates that current CO_2 concentration levels are higher and have increased more rapidly than expected; measured sea-level rise is slightly higher than previously estimated; emitted CO_2 remains in the atmosphere for thousands of years causing irreversible changes in climate and in ocean chemistry [IPCC Working Group I, 2010].

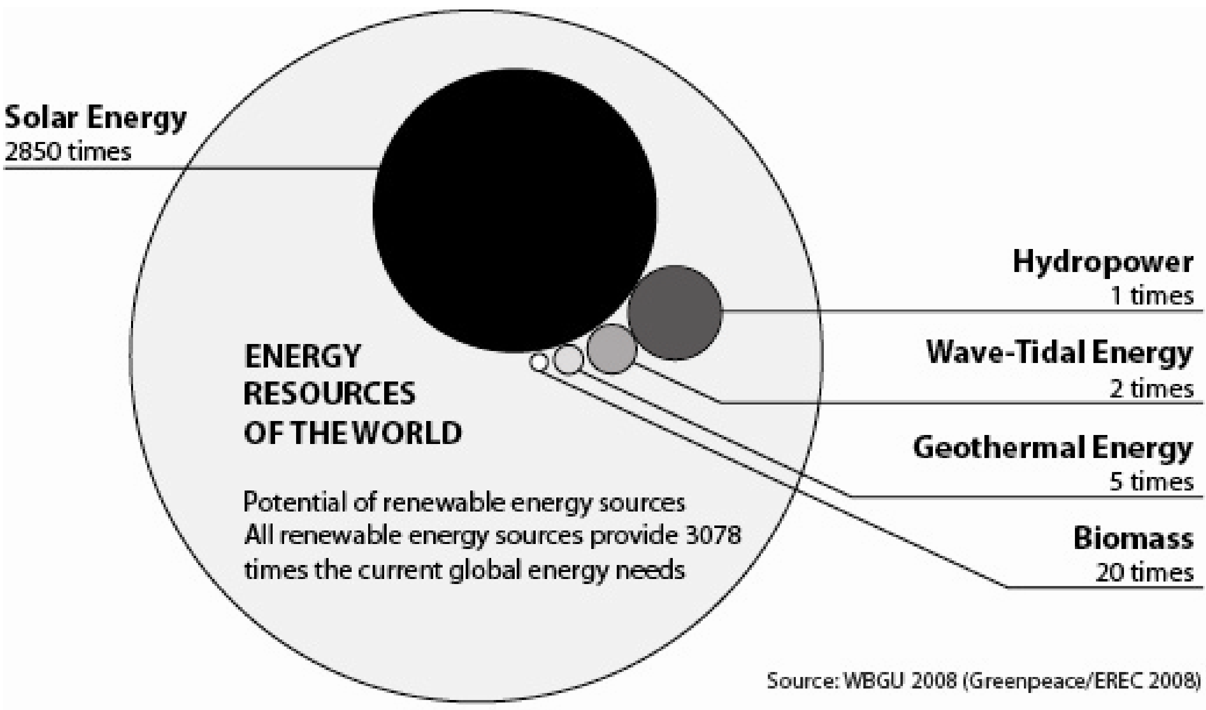

Figure 1: Theoretical Potential of Renewable energy sources compared to the global energy needs (Source: European Renewable Energy Council, 2010)

For these reasons, the energy sector is a major concern today and profound changes need to be made not only to reduce our energy use, but also to change the way it is produced. On the positive side, recent figures show that all renewable energy sources combined may provide 3078 times the current global energy needs. Among renewable energy sources, solar energy is the one that has by far the largest potential, as shown by Figure 1. By itself it is enough to ensure 2850 times the annual global energy needs [European Renewable Energy Council, 2010]. In just one day, the solar energy incident on the earth's surface equals the global energy needs during eight years [Bernardo, 2011]. Also, the Canadian Solar Building Research Network [SBRN, 2010] established that in many locations, the solar energy incident on the roof of a typical home far exceeds its energy consumption. There is thus the potential for a building to achieve, on average, net zero energy consumption if the utilization of solar energy to produce electricity, useful heat and daylight is optimized.

In spite of these facts, a large portion of the potential to utilize solar energy still remains unused today [Devin 2006]. According to the International Energy Agency [IEA 2009], this is caused by several factors:

- economical factors;
- lack of technical knowledge;
- reluctance to use 'new' technologies; and
- architectural (aesthetic) factors.

While the economic factors are gradually losing grounds as the cost of solar energy systems is slowly decreasing, it is essential to address the last three factors, which are related to workforce capacity. The recent initiatives of European Union Parliament (EUP) and California Public Utility Commission (CPUC), which establish a goal to achieve Net-Zero Energy buildings in the near future only reinforce the need to seriously address these issues. EUP with the Regulatory of the Energy Performance Building Directive (EPBD) states that all EU member states must require all new buildings to be Net-Zero Energy by 2019 [European Parliament, 2009]. In America, the CPUC has set this requirement to apply to all new residential buildings by 2020 and all new commercial buildings by 2030 [Zero Net Energy, Action Plan: Commercial Building Sector, 2010-2012]. This is in contrast to the national US target defined as 2030 for residential buildings and 2050 for commercial buildings [Energy Independence and Security Act, 2007].

As a consequence of these legislations and initiatives, architects have a significant role to play in the near future, in order to contribute to the success of net-zero energy initiatives, by designing and retrofitting buildings to very low energy use and by implementing solar energy systems and technologies in new and existing buildings. Their role is key to the success of this endeavour mainly because:

- Early design phase (EDP) decisions of building projects (such as orientation, shape, size of openings) are primarily the responsibility of the architect and,
- EDP decisions have the greatest impact on the durability and performance of any project [Potvin, 2005].

Larsson [2004] in a study of design methods used in delivering highly efficient buildings, concluded that the greatest advantages in terms of energy use depended upon decisions taken and verified at the very first phase of design. During the first few weeks of design, fundamental decisions are made that have an enormous impact on the energy consumption of the building and, therefore, the lifecycle cost [Livingston, 2007].

1.1 Task 41: Solar Energy and Architecture

Task 41 - Solar Energy and Architecture brings together research and practitioners' expertise from 14 countries in a significant project, which pursues the goal to 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 as well as new buildings.

The main objectives of Task 41 are stated below:

- To support the development of high quality architecture for buildings integrating solar energy systems and technologies;
- To improve the qualifications of the architects and the communication skills and interactions between engineers, manufacturers, clients and architects.

The overall benefit will be an increased use of passive and active solar energy in buildings, thus reducing the non-renewable energy consumption and greenhouse gas emissions. The objectives of this task are thus closely linked to the actions identified by the World Business Council for Sustainable Development i.e. to increase and train workforce capacity, and to evolve energy-efficient designs and technologies that use passive and active approaches [WBCSD, 2009].

To achieve these goals, the work plan of Task 41 is organized according to three main subtasks:

Subtask A: Architectural quality criteria; guidelines for architects and product developers by technology and application for new product development.

Subtask B: Guidelines for the development of methods and tools focusing on tools for EDP and tools for the evaluation of integration quality of various solar technologies.

Subtask C: Integration concepts and examples, and derived guidelines for architects.

1.2 Subtask B - Description and objectives

Subtask B focuses on methods and tools for solar design that architects use at an Early Design Phase (EDP). According to [Pfitzner et al, 2007], the EDP starts with the first client contact and ends with a design with recognizable functions, visualized for easy understanding and with a cost calculation to support the client's 'go/no-go' decisions. This is illustrated in Figure 2.

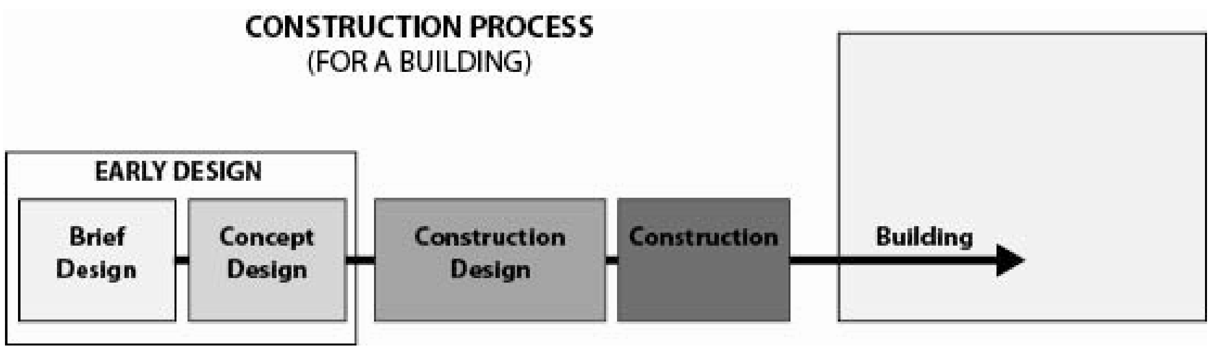

Figure 2 Construction process for a building (source: Pfitzner et al., 2007).

The two main phases in EDP are: Brief Design and Concept Design. In Brief Design, end-user needs, expectations, as well as technological and budget limitations are established and then translated into the Concept Design phase to form building requirement specifications, while taking into account the client's processes. Based on these requirement specifications, the Concept Design begins to form a building design sufficiently detailed to predict (within margins) performance, cost, and time aspects. This phase involves a process of integrating discipline-oriented concept partial designs into an 'overall concept design' which is then taken into the Construction Design Phase. Here, all details and 'how to construct' issues are developed into a complete and fully detailed design ready for construction [Pfitzner et al., 2007].

During the initial conceptual design process, it is possible to determine inputs that define the correct use of the building and provide a cost-benefit analysis of solar solutions that include future building life-cycle considerations.

Methods and tools used at the EDP should support architects and planners in taking decisions that lead to good solar buildings and support further project development into the construction design phase, while providing an evaluation of various solar technologies. An appropriate use of building envelope systems to attain a balance between active and passive solar strategies, along with the development of these EDP methods and tools, are among the main goals of IEA Task 41.

The specific objectives of Subtask B are stated below:

1. Complete an exhaustive review of existing methods and tools (state-of-the-art) that architects currently use at EDP when designing buildings which integrate active and/or passive solar components.
2. Identify current obstacles preventing architects from using existing tools to enhance design methods for solar building design.
3. Identify important needs and criteria for new or adapted methods and tools to support architectural design and integration of solar components at EDP.
4. Provide clear guidelines for developers of digital tools for architects designing solar buildings, with focus on EDP.
5. Initiate communication with tool developers (industry) in order to stimulate the development of adequate and improved digital tools.
6. In collaboration with Subtask C, collect output data, 3D models, figures, illustrations and facts produced by various tools in demonstration projects, to be included in the Communication Guidelines.
7. Disseminate the results of this research through publications in scientific and professional journals, as well as through seminars to practitioners (e.g. architects).

The first objective of Subtask B has already been reached and the results have been published as report *T.41.B1: State-of-the-Art digital tools used by architects for solar design* [Dubois & Horvat (ed.), 2010], also summarized in one conference paper [Gagnon, Dubois, Horvat, 2010]. The present report aims to meet the second and third specific objectives of Subtask B stated above by presenting the results of an international survey about digital tools and design methods used by architects in their current practice.

1.3 Objectives of the international survey

As previously stated, the objectives of the international survey sent to architects in 14 countries were:

1. To identify current barriers preventing architects from using existing tools and design methods in solar building design.
2. To identify important requirements and criteria for new or adapted methods and tools to support architectural design and integration of solar components at EDP.

The survey also aimed towards providing guidance to software developers and architects, which will be completed during the next phase of Subtask B (deliverable DB.3).

Aside from specific questions about the working methodology of the professionals, the survey included questions about computer programs which support architectural design and the integration of active and passive solar components. A total of 56 visualization and simulation tools (including BIM), were identified by the Task participants to be the most common ones. The goal was to identify which of these tools are currently used in today's architectural practice and during which stage of the design process.

The results of the survey highlight which topic areas have to be focused on when writing guidelines for software developers and architects. The feedback on existing tools will help developers to optimize and improve their tools.

2. LITERATURE REVIEW

Computer-aided architectural design software packages are adequate to support architects during the design process and to improve their skills [Parthenios, 2005]. Simulation software is designed to assist architects, engineers, developers and consultants in the design or selection and evaluation of energy systems and/or predicting overall building energy performance. The literature contains a number of studies analyzing different tools and the use of simulation or design software by building design teams. The common objectives of these studies are to promote the use of architectural software and to establish criteria for the development of future software. Among these studies published between 1993 and 2011, fifteen have been reviewed in this section. This review is organized according to three main topics: the use of tools by design teams, the use of tools during the design process and the barriers related to the use of software.

2.1 The use of tools by design teams

First of all, it is crucial to understand the way the available software is used and by whom. Back in 1999, an investigation by [Lam, Wong & Henry, 1999] aimed to understand how simulation software was used by different actors in building design in Singapore. This study indicates that hundreds of architecture firms were unaware of these types of software. In their view, the use of such tools was not a part of their designer responsibilities. They also believed that simulation software is intended for specialists. The same study revealed that consultants from Singapore used computer tools in only one case out of three. A few years later, a survey by [De Wilde et al, 2001] in the Netherlands also indicated that the majority (67%) of 34 architects participating in the study did not use specific tools to support the integration of aspects related to energy efficiency of buildings. This study also revealed that architects prefer to rely on their past experiences and precedents to support their architectural design decisions [De Wilde et al, 2001; Donn, 1997; Reinhart & Fitz, 2006].

In recent years, however, with the paradigm shift toward low energy consumption buildings, and particularly with Net Zero Energy Building (NZEB) design goal, the importance of engaging in the integrated design process from the very beginning, at the early design stages, when the architects' responsibilities are the greatest, became well understood. Yet, even the more recent studies confirmed that most simulation tools are still not adequate in providing sufficiently helpful feedback to architects at the early design phase (EDP) [Lam et al., 2004; Riehter et al., 2008; Attia et al., 2009; Weytjens et al., 2010]. Attia [2011] found that “out of 389 BPS (Building Performance Simulation) tools listed on the DOE (Department of Energy) website in 2010, less than 40 tools are targeting architect during early design phases”, Figure 3. Therefore, even though it is still true that majority of architects prefer to rely on the rule-of-thumb type of guidelines and prescriptive solutions, for those who are open to explore additional digital simulation tools that can help them in the early stages of the design, the choices of adequate software packages are still quite limited.

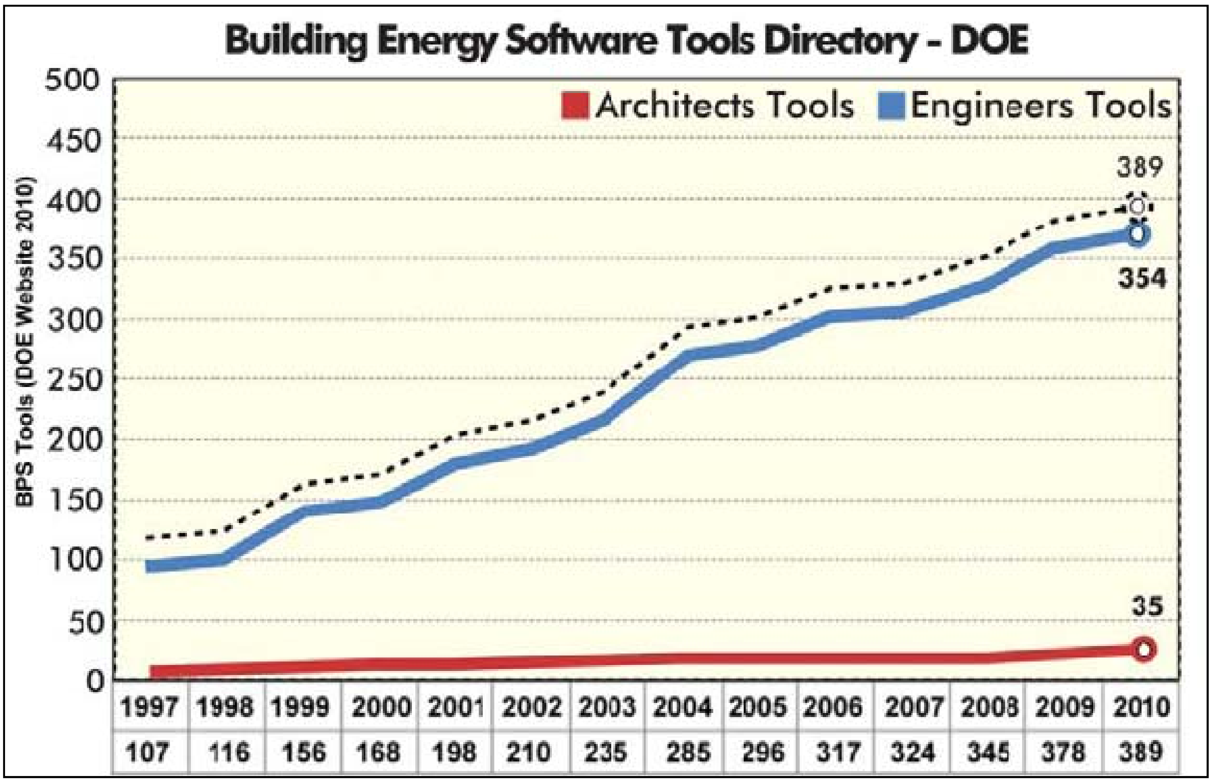

Figure 3: BPS tools developed for architects and engineers between 1997 and 2010 (Source: Attia, 2011)

2.2 The use of tools during the design process

Previous studies also indicate that design teams use available tools in different ways during the design process. Each design phase is related to specific tasks and therefore, they require different kinds of tools or a different usage of them. A survey of 20 European companies forming the InPro Group, in which 22 professionals participated, [Pfitzner et al, 2007] remarked there was a lack of tools being used for early design phase. Indeed, this survey showed that respondents involved in the early stages of design used computer tools for around 25% of their work. On the other hand, respondents from the design units indicated that 100% of their tasks were computerized. Therefore, the authors concluded that currently, software is primarily developed for advanced design stages.

Another study, done by [De Wilde et al, 2001] revealed that three quarters of the systems and components involved in the energy efficiency of buildings were already determined when the design development phase had ended. However, simulation software, which aims to support and validate the choice of these components, was used during advanced design stages, i.e. during the detailed design and production of construction drawings [De Wilde et al, 2001; Donn, 1999; Reinhart & Fitz, 2006]. Donn [1999] and [De Wilde et al, 2001] also argued that the use of advanced software does not necessarily improve building performance but that these tools are used to confirm design decisions or to validate compliance with a regulation or a building code [Pilgrim et al, 2003].

Although it appears that most tools have a confirmatory and/or validation role, some practitioners also use tools to better understand the impact of design on the performance of the building [Lam, Wong & Henry, 1999; Pilgrim et al, 2003]. In the study by [Lam, Wong & Henry, 1999], 15% of the 163 participating offices (including architecture, engineering and government) who used the tools indicated at 69% that simulation accelerated the design development and at 58,6% that simulation enabled confidence in their design choices. Participants in the study by [De Wilde et al, 2001] stated that they use these tools to optimize systems, but also to support decision-making. More recently, an internet survey of 193 natural light simulation software users indicated that the simulation results are presented to customers and reports to justify design choices [Reinhart & Fitz, 2006].

There are several reasons to use specialized computer tools in architecture. It is noted in one of the recent studies in this field [Reinhart & Fitz, 2006], that software tools are used to support the design. The study by [Reinhart & Fitz, 2006] revealed that 94% of the 127 respondents using the tools use them to compare two design options. It is interesting to note that Donn's study [1999] already outlined this trend. This study [Donn, 1999] included five sections, each focusing on a different group of users. One section was answered by 46 architects out of 130 respondents participating in workshops on the integration of passive solar in residences. These 46 architects identified the importance of having software that can analyze and compare two different models.

With respect to the early design phase as an adaptive-iterative process, energy modelling / performance simulation tools should be ideally able to support parametric studies, which is still something that is lacking in contemporary tools [Lam et al. 2004]

2.3 Barriers related to the use of software

Even if the analysis of working methods of design teams allows for the establishment of a list of criteria to improve the use of software, it is also interesting to consider the users' comments regarding their needs or the barriers they face.

In their article *"Architect friendly": a comparison of ten different building performance simulation tools*, [Attia et all, 2009] found that most of the BPS tools are not compatible with architects' working methods and needs. After conducting a survey of professional architects in the United States in 2009, based on a 249 eligible responses, they concluded that architects and designers are aspiring to create sustainable built environment and are taking serious consideration of the use of BPS tools that improves design reliability of energy efficiency and passive design. However, the problem lays in architects' interacting with such tools because of the architects' different knowledge background, knowledge processing methods and predominantly visually oriented way of thinking / problem solving [Attia et all., 2009]

Another major barrier revealed by software users is the low interoperability of tools. Interoperability is the ability to exchange data between different software without losing information. This is confirmed in the study by [Pfitzner et al, 2007], where 32% of the 22 respondents in the InPro survey mentioned that the lack of import and export features of the software they use is a major hindrance.

There are many software packages on the market which perform similar tasks [Doherty, 1997] and companies have a choice between several systems whose native formats are not necessarily compatible. However, among the tools used by professionals in the InPro survey, 68% of software used did not support standard formats or this characteristic was not known to users [Pfitzner et al, 2007].

Similarly, since the geometric acquisition for energy modelling has traditionally been a tedious and error prone process, ability to import / export 3D models between various digital tools is looked extremely favourably by majority of users, as identified by [Lam et.al, 2004].

Additional barrier to the use of simulation tools is the lack of knowledge and training available. Even though this was identified by structural and mechanical engineers who responded to the internet questionnaire developed by Pilgrim et al [2003], the situation is strikingly similar across the board with other participants in the construction industry. In Pilgrim's study, 70% of the 87 respondents stated that they had learned how the software they used functioned by self-learning. Self-learning seems to be a popular method among users of computer programs [Donn, 1997; Pilgrim et al, 2003; Reinhart & Fitz, 2006]. In addition, programs are difficult and time consuming to learn [Lam, Wong & Henry, 1999]. It also appears that the capacities and software features are not well-known among users [Pfitzner et al, 2007]. This underlines the importance of making good software documentation and simple tools available to the users.

A second part of the study by Donn [1999] included 20 interviews with American users of simulation software packages. These 20 respondents considered that basic knowledge is essential to the simulation. According to the respondents, the professionals who do not understand the process of simulation have more difficulty in interpreting the results and supporting the design decisions. The errors most often encountered in simulation are related to a lack of understanding or a misuse of software, such as incorrect settings at the start, data entry errors or omissions [Pilgrim et al, 2003].

Training could remedy this situation, as well as better documentation, given help files are often scarce [Donn, 1999]. In the survey by Doherty [1997] in New Zealand, 70% of the 47 respondents, claiming they are software users, reported that they had some form of training outside work hours over the past two years, and 66% of them were considering following up training within the next two years.

Most studies identify a multitude of comments from computer tool users about the software interface. The graphical representation in the work environment is a major concern for users [De Wilde et al, 2001; Pfitzner et al, 2007; Pilgrim et al, 2003]. Indeed, a more advanced Graphical User Interface (GUI) promotes the use of software in the design context [De Wilde et al, 2001]. The GUI is an interface by which users visually interact instead of entering command lines. The 64 American respondents (architects and engineers) in Donn's studies [1997, 1999] claimed that the GUI was important.

The interface can also be dynamic and respond in real time to the users' actions. The software can for example react instantly to changes made to the design from adjustments to simple factors such as building layout, passive solar characteristics and associated cost elements [Donn, 1999]. This kind of interface supports an iterative design process, according to [Pfitzner et al, 2007].

Most complaints raised by software users appear to be related to the inability of software to clearly represent the findings [Pilgrim et al, 2003]. Although the representation may be hindered by the software's interface, this feature also affects the display of results. [Pilgrim et al, 2003] noted that the analytical results were most often presented as tables or graphs. However, the 87 engineers interviewed in this survey claimed that these modes of representation did not provide for a means of viewing and analyzing the images as well as three-dimensional graphics. Indeed, most simulation software tools provide numerical results [Donn, 1997] and, as such, make it difficult to establish a relationship between design and performance [Donn, 1999; Pilgrim et al, 2003]. The programs are not able to provide architects with results which are presented in a useful form for the EDP [De Wilde et al, 2001; Donn, 1999]. Moreover, when the software offers this type of representation, for example by expressing a given distribution of light intensity in space, they are often very difficult to interpret and translate into intelligent design [Donn, 1999]. Similar conclusions were reached in more recent study from United States by [Attia et al, 2009], where a group of architectural professionals, educators and students were surveyed on their experiences with 10 building performance simulation tools. The study shows that graphical representation of output results is the top priority concerning the usability of an interface with 22.9% of the responses, followed by the flexibility of use and navigation (17.3%) and graphical representation of the results in 3D spatial analysis (15.7%).

While it is important to promote exchanges between designers [De Wilde et al, 2001], it is also essential to educate clients and contractors about the value of simulation results in architecture. Indeed, three of the ten studies reviewed in this section emphasize the fact that the attitude of clients often limits the use of simulation software. Clients do not generally pay for tests [Donn, 1999; Holm, 1993; Reinhart & Fitz, 2006]. Architects and engineers also have difficulty in justifying the costs of simulation to clients, even if changes made to the design according to simulation results may save money [Lam, Wong & Henry, 1999]. This is especially noticeable in the smaller projects which more often have limited budget, and where architects are forced to base their design on intuition, rather than on cohesive design based on results of building performance simulation and use of digital tools [Attia, 2010].

Three-dimensional representations appear to be an effective way to promote efficient communication with the client. The investigation of [Pfitzner et al, 2007], and echoed by [Attia et al., 2009] concluded that representations of 3D rendering, which are very realistic, are needed to give the customer a good visual impression of the project in the early design stages. However, these 3D representations should be accompanied by some form of numerical results or graphs, in order to allow for an assessment of performance in relation to a given design.

2.4 Summary of previous results

This short literature review presented an overview of software use in architectural practice as reported by articles published in the period 1993-2011. Since the studies listed cover a large period of time, the literature review also highlights developments in the acceptance and use of computer tools in architecture.

However, it is very interesting and surprising to observe that the needs expressed by users have remained relatively unchanged over time. The users continue to express their dissatisfaction with low interoperability of software, lack of training or documentation on applications, and incomprehensible or poor representation of results. The users also place the following at the forefront of their needs: the ability to work in three dimensions and the ability to obtain concrete results quickly or iteratively. This is especially noticeable when digital tools, especially performance simulation tools are architects: despite all the developments in the field, the lack of appropriate simulation tools for use by architects at the early design phase is still considerable.

3. METHODOLOGY

This report presents the result of a recent international survey, which was carried out within the framework of IEA-SHC Task 41, Subtasks A and B. The present report only focuses on the results of Subtask B: Tools and methods for solar design. The aim of this survey was to identify the barriers of existing digital tools and methods for solar design and the needs of architects for improved tools supporting the design of solar energy aspects in their architectural practice. The web-based survey was conducted internationally including 14 countries (Australia, Austria, Belgium, Canada, Denmark, France, Germany, Italy, Norway, Portugal, South Korea, Spain, Sweden and Switzerland) and was translated into ten languages. The translations were made by the experts involved in Task 41. The questions and layout of the survey was developed during the IEA-SHC Task 41 meetings and through email exchanges with the collaboration of the international experts. The survey was launched on the Internet by national coordinators of IEA-SHC Task 41. Data collection lasted from May 3rd 2010 to October 22nd 2010. Since Australia officially joined the Task 41 only in September 2010, their survey was extended until the end of November 2010.

3.1 Methods for reaching the focus group

The focus group of this survey consisted mainly of architects and other building practitioners. In each country, one national coordinator involved in Task 41 was appointed for distributing the survey. Due to various circumstances, each coordinator used a different approach for reaching their particular focus group. For example, most national architectural associations have strict regulations regarding their members' contact details, and almost in all cases, they did not provide these details to the national coordinator responsible for the survey. In some countries, architectural associations were asked to put a link to the survey on their website. In other countries, the national coordinator placed announcements of the survey's launch in architectural magazines, or on websites of those architectural magazines and/or newsletters. One important difficulty about linking the survey through these association websites and/or newsletter was the fact that it makes it impossible to know how many professionals were actually reached and, therefore impossible to calculate exact response rates. Another way to reach the focus group was by building a special database of architects from the public telephone directories as well as from the lists provided by different organizations in the building industry. The next sections summarize the approach used to reach the focus group in each country.

3.1.1 Australia

In Australia, the survey was sent out via the Australian Institute of Architects (AIA) to approximately 9,000 members but it is impossible to be sure that the email sent reached all recipients. The national Australian coordinator was also able to encourage architects to complete the surveys during tours of the country to deliver an AIA national seminar series on integrating solar technologies.

3.1.2 Austria

In Austria, the involved institutes compiled a comprehensive distribution list from their contacts through regular cooperation with Austrian authorities, architecture and engineering offices, as well as manufacturers and installers concerned with solar technology. The survey was sent out via this distribution list addressing about 100 contacts, only counting direct addresses and no forwarding from the contacts which were done due to responses. In addition, the survey was sent out via newsletters and mailing lists, such as the expert platform KinG (Competence network for innovative building service engineering) that involves many architects and engineers, manufacturers, installers and real estate developers, and finally it was sent to specific members of the Austrian Architectural Association 'Arch+Ing'. As the 'Arch+Ing' holds an exclusive address list of all registered architects in

Austria which is restricted to their own mailing, the survey had to be forwarded to members with the plea for distribution. It was not possible to maintain a full list of received contributions from the 'Arch+Ing', but due to some direct feedback it can be concluded that it got well distributed within the Arch+Ing as well.

3.1.3 Belgium

In Belgium, the national Association of Architects has strict rules in place about providing their contact list information to others. Since it is very complicated to obtain required permission, the national coordinator of Belgium collected e-mail addresses of all the contacts from her own research team (Architecture et Climat, Université Catholique de Louvain). This database was updated with public information collected from the public telephone directories and with personal contacts in architectural offices. The database included a total of 179 e-mail addresses.

3.1.4 Canada

In Canada, the national coordinator created a special database of architects from the Royal Architecture Institute of Canada – Institut royal d'architecture du Canada (RAIC – IRAC) and complemented it by information from public telephone directories. This database was also supplemented with other lists provided by different organisations in the building industry as well as personal contacts in architectural offices. The Canadian database included a total of 1050 e-mail addresses. Surveys were distributed both in English and French.

3.1.5 Denmark

In Denmark, the survey was distributed through two channels: the national association of architects (Akademisk Arkitektforening) sent the survey through their two networks: 'Environmental Network' and 'Climate Network', to 230 members by direct e-mail. The survey was also distributed through the association Solar City Copenhagen by direct mail to members including 35 architects working with solar energy, and distribution to the architects in the Copenhagen Municipality.

3.1.6 France

France's participation in the Task 41 until September 2010 was informal. The national representative voluntarily participated in the development and distribution of the surveys. The links for both surveys (Subtask A and Subtask B) were posted on the website of the *Ordre des architects* and also distributed through Order's online newsletter. However, due to the lack of funding, they ceased further participation. Therefore, no information could be collected regarding how many professionals were actually reached.

3.1.7 Germany

In Germany, it was not possible to get a personal email address for every office, or to get a list of all German architects. So, the collection of addresses was initiated with known professionals (architects, engineers, etc.). Then, an internet research was done. It would have been possible to get more email addresses out of the public telephone directory/ Branch Book, but that was considered too time-consuming. Finally, the survey was sent out to 76 professionals, including architects, engineers, and manufacturers, ten organizations and approximately 700 persons via the Fraunhofer Institute for Solar Energy Systems mailing list. Organizations were asked to distribute the survey link to their members or newsletter subscribers. One organization (DGS – German Section of the International Solar Energy Society) sent the survey link in a newsletter, one refused to send out the link, and others provided no feedback. In total, the German link was sent to at least 776 building practitioners in Germany; however the real number is unknown.

3.1.8 Italy

In Italy, the link to the survey was published on six websites for architects. The link was presented with a short description of the Task 41 activities. In addition, the survey was sent to 60 000 national architects (through a newsletter of the web site Edilio (www.edilio.it), and to 100 local architects who had previously agreed to be registered into the Task 41 Italian database.

3.1.9 Norway

The Norwegian group have distributed the survey by e-mail to their own professional network. The e-mail has been sent to 244 persons with personal contact, mainly practising architects. Additionally the survey has been sent to the unknown number of members of Norsk Solenergiforening (http://www.solenergi.no/), a Norwegian Solar Energy Society whose mandate is to promote increased use of solar energy and is also affiliated with International Solar Energy Society (ISES).

3.1.10 Portugal

In Portugal, the national coordinator collected e-mail addresses from a personal list of architects, engineers, academics and educators (university and research teams), manufacturers and organizations. The database was then updated with a collaborative and interactive 'email forwarding' between all the people involved and their contacts. In addition, the survey was distributed within members of the Portuguese Architects Association.

3.1.11 South Korea

In South Korea, the contact lists for the survey were initially taken from the address book of 2009 Korea Institute of Registered Architects with the balance of office size, practitioner's age and locations. Later, the national coordinator added more lists of the local architects who attended the sustainable architectural design academies organized by a local architect's organization and personal contacts. The survey was finally distributed to 286 practicing architects in South Korea.

3.1.12 Spain

In Spain, the national coordinators got in touch with the different Councils of Architects for every region (18 regions in total, some of them with sub-regions). A complete list of the different regions is summarized at the National Spanish Architects Council (Consejo Superior de los Colegios de Arquitectos de España, www.cscae.com). For each region the survey was announced to the architects through different web pages and/or official mailing list.

3.1.13 Sweden

In Sweden, the survey was distributed through the following channels:

- Style, a travelling agency for architectural travels, with a vast contact list of 7000 architects, but it was unfortunately impossible to send out a reminder to fill the survey a little later in the process.
- The national association of architects (Sweden's Architects, SA) helped by sending out two calls, the initial one and a reminder. They also sent the survey through their network on 'Environment & Technology', not to all SA members. The information also appeared for a while on the SA homepage under 'Environment & Technology'.
- The survey was also distributed within the company White architects throughout Sweden (~500 persons) in June 2010, where half of the recipients received an email with questionnaire A mentioned first and questionnaire B as second, and the other half received the same email but with the questionnaires in reverse order. A reminder was sent in August 2010 and another one in October 2010.
- In August 2010, 31 offices were contacted through a list of architects connected to a national R&D association, ARKUS. The connected architecture offices consisted of 1-75

persons, where the average amount of architects per office was 25. A reminder was also sent in October 2010 to the ARKUS list.

3.1.14 Switzerland

In Switzerland, the survey was sent by email in three languages (French, German and Italian) to 100 authorities, 500 architects randomly chosen from *Swiss Architects* webpage, 80 manufacturers and 240 installers. In addition, the Swiss Society of Engineers and Architects (SIA) included the survey link into its newsletter, sent out to almost 15’000 members. It was also published on various websites and forwarded using various mailing lists of associations. The following websites and associations are some examples of the ones used to reach the focus group in Switzerland : Swissolar-schweizerischen Fachverband für Sonnenenergie, SUPSI (La Scuola universitaria professionale della Svizzera italiana), Accademie d'architecture Mendrisio, Swissengineering, Schweizerische Zentrale Fenster und Fassaden, www.world-architects.com and www.ee-news.ch.

3.2 Questionnaire

Questions and survey layouts were developed during the IEA-SHC Task 41 meetings and through e-mail exchanges with the collaboration of international experts. The survey consisted of 22 questions and included three question types: multiple choices of specific categories, a single selection of a specific category and open end question (free text). For example, the questions with multiple choices of specific categories gave the respondents the opportunity to select which tools they used in which design phase, or which decision they made in which design phase. Some of the multiple choice questions presented a list of the most expected answers.

To gather the desired data, the questions were divided into the following categories:

A. Solar energy in general:

Question 1

In your current architectural practice, how would you rate the importance of the use of solar energy (e.g. use of passive solar gains, solar thermal, photovoltaics, etc.)?

<important, neutral, unimportant, I don’t know>

Question 2

How often do your projects include: photovoltaic technologies for electricity, solar thermal technologies for domestic hot water, solar thermal technologies for cooling, passive use of solar gains for heating, daylight utilization strategies?

<always, often, sometimes, rarely, never>

B. The design methods:

Question 3

In which design phase would you first consider the integration of solar energy technologies?

<conceptual phase, preliminary design, detailed design, construction drawings>

Question 4

Among the following categories, identify up to three categories which correspond best to your own design process:

<experiences, rules of thumb, design guidelines, computer simulations, expert systems architecture, interactions with the owner, interactions with future users, several propositions, collaboration with others>

Question 5
How would you handle decision making for the integration of solar energy technologies in your project in the case of smaller, less complex projects?
<do it myself; consult a colleague architect; involve an internal solar energy consultant; involve an external solar energy consultant; involve a building science specialist; arrange multidisciplinary workshops; involve other profession>

Question 6
How would you handle decision making for the integration of solar energy technologies in your project in the case of larger, more complex projects?
<do it myself; consult a colleague architect; involve an internal solar energy consultant; involve an external solar energy consultant; involve a building science specialist; arrange multidisciplinary workshops; involve other profession>

C. Tools for solar design:
Question 7
How would you describe your current skills regarding: graphic solar design methods, CAAD, solar design tools in CAAD, and advanced tools)?
<very advanced, advanced, fair, poor, very poor>

Question 8
In the list below, identify at which design stage you use the following computer programs
(8a: CAAD tools: Vectorworks, Rhinoceros 3D, Microstation, Lightworks, Houdini, Form-Z, Digitial project, Cinema 4D, Caddie, Blender, ArchiCad, 3DS Max)
(8b: Visualization tools: Yafaray, V-Ray, RenderZone, Renderworks, Renderman, POV-ray, Mental Ray, Maxwell Render, LuxRender, LightWave, Flamingo, Artlantis)
(8c: Simulation tools: RETScreen, Radiance, PVSyst, PV*SOL, Polysun, LESOSAI, IES VE, IDA ICE, eQUEST, Energy Design Performance, Ecotect, Design Performance Viewer, DesignBuilder, Daysim, bSol, BKI Energieplanner)
<conceptual phase, preliminary design, detailed design, construction drawings>

Question 9
What are the 3 factors that most influence the choice of software you use?
<user-friendly design interface, cost, simulation capacity, interoperability with other software, availability of scripting feature, availability of plug-in(s), quality of output (images), 3d interface, other>

Question 10
For the programs you currently use, express how satisfied you are with their support for solar building design:
(10a: CAAD programs: Vectorworks, Rhinoceros 3D, Microstation, Lightworks, Houdini, Form-Z, Digital project, Cinema 4D, Caddie, Blender, ArchiCad, 3DS Max)
(10b: Visualization tools: Yafaray, V-Ray, RenderZone, Renderworks, Renderman, POV-ray, Mental Ray, Maxwell Render, LuxRender, LightWave, Flamingo, Artlantis)
(10c: Simulation tools: RETScreen, Radiance, PVSyst, PV*SOL, Polysun, LESOSAI, IES VE, IDA ICE, eQUEST, Energy Design Performance, Ecotect, Design Performance Viewer, DesignBuilder, Daysim, bSol, BKI Energieplanner)
<very satisfied, satisfied, neutral, dissatisfied, very dissatisfied>

Question 11
Are there any barriers to your use of available tools related to architectural integration of solar design?
<The tools are not adequately supporting the conceptual design stage; The tools are too expensive; The tools are too complex (high learning curve) ; Using the tools takes too much time; The tools are too systemic (do not support integration of active/passive/daylight design); The tools are not integrated in our normal workflow; The tools are not integrated in our CAAD software; The tools are too simplistic and do not give me the information I require; No, I find available tools quite satisfactory; I don't know / not applicable; Other>

Question 12
Do you see a need for improved tools to support the integration of solar building design?
<Yes, we need improved tools for visualization (architectural integration); Yes, we need improved tools for preliminary sizing of solar energy systems; Yes, we need improved tools for providing key data (numbers) about solar energy; Yes, we need tools that provide explicit feedback (key data) in connection with building massing and orientation; No, I find available tools quite satisfactory; I don't know / not applicable; Other>

Question 13
Please specify other needs regarding tools or methods:
(open question)

The questionnaire ended with general inquiries concerning the type of architectural office the respondents worked in and personal informant questions.

Informative factual questions (for statistical purposes only)
Question 14
Number of employees in your firm:
<Less than 3; 3 to 10; 11 to 50; More than 50>

Question 15
Among the following building categories, which one(s) correspond(s) the most to your architectural practice?
<Building renovation; New buildings; Residential buildings; Commercial buildings: retail stores, shopping centers, etc.; Commercial buildings: office buildings, Educational buildings: schools, kindergartens, etc.; Institutional buildings: hospitals, health care facilities; Institutional buildings: museums, exhibition centers, libraries, etc.; Government buildings; Industry / factory / storage buildings; Other>

Question 16
Among the following categories, identify up to three categories which correspond best to your own architectural design process?
<Intuitive design process (i.e. instinctive decisions made without conscious thought. It often refers to the architect's experience.); Integrated design process –IDP (collaboration with others professionals in multidisciplinary teams); Participatory design (interaction between the future users of the building, e.g. public participation); Energy-oriented design (i.e. practicing sustainability with calculator and computer simulation); Other>

Question 17
Among the following categories, identify the category which corresponds best to your own architectural practice?

<Traditional (conventional) practice with variety of projects; Traditional (conventional) practice with focus on building renovation or restoration; Design-Build (DB); Construction management (CM); Other>

Question 18
Is your firm active...
<Nationally; Internationally; Both nationally and internationally>

Personal factual questions (for statistical purposes only)
Question 19
When were you born?
(open question)

Question 20
Gender:
<male, female>

Question 21
Profession:
<Architect / Designer, Engineer, Physicist, Other>

Question 22
Professional experience:
<Less than 5 years; 5 to 10 years; more than 10 years>

The questionnaire ended with an open question ('Please add here any comment you wish to add to this survey').

The questionnaire and its layout as presented to the respondents are provided in Appendix A.

3.3 Response rates

A total of 627 questionnaires were received for Subtask B. Of these, only 350 were analysed since many questionnaires (277) were returned almost empty. However, since 78 questionnaires were returned with only a few unanswered questions, they were considered in the analysis.

An analysis of the incomplete versus complete questionnaires showed that the incomplete questionnaires were mostly empty. It seems that the respondents stopped answering after the first or second question. This was due to the fact that both questionnaires for Subtask A and B started with the same questions and some respondents may have thought they were answering the same questionnaire twice, which was a methodological flaw in the design of the questionnaires. Table 1 presents the distribution of complete and incomplete questionnaires by participating country as well as the amount of questionnaires distributed directly by emails and indirectly via links on websites, magazines, etc.

It can be, thus, claimed that more than 5 800 building practitioners were directly contacted by e-mail and the estimate is that potentially another 105 000 were contacted indirectly through announcements on websites or magazines in 14 countries. Internationally, 627 questionnaires were returned. However, among the returned questionnaires 277 had to be removed because they did not contain more than one or two answered questions. Thus, only 350 questionnaires (272 complete and 78 missing few questions) were used for the analysis. It is difficult to estimate the response rate with precision because we do not know if the respondents reacted to a direct e-mail or an indirect call through a website link. Table 1 also shows that the response rate varies widely between countries; the assumption is that this is a result of the methods used for survey distribution, as well as the presence of solar architecture and application of active solar strategies in the particular country. However, if we sum up all valid questionnaires (350) and divide this number by the total amount of direct e-mails sent, we obtain a response rate of 5.9%, which is assumed an 'acceptable' response rate for this type of survey.

Table 1: Amount of respondents reached by direct e-mails or indirectly through links on websites, complete, incomplete questionnaires (missing few questions) and empty questionnaires by participating country

Country		Indirect contact (i.e. website)	Direct e-mail	Complete	Missing few quest.	Empty	Total	Resp. rate (indirect) %	Resp. rate (direct) %
Australia		est. 9 000	0	**78**	**6**	49	133	0.9	n/a
Austria		90	180	**17**	**1**	13	31	20.0	10.0
Belgium		n/a	179	**16**	**5**	9	30	n/a	11.7
Canada	Eng.			**20**	**9**	15	44		
	Fr.			**11**	**3**	13	27		
	Total	n/a	1050	**31**	**12**	28	71	n/a	4.1
Denmark		n/a	265	**2**	**0**	2	4	n/a	0.8
France		est. 29 000	0	**8**	**0**	1	9	0.0	n/a
Germany		n/a	776	**8**	**10**	28	46	n/a	2.3
Italy		est. 60 000	100	**13**	**13**	34	60	0.0	26.0
Norway		unknown	244	**10**	**12**	17	39	n/a	9.0
Portugal		n/a	59	**6**	**0**	19	25	n/a	10.2
S. Korea		n/a	286	**33**	**3**	34	60	n/a	26.0
Spain		n/a	n/a	**7**	**4**	8	19		
Sweden		est. 7 000	1775	**27**	**11**	25	63	0.5	2.1
Switzerland	Fr.			**1**	**0**	1	2		
	Ger.			**7**	**4**	8	19		
	It.			**8**	**0**	9	17		
	Total	n/a	920	**16**	**1**	27	44	n/a	1.8
Total			5 834	**272**	**78**	277	627	0.5	5.9

It is important to emphasize that the authors are aware of the fact that there is a risk that the respondents are those who are interested in the issues of solar energy and who either have experience with integrating solar energy in architecture or are willing to do so. This, in itself, constitutes a bias of the research. The low response rate for the survey generally shows that building practitioners, mainly architects, lack interest in the topic or time for answering surveys, which bears consequences for the future implementation of solar strategies in architecture.

3.4 Data analysis

Data was collected by the Canadian experts in Task 41 using the Questionform web service [www.questionform.com , 2010], where the survey was hosted. Data from this web service was exported to Microsoft Excel and results were presented graphically and by using descriptive statistics. These results were shared with the national coordinators of all the countries involved, and they were asked to make an analysis of their national results, which will be presented in further publications. The general international results were analysed by the Canadian Subtask leaders, Canadian experts, and a Swedish expert.

4. RESULTS

4.1 Description of respondents

A series of questions at the end of the questionnaire (Q. 14, 15, 18 to 22) aimed to establish the participants' profile. These questions included the following aspects:

- description of architectural firm;
- size of architectural firm;
- scope of architectural practice;
- type of building projects designed;
- project delivery method;
- age (year of birth);
- gender;
- profession (architect, engineer, physicist or other);
- professional experience.

4.1.1 Description of architectural firm (Q. 14, 18)

Two questions (Q. 14 and 18) aimed at describing the firm in which the respondents worked. Figures 4 and 5 present the distribution of answers for all countries for questions 14 and 18 respectively.

Figure 4: Distribution of answers for question 14: 'number of employees in your firm' for all countries (n=282)

A total of 282 respondents answered question 14. The results indicate that the majority of respondents worked in relatively small firms and mostly on a national level.

Figure 4 indicates that the majority of respondents worked in small firms: nearly 34% (n=96) of the respondents worked in offices with less than three employees and 32% (n=91) in offices with 3 to 10 employees. A minority of respondents (approx. 15%, n=43) worked in large offices with 11-50 employees and 18% (n=52) worked in very large offices of more than 50 employees.

A total of 268 respondents answered question 18. Figure 5 shows that the majority of their firms (71%, n=191) were active nationally, 23% (n=61) were active both nationally and internationally and a small number of respondents (6%, n=16) only worked internationally.

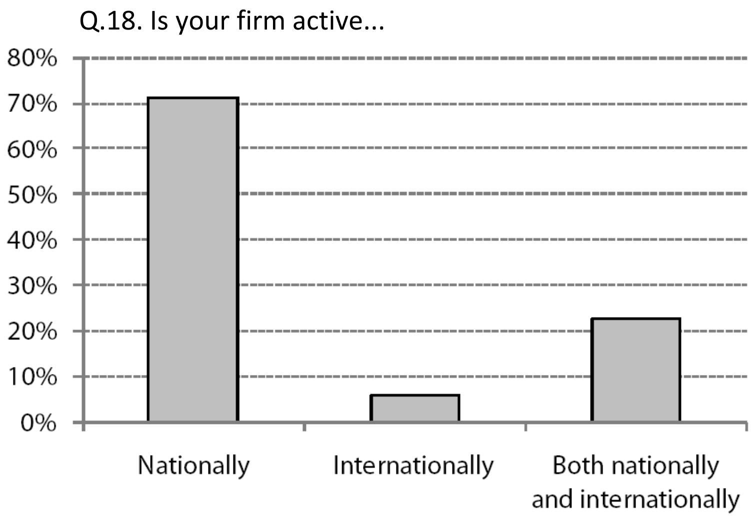

Figure 5: Distribution of answers for question 18 'is your firm active…nationally, internationally or both', for all countries (n=268)

4.1.2 Type of architectural practice (Q. 15)

One question (Q.15) aimed at identifying which categories of building projects the respondents were responsible for. Figure 6 and Figure 7 present the distribution of answers for all countries.

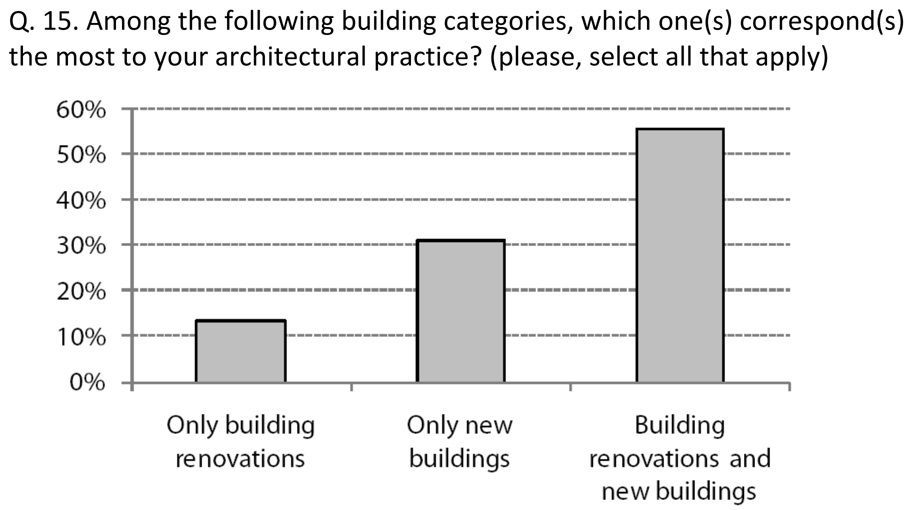

Figure 6: Distribution of answers for question 15 'among the following building categories, which one(s) correspond(s) the most to your architectural practice', for all countries (n=266).

A total of 266 selections were made for the first part of this multiple-choice question. Some 56% (n=148) of respondents selected both categories 'Building renovations' and 'New buildings', 14% (n=36) selected only 'Building renovations' and 31% (n=82) selected only 'New buildings'. The results thus indicate that the majority of respondents worked both with new buildings and with building renovations.

In the second part of question 15, the respondents were also invited to specify the types of buildings they worked on. A total of 808 selections were recorded for this multiple choice question. Of these 808 selections, Figure 7 shows that the building categories which corresponded the most to the architectural practice of respondents were: 'Residential buildings' with 27% (n=220) of all selections, 'Commercial buildings: office buildings' with 15% (n=123) of all selections, 'Educational buildings: schools, kindergarten, etc.' with 14% (n=112) of all selections, and 'Commercial buildings : retail stores, shopping centres, etc.' with 11% (n=89) of all selections. Only 8% (n=67) of all selections were for 'Industries, factory and storage buildings category', 7% (n=59) were for 'Government buildings', 7% (n=58) were for 'Institutional buildings: hospitals and health care facilities' and 6% (n=52) for 'Institutional buildings: museums, exhibition centres, libraries, etc.'

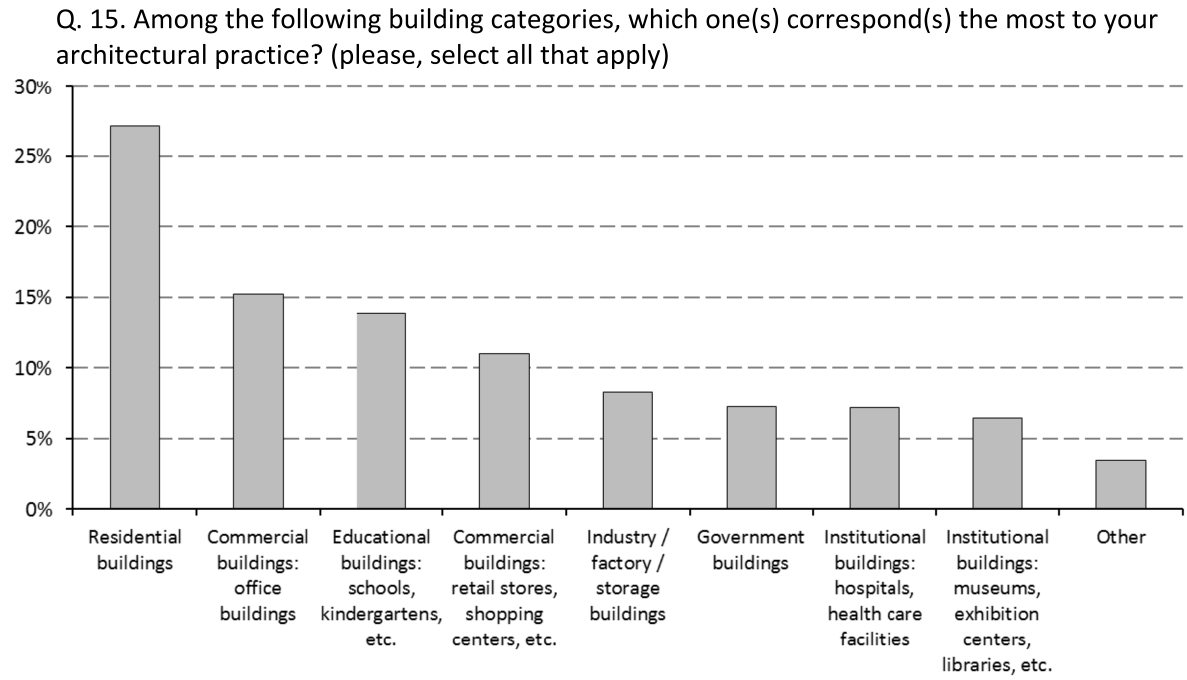

Figure 7: Distribution of answers for question 15 'among the following building categories, which one(s) correspond(s) the most to your architectural practice', for all countries (n=808).

Only 3% (n=28) of all selections were for 'Other' building types. In these cases, people had the opportunity to write which kind of buildings they were specifically working on. Many respondents wrote that they worked on urban planning projects, three wrote that they worked on worship buildings like churches, two worked on railway stations, and the following single answers were also recorded: sport and recreational facilities, small retail fit out and private health clinics, renderings for architectural and media, rural developments, building restoration, research facilities and labs, farm buildings, research, consultation, landscape architecture, infrastructure and building prototypes.

4.1.3 Project delivery method (Q. 17)

Question 17 aimed at determining the Contractual methods / methods of project delivery most used by respondents. The clarification between the methods was also provided in the question as a following image:

Contractual methods/ Methods of project delivery *Contractual methods establish communication, coordination and contracts between the owner, contractor and designer.*		
Traditional (conventional) method also called DBB (Design-Bid-Build)	**DB (Design-Build)**	**CM (Construction management)**
Owner **Architect** **Contractor** The owner has separate contracts with the architect and contractor. DBB includes contests, charettes and competitions.	**Owner** **Architect/Contractor team** The owner contacts one entity which is responsible for managing the whole project. DB includes Fast-track which means that construction is started before the design is complete to compress the time required.	**Owner** **Architect** **CM** The owner contracts with both an architect and a construction manager who manages with both design and construction.

Figure 8: Clarification of different contractual methods/methods of project delivery, as presented in the Q.17

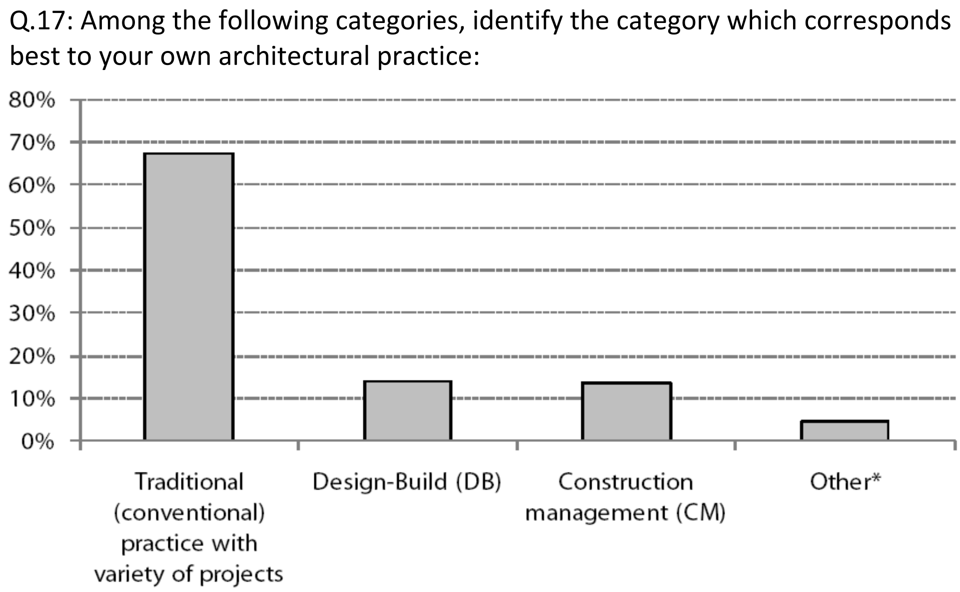

Figure 9: Distribution of answers for question 17 'among the following categories, identify the category which corresponds best to your own architectural practice', for all countries (n=287)

Figure 9 presents the distribution of answers for all countries. It indicates that the majority of respondents (67%; n=193) used a traditional (conventional) project delivery method. Only 14% (n=41) used the design-build method, 14% (n=39) used construction management and 5% (n=14) used other methods. By Other, majority of answers were: ‘owner built’, one was: ‘turn-key method’ and one was ‘all of the above’.

4.1.4 Age, gender, profession, professional experience (Q. 19, 20, 21, 22)

Questions 19 to 22 aimed at describing the personal profile of the respondents. Figures 10-13 present the distribution of answers for all countries.

Age

A total of 258 respondents answered this personal informative question. Figure 10 shows that a large number of respondents were born in the 1960s (28%, n=73) and 1970s (27%, n=70). It also shows that 11% (n=29) of respondents were born in the 1940s, 25% (n=64) in the 1950s, and 8% (n=20) in the 1980s. Only 1% (n=2) of respondents were born in the 1930s. Thus, more than 75% of respondents were between 30 and 59 years old, with a relatively balanced distribution between respondents belonging to the three main age groups (30, 40 and 50), and professionally at the peak of their carriers.

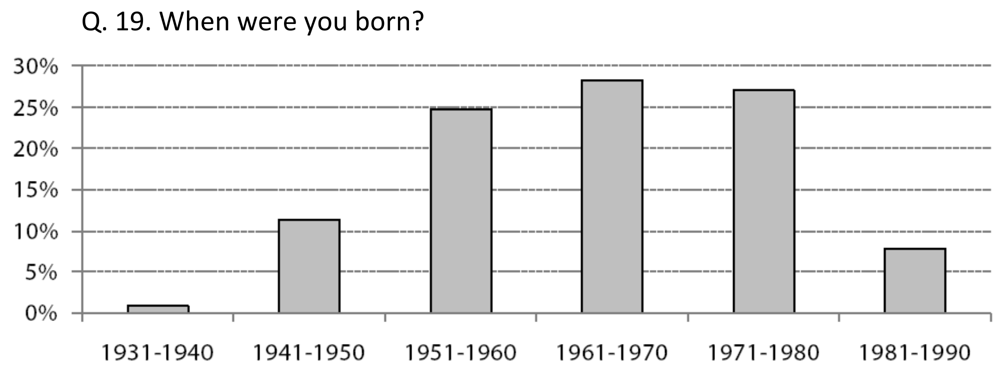

Figure 10: Distribution of answers for question 19 about age, for all countries (n=258).

Gender

Figure 11 shows that the majority (66%, n=179) of respondents were males.

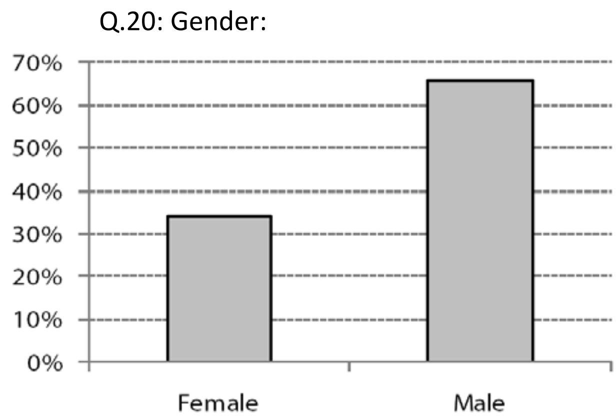

Figure 11: Distribution of answers for question 20 about gender, for all countries (n=272)

Profession

Figure 12 shows that the vast majority, 88% (n=239) of respondents were architects. Only 7% (n=18) were engineers, and 1% (n=2) were physicists. Only 5% (n=13) of respondents selected 'Other profession'. These respondents added comments next to their answers indicating that they were: architect-engineer and renewable energy technician, professors, researcher, environmental consultant, contractor, surveyor, facilities manager, solar thermal design engineer, insulator/tinsmith, etc. Such answers are not surprising, since the profession primarily targeted in this survey were architects, as described in the methods of reaching for respondents.

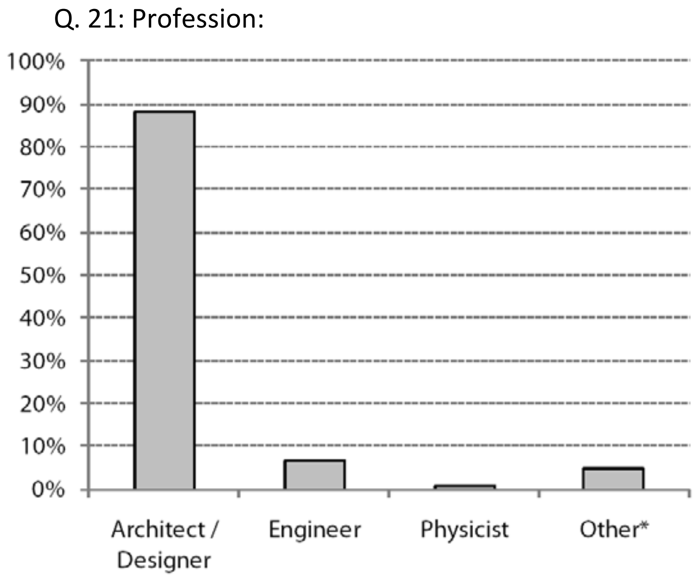

Figure 12: Distribution of answers for question 21 about profession, for all countries (n=272).

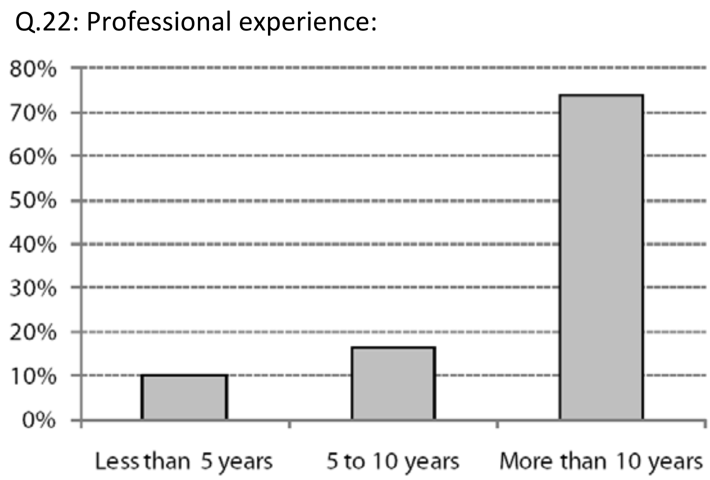

Figure 13: Distribution of answers for question 22 about professional experience, for all countries (n=271).

Professional experience

Figure 13 shows that the majority of respondents (74%, n=200) had more than 10 years of professional experience. The other respondents had 5 to 10 years of experience (16%, n=44) and 10% (n=27) had less than 5 years of experience.

4.2 General questions related to solar energy use

4.2.1 Importance of solar energy in actual practice (Q. 1)
The first question (Q.1) aimed at determining the importance attributed to solar energy aspects in the architectural practice. Figure 14 presents the distribution of answers for all countries.

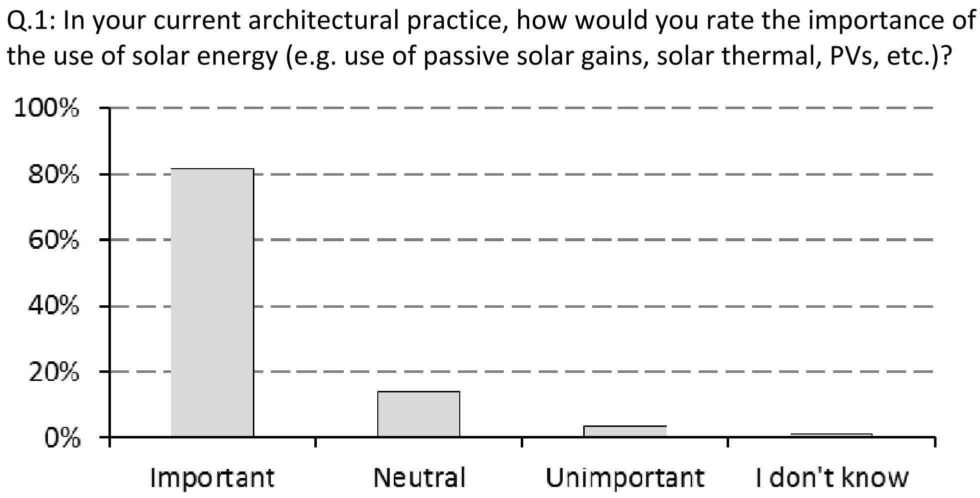

Figure 14: Distribution of answers for question 1 about importance of solar aspects in current architectural practice, for all countries (n=346).

A total of 346 respondents answered this question. Figure 14 shows that the majority of respondents (82%, n=282) considered the use of solar energy in architecture as 'important'. A minority of respondents (14%, n=49) were 'neutral' about solar energy aspects and merely 3% (n=11) rated it as 'unimportant'. Only 1% (n=4) of respondents answered 'I don't know' to this question. The clear outcome of this question could be a result of a large proportion of those who decided to participate in this survey is already interested in the topic.

4.2.2 Occurrence of solar energy systems in actual projects (Q. 2)
One question (Q. 2) concerned the inclusion of solar design aspects in the actual architectural practice of the respondents. Figure 15 (on the next page) presents the distribution of answers for all countries.

The number of respondents for each technology varied because some respondents did not select any answer for some questions. This may indicate their lack of knowledge about the technology. Figure 15 shows that, at an international level, only 6% (n=21) of respondents always include photovoltaic technologies for electricity in their projects, and 17% (n=58) integrate it often. Some 28% (n=95) of respondents answered that they use photovoltaic technologies sometimes, 26% (n=87) use them rarely and 23% (n=80) answered that they never use them.

Concerning solar thermal systems for domestic hot water (DHW), 16% (n=54) of respondents said they always include them in their projects, 31% (n=106) use them often and 25% (n=84) integrate them sometimes. Some 18% of respondents (n=62) rarely use them and 11% (n=36) answered that they never use these systems.

Regarding solar thermal systems for heating, only 6% (n=19) of respondents always use them, 14% (n=46) use them often and 28% (n=93) use them sometimes. Almost a third (29%, n=95) of respondents rarely use solar thermal systems for heating and a quarter (24%; n=78) never include these systems in their projects. Note that the distribution of answers for this question is similar to that of 'Photovoltaic for electricity'.

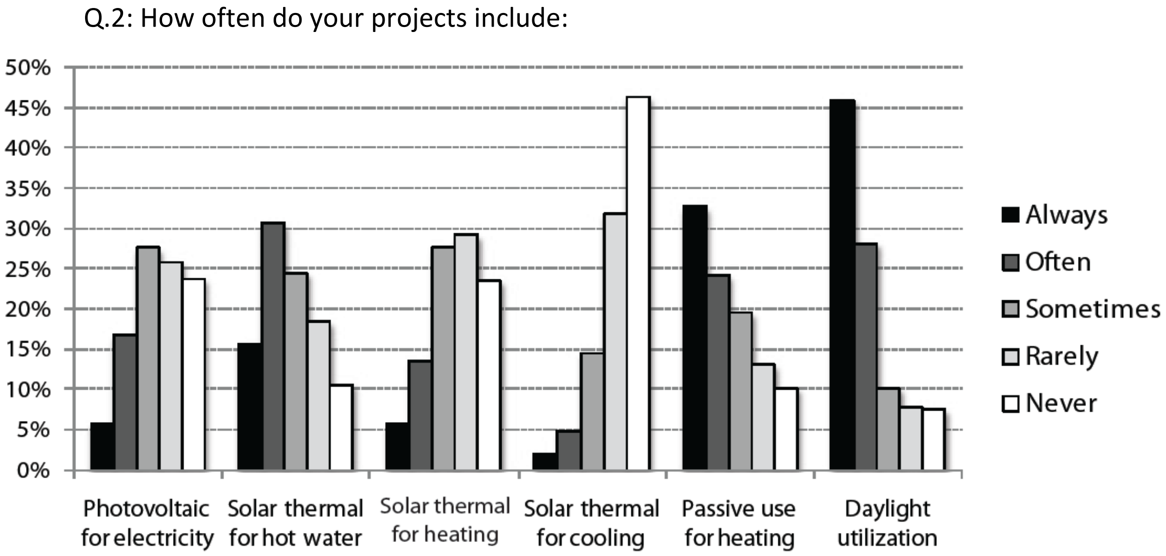

Figure 15: Distribution of answers for question 2 about occurrence of solar energy systems used, for all countries (n=325 to 342).

As for the solar thermal systems for cooling, only 2% (n=7) of respondents always use these systems in their projects and 5% (n=16) include them often. Some 15% (n=48) use them sometimes, about a third (32%, n=103) of respondents use them rarely and the majority (46%, n=151) answered that they never use solar thermal systems for cooling. The results clearly show that these systems are still not used in the countries involved in IEA-SHC Task 41, which was an expected result since this technology is more relevant in hot climates.

Regarding passive solar for heating, a third (33%, n=111) of the respondents answered that they always use these strategies in their projects and 25% (n=83) said they use them often. Some 20% (n=67) of respondents answered that they use them sometimes, 13% (n=43) use them rarely and only 10% (n=34) said they never consider passive solar strategies in their projects.

Finally, about daylight utilization, a large proportion of respondents (46%, n=157) answered that they always include daylight utilization in their projects, and 28 % (n=95) answered that they use it often. Some 10% (n=35) of respondents use it sometimes, and only 8% (n=27) answered that they rarely include daylight utilization strategies in their work while 7% (n=25) never do. The distribution of answers clearly shows that daylight utilization is the most frequently used solar strategy in buildings, followed by the exploitation of passive solar heat gains.

4.3 Questions concerning design methods

4.3.1 Design process (Q.16)

Question 16 aimed at determining which methods were used in the design process. Figure 16 presents the distribution of answers for all countries.

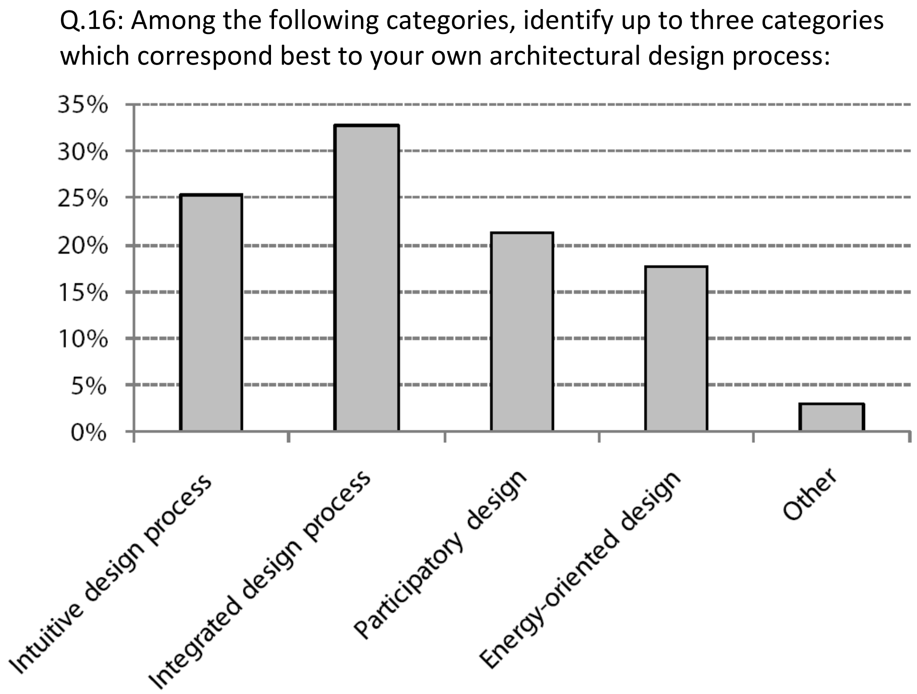

Figure 16: Distribution of answers for question 16 'among the following categories, identify up to three categories which correspond best to your own architectural design process?' for all countries (n=587)

Intuitive design process is described in a survey as 'instinctive decisions made without conscious thought; often refers as architect's experience'. Integrated design process (IDP) refers to collaboration with other professionals in multidisciplinary teams. Participatory design is clarified as 'interaction with future users of the building, e.g. public participation', and energy-oriented design refers to practicing sustainability with calculator and computer simulation.

Since respondents were able to choose up to three selections, the total number of "clicks" was 587. Out of that, 25% (n=149) responses were about Intuitive design process, 33% (n=192) about IDP, 21% (n=125) about Participatory process and 18% (n=103) about Energy-oriented design process. Only 3% (n=18) answers were about 'Other' type of method, and this included a variety of options, such as: 'Compliance with specific building type design guidelines', 'focus on innovation and emerging systems', 'evidence based design', 'combination of intuition and university acquired knowledge', etc.

4.3.2 Design phase where solar energy is considered (Q. 3)

Question 3 aimed at determining the moment, during the design process, when the professionals first considered the integration of solar energy technologies. Figure 17 presents the distribution of answers for all countries.

Figure 17 shows that 69% (n=234) of respondents considered the integration of solar energy technologies during the conceptual phase. About 27 % (n=91) considered it in the preliminary design phase, 3% (n=9) in the detailed design phase and only 1% (n=3) in the construction drawings phase.

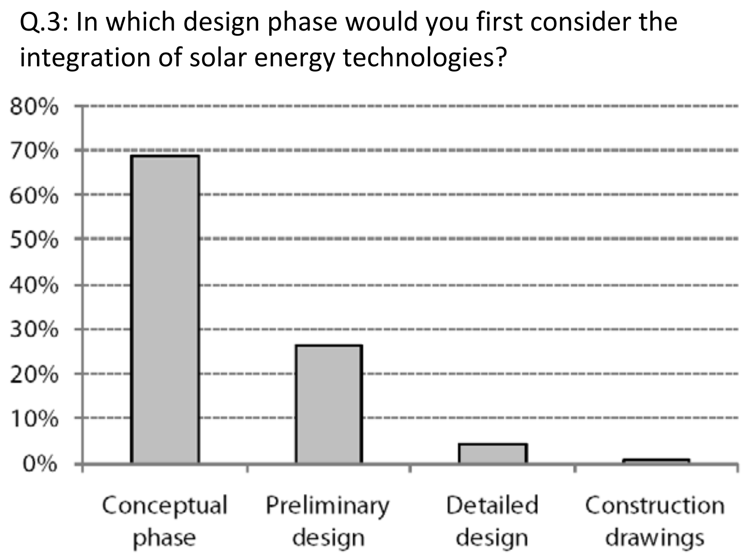

Figure 17: Distribution of answers for question 3 about the moment in the design process when solar energy technologies are first considered, for all countries (n=337).

4.3.3 Design process (Q. 4)

Question 4 aimed at determining the methods used in the design process. Figure 18 presents the distribution of answers for all countries.

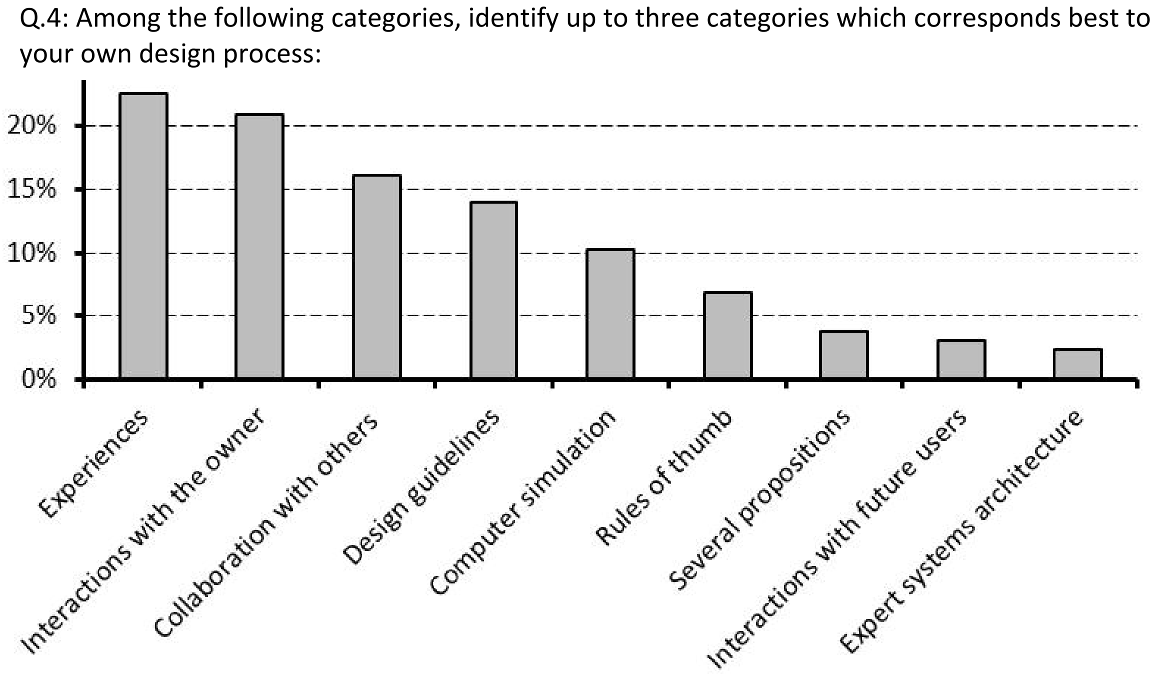

Figure 18: Distribution of answers for question 4 about design process, for all countries, (n=913).

Response to this question shows that architects are still relying on experience (their own or from others), but also interact quite well with others: from building owners to future users.

A total of 913 selections were recorded for this multiple-choice question. Figure 18 shows that the most popular design processes selected were 'Experiences' (23%, n=206), 'Interactions with the owner' (21%, n=190) and 'Collaboration with others' (16%, n=147). The next most popular choices were 'Design guidelines' (14%, n=130), and 'Computer simulations' (10%, n=94). Finally, the least popular choices were 'Rules of thumb' (7%, n=63), 'Several propositions' (4%, n=33), 'Interactions with future users of the building (i.e. public participation)' (3%, n=29), and 'Expert systems architecture (i.e. concept research)' (2%, n=21).

4.3.4 Way to handle decision making in small projects (Q. 5)

Question 5 aimed to determine how the integration of solar energy technologies was handled in the design process of small projects. Figure 19 (on the following page) presents the distribution of answers for all countries.

Q. 5: How would you handle the decision making for the integration of solar energy technologies in your project in case of smaller, less complex projects? (please, select all that apply)

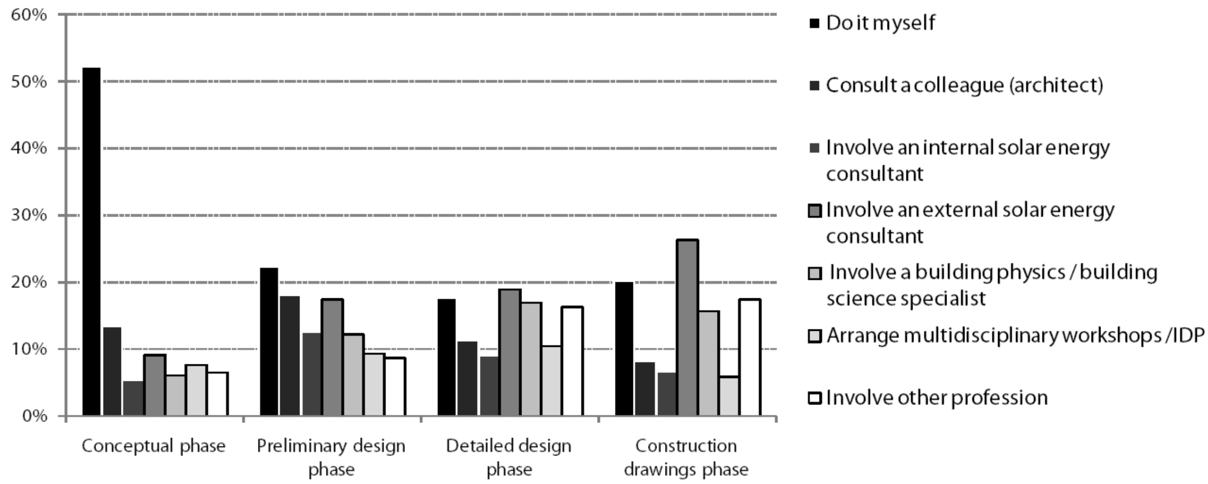

Figure 19: Distribution of answers for question 5 about methods of design in case of small projects, for all countries (n=1745).

The results generally indicate that the architect is more likely to rely on his own experience during the beginning of the design process but as the design progresses, internal as well as external consultants begin to be involved.

Conceptual Design Phase

A total of 1745 selections were recorded for this multiple-choice question. Of these 1745 selections, 440 selections were for the conceptual phase, 549 were for the preliminary design phase, 417 were for the detailed design phase, and 339 were for the construction design phase. Figure 19 shows that, in the conceptual phase, 53% (n=232) of selections were for handling integration of solar energy technologies by themselves ('Do it myself'). Only 13% (n=59) of selections were for 'Consult a colleague architect', 5% (n=23) were for 'Involve an internal solar energy consultant', 9% (n=39) were for 'Involve an external solar energy consultant', 6% (n=26) of selections were 'Involve a building physics/building science specialist', 8% (n=33) were for 'Arrange multidisciplinary workshops /IDP' and 6% (n=28) were for 'Involve other professions'.

Preliminary Design Phase
Out of the 549 selections for the preliminary design phase, 23% (n=124) were for 'Do it myself', 18% (n=98) were for 'Consult a colleague architect', 13% (n=69) for 'Involve an internal solar energy consultant', 17% (n=95) for 'Involve an external solar energy consultant', 12% (n=65) for 'Involve a building science specialist', 9% (n=52) for 'Arrange multidisciplinary workshops' and 8% (n=46) for 'Involve other professions'.

Detailed Design Phase
Out of the 417 selections recorded for the detailed design phase, 18% (n=73) were for 'Do it myself', 11% (n=47) were for 'Consult a colleague architect', 9% (n=38) for 'Involve an internal solar energy consultant', 19% (n=78) for 'Involve an external solar energy consultant', 17% (n=71) for 'Involve a building science specialist', 10% (n=43) for 'Arrange multidisciplinary workshops' and 16% (n=67) for 'Involve other professions'.

Construction Drawings Phase
Out of the 339 selections for the construction drawings phase, 20% (n=69) were for 'Do it myself', 8% (n=28) for 'Consult a colleague architect', 7% (n=23) for 'Involve an internal solar energy consultant', 26% (n=89) for 'Involve an external solar energy consultant', 15% (n=52) for 'Involve a building science specialist', 6% (n=20) for 'Arrange multidisciplinary workshops' and 17% (n=58) for 'Involve other professions'.

4.3.5 Way to handle decision making in large project (Q. 6)
Question 6 aimed at determining how the integration of solar energy technologies was handled in the design process of larger, more complex projects. Figure 20 presents the distribution of answers for all countries.

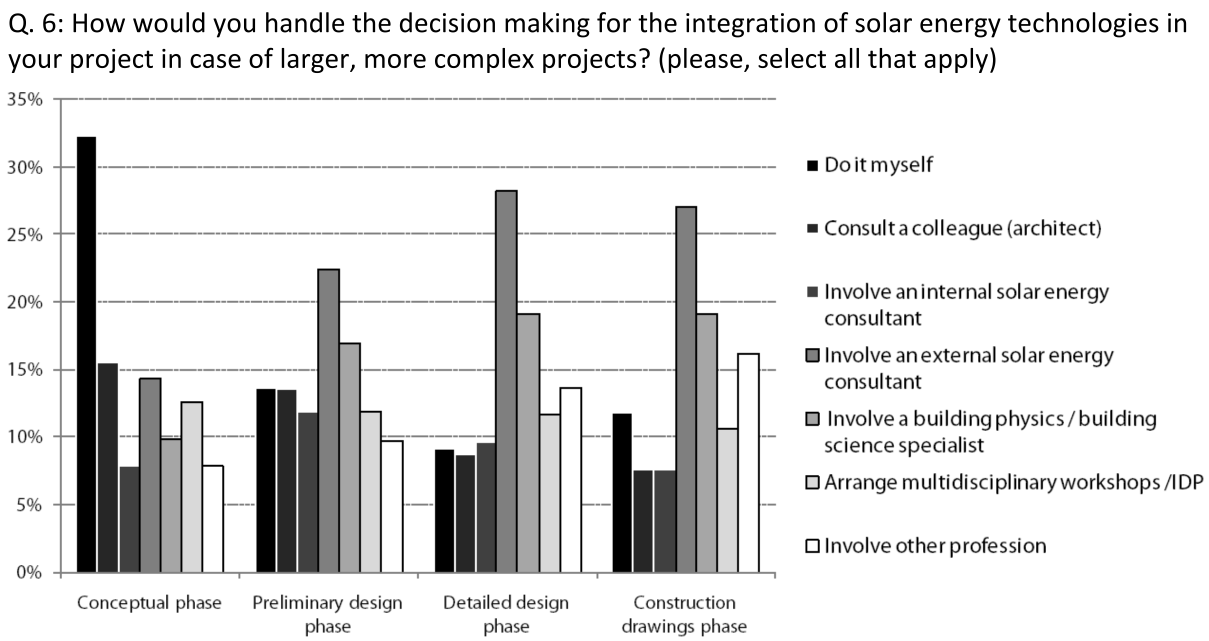

Figure 20: Distribution of answers for question 6 about design methods in case of larger, more complex projects, for all respondents (n=1892).

In general, the results indicate that the architect is more likely to involve other professionals or consultants in larger, more complex projects than in smaller projects.

Conceptual Design Phase
A total of 1892 selections were recorded for this multiple-choice question. Of these 1892 selections, 506 selections were for the conceptual phase, 595 selections were for the preliminary design phase, 456 selections were for the detailed design phase and 335 selections were for the construction drawings phase. Figure 20 shows that, in the conceptual phase, 32% (n=164) of selections were for handling integration of solar energy technologies by themselves ('Do it myself'), 15% (n=78) of selections were for 'Consult a colleague architect', 8% (n=40) were for 'Involve an internal solar energy consultant', 14% (n=72) were for 'Involve an external solar energy consultant', 10% (n=49) were for 'Involve a building science/physics specialist', 12% (n=63) were for 'Arrange multidisciplinary workshops /IDP' and 8% (n=40) were for 'Involve other professions'.

Preliminary Design Phase
Out of the 595 selections for the preliminary design phase, 14% (n=81) were for 'Do it myself', 13% (n=80) were for 'Consult a colleague architect', 12% (n=70) were for 'Involve an internal solar energy consultant', 23% (n=134) were for 'Involve an external solar energy consultant', 17% (n=101) were for 'Involve a building science specialist', 12% (n=71) were for 'Arrange multidisciplinary workshops' and 10% (n=58) were for 'Involve other professions'.

Detailed Design Phase
Out of the 456 selections made for the detailed design phase, 9% (n=42) were for 'Do it myself', 9% (n=40) were for 'Consult a colleague architect', 9% (n=43) were for 'Involve an internal solar energy consultant', 28% (n=128) were for 'Involve an external solar energy consultant', 19% (n=86) were for 'Involve a building science specialist', 12% (n=54) were for 'Arrange multidisciplinary workshops' and 14% (n=63) were for 'Involve other professions'.

Construction Drawings Phase
Out of the 335 selections for the construction drawings phase, 12% (n=40) were for 'Do it myself', 8% (n=26) were for 'Consult a colleague architect', 7% (n=25) were for 'Involve an internal solar energy consultant', 27% (n=91) were for 'Involve an external solar energy consultant', 19% (n=63) for 'Involve a building science specialist', 10% (n=35) were for 'Arrange multidisciplinary workshops' and 16% (n=55) were for 'Involve other professions'.

4.4 Questions concerning tools

4.4.1 Skills with the use of tools (Q. 7)
One question (Q. 7) aimed to establish the current skills of respondents with different tools for solar design. The possible choice of tools to select was: graphical tools (i.e. solar charts), computer aided architectural design software (CAAD), solar design tools included in CAAD software, and energy simulation software. Figure 21 (next page) presents the distribution of answers for all countries.

In general, the results indicate that the more specialized the tools are, the less advanced are the skills of the architects.

For graphical solar design methods, i.e. solar charts, a total 310 selection were recorded. Figure 21 shows that, out of these 310 selections, 10% (n=31) considered their skills as 'very advanced', 20% (n=63) as 'advanced', 37% (n=114) as 'fair', 20% (n=61) as 'poor' and 13% (n=41) as 'very poor'.

Q.7: How would you describe your current skills?

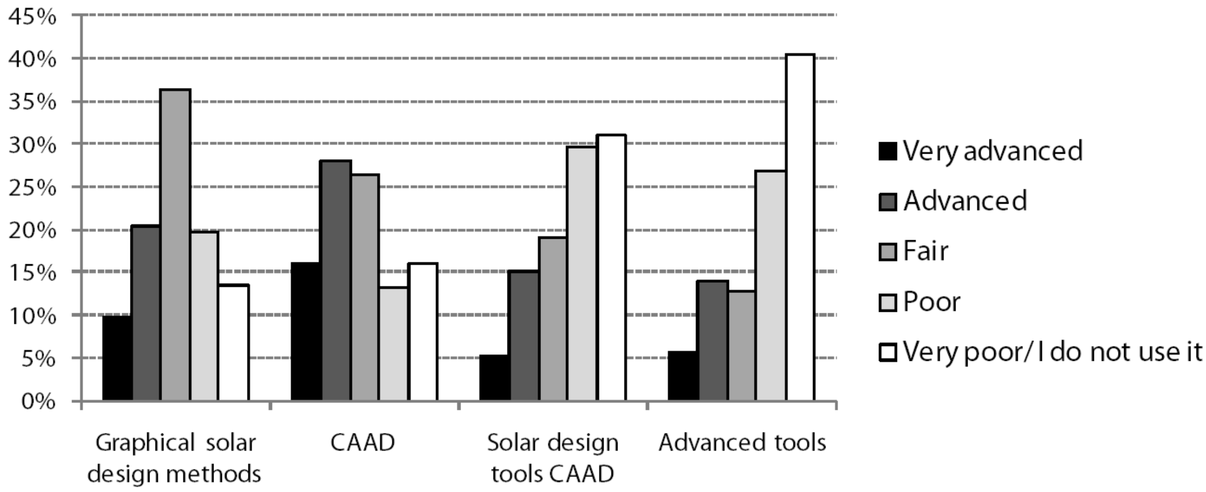

Figure 21: Distribution of answers for question 7 about the skills with the use of different tools, for all countries (n= 303-310).

Regarding CAAD tools, a total of 307 selections were recorded. Figure 21 shows that, out of these 307 selections, 16% (n=49) were for 'very advanced', 28% (n=86) for 'advanced', 27% (n=82) for 'fair', 13% (n=16) for 'poor' and 16% (n=50) for 'very poor'.

Concerning solar design tools in CAAD, a total of 303 selections were recorded. Out of these 303 selections, only 5% (n=16) were for 'very advanced', 15% (n=46) were for 'advanced', 19% (n=57) were for 'fair', about a third (30%, n=90) were for 'poor' and nearly a third (31%, n=94) were for 'very poor'.

Finally, concerning advanced solar or energy simulation tools, 310 selections were recorded for this item. Only 6% (n=18) answered that they consider their skills as 'very advanced', 14% (n=43) as 'advanced', 13% (n=40) as 'fair', 27% (n=83) as 'poor' and over a third (41%, n=126) as 'very poor'.

4.4.2 Computer programs used according to design phase (Q. 8)

The following question (Q. 8) aimed to determine which software tools are used by respondents in their current architectural practice and at which phase of the design process these tools are used. The software packages included in the choice of answers are those selected for the report *T.41.B.1. State-of-the-art of digital tools for solar design used by architects* [see Dubois & Horvat (ed.), 2010]. The software packages have been classified according to three categories: Computer-aided architectural design (CAAD), visualization tools and simulation tools.

CAAD programs used according to design phase (Q. 8a)

Figure 22 (on the following page) presents the distribution of answers for all countries, for CAAD tools.

A total of 1623 selections were recorded for this multiple-choice question concerning CAAD tools, indicating that most respondents use more than one tool. Out of these, 439 selections were for conceptual phase, 481 were for the preliminary design phase, 375 were for the detailed design phase and 328 were for the construction design phase.

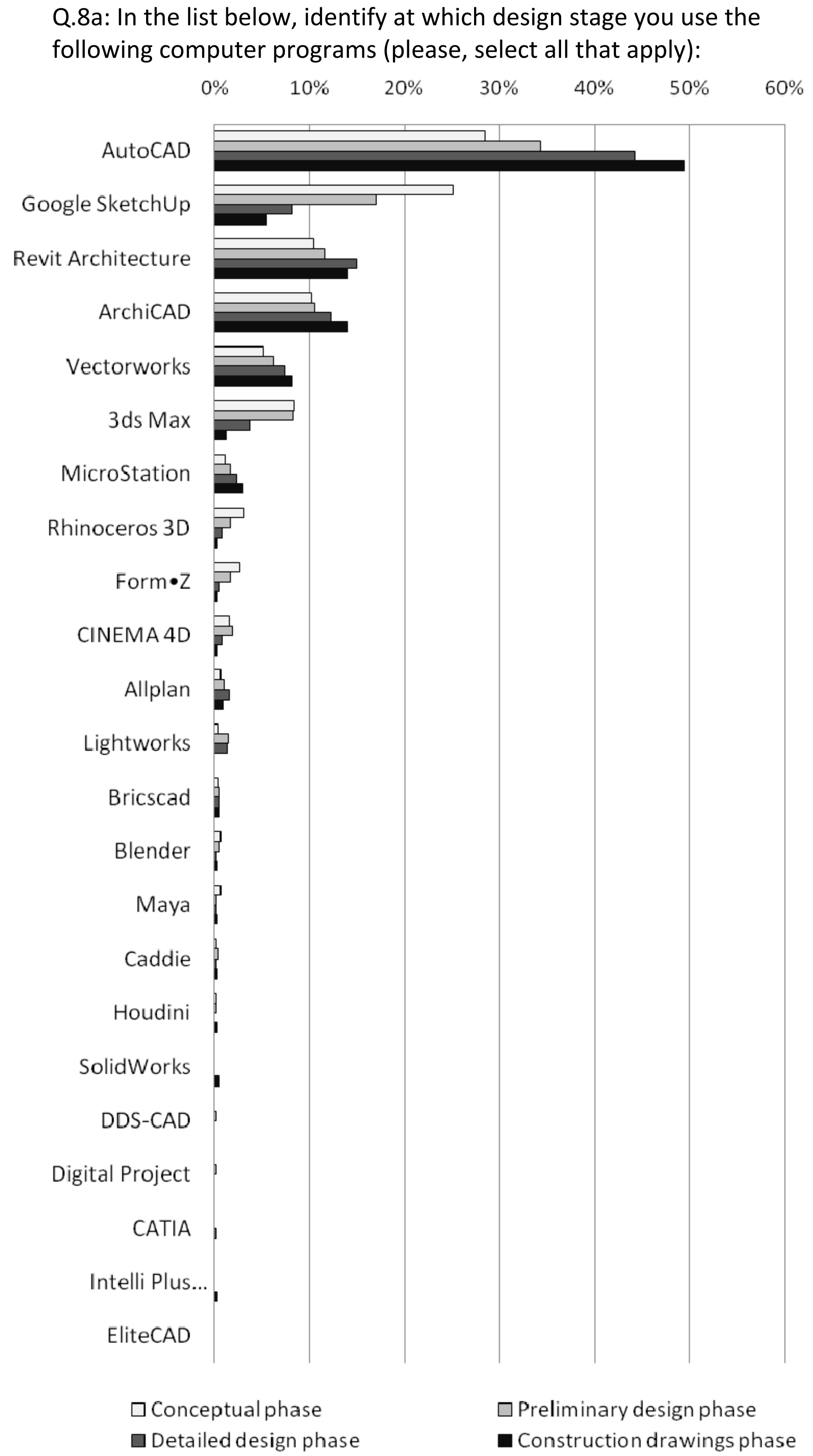

Figure 22: Distribution of answers for question 8a about CAAD software per design phase for all countries (n=1623).

The results thus generally indicate that AutoCAD is the most popular program but that this program is preferred for advanced design phases. The same trend can be observed in the case of Revit and ArchiCAD. Google SketchUp is the second most used software but the distribution of answers indicates that this program is preferred at EDP rather than advanced design phases, which is expected, knowing this program's capabilities and intentions.

Conceptual Design Phase
Figure 22 shows that AutoCAD was the program most often selected by respondents (29%, n=125) for the conceptual design phase. For the same design phase, 25% (n=110) of selections were for the program Google SketchUp, 11% (n=46) were for Revit Architecture, 10% (n=45) were for ArchiCAD, 8% (n=37) were for 3ds Max and 5% (n=23) were for Vectorworks. The other programs were selected by less than 3% of respondents.

Preliminary Design Phase
Out of the 481 selections made for the preliminary design phase, 34% (n=165) were for AutoCAD, 17% (n=82) of selections were for Google SketchUp, 12% (n=56) were for Revit Architecture, 11% (n=51) were for ArchiCAD, 8% (n=40) were for 3ds Max, and 6% (n=30) were for Vectorworks. The other programs were selected by less than 2% of respondents.

Detailed Design Phase
Out of the 375 selections for the detailed design phase, 44% (n=166) were for AutoCAD, 15% (n=56) of selections were for Revit Architecture, 12% (n=46) were for ArchiCAD, 8% (n=31) were for Google SketchUp, 7% (n=28) were for Vectorworks and 4% (n=14) were for 3ds Max. The other programs were selected by less than 2% of respondents.

Construction Drawings Phase
Out of the 328 selections for the construction design phase, 49% (n=162) were for AutoCAD, 14% (n=46) were for Revit Architecture, 14% (n=46) were for ArchiCAD, 8% (n=27) were for Vectorworks, 5% (n=18) were for Google SketchUp and 3% (n=10) were for Microstation. The other programs were selected by less than 1% of respondents.

Visualization programs used according to design phase (Q. 8b)
Figure 23 (next page) present the distribution of answers for all countries for visualization tools.

A total of 197 selections were recorded for this multiple-choice question concerning visualization tools. Out of these 197 selections, 62 selections were for conceptual phase, 74 were for the preliminary design phase, 39 were for the detailed construction phase and 22 were for the construction design phase. In comparison to CAAD tools, there seems to be a less agreement between respondents regarding the preferred visualization tool.

Considerably less selections made for visualization tools in comparison to CAAD tools (n=197 vs. n=1623) may seem like a surprise at first, and possible indication that visualization tools are not used by architects as much compared to CAAD tools. However, one should bear in mind that visualization tools are also complex and rendering time can be quite long. It is quite possible that every architectural office does not have visualization tool expert, but rather outsource the visualization / final representation of their projects to architectural firms who specialize in such work. It is quite possible that specialists in visualization didn't take part in great numbers in this survey, since it is titled: Tools and methods for solar design, and it is not obvious at first glance that their experiences may be useful contribution as well.

Q. 8b: In the list below, identify at which design stage you use the following computer programs (please, select all that apply):

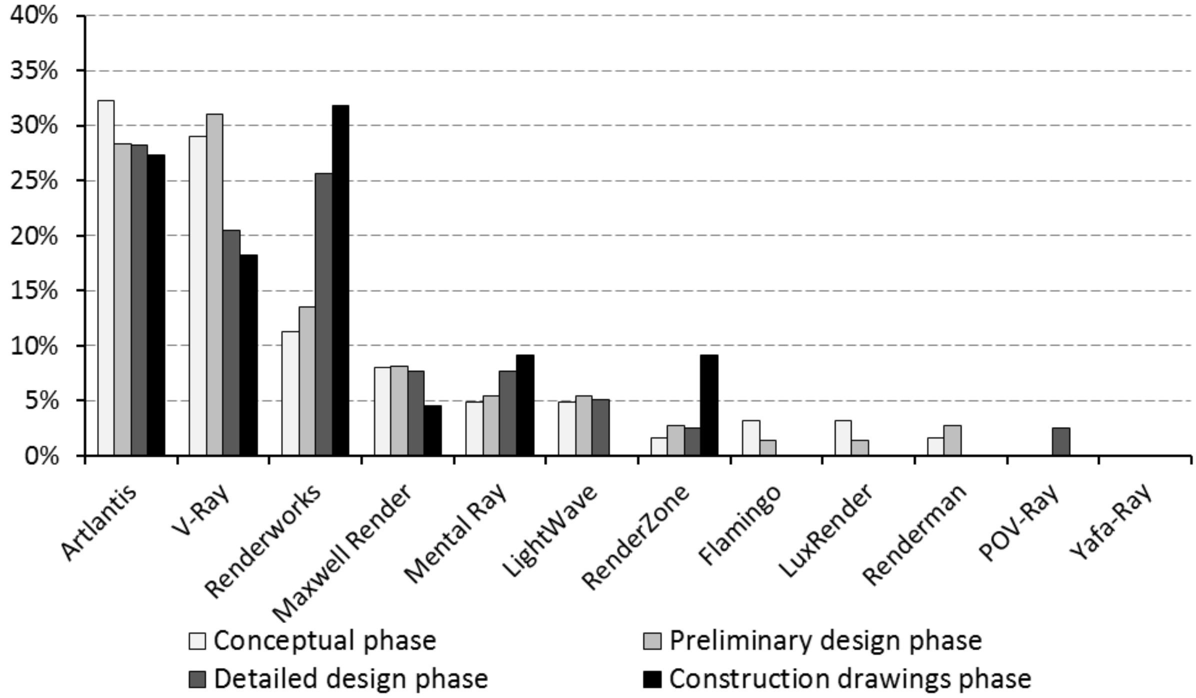

Figure 23: Distribution of answers for question 8b about visualization software used per design phase for all countries (n=197).

Conceptual Design Phase

Out of the 62 selections for the conceptual design phase, 32% (n=20) were for the program Artlantis, 29% (n=18) were for V-Ray, 11% (n=7) were for Renderworks, 8% (n=5) were for Maxwell Render, 5% (n=3) were for Mental Ray and 5% (n=3) for LightWave. The other programs were used by less than 3% of respondents.

Preliminary Design Phase

Out of the 74 selections for the preliminary design phase, 31% (n=23) were for the program V-Ray, 28% (n=21) were for Artlantis, 14% (n=10) were for Renderworks, 8% (n=6) were for Maxwell Render, 5% (n=4) were for Mental Ray, 5% (n=4) for LightWave. The other programs were used by less than 3% of respondents.

Detailed Design Phase

Out of the 39 selections for the detailed design phase, 28% (n=11) were for the program Artlantis, 26% (n=10) were for Renderworks, 21% (n=8) were for V-Ray, 8% (n=3) were for Maxwell Render, and 8% (n=3) were for Mental Ray. The other programs were used by less than 3% of respondents.

Construction Drawings Phase

Out of the 22 selections for the construction design phase, 32% (n=7) were for the program Renderworks, 27% (n=6) were for Artlantis, 18% (n=4) were for V-Ray, 9% (n=2) were for Mental Ray, and 9% (n=2) were for Render Zone. The other programs were used by a non significant amount of respondents.

Simulation programs used according to design phase (Q. 8c)
Figure 24 presents the distribution of answers for simulation programs for all countries.

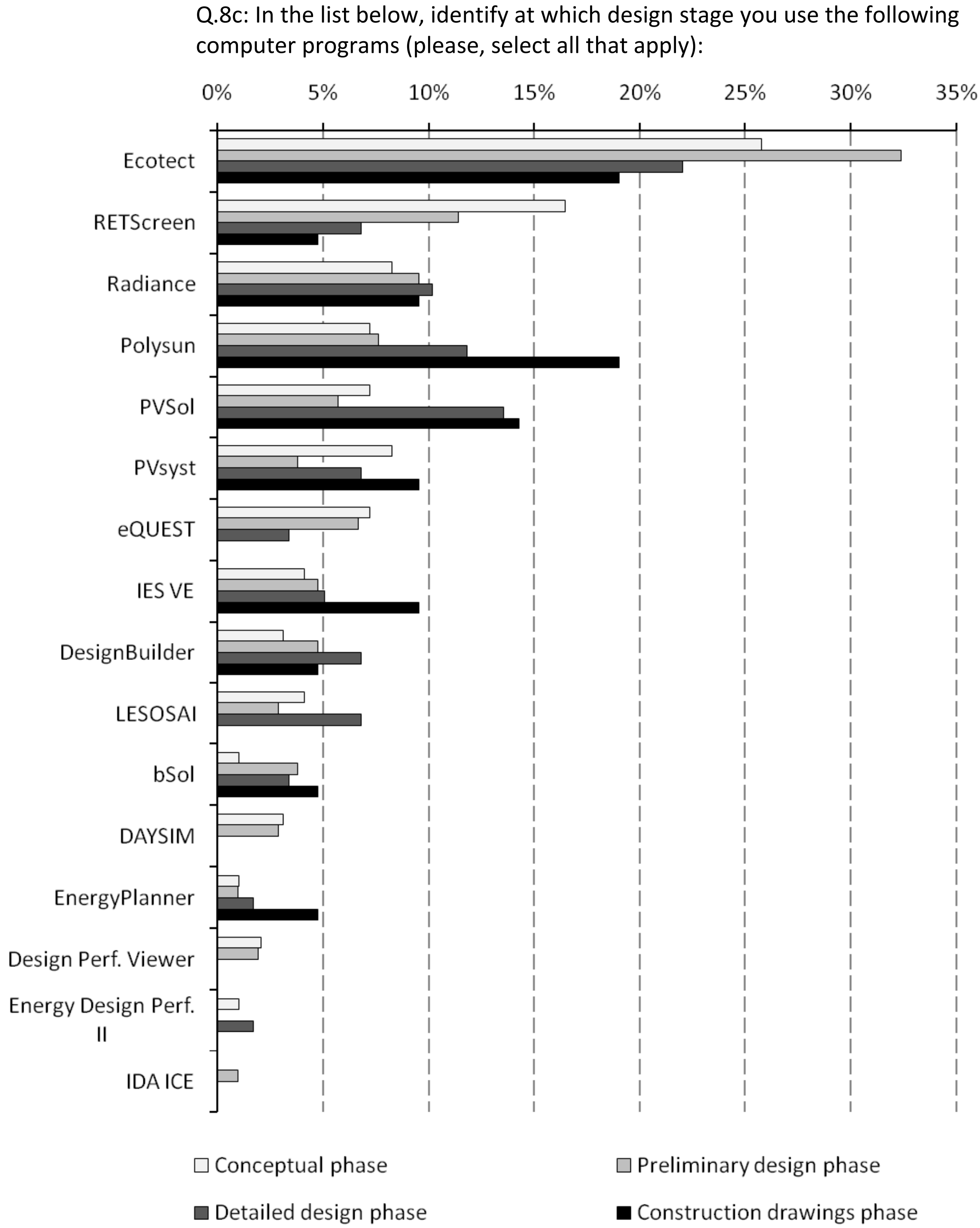

Figure 24: Distribution of answers for question 8 about simulation software used per design phase, for all countries (n=282).

A total of 282 selections were made for this multiple-choice question concerning simulation tools. Out of these 282 selections, 97 selections were for the conceptual design phase, 105 were for the preliminary design phase, 59 were for the detailed design phase, and 21 were for the construction design phase.

In general, the results for simulation tools indicate that a large variety of tools are used in practice, with Ecotect dominating in popularity throughout all the phases, especially in conceptual design and preliminary design phases. This is not a complete surprise considering its compatibility with CAD tools and its visual, 3D output which is very important for architects, as been discussed in the literature review. Although some scientists and building physicist have raised concerns about the Ecotect's accuracy, at least for the scientific purposes, Ecotect can be quite sufficient for the early design stage and for comparison between various design proposals. Second place in the acceptance for solar design tools in the early design stage is RETScreen, which is relatively simple to use, but is completely numerical, both in input and output, which is in opposition with the above mentioned criteria. As the design stages progress, the more complex, 'sizing' tools such as Polysun and PVSys are gaining advance, as expected. It is also important to note that the popularity of certain programs is connected with regional (country by country) preferences. The next stage of this project will analyse responses by regions in order to identify those differences.

Conceptual Design Phase
Figure 24 shows that Ecotect is the program most often selected by respondents, for the conceptual phase (26%, n=25). For the same design phase, 16% (n=16) of selections were for the program RETScreen and 8% (n=8) for Radiance, 8% (n=8) for PVSol, 7% (n=7) for Polysun, 7% (n=7) for PVsyst and 7% (n=7) for eQUEST. The other programs were selected by less than 4% of respondents.

Preliminary Design Phase
In the preliminary design phase, Ecotect is still a leading tool of choice for architects with 32% votes (n=34 out of total 105 selections). Far below with 11% (n=12) is RETScreen on the second place and Radiance with close 10% (n=10). Following are 8% (n=8) for Polysun, 7% (n=7) for eQUEST, and 6% (n=6) for PVsyst. The other programs were selected by less than 5% of respondents.

Detailed Design Phase
Out of the 59 selections for the detailed design phase, 22% (n=13) were for Ecotect again, 14% (n=8) were for PVsyst, 12% (n=7) were for Polysun, 10% (n=6) were for Radiance, and the programs RETScreen, PVSol, Design Performance Viewer and LESOSAI were each selected by 7% (n=4) of respondents for this design phase. The other programs were selected by less than 5% of respondents.

Construction Drawings Phase
Ecotect and Polysun are sharing the position for the top preferred digital tool for the construction drawing phase: out of the 21 selections both Ecotect and Polysun have 19% (n=4) each, 14% (n=3) for PVsyst, and the programs Radiance, PVSol, IES VE were each selected by 10% (n=2) respondents. The other programs were selected by less than 5% of respondents.

4.4.3 Factors influencing the choice of design tool (Q. 9)
Question 9 aimed to determine which factors influence the choice of design tools of professionals. Figure 25 presents the distribution of answers for all countries.

For this question, the respondents were allowed to select three answers. A total of 826 selections were recorded for this multiple-answer question. Figure 25 shows that the main factor influencing the choice of software used is ‘User-friendly design interface’ with 27% (n=223) of selections, followed by ‘Cost of software’ for 20% (n=169) of respondents and ‘Interoperability with other software’ for 18% (n=146) of respondents. The next most popular factors were ‘Simulation capacity’ (13%, n=106), ‘Quality of output (images)’ (8%, n=70), and ‘3d interface’ (6%, n=52). Finally, factors with the least influence on the choice of software used by respondents were ‘Availability of plug-in(s)’ (2%, n=14) and ‘Availability of scripting feature’ (1%, n=5).

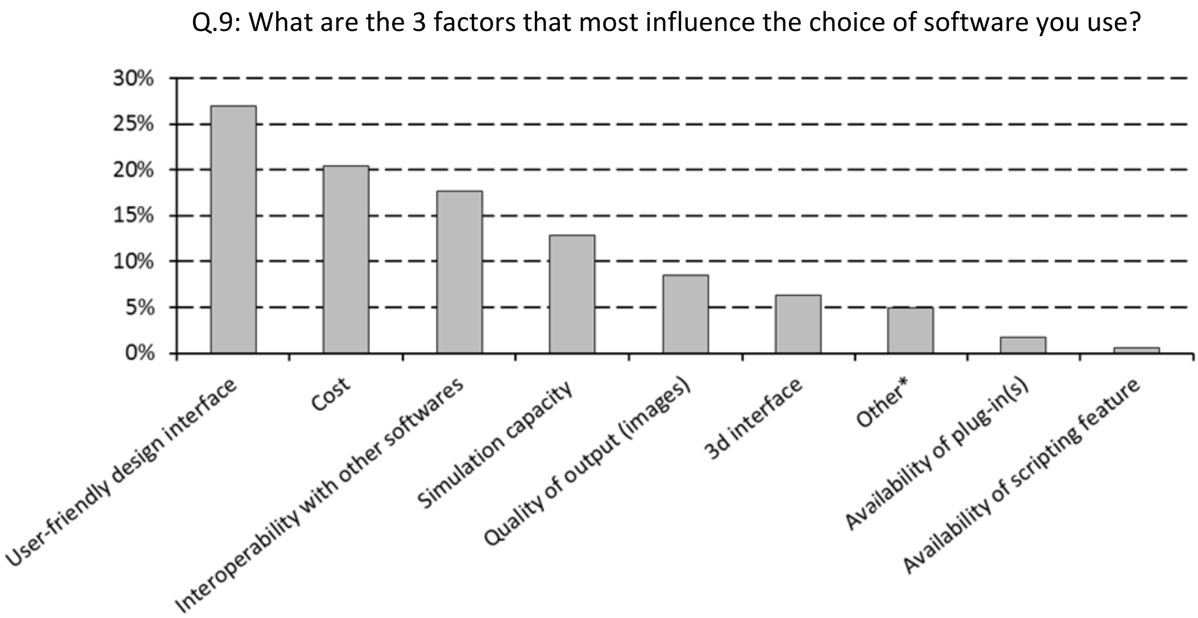

Figure 25: Distribution of answers for question 9 about factors influencing the choice of software used (n=826).

Only 5% (n=41) of respondents selected ‘Other’ factors. One person mentioned they have their own software in the company, and another one said that it was his colleague who selected the software. Many answered that the choice of software was made by the office where they worked and that they could not influence this decision. One wrote that he uses the software learned at the university. Another one wrote that it was important to be able to use the same program throughout the whole design process. A few said that they use the software which complied with the one used by a sub-consultant. One respondent wrote: ‘Hand drawing / sketches, models and physical models are still important tools when we develop the concept phase’. Two respondents noted that availability of training and experience with the software are really important factors because learning new software is time consuming. Many respondents wrote that the popularity of the software within the industry (being a market leader) is an important factor. One respondent even wrote ‘being a market leader, AutoCAD (sadly)’, indicating his dissatisfaction with AutoCAD. Many also said that the client requires the use of specific software. Other comments concerned the reliability of simulation results provided, the flexibility and adaptability of software to situations, the stability (‘inertia’) of software (no update required), the capacity to simplify preliminary data, knowledge about the software within the company, the capacity to support the integrated management of projects, graphical quality, available training and experience, etc. A few respondents answered that they do not use any software.

4.4.4 Satisfaction concerning computer programs for solar design (Q. 10)

One question (Q.10) 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 in question 8.

Satisfaction concerning CAAD tools for solar design (Q. 10a)

Figure 26 presents the distribution of answers for CAAD programs, for all countries.

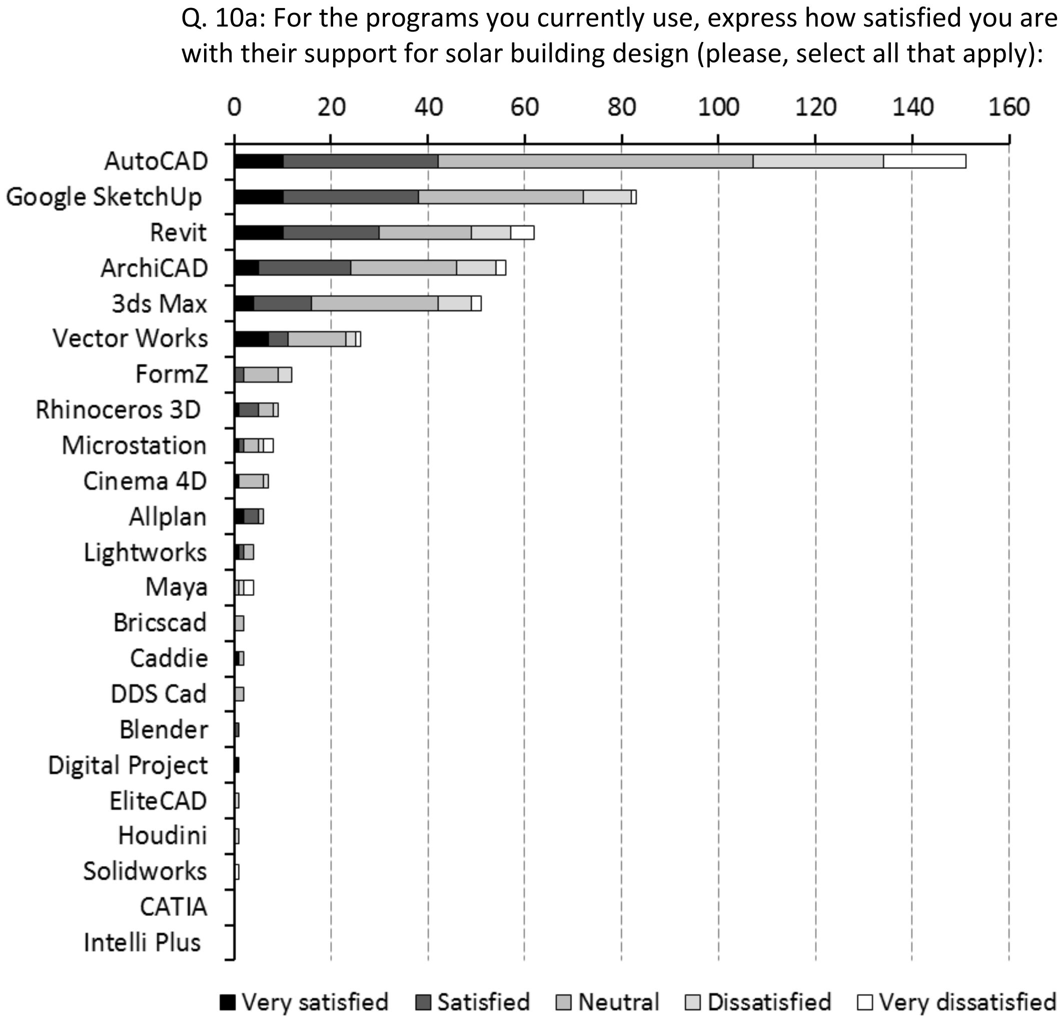

Figure 26: Distribution of answers (number of selections) for question 10 about satisfaction of users of CAAD software used, for all countries (n=490).

A total of 490 selections were made for this multiple-choice question about CAAD programs. For the program AutoCAD, 151 selections were recorded. Out of these 151 selections, 7% (n=10) corresponded to 'very satisfied', 21% (n=32) to 'satisfied', 43% (n=65) to 'neutral', 18% (n=27) to 'dissatisfied, and 11% (n=17) to 'very dissatisfied'. It is worth noting that the majority (72%, n=109) of respondents who use this program were neutral to very dissatisfied and 28% were satisfied to very satisfied for this program, which is the most widely used program.

For the second most used program, Google SketchUp, a total of 83 selections were recorded with 12% (n=10) 'very satisfied', 34% (n=28) 'satisfied', 41% (n=34) 'neutral', 12% (n=10) 'dissatisfied' and only 1% (n=1) 'very dissatisfied'. Almost half (46%, n=38) of respondents thus said they were 'satisfied' to 'very satisfied' with Google SketchUp, while 54% (n=45) said they were 'neutral' to 'very dissatisfied' with this program.

For the third most used program, Revit, a total of 62 selections were recorded with 16% (n=10) 'very satisfied', 32% (n=20) 'satisfied', 31% (n=19) 'neutral', 13% (n=8) 'dissatisfied' and 8% (n=5) 'very dissatisfied'. Thus 52% of respondents were 'neutral' to 'very dissatisfied' with this program while 48% were 'satisfied' or 'very satisfied'.

For ArchiCAD, 56 selections were recorded with 9% (n=5) 'very satisfied', 34% (n=19) 'satisfied', 39% (n=22) 'neutral', 14% (n=8) 'dissatisfied' and 4% (n=2) 'very dissatisfied'. For 3ds Max, 51 selections were recorded with 8% (n=4) 'very satisfied', 24% (n=12) 'satisfied', 51% (n=26) 'neutral', 14% (n=7) 'dissatisfied', and 4% (n=2) 'very dissatisfied'. Finally, for Vector Works, 26 selections were recorded, of which 27% (n=7) were 'very satisfied', 15% (n=4) were 'satisfied', 46% (n=12) were 'neutral', 8% (n=2) were 'dissatisfied', and 4% (n=1) were 'very dissatisfied'.

Satisfaction concerning visualization tools for solar design (Q. 10b)
Figure 27 presents the distribution of answers for visualization programs, for all countries.

Q.10b: For the programs you currently use, express how satisfied you are with their support for solar building design (please, select all that apply):

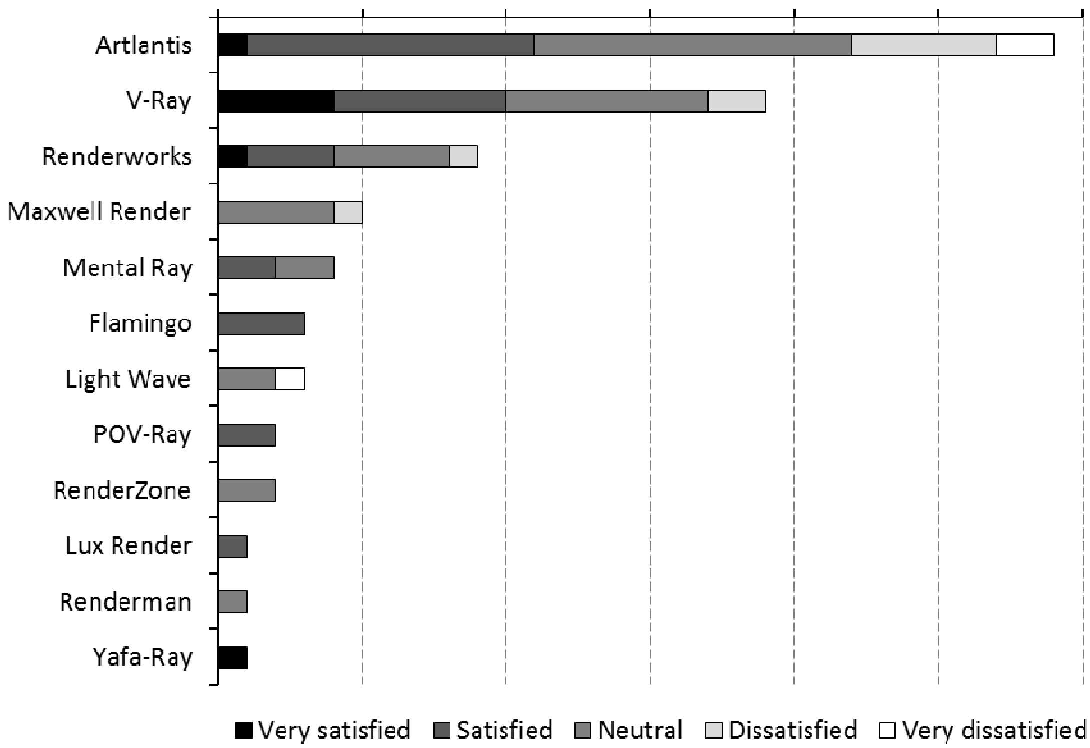

Figure 27: Distribution of answers (number of selections) for question 10 about satisfaction of users for visualization software used, for all countries (n=79).

A total of 79 selections were recorded for this multiple-choice question about visualization programs. For the program Artlantis, 29 selections were recorded with 3% (n=1) ‘very satisfied’, 34% (n=10) ‘satisfied’, 38% (n=11) ‘neutral’, 17% (n=5) ‘dissatisfied’ and 7% (n=2) ‘very dissatisfied’. For V-Ray, 19 selections were recorded with 21% (n=4) ‘very satisfied’, 32% (n=6) ‘satisfied’, 37% (n=7) ‘neutral’, 11% (n=2) ‘dissatisfied’ and 0% (n=0) ‘very dissatisfied’. For Renderworks, 9 selections were recorded with 11% (n=1) ‘very satisfied’, 33% (n=3) ‘satisfied’, 44% (n=4) ‘neutral’, 11% (n=1) ‘dissatisfied’ and 0% (n=0) ‘very dissatisfied’. The other programs were selected by less than 5 respondents.

Satisfaction concerning simulation tools for solar design (Q. 10c)
Figure 28 presents the distribution of answers for simulation programs, for all countries.

Q.10c: For the programs you currently use, express how satisfied you are with their support for solar building design (please, select all that apply):

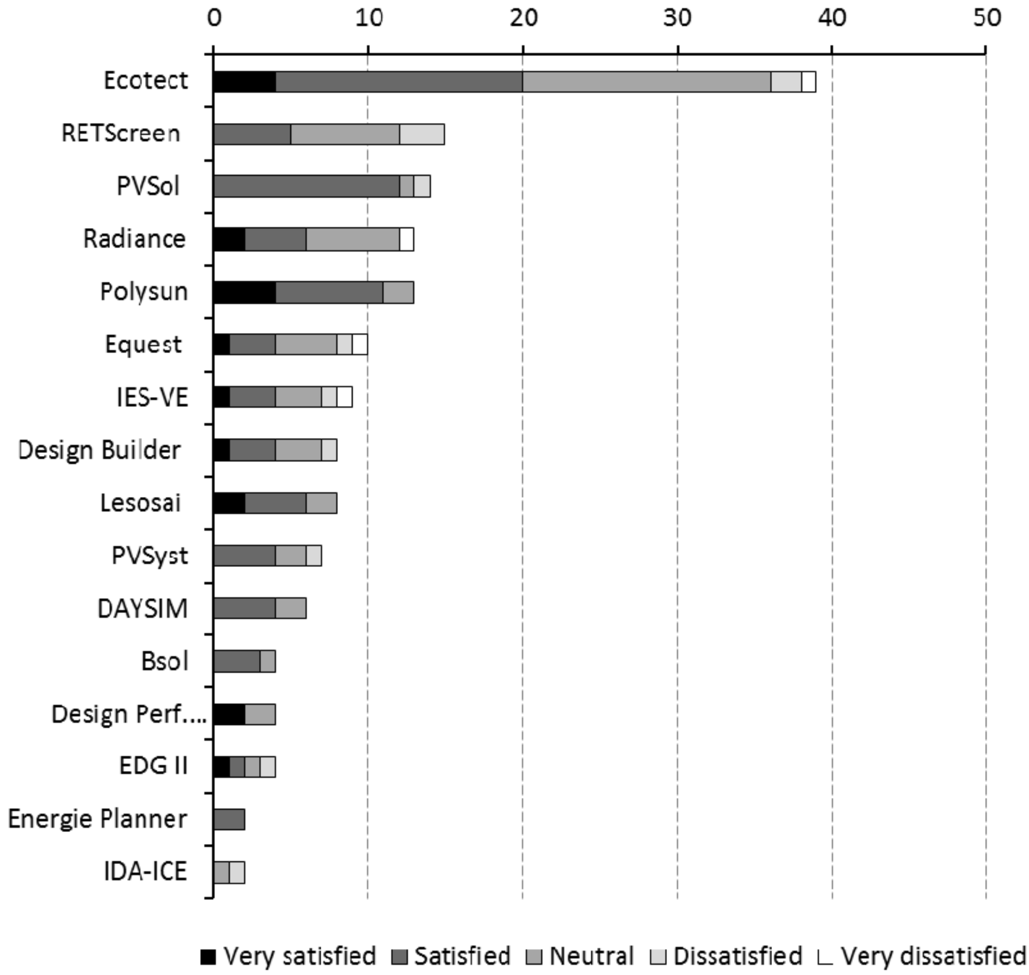

Figure 28: Distribution of answers (number of selections) for question 10 about satisfaction of users for simulation software used, for all countries (n=158).

It is interesting to note that in general, there are not many votes for utter dissatisfaction of any of the programs. However, the number of responses for this category of software packages is considerably lower than with CAD tools, for example (n=158 vs. n=490). It can be assumed, therefore, that those architects who are using simulation tools have acquired a level of skills and have gotten used to them.

A total of 158 selections were recorded for this multiple-choice question about simulation programs. Ecotect is leading again: total of 39 selections were recorded with 10% (n=4) 'very satisfied', 41% (n=16) 'satisfied' and 41% (n=16) 'neutral' and only small number of respondents deemed it unsatisfactory (5% (n=2) 'dissatisfied' and 3% (n=1) 'very dissatisfied'). For RETScreen, 15 selections were recorded with 0% (n=0) 'very satisfied', 33% (n=5) 'satisfied', 47% (n=7) 'neutral', 20% (n=3) 'dissatisfied' and 0% (n=0) 'very dissatisfied'. For PVsol, 14 selections were recorded with 0% (n=0) 'very satisfied', 86% (n=12) 'satisfied', 7% (n=1) 'neutral', 7% (n=1) 'dissatisfied' and 0% (n=0) 'very dissatisfied'. For Radiance, 13 selections were recorded with 15% (n=2) 'very satisfied', 31% (n=4) 'satisfied', 46% (n=6) 'neutral', 0% (n=0) 'dissatisfied' and 8% (n=1) 'very dissatisfied'. For Polysun, 13 selections were recorded with 31% (n=4) 'very satisfied', 54% (n=7) 'satisfied', 15% (n=2) 'neutral', 0% (n=0) 'dissatisfied' and 0% (n=0) 'very dissatisfied'. The other programs were selected by less than 10 respondents.

4.4.5 Barriers related to tools (Q. 11)

One question (Q. 11) aimed to identify barriers to the use of solar design tools. Figure 29 presents the distribution of answers for all countries.

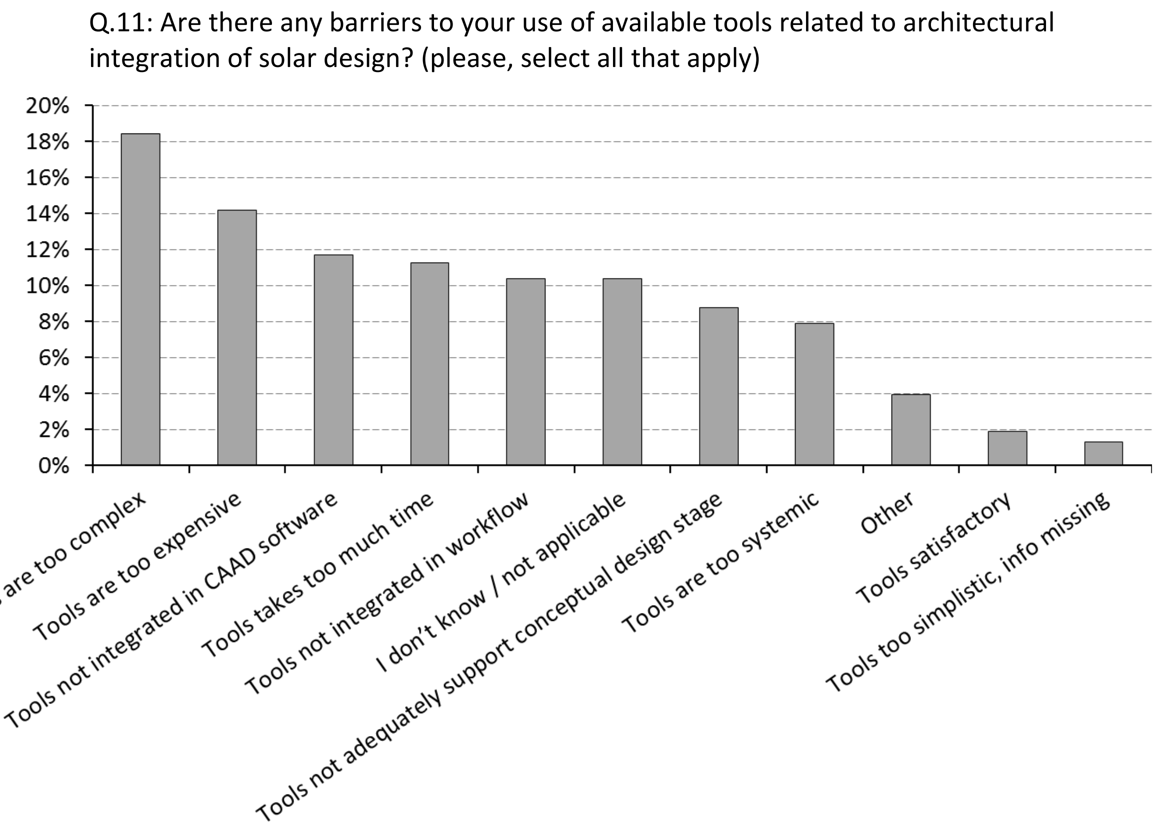

Figure 29: Distribution of answers for question 11 about barriers related to the use of the tools for the architectural integration of solar design. (n=685).

A total of 685 selections were recorded for this multiple-choices question. Figure 29 shows that the most often selected answers for this question were 'Tools are too complex' (18%, n=126), 'Tools are too expensive' (14%, n=97), 'Tools are not integrated in our CAAD software' (12%, n= 80) and 'Using the tools takes too much time' (11%, n=77). Two choices had each 10% (n=71) of selections: 'Tools are not integrated in our normal workflow' and 'I don't know/not applicable'. Some 9% (n=60) of selections corresponded to 'Tools do not adequately support the design process' and 8% (n=54) to 'Tools are too systemic'. Only 2% (n=13) of selections were for 'No, I find the tools quite satisfactory', which clearly indicates that improvements are needed in this field.

Some of the comments written in the field 'others' are translated here: 'Typical architectural fees do not cover such investigations', 'Clients not interested in this level of detail', 'Not in charge of these aspects in the office' (many respondents answered this), 'Complex assessments are made by external specialists', 'Some tools are USA specific and not Australian regional specific, which is a problem', 'Too few years of practice left to merit learning the tools, 'Never heard of these tools', 'Personally incapable of using such tools, someone else in the office is responsible for it', 'Many cultures worked energy efficiency out without computers, it should be intuitive', 'Revit and Autodesk auto architect are just fine', 'Too much time to invest for a sparse utilization', 'Have not yet invested the time to integrate in normal work pattern', 'Lack of knowledge', 'Lack of time', 'For small projects, tools are too academic and not able to simulate real world conditions', 'Unaware of the tools that are available and would find it difficult to know where to start', 'Do not know if our software has any tool for solar design nor whether the staff use them', 'Sub-consultants do all the energy calculations', 'I see energy-related work as an extern field of competence, not the responsibility of the architect and there is a limitation about how many fields of competence an architect can stay updated with… there are many themes an architect has to handle at the concept phase already', 'Our own program is very user-friendly and precise', 'I miss an integrated tool that includes all relations to energy and indoor climate and which allows good visualization', 'I have used T*Sol a couple of years ago but it lacked some system solutions and many suppliers of solar panels, which made it less useful, we used also TRNsys, which was difficult to learn but very flexible', 'We've just started to use EcoDesigner (Graphisoft/ArchiCAD) which seems to be useful', etc.

4.4.6 Suggested improvements in tools (Q. 12)

The following question (Q. 12) aimed to identify the needs of practitioners related to tools and methods to support the integration of solar architecture. Figure 30 (next page) presents the distribution of answers for all countries.

A total of 1382 selections were recorded for this multiple-choice question. Among these selections, 425 were for the conceptual design phase, 508 were for the preliminary design phase, 286 were for the detailed design phase, and 163 were for the construction design phase. In general, the results indicate that visualization is more important at EDP and key numbers or elements for sizing solar systems are more important at more advanced design phases.

Conceptual Design Phase

Figure 30 shows that, for the conceptual design phase, 28% (n=119) of selections concerned 'Improved tools for visualization', 20% (n=83) of selections were for 'Improved tools for preliminary sizing of solar systems', 15% (n=65) concerned 'Improved tools for providing key data (numbers) about solar energy', and 18% (n= 78) were for 'Tools that provide explicit feedback (key data) in connection with building massing and orientation'. Only 4% (n=17) of selections were for 'No, I find available tools quite satisfactory', and 12% (n=50) for 'I don't know /not applicable'. Also, 3% (n=13) of respondents mentioned 'Other' needs or comments for conceptual design phase. One respondent mentioned that rules of thumb are sufficient at conceptual design phase, as long as the results are not checked. Another respondent noted that 'the tools must eventually be simple and intuitive without the need for special expertise; efficiency and finance calculations are more important than visualization'.

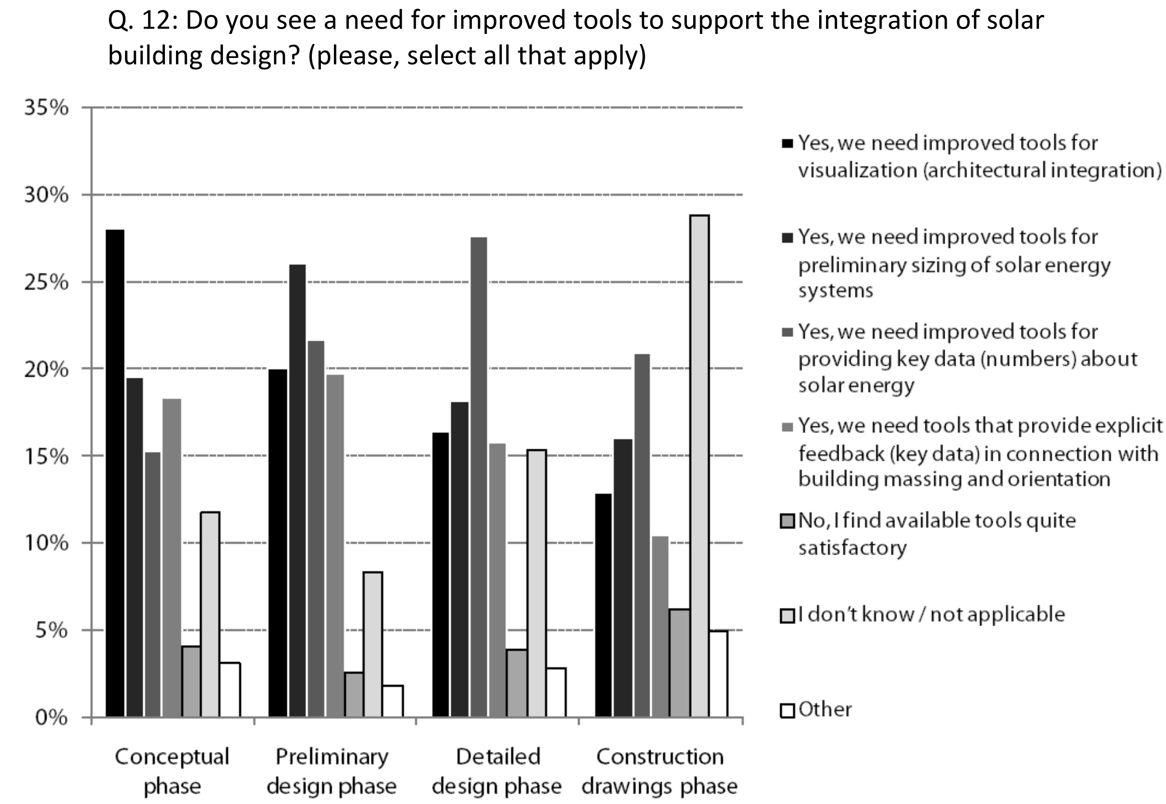

Figure 30: Distribution of answers for question 12 about needs for improved tools to support solar building design (n=1382).

Preliminary Design Phase

Out of the 508 selections recorded for the preliminary design phase, 20% (n=102) concerned 'Improved tools for visualization (architectural integration)', 26% (n=132) were for 'Improved tools for preliminary sizing of solar energy systems', 22% (n=110) were for 'Improved tools for providing key data (numbers) about solar energy', and 20% (n=100) of selections concerned 'Tools that provide explicit feedback (key data) in connection with building massing and orientation'. Only 3% (n=13) of selections were for 'No, I find available tools quite satisfactory', and 8% (n=42) chose 'I don't know /not applicable'. Also, 2% (n=9) of respondents answered 'Other' needs.

Detailed Design Phase

Out of the 286 selections for the detailed design phase, 16% (n= 47) answered they need 'Improved tools for visualization (architectural integration)', 18% (n=52) said they need 'Improved tools for preliminary sizing of solar energy systems', 28% (n=79) said they need 'Improved tools for providing key data (numbers) about solar energy', and 16% (n=45) said they need 'Tools that provide explicit feedback (key data) in connection with building massing and orientation'. Only 4% (n=11) answered 'No, I find available tools quite satisfactory', 15% (n=44) chose 'I don't know /not applicable' and 3% (n=8) answered 'Other' needs.

Construction Drawings Phase
Out of the 163 selections recorded for the construction drawings phase, 13% (n=21) said they need ‘Improved tools for visualization (architectural integration)’, 16% (n= 26) said they need ‘Improved tools for preliminary sizing of solar energy systems’, 21% (n=34) said they need ‘Improved tools for providing key data (numbers) about solar energy’, and 10% (n=17) said they need ‘Tools that provide explicit feedback (key data) in connection with building massing and orientation’. Some 6% (n=10) considered ‘No, I find available tools quite satisfactory’, 29% (n=47) chose ‘I don’t know /not applicable’ and 5% (n=8) selected ‘Other’ needs.

Two general comments were recorded by two different respondents. The first respondent mentioned that he/she felt ‘no need of specific tools, but those that exist now include the possibility of calculating the energy contribution (e.g. DesignBuilder and Ecotect)’. He/she also mentioned that ‘visualization is secondary in the process of decision making’. The second respondent wrote that ‘passive technology requires only a few, simple rules. It is much simpler than the earlier, now obsolete solar architecture’.

4.4.7 Comments regarding improvements in tools (Q.13)

Next question (Q. 13) aimed to identify the needs of practitioners related to tools and methods supporting the integration of solar architecture. This question aimed to elicit personal opinions from respondents about the availability of tools and their use. A total of 65 comments and suggestions have been recorded for this open end question. Table 2 presents the answers of question 13 from all respondents.

Table 2: Answers for open question 13 about any need, comment or suggestion related to tools or method for solar design (n=65).

COUNTRY	COMMENT
Australia	
	Anything we use needs to be very user-friendly. We cannot afford to shut down our office to train all of our staff in new software / technologies.
	Free online assessment, similar to NETHERS etc.
	A more unified document production process, all round.
	Method is good - teach me a method, but please don’t give me another tool or another expert....
	Training.
	Green technique.
	In my home state of NSW we have to use Basix (web based tool) to achieve the regulated goals of energy efficency and water saving. Any useful tool should be allowed as an alternative to the Basix tool, that will require a change of legislation and/or regulation. The energy assessment area in NSW is a ‘closed shop’ and not open to competition.
	It would be nice to have one system relating to all Australia instead of individual states and Territories. Uniformity and simplicity for all to use
	Perhaps the tools are only useful for large scale buildings. Not small buildings/ dwellings.
	I am not all that computer savvy and have a small practice. I need to be introduced to the tools available, have excellent tuition on how to use them and also be able to afford it. Subsidies for this sort of thing could certainly enhance results in general.

	Education.
	A solar building design package compatible with Maya.
	Cross integration with BCA compliant energy rating software.
	Tools for Dummies.
	HOMER is a useful and simple Renewable Energy tool.
Austria	
	tools gibt/gäbe es genug - nur: keiner verwendet sie (hab ich das gefühl - keine verpflichtung zur kontrolle - keine genauen angaben/planungen/ausführungen - keine überprüfung > kein kläger > kein richter > kein/wenig interesse und nach 5 jahren wird die anlage stillgelegt "weils eh net funktioniert" leider - heute bin ich nicht sehr positiv eingestellt. *There are sufficient tools – only: nobody uses them. I feel - no commitment for control - no correct specifications/planning/construction - no inspections > no complainant > no judge, no or little interest and after 5 years the plant is shut down "because anyways it doesn´t work", a pity – today I don´t respond that positive. (Interpretation help: the writer is complaining about the lack of interest in a well working PV or ST system and the lack of control mechanisms. There is a German saying: If there is no complainant, there is no judge. It seems, that in the past he/she was convinced by solar technologies, but was disappointed and that for changed his/her mind.)*
	Ich finde, ein offenes, Kenntnissreiches , integrales Planungsteam, das nicht auf bestimmte Produkte und Prozesse fixiert ist kann die meisten Planungs- und Bauprobleme durchaus lösen. Die Frage ist eher, ob BauherreInnen ein solches Team bezahlen wollen. *I think, an open, well-informed, integral planning team, which is not focussed on certain products and processes, can solve most planning and construction problems. The question is: if the awarding authority is willed to pay such a team.*
	CAD Progrmme und Tools sollten einfach zu bedienen sein und bereitsin der Entwurfsphase Möglichkeiten und Dimmensionen der Solaren Nutzung bekanntgeben. - Orientierung, Größe der Solareinheiten Nutzung. *CAD programs and tools should be easy to handle and during EDP it should already give possibilities and dimensions of utilization of solar energy. – Orientations, size of solar unit.*
Belgium	
	Méthodes claires et simples de pré-dimensionnement (règles de calcul, tables, ...). *Clear and simple methods of preliminary sizing (calculation rules, tables, ...).*
	Plus d'information concrète et scientifique permettant l'évaluation des différents systèmes. *More concrete and scientific information for evaluating different systems.*
	Intégration des orientations, de l'horizon et des saisons pour optimiser les apports solaires et ne pas favoriser inutilement la surchauffe. *Integration of orientations, horizon and seasons to maximize solar gains and*

	not encourage unnecessary overheating.
	Catalogue produits disponibles sur le marché. *Catalogue of products available on the market.*
Canada	
	We need a tool that models the energy use related to envelope/mass, is accurate, and seamless with Revit.
	I need a simple tool that integrates with AutoCAD and/or SketchUp to quickly assess optimum building orientation, material attributes for computing thermal mass, etc.
	The problem is that many are trying to do these things without architect input. Architects have been designing solar projects for at least 30 years. It is only now that they are becoming more economically viable.
	Our problem is with new “tools” in general- COST and TIME. We need something more effec-tive in both areas, again, sadly...
	Better availability of building physics services (Trans solar).
	Convenience of integration with all software packages and market evaluation tools would assist us in integrating the active solar technologies into our designs.
	More rules of thumb and simple examples.
	Ease of use on MAC computers would be great.
	Industry needs to embrace IFC import & export to ensure operability, rather than suppliers targeting a single vendor’s proprietary platform.
	Calcul de l’inertie thermique p/r aux matériaux de surface et/ou la structure (ex: béton). *Calculation of the thermal inertia with respect to surface materials and / or structure (e.g. concrete).*
	Connaissance d’une méthodologie simple et d’outils facilement accessibles pour appuyer les décisions initiales dans le processus de design et approfondir les solutions constructives. *Knowledge of simple and easily accessible tools to support decisions in the initial design pro-cess and deepen the constructive solutions.*
	Possibilité de voir la relation entre la conception utilisant l’énergie solaire et l’impact écono-mique final (coût de construction VS coût d’opération), notamment lors de la conception et de l’étape préliminaire. *Possibility to see the relationship between design using solar energy and the final economic impact (cost vs. construction cost of operation), especially in the design and the preliminary stage.*
	Développer un outil capable d’intégrer un modèle venant d’un modeleur diverse et permettant de quantifier les gains. *Develop a tool capable of integrating a model from a diverse modeller and allowing quantifying gains.*
	Éclairage. *Lighting.*
	Analyse des impacts du bâti et des aménagements paysagés particulièrement

	en milieu urbain. *Analysis of the impact of buildings and landscaping especially in urban areas.*
Denmark	
	More general and intuitive programs.
France	
	Détermination des zones d'ombres, trop souvent non intégrée. *Determination of shadow areas, most often not integrated*
	Esquisse: approche par l'expérience et pour la suite des études il faut des outils très simples pour confirmer l'approche, la modifier et donner des éléments quantitatifs. *Sketch: approach and experience for further studies are needed and simple tools to confirm the approach, modify it and give quantitative elements.*
	Outils, connaissances, formation pour approfondir mes compétences en thermique passive. *Tools, knowledge, training to improve my skills in passive thermal.*
Germany	
	Entwurfsunterstützung bedarf/ gebäudeoberflächen/ systemvarianten tga. *Aid for conceptual design: demand/surface area of building/system alternatives, building services equipment*
	When not introduced fully into solar architecture during the education, one cannot compensate for this later and solar energy is unlikely to be used later. Detailed simulation requires in-depth knowledge of tools or no meaning full outcome will come from it. Solar energy should be major part of any architects education path.
Italy	
	Un software unico riconosciuto in sede ue facile da usare facile da apprendere: con corsi di formazione diffusi, brevi, chiari e facilmente frequentabili. *Unique software recognized within the EU, easy to use and easy to learn: with training courses, which are brief, clear and easy to attend.*
	Mancanza di disponibilità degli architetti e della soprintendenza *Lack of availability of architects and of the superintendence** *(*"Superintendence" in Italy is the regional board of the ministry of cultural heritage and environmental conservation)*.
	Semplicità nei metodi e chiarezza. *Simplicity in the methods and comprehensibility.*
	In italia non si ha ancora la sensibilita' alle energie solari applicate , semplicemente per un attri-to dei costruttori a risparmiare sul costruito, in varie province del nord italia ora sono obbligatorie, ma i costruttori o impiantisti puntano sulla bassa qualita dei materiali. *In Italy the sensibility regarding solar energy systems is not yet developed*

	mainly because the manufacturers in the building sector tend to economize on constructions; In several Northern Provinces the use of solar systems in buildings is required by law but the manufacturers and installers use low quality materials.
Norway	
	Verktøy må kunne handtere kobinerte systemer. *Tools must be able to handle combined systems.*
	Verktøy for solinnstråling og utetemperaturer på gitte geografiske steder enkelt integrert i sole-nergiprogrammvare. Gode og variable systemløsninger integrert i programmet med muligheten for å kombinere solenergi med flere andre varmekilder (bio, varmpepumpe, el, etc.) Oppdaterte data fra leverandører om mulig! *Tools for solar radiation and outdoor temperatures at given geographical locations easily integrated into the solar software product. Good and variable system solutions integrated into the program with the ability to combine solar energy with other heat sources (bio, heat pumps, electricity, etc.). Updated data from suppliers if possible!*
Portugal	
	Ferramentas de simulação dinamica, em base horária, mensal e anual, que integrem todos os aspectos da eficiencia energética incluindo o solar térmico e fotovoltaico. para que possam ser utilizadas por arquitectos nas fases iniciais de projecto deverão, nas fases iniciais de projecto, ter "templates" adequados a cada paìs, reduzido nº de variáveis (ex. apenas caracterização do edifício e sistemas tipo). No caso do clima português o risco de sobreaquecimento é elevado pelo que as ferramentas simplificadas (base anual ou sazonal tipo RCCTE) não são as mais indicadas. *In order to be used by architects in early design stages, dynamic simulation tools, incorporating all aspects of energy efficiency – on hourly, monthly and annual basis, including solar thermal and photovoltaic's performance -, should include climate templates appropriate to each country, and a reduced number of variables regarding building typologies and construction systems. In the case of Portuguese climate, where overheating risk is significant, simplified tools (with only seasonal or annual weather data, of the type of RCCTE*) are not the most suitable.* **RCCTE is the acronym of Regulation on Energy Performance Characteristics of Buildings (Regulamento das Características de Comportamento Térmico dos Edifícios)]*
South Korea	
	프로그램의 적정한 비용과 학습의 기회가 부여되어야 사용빈도가 높아질수 있으며 설계비의 인상이 병행되어야 한다. *For frequent use, reasonable price of software and training opportunity are needed, and design fees should be increased.*
	이용이 편리하면서, 결과를 신뢰할 수 있도록 주요 요소들 선정 및 요소 입력방법과 그 결과의 신뢰성에 유의 *To pay attention to main elements selection and input a method for easy-to-*

	use and credibility of output.
	우리나라 태양에너지건축 현황이 시작단계임을 고려하여 초기에는 표준화된 프로그램을 운용하여 클라이언트 및 건축시공자 , 설계자들이 간편하게 태양에너지건축 에 접근토록 보급한 다음 정착단계에서 다양한 운용 프로그램을 보급 사용하도록 하는 방안을 제시합니다. *Considering the beginning stage of solar buildings in Korea, at first standardized (simple) program that clients, builders and designers can easily use could be used and at the next stage more complex program can be considered.*
Spain	
	Unificación en una o muy pocas herramientas *Unification of one or very few tools.*
	Es necesario programas de simulación más sencillos para las fases iniciales. *You need simple simulation programs for the initial phases.*
Sweden	
	Economics of Solar technologies e.g. PV vs Thermal are a main determinant, but it is hard to get reliable up to date cost information.
	Easy availability as a plug-in for Archicad would be the perfect way to integrate this design into my workflow.
	More specialized consultants that are good in using the simulation programs for solar Energy systems.
	More knowledge in general.
	Possible exchange with other file-formats.
Switzerland	
	Was breit angewendet werden soll, muss ganz einfach sein. In der Passivhaustechnik im Klima des schweizerischen Mittellands: - Wärmebedarf 0.3-0.4 (mit Brauchwarmwasserrückgewin-nung) $W/m^2_{EBF}K$ - opake AF gleich oder besser als 0.12 W/m^2K - Fenster inkl. Rahmen gleich oder besser als 0.8 W/m2K (25-35 % FF/EBF, mind. 40 % südorientiert, ohne festen, aber mit automatischem, flexiblem Sonnenschutz) - Baumasse in den Zwischendecken (mind. 20 cm Beton/Geschoss äquivalent) Mehr muss man nicht wissen. - Zwangslüftung mit Wärme-rückgewinnung *What is meant to be applied in general has to be very simple. For passive house technology in the climate of the Swiss midland:* *- heat demand 0,3-0,4 (including recovery of hot potable water) $W/(m^2_{ERA}K)$* *- opaque external areas ≤ 0,12 $W/(m^2K)$* *- windows including frame ≤ 0,8 $W/(m^2K)$ (20-35% Window area/ERA, at least 40% south orientated, without fixed, but with automatic and flexible sunblind* *- cubic capacity of intermediate ceilings (at least 20cm concrete equivalent per level* *More you don’t have to know.* *- forced ventilation with heat recovery*

	(Clarification: ERA: Energy reference area)
	Mit etwas grösserem Blickwinkel gemäss letzter Seite: Berechnung Nach SIA 380/1 für Energienachweis, Minergie, ... an Hand der ins CAD eingegebenen Daten mit fortlaufender Aktualisierung wäre natürlich super. *With an a little wider angle of view corresponding to the last page: Calculation according to SIA 380/1 for energy verification, Minergie, … with the help of the data inserted into CAD with continuous updating would of course be excellent.*
	Necessario poter realizzare un edificio completo in 3d che preveda la localizzazione dell'edifi-cio stesso ed il suo bilancio termico completo. *Need to be able to create a building 3D model, which includes the climate location of the building and its complete energy thermal balance.*
	In realtà io mi appoggio a consulenti, pero' mse ci fossero degli strumenti rapidi e consociuti per valutare velocemente in fase preliminare lìopportunità di utilizzare sistemi solari/passivi....lo userei. *Actually I am involving solar energy consultants, but if there were rapid and well known tools to quickly assess the opportunity of using solar systems (the active and passive ones) at an early stage, I would use them.*

5. CONCLUSIONS

5.1 Conclusions of the literature review

In the first part, this report provides a literature review of studies undertaken up to date which identifies the needs and considerations of simulation tools for architectural practice. Studies reviewed are published over the period between 1993 and2011 and revealed that the needs expressed by users, especially by architects, remained relatively unchanged over time: tools are perceived as not user friendly, time consuming to master, expensive and with not clear visual output, suitable for architects' knowledge base and thinking /problem solving process. It is clear that the profession have been seeking a visual tool that is easily interoperable between different modelling software packages and has the ability to be modified while providing meaningful results, and which can be used throughout the whole design process.

5.2 Conclusions of the international survey study

In the second part, this report presents the results of the international survey that was conducted by 14 participating countries under Subtask B of the IEA SHC Task 41 work programme. The international response rate was estimated to be 5.9%, counting only entirely and significantly completed surveys and directly contacted members of the focus group. In some countries, the survey was presented in a newsletters and on associations' websites, where potentially reached much broader audience; but this also makes it impossible to calculate precise response rate. Although 5.9% response rate can be considered acceptable for this type of survey, in some countries the response rate was remarkably low, indicating a general lack of interest or importance attributed to this topic.

On the positive side, an overwhelming importance (80% of respondents) was given to the use of solar energy in architectural practice. However, a similar proportion either occasionally, rarely or not at all applied solar energy technology design in their projects; whereas almost half included aspects of solar passive design. There may be a variety of reasons for this: from economical viability in certain countries, to owners (and architects) interest in implementing active solar systems, to potential 'know-how' required for such aspect of the design.

An integrated design process (IDP) was favoured with 68% considering solar applications at the conceptual phase or preliminary design phase. However, about half of the respondents handled delivery of small scale solar energy related projects on their own, which is understandable, because small projects are usually less complex and/or more often tend to have limited budget so IDP may not be viable solution. This dropped to 32% for larger projects where either a colleague architect was consulted or external assistance was sought. This was especially the case during the detailed design phase.

AutoCAD was the most frequently used software program, followed by Google SketchUp. Interestingly, 28% of AutoCAD users are satisfied with its support of solar building design, even though AutoCAD only permits visualization of daylight, 43% are neutral and 'only' 29% are dissatisfied. Google SketchUp offers additional features for solar design including daylight, shading analysis and basic results for energy performance of buildings. It's appropriate for the Early Design Phase (EDP) and almost half of the users are satisfied (46%, dissatisfied: 13%) with the tool. There are different Add-Ons/Plug-Ins for Revit that also permit daylight and energy simulations. 48% stated they were satisfied (21% were dissatisfied) with the support of solar design. ArchiCAD can also be linked to energy simulation programs, such as Ecotect in order to analyse the solar design. Some 43% of respondents are satisfied, but 18% remain dissatisfied. For Google SketchUp, Revit and ArchiCAD, 31 to 41% chose the answer 'neutral'.

The visualization tools selected by the majority of respondents are Artlantis, V-Ray and Renderworks. In general, most users are satisfied with or neutral about the tools (75-90%). However, overall response rates for visualization tools are very low, especially in comparison with CAD tools, so no further interpretation was done.

Simulation tools seem to be perceived as somewhat complicated in nature, time consuming and expensive. The following five simulation programs were selected by the majority of respondents: Ecotect, in considerable lead over the others, especially for the Conceptual and Preliminary design stage, followed by RETScreen, Radiance, PVSol, and Polysun. Other simulation tools have small number of declared users, so the answers cannot be interpreted with certainty. Last two (PVSol and Polysun) software tools seem to be more accepted for the design development and construction drawing phase, being more complex, 'sizing' tools. The popularity of Ecotect among those architects who are using simulation tools, can be understandable considering its interoperability with AutoCAD and ArchiCAD as the most dominant software packages in today's practice, but also for its 3D visual output and relatively fast response, which makes it suitable for a quick comparison of various design proposals. Only 8% of all Ecotect users are dissatisfied with its support of solar design. Still, it is important to emphasize that number of responses regarding simulation tools are considerably less than those for CAD tools (n=282 vs. n=1623), which indicates that the simulation tools are not used very much by architects.

This is also reflected in the question about architects' self-assessment of solar design skills: only a small proportion of those who responded indicated any advanced proficiency of solar design simulation modelling: 6% for advanced and 14% for very advanced. These answers suggest a need to upskill and inform practitioners more appropriately on the functionality and practicality of different software tools with respect to the architectural design process.

In addition, this report has identified that the necessary conditions to use and to run the tools is not easy to obtain because tools are too complex in nature. Considering the amount and complexity of information required, several procedures require special competences that architects do not possess and guidance is not provided. Also, the high price of these tools can be considered a barrier to their diffusion and use. The absence of a clear methodology to apply to EDP is another problem in being able to effectively maximize the solar energy benefits of a given project and its specific characteristics.

Finally, the results show that tools for solar design need to be more user-friendly, 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 preferably as 3D output, and that tools need a better visualisation especially for active solar energy systems.

5.3 Additional thoughts

One of the indirect findings of this survey is that there is a need for an easy to use and integrated tool that is applicable to the pre-design phase. Such a tool would be of benefit to all participants in the building process and contribute to associated life-cycle costs benefits of buildings. If this could be introduced at the pre-design phase for new and existing buildings with a focus on passive and active systems of solar energy, this will significantly reduce the global environmental impact of building growth.

In another way, the opportunities created by the decision in 2009 of the European Union Parliament to endorse the regulatory Energy Performance Building Directive and the motion plan official Energy Code to all USA, reinforce the importance of using tools in the EDP to guarantee the correct introduction of solar systems for all building types.

5.4 Limitations

The major problem concerning the use of surveys was the low participation rate and the generalisation of the findings and resulting conclusions. The strong bias towards computer simulations indicates that many participants have been recruited through personal mailing lists and from national professional lists. This presents the possibility that, in some regions, the wider population of architectural professionals were not reached. This was also confirmed by national representatives after the survey had ended. Also, there is a risk that the respondents are those who are interested in the issues of solar energy which in itself constitutes a significant bias of this research. In addition, the data analysis does not include a statistical analysis to test and prove the sample representation of the population. Therefore, the survey findings are not statistically representative. However, the results outline patterns and tendencies among the design community of architects internationally. In order to identify variations and preferences on a country-by-country basis, additional analysis will be done in summer 2011.

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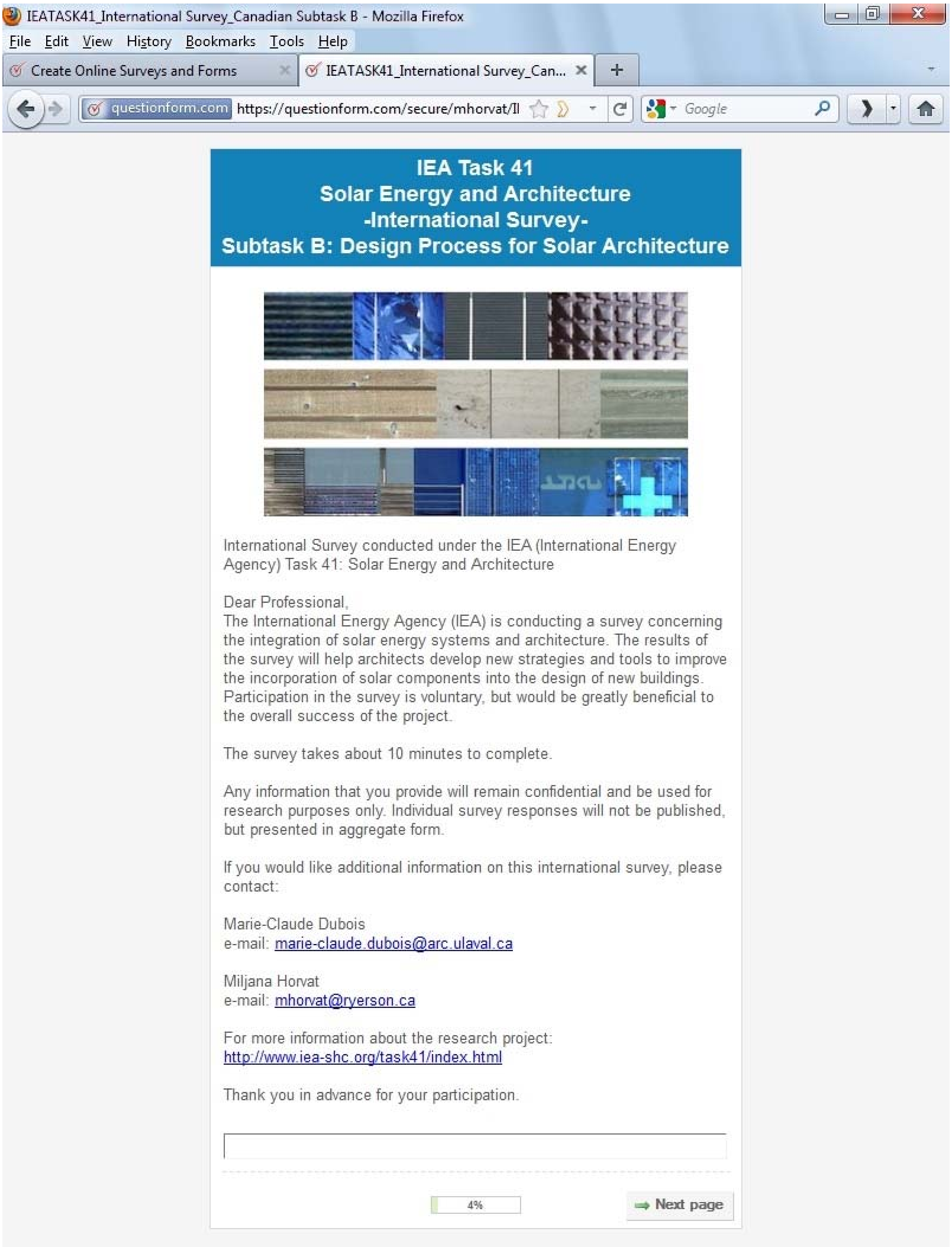
APPENDIX A:
INTERNATIONAL SURVEY INTERFACE

Presented here is only the survey in English. Screen-shots of surveys in all other languages are available by request from the authors



IEA Task 41
Solar Energy and Architecture
-International Survey-
Subtask B: Design Process for Solar Architecture

International Survey conducted under the IEA (International Energy Agency) Task 41: Solar Energy and Architecture

Dear Professional,
The International Energy Agency (IEA) is conducting a survey concerning the integration of solar energy systems and architecture. The results of the survey will help architects develop new strategies and tools to improve the incorporation of solar components into the design of new buildings. Participation in the survey is voluntary, but would be greatly beneficial to the overall success of the project.

The survey takes about 10 minutes to complete.

Any information that you provide will remain confidential and be used for research purposes only. Individual survey responses will not be published, but presented in aggregate form.

If you would like additional information on this international survey, please contact:

Marie-Claude Dubois
e-mail: marie-claude.dubois@arc.ulaval.ca

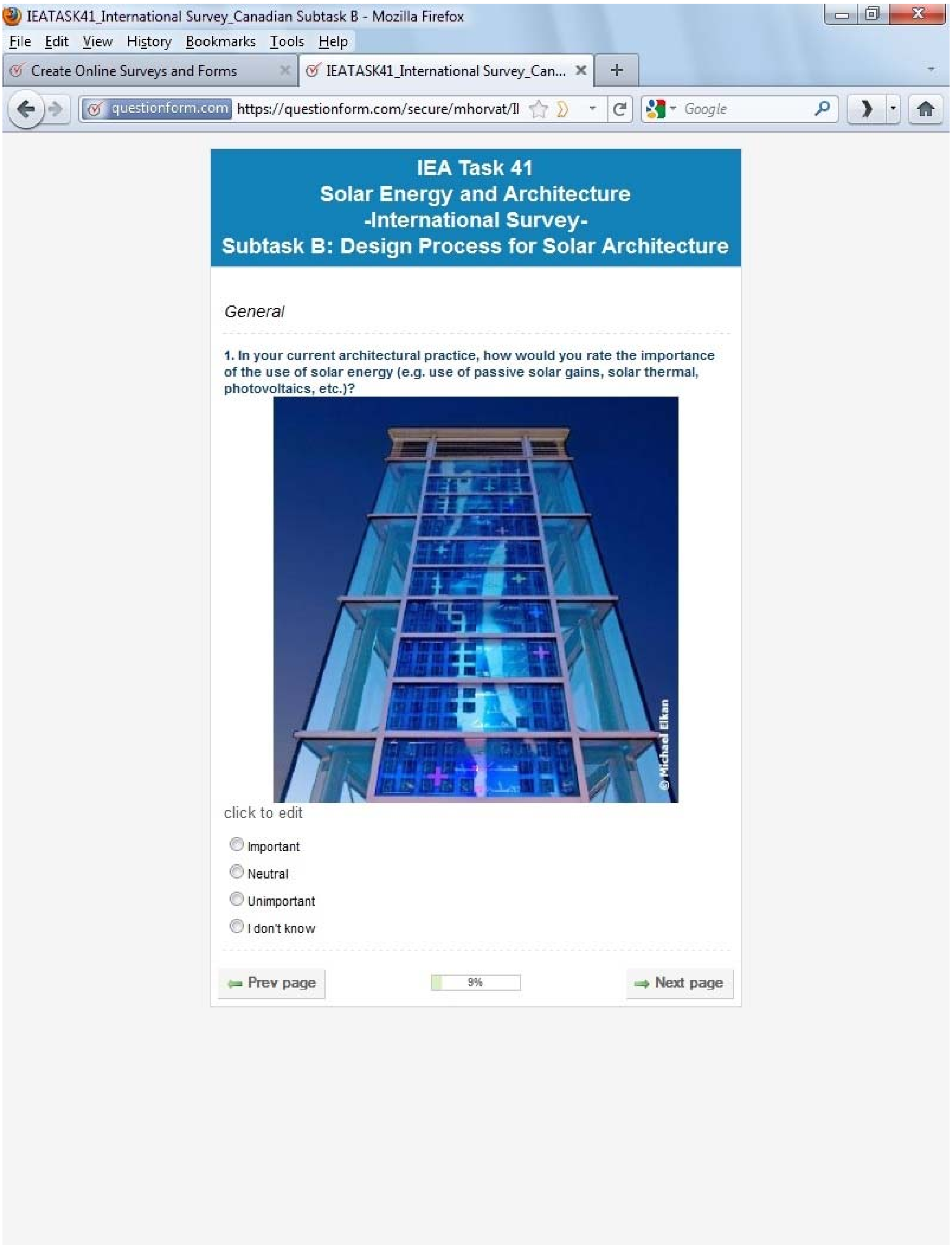
Miljana Horvat
e-mail: mhorvat@ryerson.ca

For more information about the research project:
http://www.iea-shc.org/task41/index.html

Thank you in advance for your participation.

4%

Next page


IEATASK41_International Survey_Canadian Subtask B - Mozilla Firefox
File Edit View History Bookmarks Tools Help
Create Online Surveys and Forms
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questionform.com https://questionform.com/secure/mhorvat/Il
Google
IEA Task 41
Solar Energy and Architecture
-International Survey-
Subtask B: Design Process for Solar Architecture
General
1. In your current architectural practice, how would you rate the importance of the use of solar energy (e.g. use of passive solar gains, solar thermal, photovoltaics, etc.)?
© Michael Elkan
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Important
Neutral
Unimportant
I don't know
Prev page
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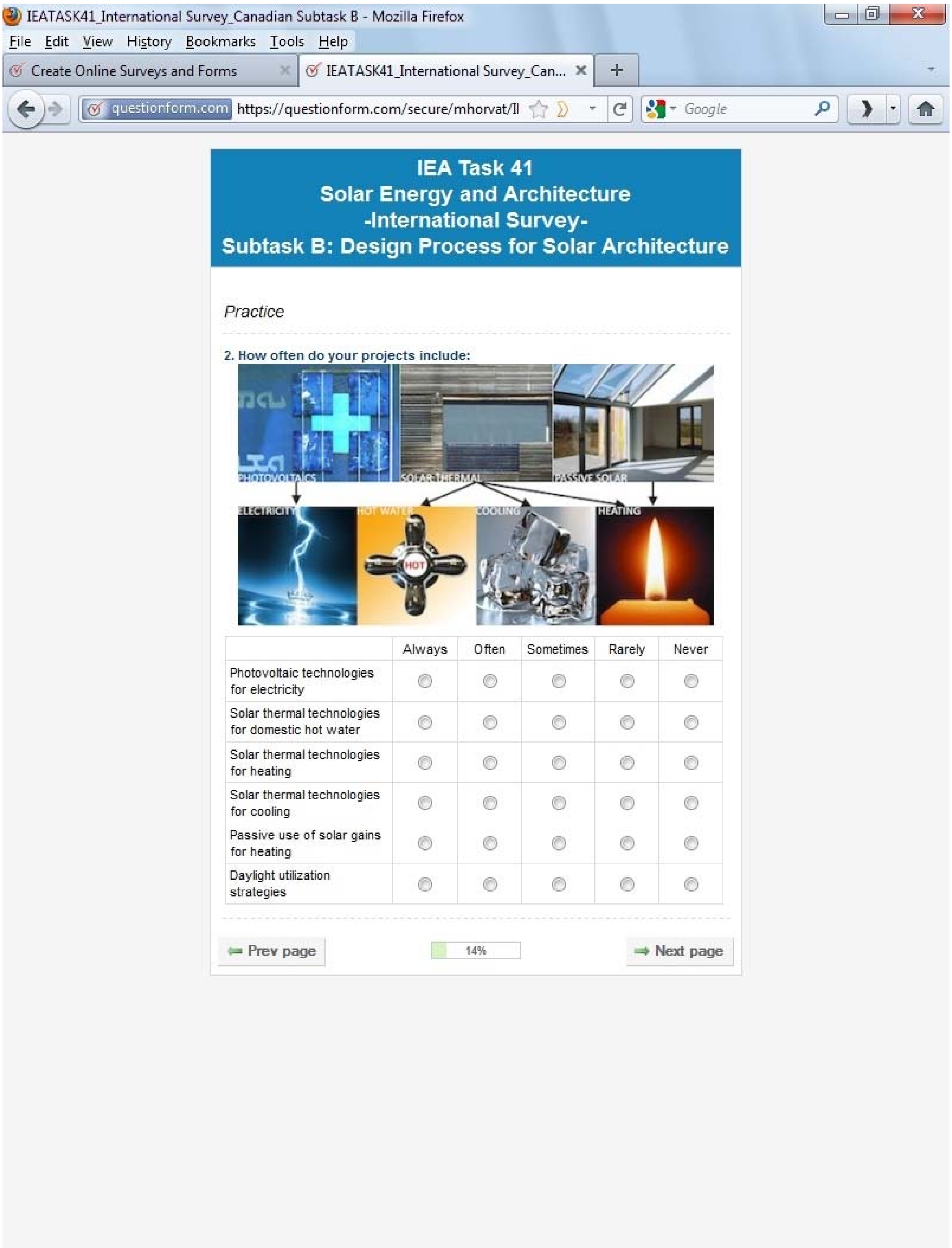
IEATASK41_International Survey_Canadian Subtask B - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Create Online Surveys and Forms | IEATASK41_International Survey_Can...

questionform.com https://questionform.com/secure/mhorvat/Il

IEA Task 41
Solar Energy and Architecture
-International Survey-
Subtask B: Design Process for Solar Architecture

Practice

2. How often do your projects include:

	Always	Often	Sometimes	Rarely	Never
Photovoltaic technologies for electricity	○	○	○	○	○
Solar thermal technologies for domestic hot water	○	○	○	○	○
Solar thermal technologies for heating	○	○	○	○	○
Solar thermal technologies for cooling	○	○	○	○	○
Passive use of solar gains for heating	○	○	○	○	○
Daylight utilization strategies	○	○	○	○	○

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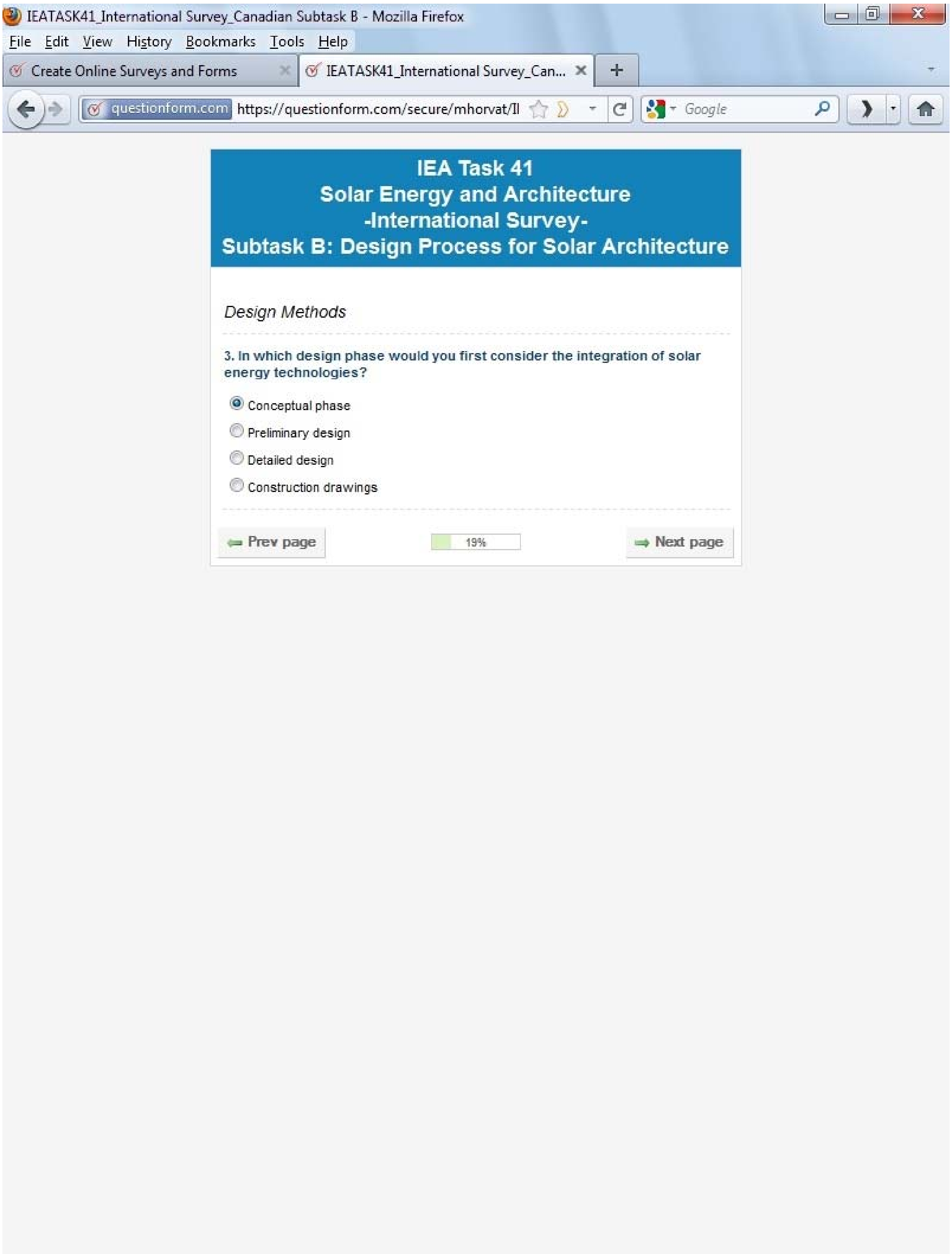
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IEA Task 41
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Subtask B: Design Process for Solar Architecture
Design Methods
3. In which design phase would you first consider the integration of solar energy technologies?
Conceptual phase
Preliminary design
Detailed design
Construction drawings
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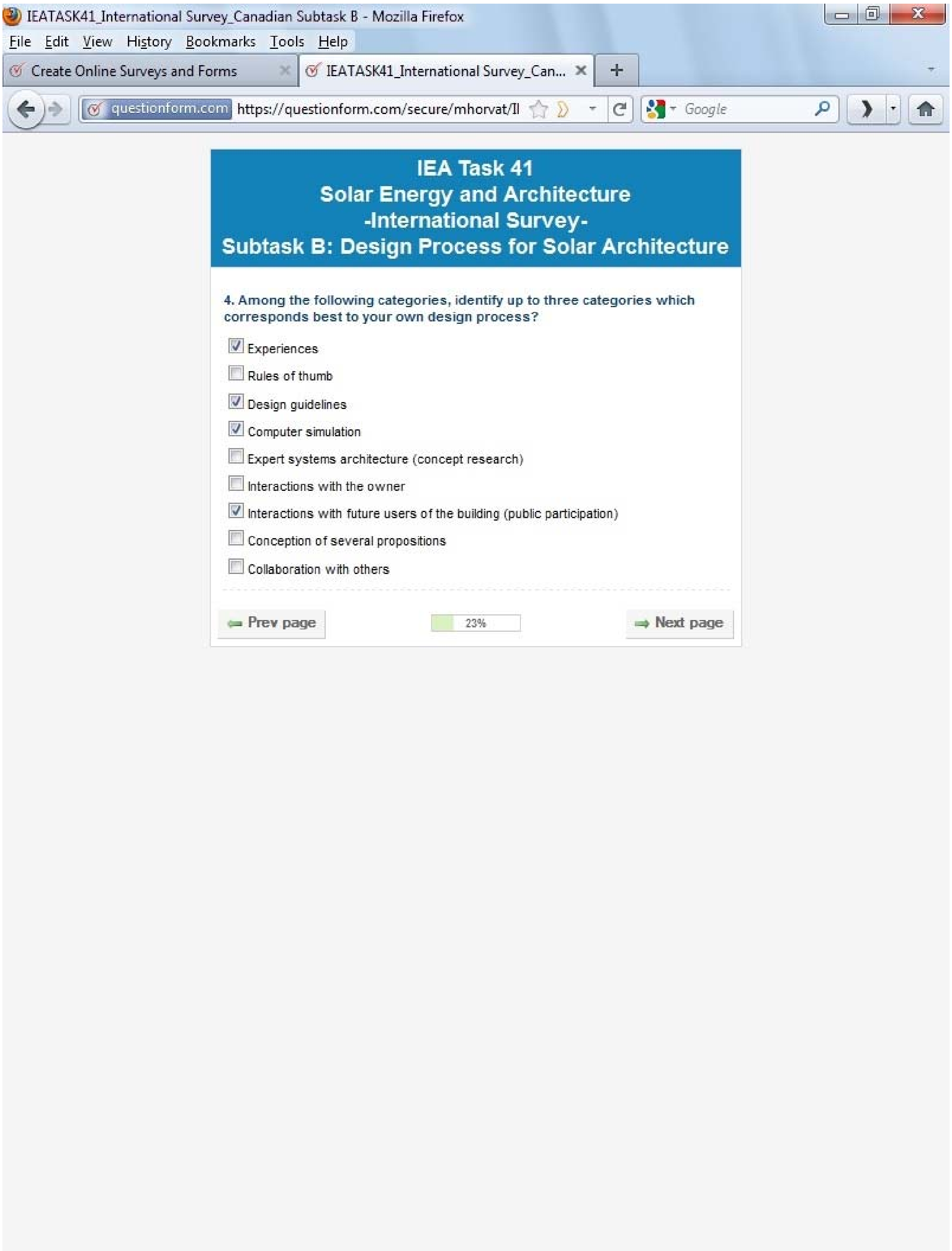
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4. Among the following categories, identify up to three categories which corresponds best to your own design process?
Experiences
Rules of thumb
Design guidelines
Computer simulation
Expert systems architecture (concept research)
Interactions with the owner
Interactions with future users of the building (public participation)
Conception of several propositions
Collaboration with others
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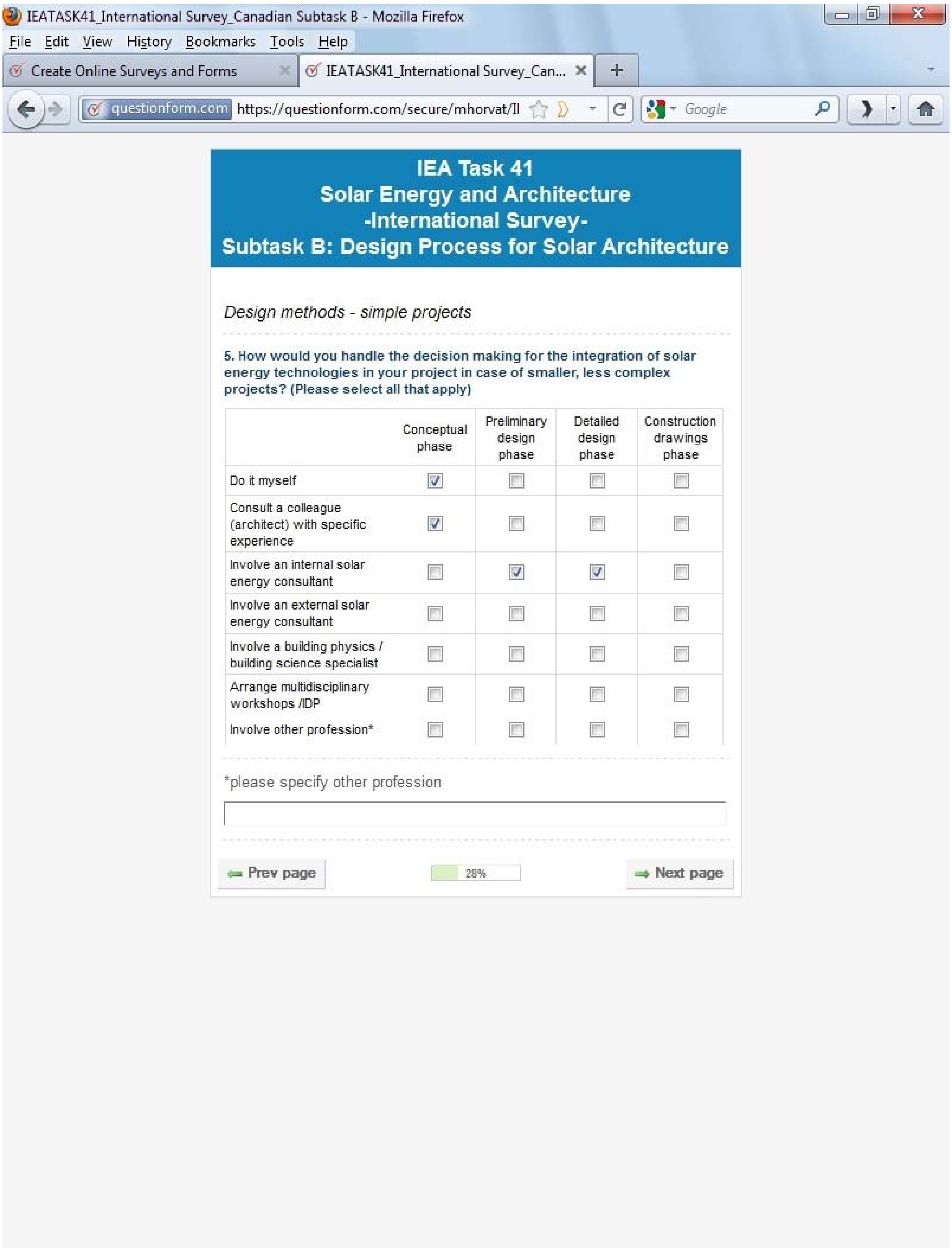

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Design methods - simple projects

5. How would you handle the decision making for the integration of solar energy technologies in your project in case of smaller, less complex projects? (Please select all that apply)

	Conceptual phase	Preliminary design phase	Detailed design phase	Construction drawings phase
Do it myself	☑	☐	☐	☐
Consult a colleague (architect) with specific experience	☑	☐	☐	☐
Involve an internal solar energy consultant	☐	☑	☑	☐
Involve an external solar energy consultant	☐	☐	☐	☐
Involve a building physics / building science specialist	☐	☐	☐	☐
Arrange multidisciplinary workshops /IDP	☐	☐	☐	☐
Involve other profession*	☐	☐	☐	☐

*please specify other profession

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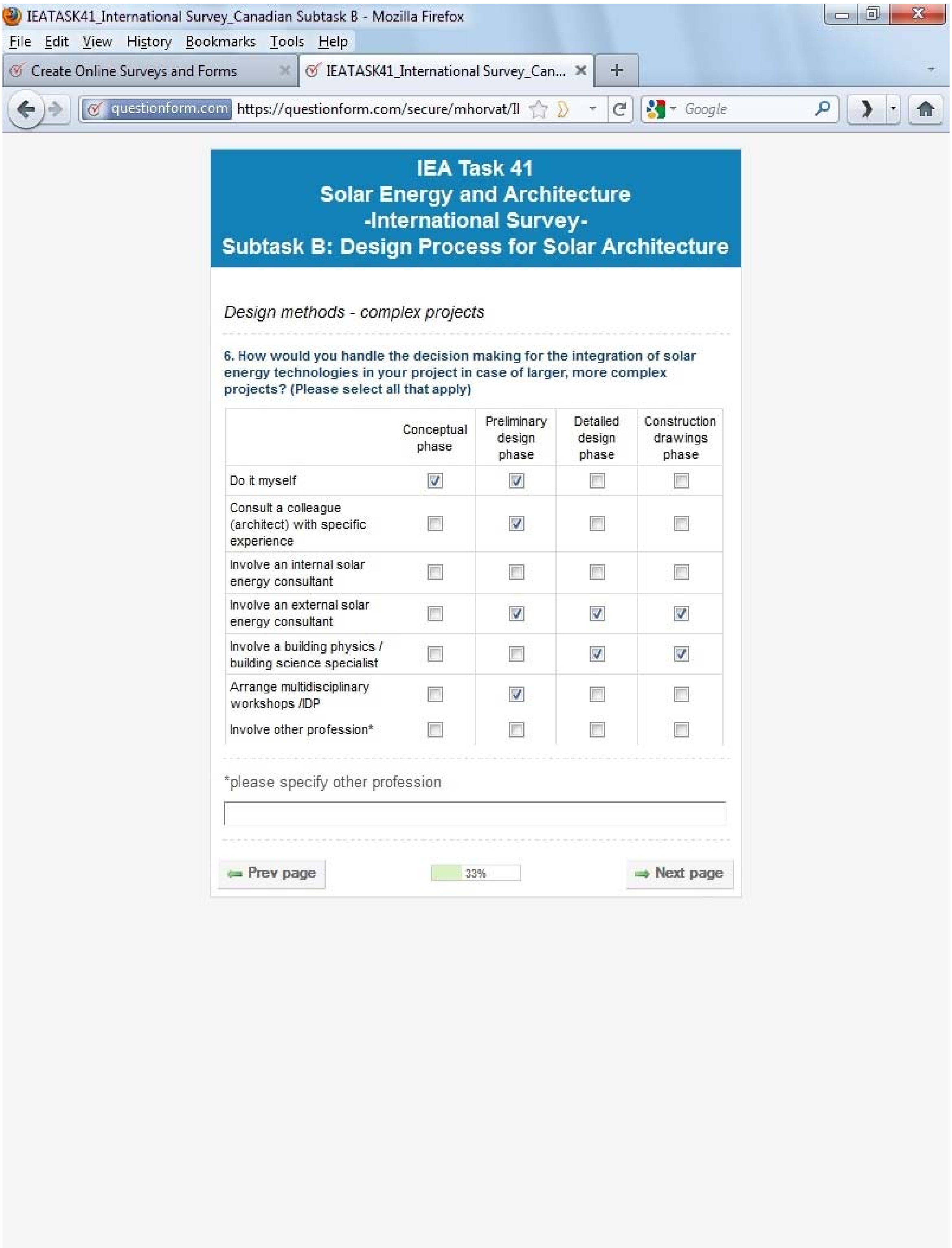

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Design methods - complex projects

6. How would you handle the decision making for the integration of solar energy technologies in your project in case of larger, more complex projects? (Please select all that apply)

	Conceptual phase	Preliminary design phase	Detailed design phase	Construction drawings phase
Do it myself	☑	☑	☐	☐
Consult a colleague (architect) with specific experience	☐	☑	☐	☐
Involve an internal solar energy consultant	☐	☐	☐	☐
Involve an external solar energy consultant	☐	☑	☑	☑
Involve a building physics / building science specialist	☐	☐	☑	☑
Arrange multidisciplinary workshops /IDP	☐	☑	☐	☐
Involve other profession*	☐	☐	☐	☐

*please specify other profession

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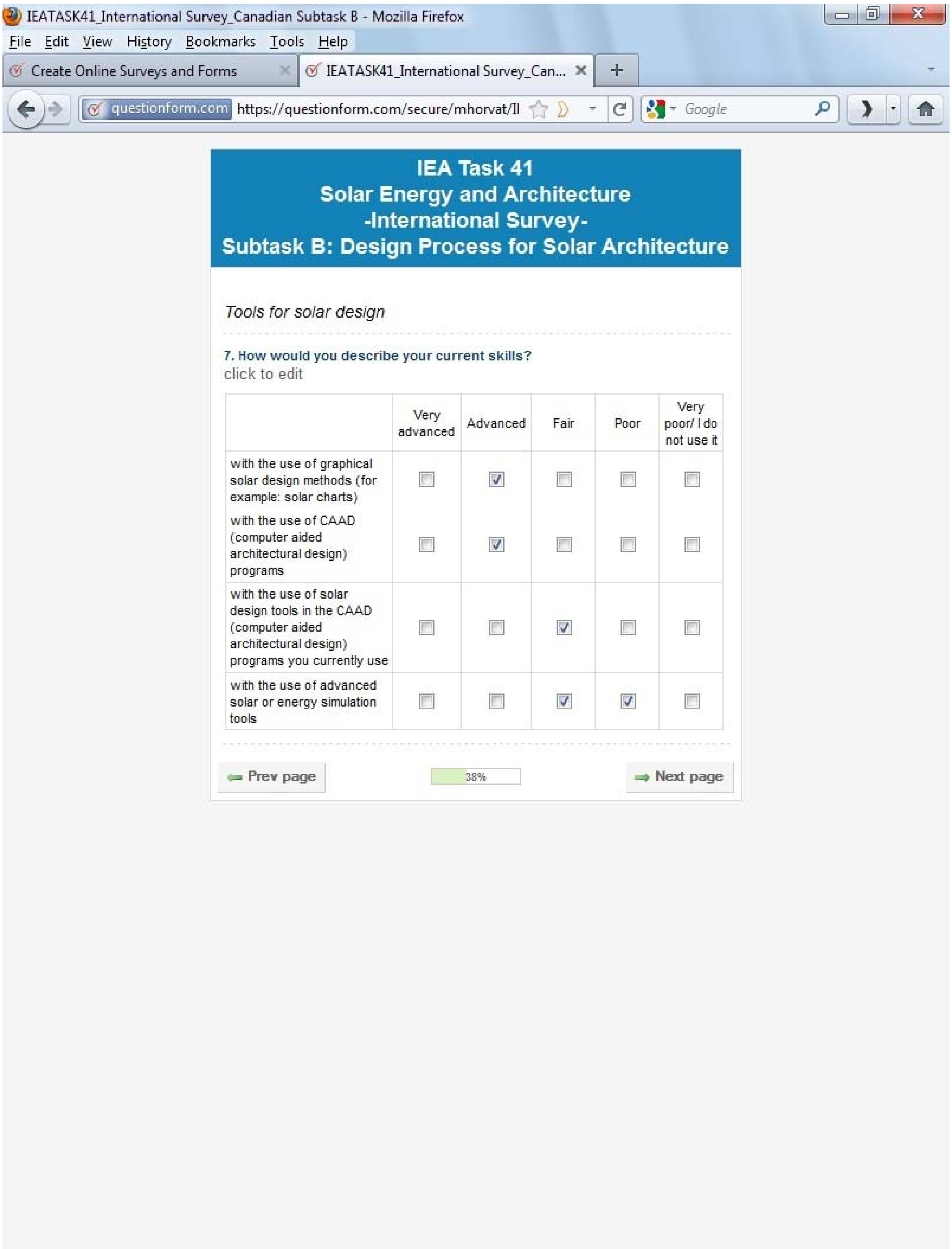

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Subtask B: Design Process for Solar Architecture

Tools for solar design

7. How would you describe your current skills?
click to edit

	Very advanced	Advanced	Fair	Poor	Very poor/ I do not use it
with the use of graphical solar design methods (for example: solar charts)	☐	☑	☐	☐	☐
with the use of CAAD (computer aided architectural design) programs	☐	☑	☐	☐	☐
with the use of solar design tools in the CAAD (computer aided architectural design) programs you currently use	☐	☐	☑	☐	☐
with the use of advanced solar or energy simulation tools	☐	☐	☑	☑	☐

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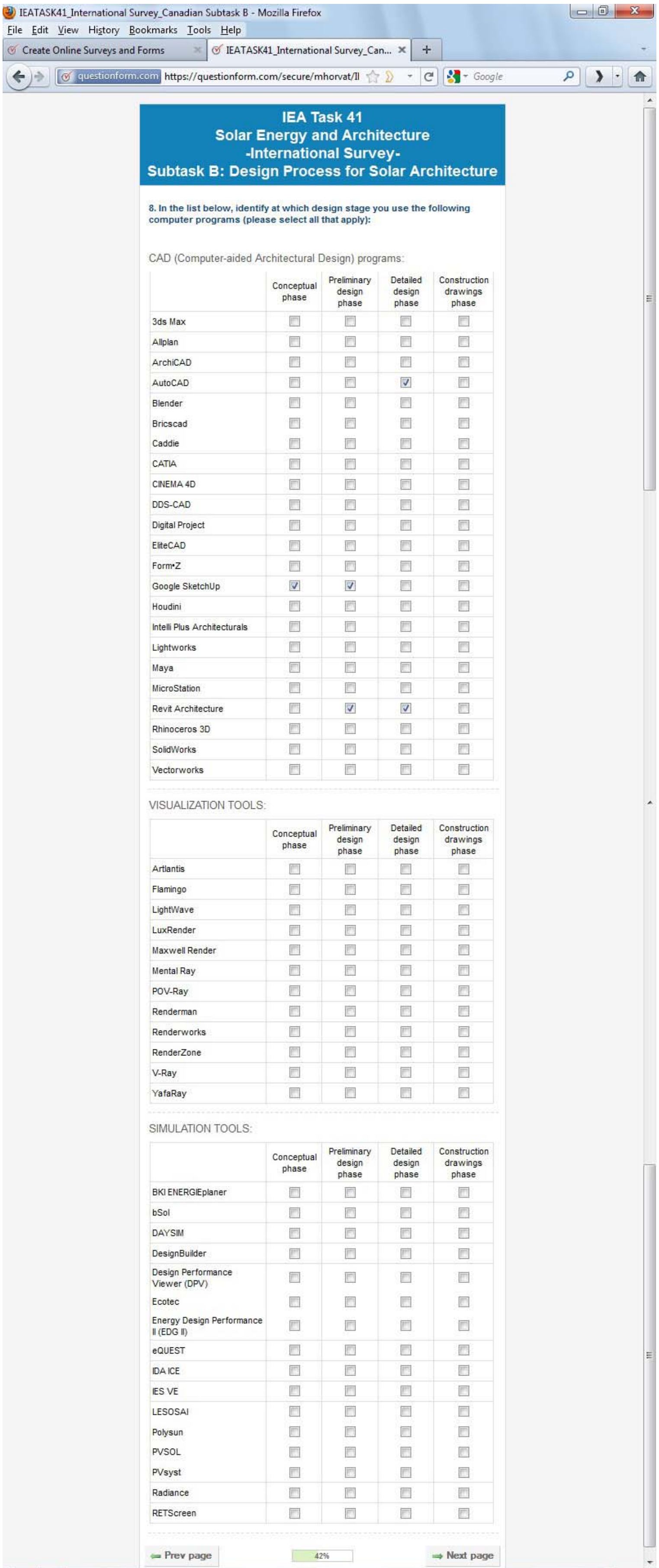

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8. In the list below, identify at which design stage you use the following computer programs (please select all that apply):

CAD (Computer-aided Architectural Design) programs:

	Conceptual phase	Preliminary design phase	Detailed design phase	Construction drawings phase
3ds Max	☐	☐	☐	☐
Allplan	☐	☐	☐	☐
ArchiCAD	☐	☐	☐	☐
AutoCAD	☐	☐	☑	☐
Blender	☐	☐	☐	☐
Bricscad	☐	☐	☐	☐
Caddie	☐	☐	☐	☐
CATIA	☐	☐	☐	☐
CINEMA 4D	☐	☐	☐	☐
DDS-CAD	☐	☐	☐	☐
Digital Project	☐	☐	☐	☐
EliteCAD	☐	☐	☐	☐
Form•Z	☐	☐	☐	☐
Google SketchUp	☑	☑	☐	☐
Houdini	☐	☐	☐	☐
Intelli Plus Architecturals	☐	☐	☐	☐
Lightworks	☐	☐	☐	☐
Maya	☐	☐	☐	☐
MicroStation	☐	☐	☐	☐
Revit Architecture	☐	☑	☑	☐
Rhinoceros 3D	☐	☐	☐	☐
SolidWorks	☐	☐	☐	☐
Vectorworks	☐	☐	☐	☐

VISUALIZATION TOOLS:

	Conceptual phase	Preliminary design phase	Detailed design phase	Construction drawings phase
Artlantis	☐	☐	☐	☐
Flamingo	☐	☐	☐	☐
LightWave	☐	☐	☐	☐
LuxRender	☐	☐	☐	☐
Maxwell Render	☐	☐	☐	☐
Mental Ray	☐	☐	☐	☐
POV-Ray	☐	☐	☐	☐
Renderman	☐	☐	☐	☐
Renderworks	☐	☐	☐	☐
RenderZone	☐	☐	☐	☐
V-Ray	☐	☐	☐	☐
YafaRay	☐	☐	☐	☐

SIMULATION TOOLS:

	Conceptual phase	Preliminary design phase	Detailed design phase	Construction drawings phase
BKI ENERGIEplaner	☐	☐	☐	☐
bSol	☐	☐	☐	☐
DAYSIM	☐	☐	☐	☐
DesignBuilder	☐	☐	☐	☐
Design Performance Viewer (DPV)	☐	☐	☐	☐
Ecotec	☐	☐	☐	☐
Energy Design Performance II (EDG II)	☐	☐	☐	☐
eQUEST	☐	☐	☐	☐
IDA ICE	☐	☐	☐	☐
IES VE	☐	☐	☐	☐
LESOSAI	☐	☐	☐	☐
Polysun	☐	☐	☐	☐
PVSOL	☐	☐	☐	☐
PVsyst	☐	☐	☐	☐
Radiance	☐	☐	☐	☐
RETScreen	☐	☐	☐	☐

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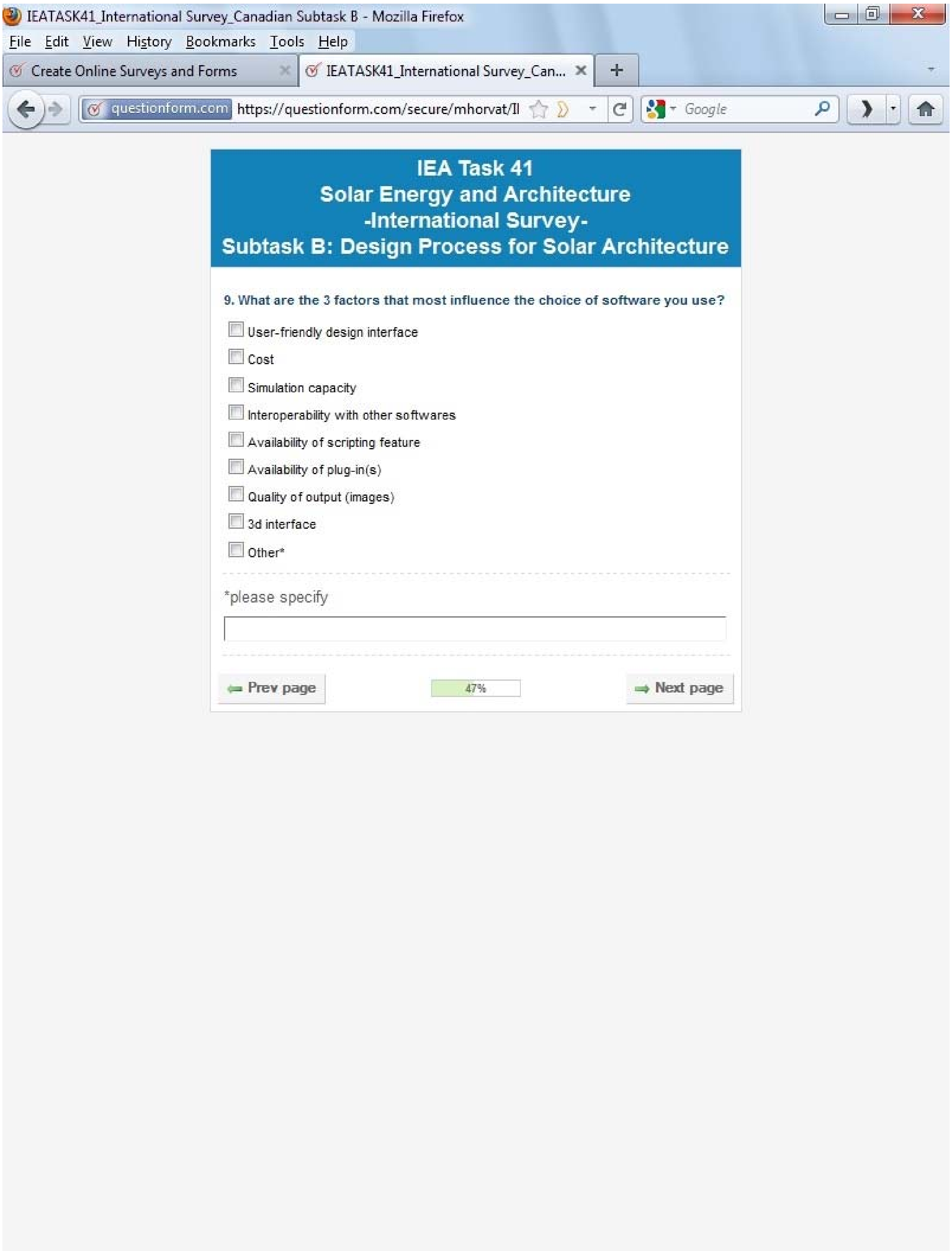
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Subtask B: Design Process for Solar Architecture
9. What are the 3 factors that most influence the choice of software you use?
User-friendly design interface
Cost
Simulation capacity
Interoperability with other softwares
Availability of scripting feature
Availability of plug-in(s)
Quality of output (images)
3d interface
Other*
*please specify
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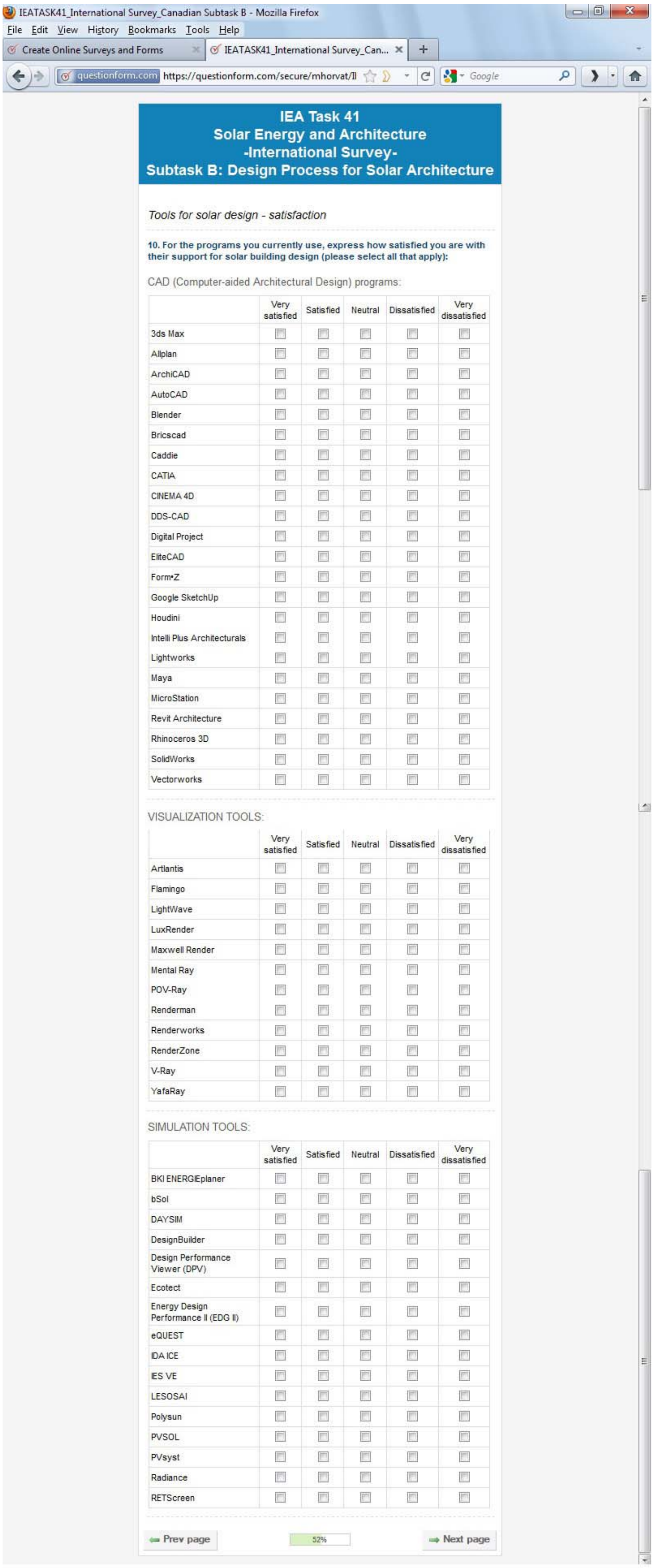

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IEA Task 41
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Subtask B: Design Process for Solar Architecture

Tools for solar design - satisfaction

10. For the programs you currently use, express how satisfied you are with their support for solar building design (please select all that apply):

CAD (Computer-aided Architectural Design) programs:

	Very satisfied	Satisfied	Neutral	Dissatisfied	Very dissatisfied
3ds Max	☐	☐	☐	☐	☐
Allplan	☐	☐	☐	☐	☐
ArchiCAD	☐	☐	☐	☐	☐
AutoCAD	☐	☐	☐	☐	☐
Blender	☐	☐	☐	☐	☐
Bricscad	☐	☐	☐	☐	☐
Caddie	☐	☐	☐	☐	☐
CATIA	☐	☐	☐	☐	☐
CINEMA 4D	☐	☐	☐	☐	☐
DDS-CAD	☐	☐	☐	☐	☐
Digital Project	☐	☐	☐	☐	☐
EliteCAD	☐	☐	☐	☐	☐
Form•Z	☐	☐	☐	☐	☐
Google SketchUp	☐	☐	☐	☐	☐
Houdini	☐	☐	☐	☐	☐
Intelli Plus Architecturals	☐	☐	☐	☐	☐
Lightworks	☐	☐	☐	☐	☐
Maya	☐	☐	☐	☐	☐
MicroStation	☐	☐	☐	☐	☐
Revit Architecture	☐	☐	☐	☐	☐
Rhinoceros 3D	☐	☐	☐	☐	☐
SolidWorks	☐	☐	☐	☐	☐
Vectorworks	☐	☐	☐	☐	☐

VISUALIZATION TOOLS:

	Very satisfied	Satisfied	Neutral	Dissatisfied	Very dissatisfied
Artlantis	☐	☐	☐	☐	☐
Flamingo	☐	☐	☐	☐	☐
LightWave	☐	☐	☐	☐	☐
LuxRender	☐	☐	☐	☐	☐
Maxwell Render	☐	☐	☐	☐	☐
Mental Ray	☐	☐	☐	☐	☐
POV-Ray	☐	☐	☐	☐	☐
Renderman	☐	☐	☐	☐	☐
Renderworks	☐	☐	☐	☐	☐
RenderZone	☐	☐	☐	☐	☐
V-Ray	☐	☐	☐	☐	☐
YafaRay	☐	☐	☐	☐	☐

SIMULATION TOOLS:

	Very satisfied	Satisfied	Neutral	Dissatisfied	Very dissatisfied
BKI ENERGIEplaner	☐	☐	☐	☐	☐
bSol	☐	☐	☐	☐	☐
DAYSIM	☐	☐	☐	☐	☐
DesignBuilder	☐	☐	☐	☐	☐
Design Performance Viewer (DPV)	☐	☐	☐	☐	☐
Ecotect	☐	☐	☐	☐	☐
Energy Design Performance II (EDG II)	☐	☐	☐	☐	☐
eQUEST	☐	☐	☐	☐	☐
IDA ICE	☐	☐	☐	☐	☐
IES VE	☐	☐	☐	☐	☐
LESOSAI	☐	☐	☐	☐	☐
Polysun	☐	☐	☐	☐	☐
PVSOL	☐	☐	☐	☐	☐
PVsyst	☐	☐	☐	☐	☐
Radiance	☐	☐	☐	☐	☐
RETScreen	☐	☐	☐	☐	☐

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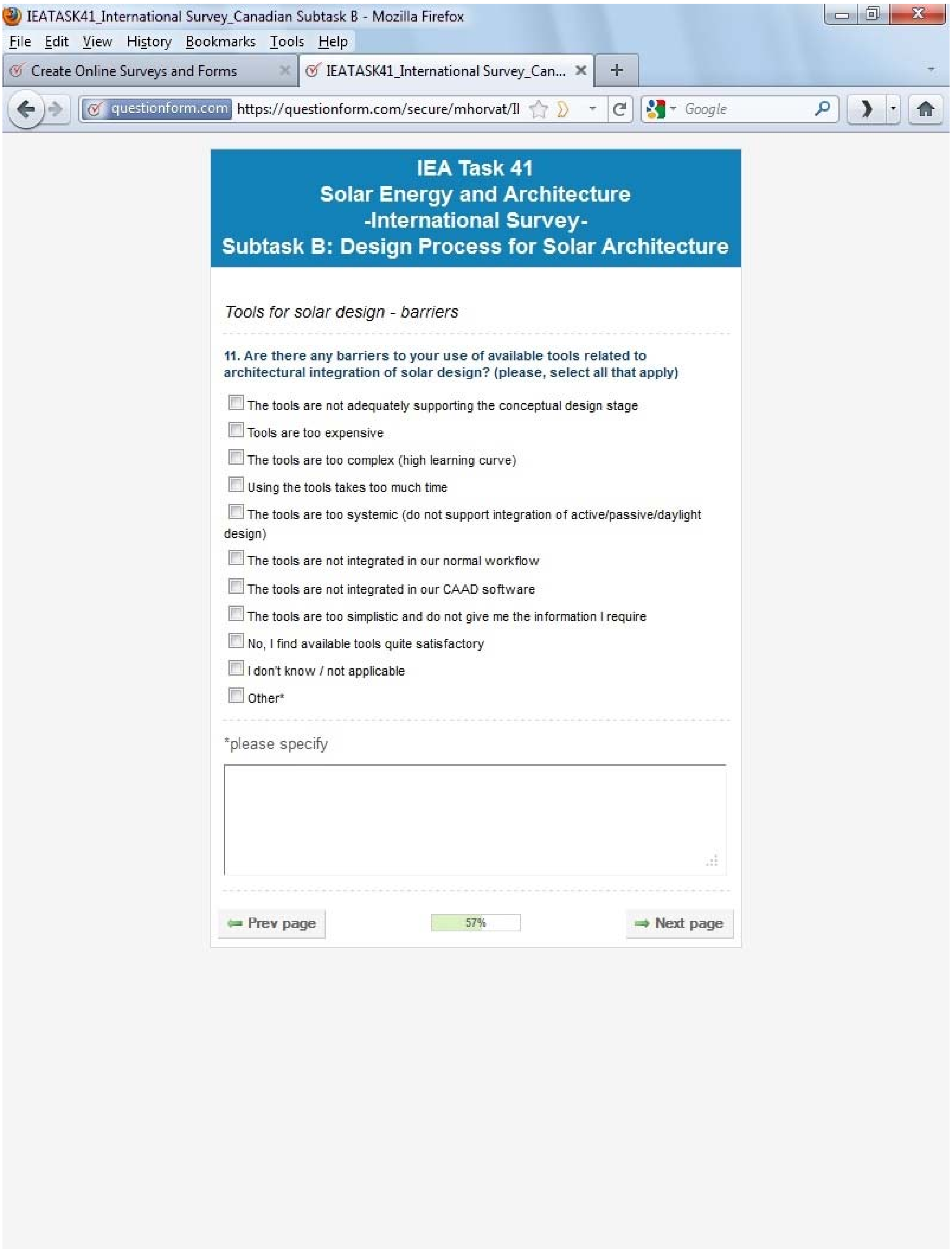

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IEA Task 41
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Subtask B: Design Process for Solar Architecture

Tools for solar design - barriers

11. Are there any barriers to your use of available tools related to architectural integration of solar design? (please, select all that apply)

- [ ] The tools are not adequately supporting the conceptual design stage
- [ ] Tools are too expensive
- [ ] The tools are too complex (high learning curve)
- [ ] Using the tools takes too much time
- [ ] The tools are too systemic (do not support integration of active/passive/daylight design)
- [ ] The tools are not integrated in our normal workflow
- [ ] The tools are not integrated in our CAAD software
- [ ] The tools are too simplistic and do not give me the information I require
- [ ] No, I find available tools quite satisfactory
- [ ] I don't know / not applicable
- [ ] Other*

*please specify

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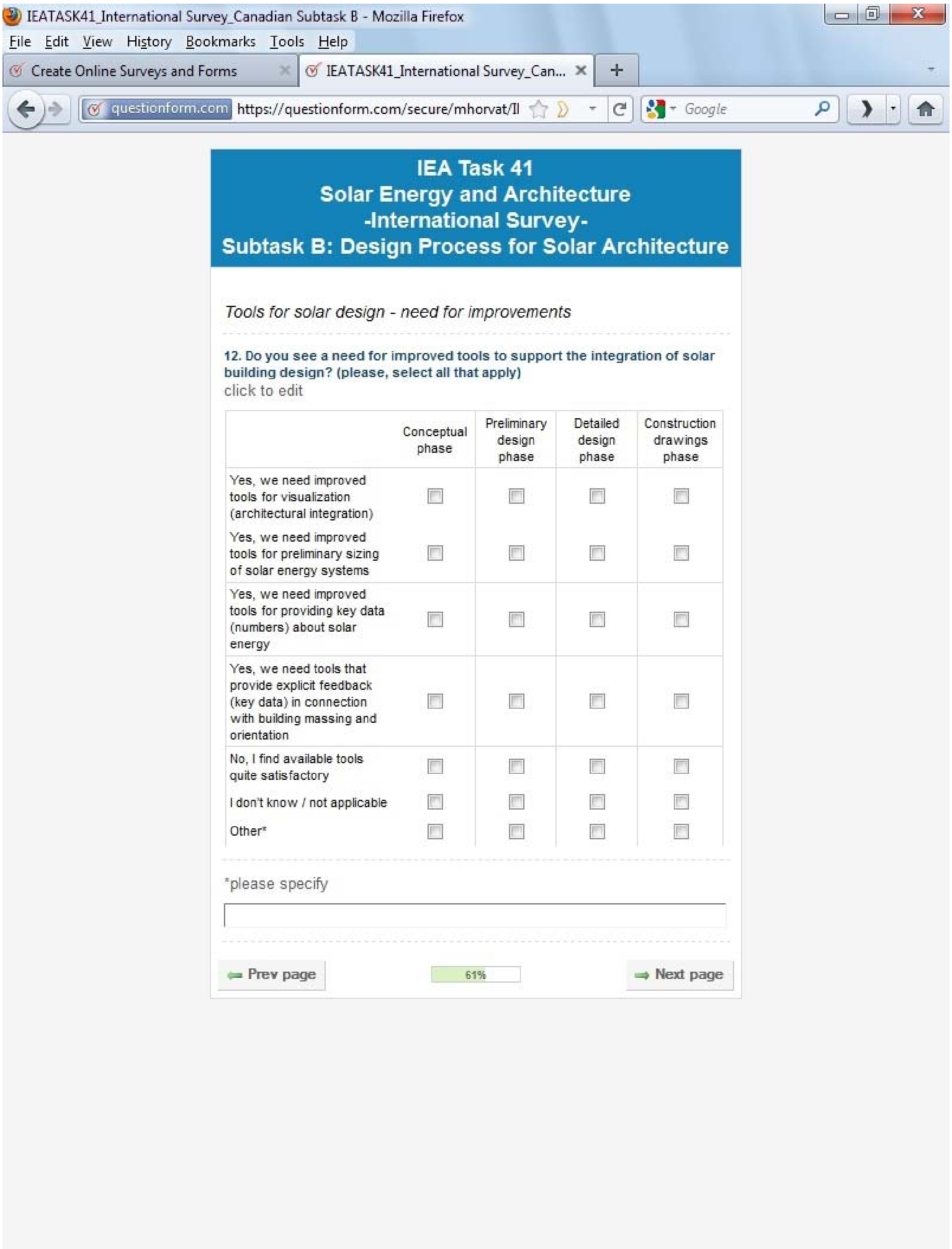

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IEA Task 41
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Subtask B: Design Process for Solar Architecture

Tools for solar design - need for improvements

12. Do you see a need for improved tools to support the integration of solar building design? (please, select all that apply)

click to edit

	Conceptual phase	Preliminary design phase	Detailed design phase	Construction drawings phase
Yes, we need improved tools for visualization (architectural integration)	☐	☐	☐	☐
Yes, we need improved tools for preliminary sizing of solar energy systems	☐	☐	☐	☐
Yes, we need improved tools for providing key data (numbers) about solar energy	☐	☐	☐	☐
Yes, we need tools that provide explicit feedback (key data) in connection with building massing and orientation	☐	☐	☐	☐
No, I find available tools quite satisfactory	☐	☐	☐	☐
I don't know / not applicable	☐	☐	☐	☐
Other*	☐	☐	☐	☐

*please specify

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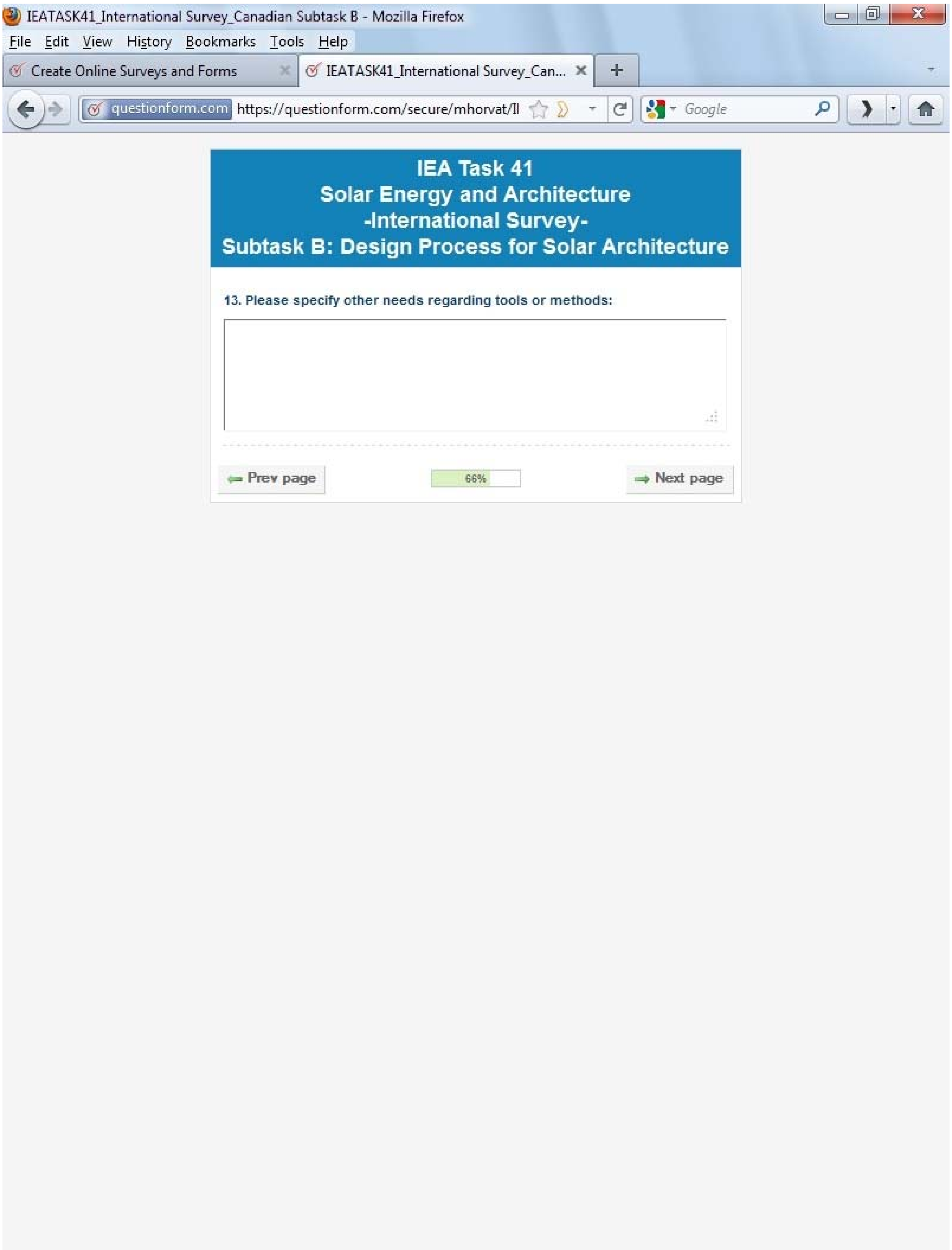
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13. Please specify other needs regarding tools or methods:
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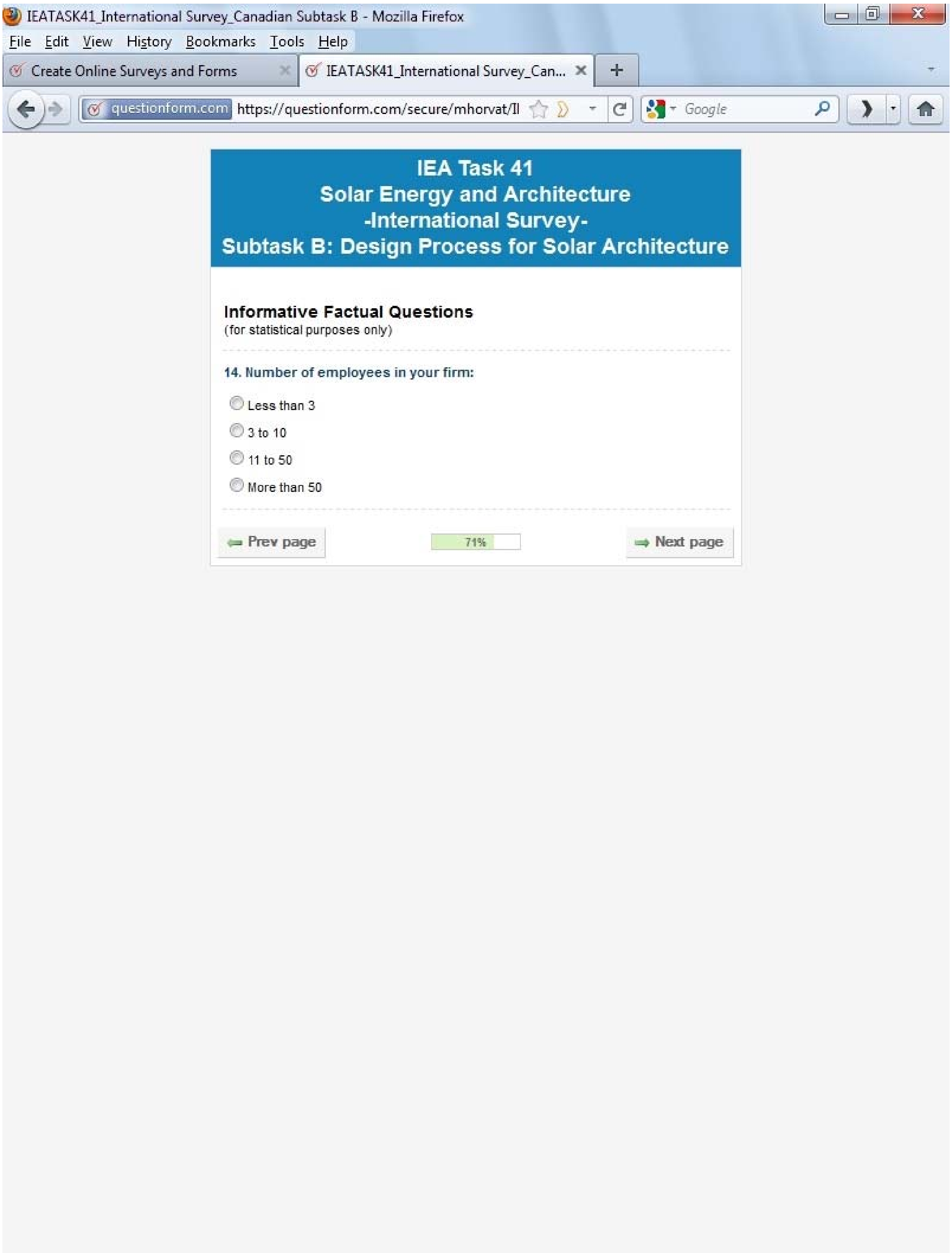
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Informative Factual Questions
(for statistical purposes only)
14. Number of employees in your firm:
Less than 3
3 to 10
11 to 50
More than 50
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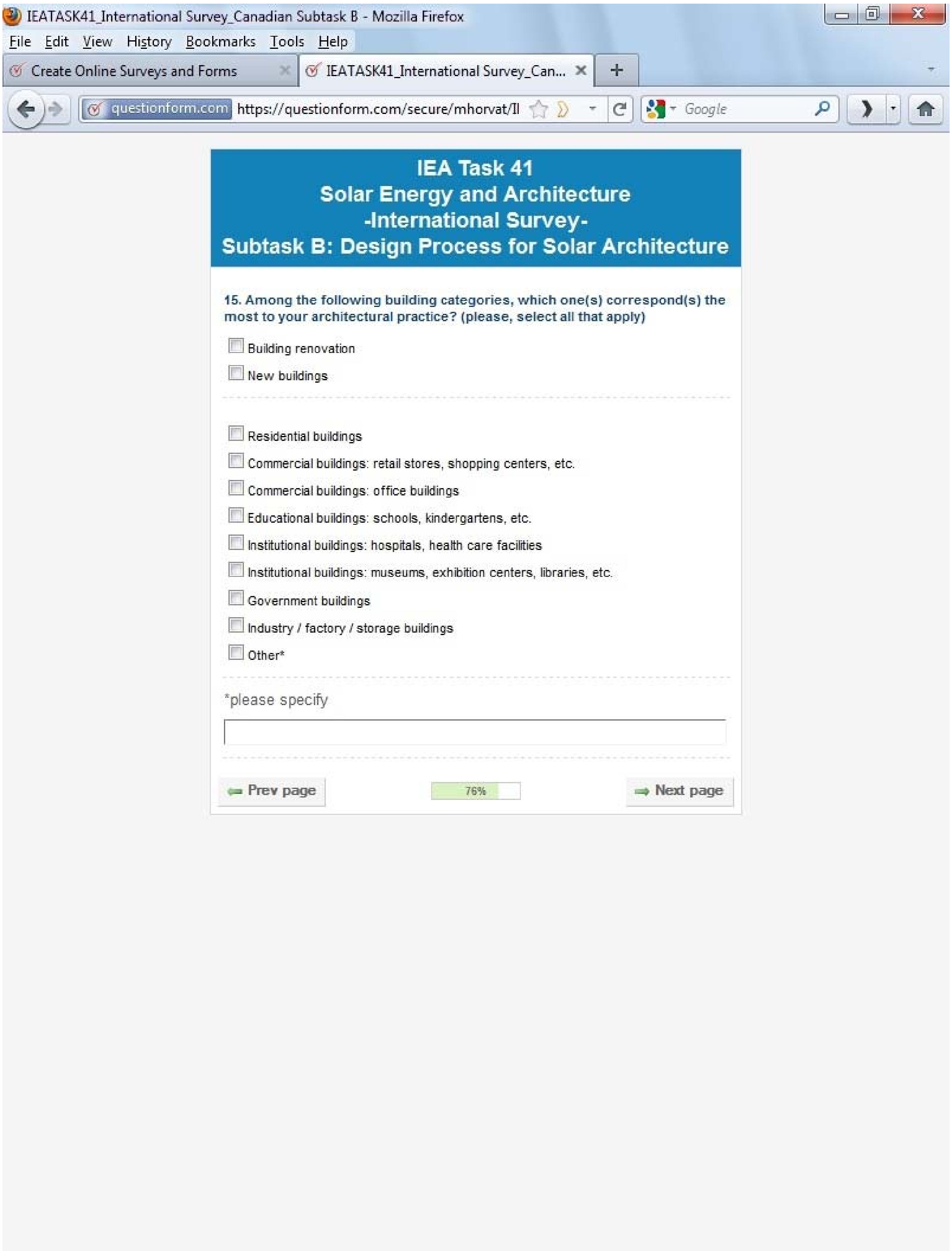

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15. Among the following building categories, which one(s) correspond(s) the most to your architectural practice? (please, select all that apply)

- [ ] Building renovation
- [ ] New buildings

- [ ] Residential buildings
- [ ] Commercial buildings: retail stores, shopping centers, etc.
- [ ] Commercial buildings: office buildings
- [ ] Educational buildings: schools, kindergartens, etc.
- [ ] Institutional buildings: hospitals, health care facilities
- [ ] Institutional buildings: museums, exhibition centers, libraries, etc.
- [ ] Government buildings
- [ ] Industry / factory / storage buildings
- [ ] Other*

*please specify

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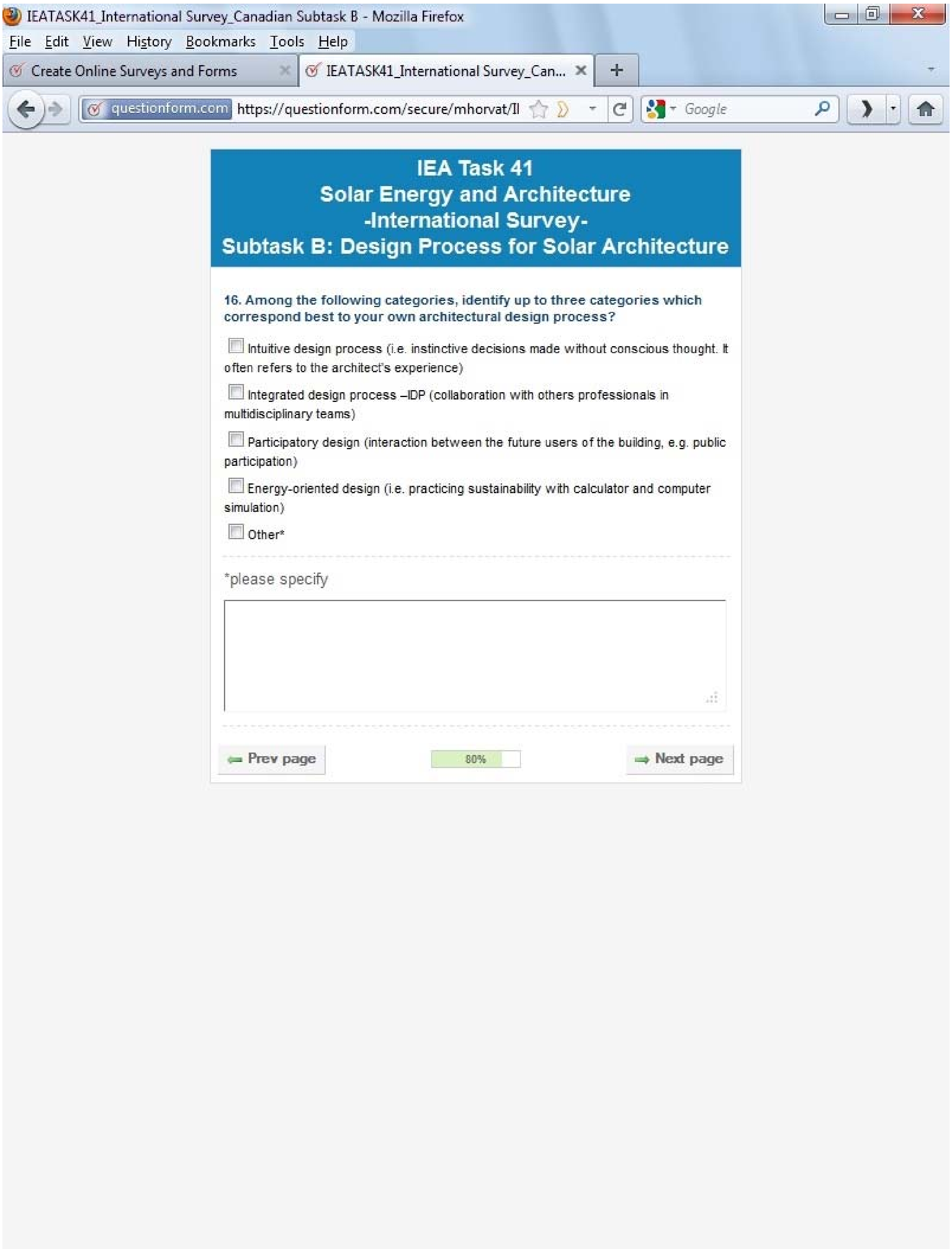

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16. Among the following categories, identify up to three categories which correspond best to your own architectural design process?

- ☐ Intuitive design process (i.e. instinctive decisions made without conscious thought. It often refers to the architect's experience)
- ☐ Integrated design process –IDP (collaboration with others professionals in multidisciplinary teams)
- ☐ Participatory design (interaction between the future users of the building, e.g. public participation)
- ☐ Energy-oriented design (i.e. practicing sustainability with calculator and computer simulation)
- ☐ Other*

*please specify

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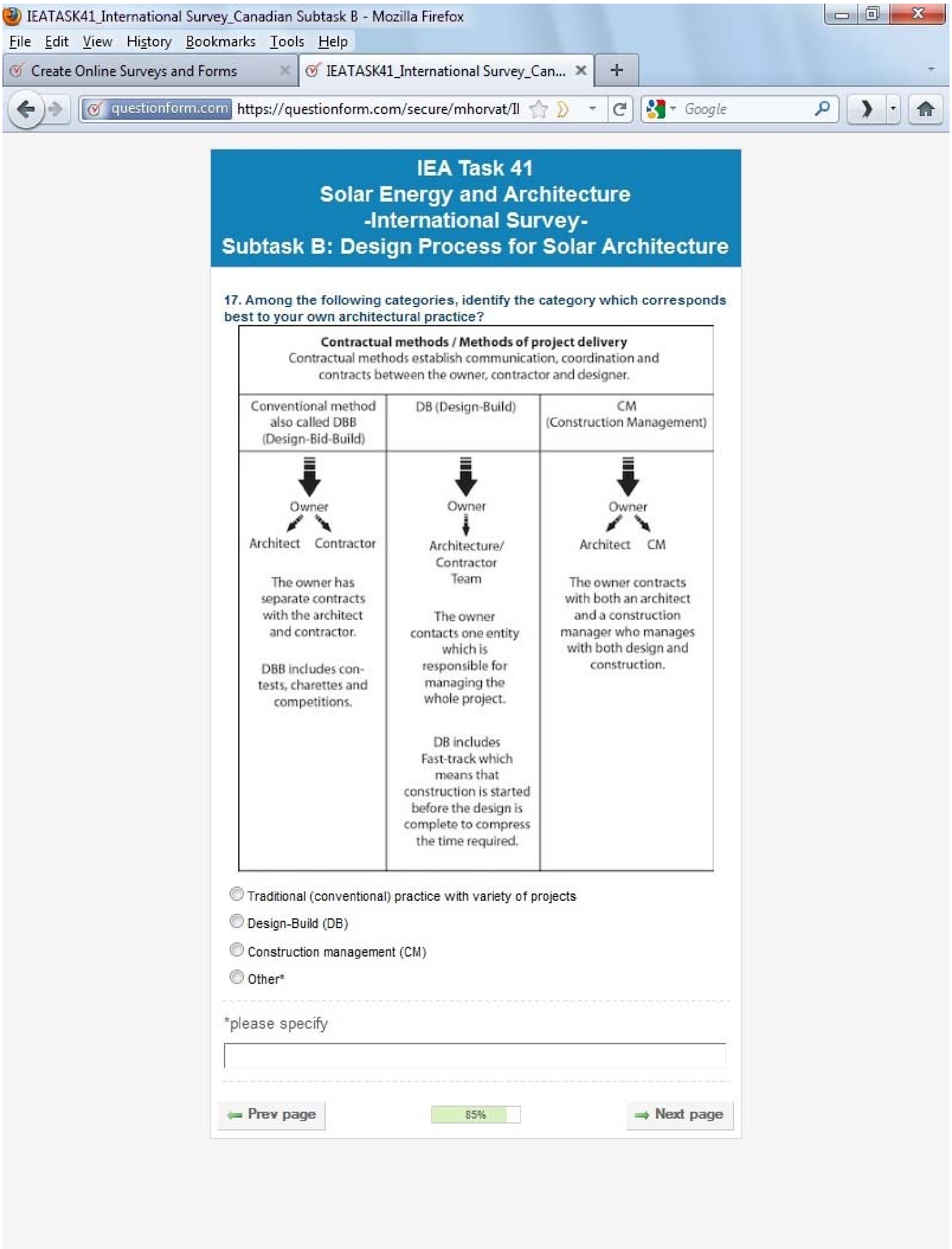

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17. Among the following categories, identify the category which corresponds best to your own architectural practice?

Contractual methods / Methods of project delivery
Contractual methods establish communication, coordination and contracts between the owner, contractor and designer.

Conventional method also called DBB (Design-Bid-Build)	DB (Design-Build)	CM (Construction Management)
Owner → Architect, Contractor	Owner → Architecture/ Contractor Team	Owner → Architect, CM
The owner has separate contracts with the architect and contractor. DBB includes contests, charettes and competitions.	The owner contacts one entity which is responsible for managing the whole project. DB includes Fast-track which means that construction is started before the design is complete to compress the time required.	The owner contracts with both an architect and a construction manager who manages with both design and construction.

- Traditional (conventional) practice with variety of projects
- Design-Build (DB)
- Construction management (CM)
- Other*

*please specify

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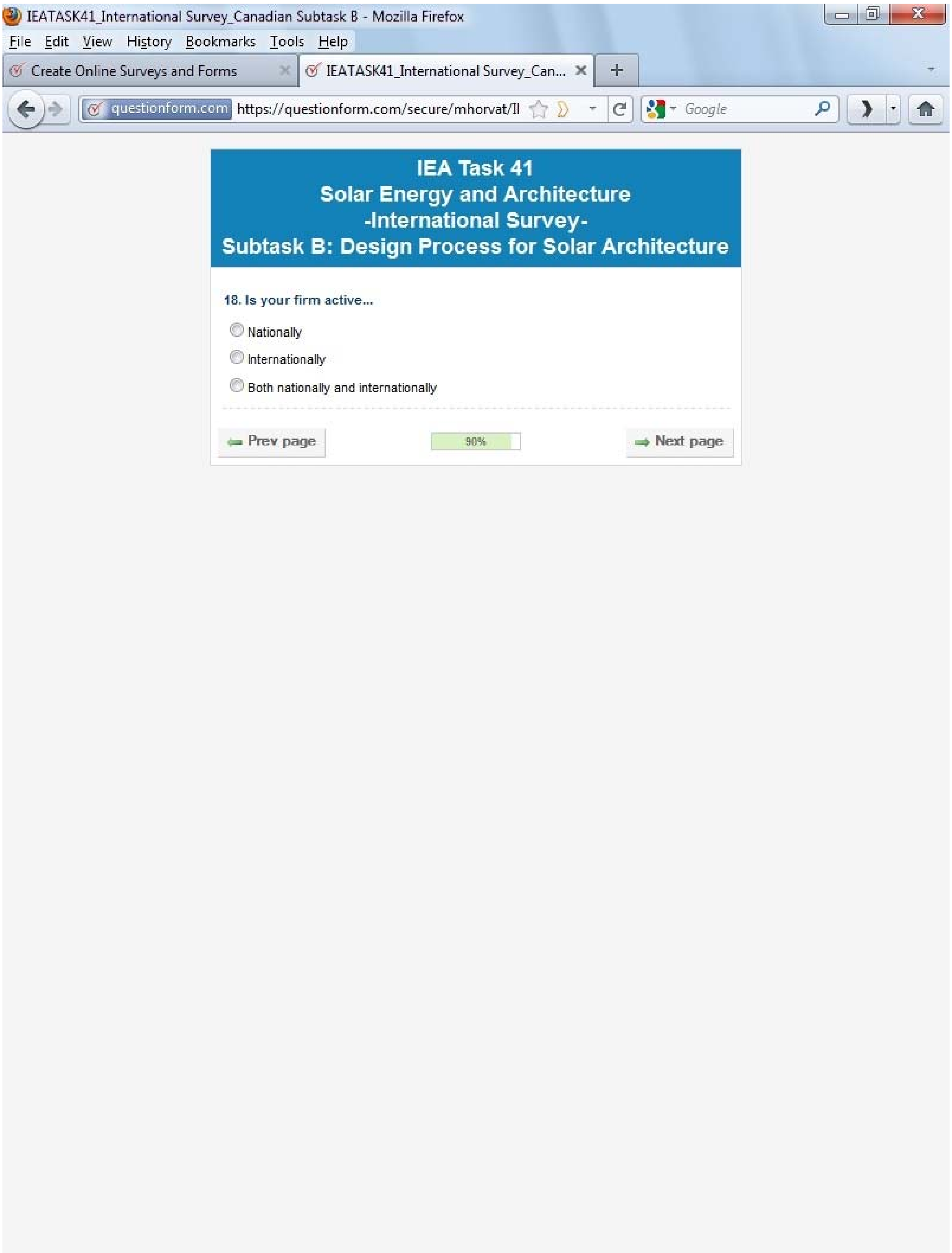
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18. Is your firm active...
Nationally
Internationally
Both nationally and internationally
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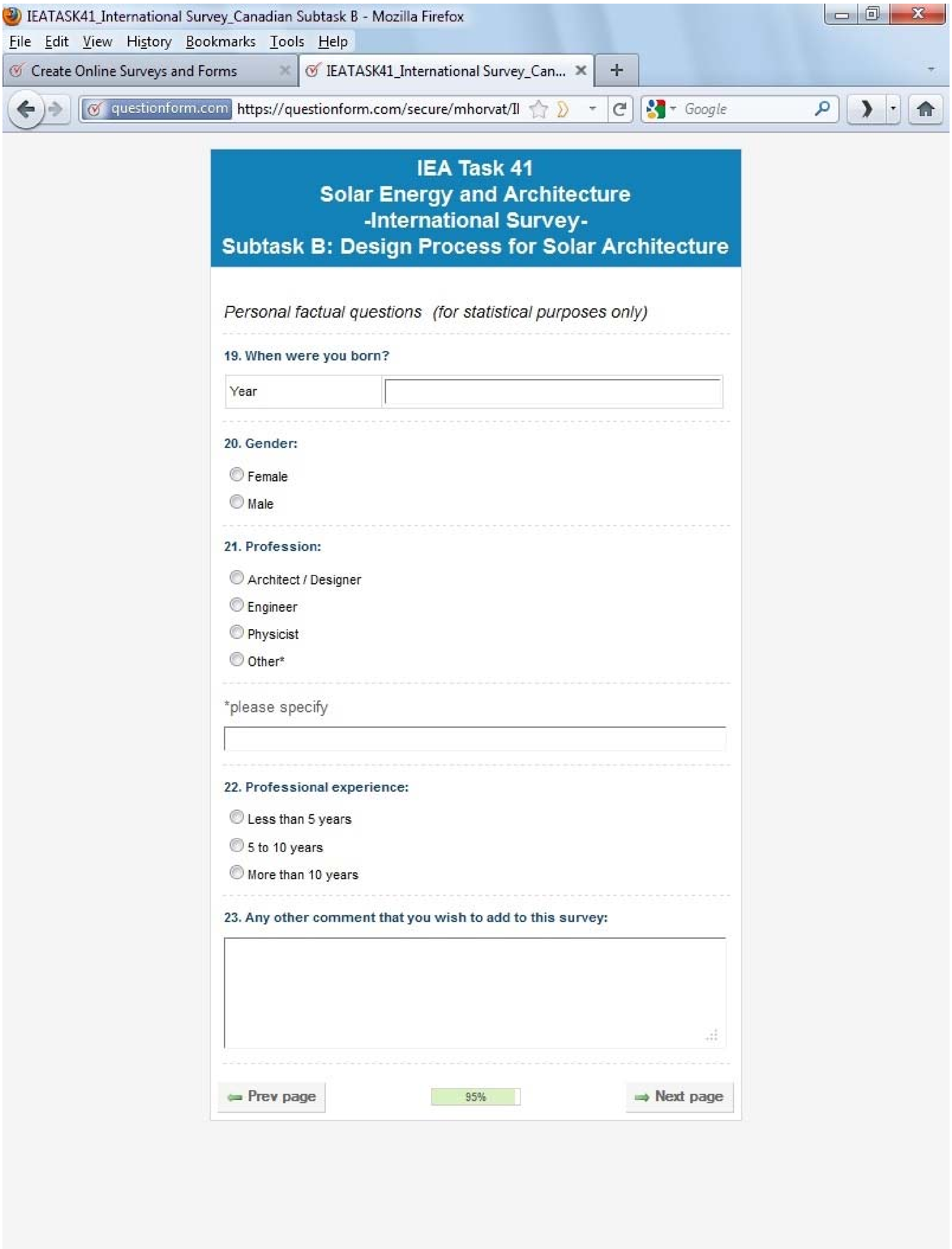

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Personal factual questions (for statistical purposes only)

19. When were you born?

Year

20. Gender:

- Female
- Male

21. Profession:

- Architect / Designer
- Engineer
- Physicist
- Other*

*please specify

22. Professional experience:

- Less than 5 years
- 5 to 10 years
- More than 10 years

23. Any other comment that you wish to add to this survey:

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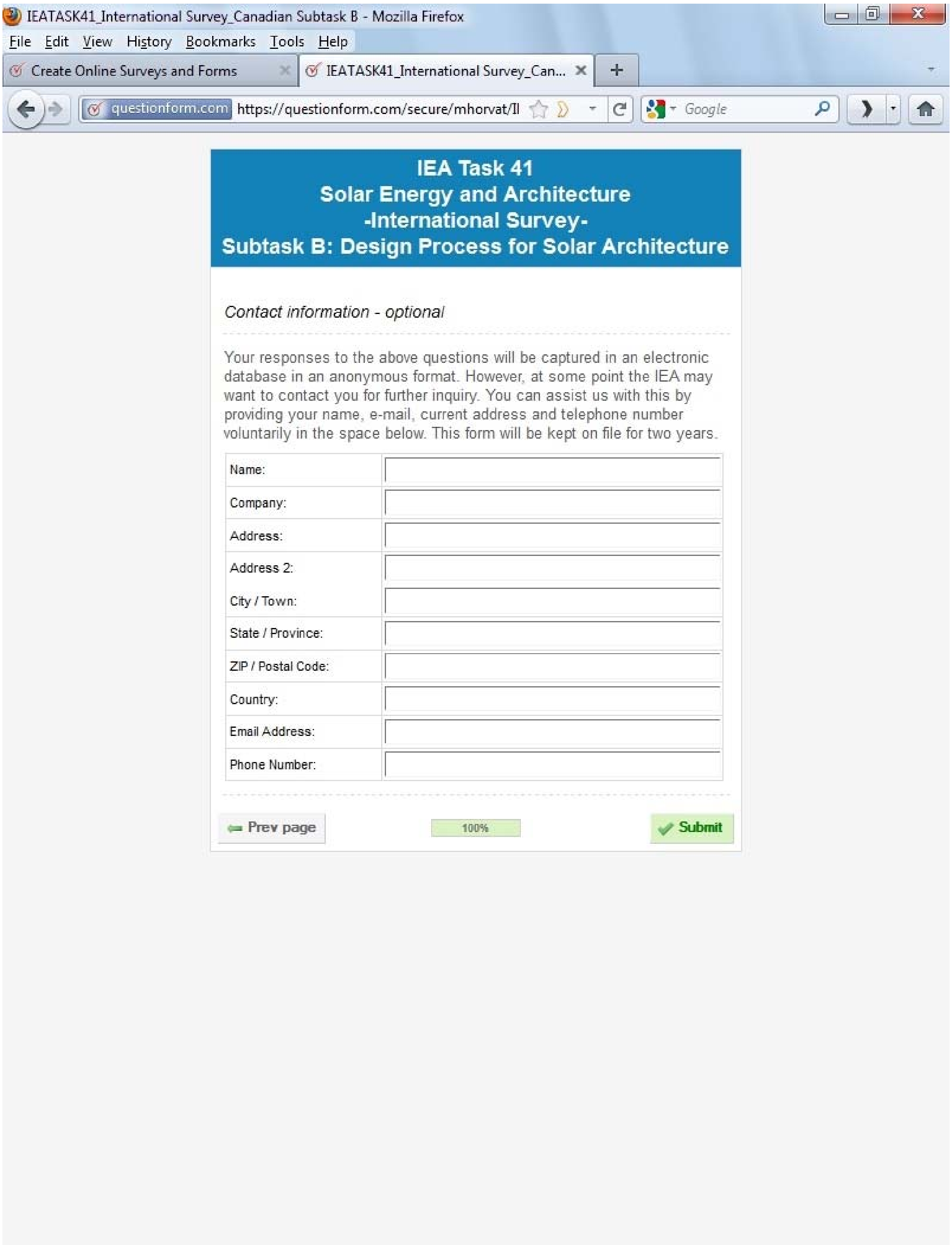
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Contact information - optional

Your responses to the above questions will be captured in an electronic database in an anonymous format. However, at some point the IEA may want to contact you for further inquiry. You can assist us with this by providing your name, e-mail, current address and telephone number voluntarily in the space below. This form will be kept on file for two years.

Name:	
Company:	
Address:	
Address 2:	
City / Town:	
State / Province:	
ZIP / Postal Code:	
Country:	
Email Address:	
Phone Number:	

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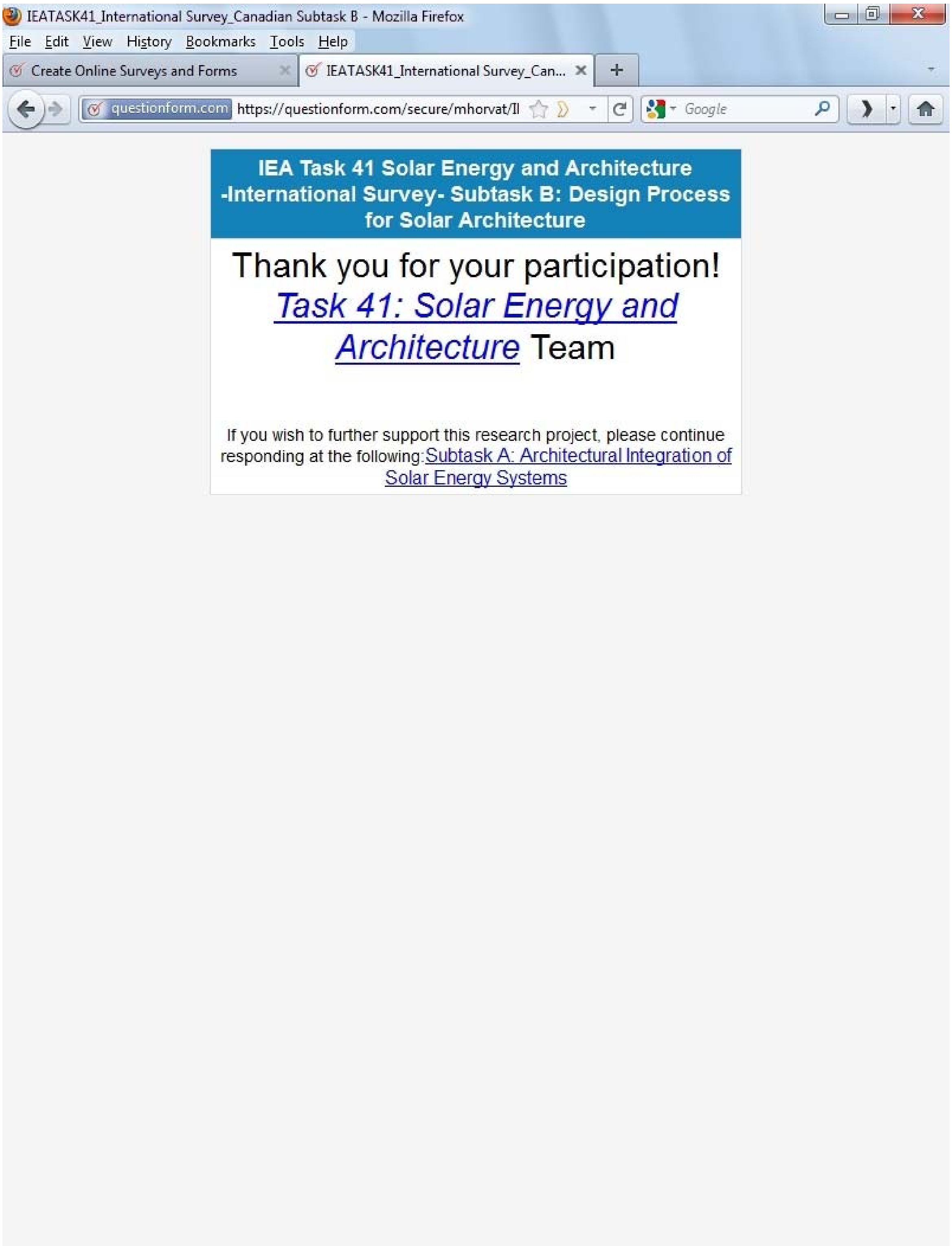
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Thank you for your participation!
Task 41: Solar Energy and Architecture Team
If you wish to further support this research project, please continue responding at the following: Subtask A: Architectural Integration of Solar Energy Systems

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA Solar Heating and Cooling Programme

The *International Energy Agency* (IEA) is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD) based in Paris. Established in 1974 after the first "oil shock," the IEA is committed to carrying out a comprehensive program of energy cooperation among its members and the Commission of the European Communities.

The IEA provides a legal framework, through IEA Implementing Agreements such as the *Solar Heating and Cooling Agreement*, for international collaboration in energy technology research and development (R&D) and deployment. This IEA experience has proved that such collaboration contributes significantly to faster technological progress, while reducing costs; to eliminating technological risks and duplication of efforts; and to creating numerous other benefits, such as swifter expansion of the knowledge base and easier harmonization of standards.

The *Solar Heating and Cooling Programme* was one of the first IEA Implementing Agreements to be established. Since 1977, its members have been collaborating to advance active solar and passive solar and their application in buildings and other areas, such as agriculture and industry. Current members are:

Australia	Finland	Singapore
Austria	France	South Africa
Belgium	Italy	Spain
Canada	Mexico	Sweden
Denmark	Netherlands	Switzerland
European Commission	Norway	United States
Germany	Portugal	

A total of 49 Tasks have been initiated, 34 of which have been completed. Each Task is managed by an Operating Agent from one of the participating countries. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition to the Task work, a number of special activities—Memorandum of Understanding with solar thermal trade organizations, statistics collection and analysis, conferences and workshops—have been undertaken.

Visit the Solar Heating and Cooling Programme website - **www.iea-shc.org** - to find more publications and to learn about the SHC Programme.

Current Tasks & Working Group:

Task 36	*Solar Resource Knowledge Management*
Task 38	*Solar Thermal Cooling and Air Conditioning*
Task 39	*Polymeric Materials for Solar Thermal Applications*
Task 40	*Towards Net Zero Energy Solar Buildings*
Task 41	*Solar Energy and Architecture*
Task 42	*Compact Thermal Energy Storage*
Task 43	*Solar Rating and Certification Procedures*
Task 44	*Solar and Heat Pump Systems*
Task 45	*Large Systems: Solar Heating/Cooling Systems, Seasonal Storages, Heat Pumps*
Task 46	*Solar Resource Assessment and Forecasting*
Task 47	*Renovation of Non-Residential Buildings Towards Sustainable Standards*
Task 48	*Solar Cooling - Quality Assurance Measures for Solar Thermally Driven Heating and Cooling Systems*
Task 49	*Solar Heat Integration in Industrial Processes*

Completed Tasks:

Task 1	*Investigation of the Performance of Solar Heating and Cooling Systems*
Task 2	*Coordination of Solar Heating and Cooling R&D*
Task 3	*Performance Testing of Solar Collectors*
Task 4	*Development of an Insolation Handbook and Instrument Package*
Task 5	*Use of Existing Meteorological Information for Solar Energy Application*
Task 6	*Performance of Solar Systems Using Evacuated Collectors*
Task 7	*Central Solar Heating Plants with Seasonal Storage*
Task 8	*Passive and Hybrid Solar Low Energy Buildings*
Task 9	*Solar Radiation and Pyranometry Studies*
Task 10	*Solar Materials R&D*
Task 11	*Passive and Hybrid Solar Commercial Buildings*
Task 12	*Building Energy Analysis and Design Tools for Solar Applications*
Task 13	*Advanced Solar Low Energy Buildings*
Task 14	*Advanced Active Solar Energy Systems*
Task 16	*Photovoltaics in Buildings*
Task 17	*Measuring and Modeling Spectral Radiation*
Task 18	*Advanced Glazing and Associated Materials for Solar and Building Applications*
Task 19	*Solar Air Systems*
Task 20	*Solar Energy in Building Renovation*
Task 21	*Daylight in Buildings*
Task 22	*Building Energy Analysis Tools*
Task 23	*Optimization of Solar Energy Use in Large Buildings*
Task 24	*Solar Procurement*
Task 25	*Solar Assisted Air Conditioning of Buildings*
Task 26	*Solar Combisystems*
Task 27	*Performance of Solar Facade Components*
Task 28	*Solar Sustainable Housing*
Task 29	*Solar Crop Drying*
Task 31	*Daylighting Buildings in the 21st Century*
Task 32	*Advanced Storage Concepts for Solar and Low Energy Buildings*
Task 33	*Solar Heat for Industrial Processes*
Task 34	*Testing and Validation of Building Energy Simulation Tools*
Task 35	*PV/Thermal Solar Systems*
Task 37	*Advanced Housing Renovation with Solar & Conservation*

Completed Working Groups:

CSHPSS; ISOLDE; Materials in Solar Thermal Collectors; Evaluation of Task 13 Houses; Daylight Research