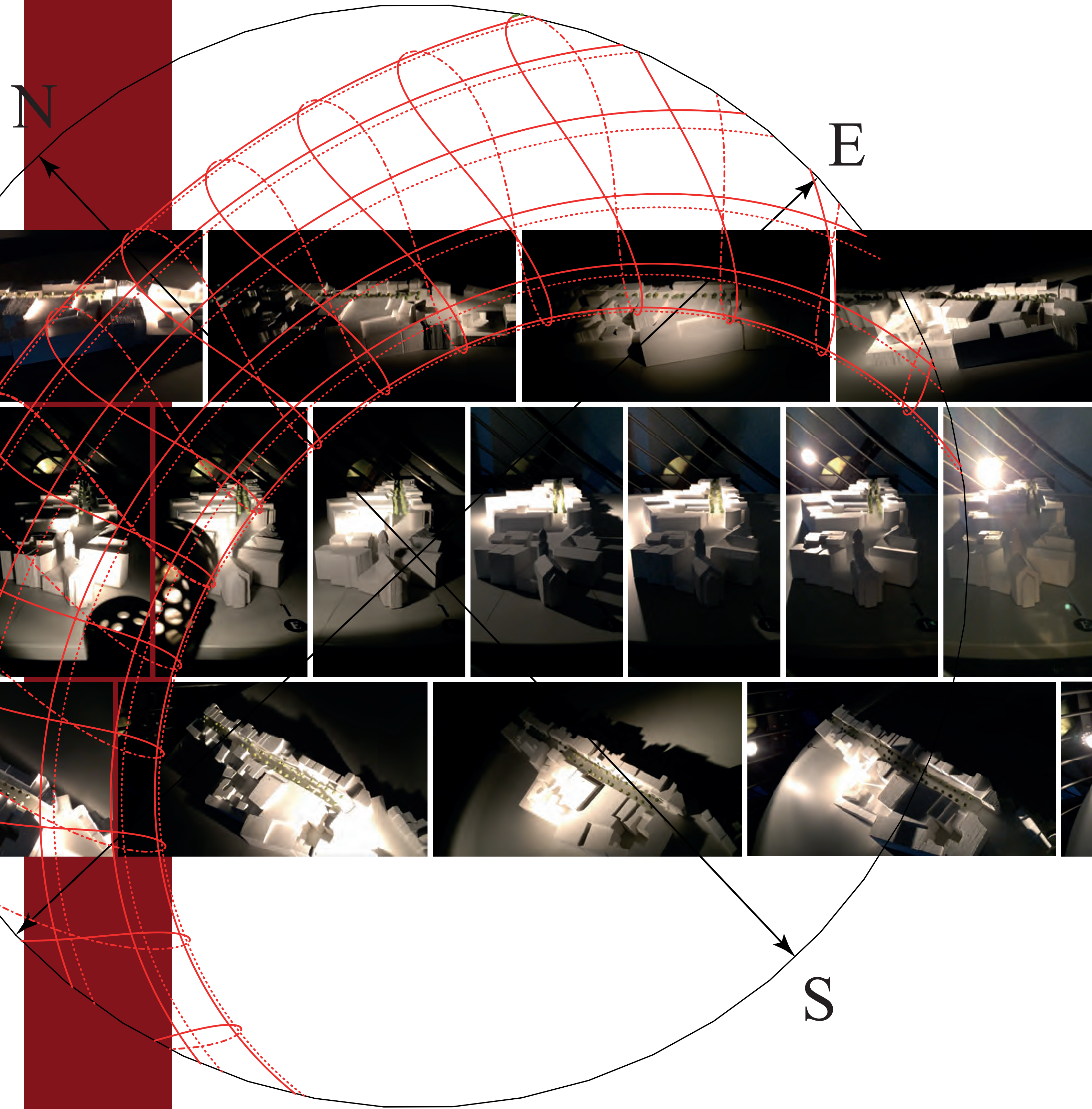

State-of-the-art of Education on Solar Energy in Urban Planning

Part I: Approaches and Methods in Education

IEA SHC TASK 51 | SOLAR ENERGY IN URBAN PLANNING | HTTP://TASK51.IEA-SHC.ORG

IEA SHC Task 51 Solar Energy in Urban Planning

Task 51/Report D1 Part 1

State-of-the-Art of Education on Solar Energy in Urban Planning

Part I: Approaches and Methods in Education

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Abstract & Summary

Abstract

A part of IEA SHC Task 51, this report focuses on education in order to strengthen the knowledge and competence of relevant stakeholders in solar energy in urban planning. The core of this study is to create substantial links between ‘research and education’ as well as between ‘research and practice’. Knowledge gaps in current education were investigated, reasons for these gaps were identified and solutions and strategies are proposed to overcome these shortcomings.

The aim of this part of the research project is to inform students as well as urban planners and professionals within the field of urban planning about the current offer of relevant courses at universities and in continuing professional development (CPD) programs.

The modus operandi of evaluating existing courses dealing with the topic of solar energy and existing CPD programs was based on general online research by nine participating countries, followed by a questionnaire and survey. After identifying and analysing these programs, interviews with various educators with different levels of experience were conducted in order to further investigate the individual approaches of the applied methods behind teaching solar energy in urban planning.

The evaluation of the survey showed that solar energy as it relates to urban planning was rarely part of the curriculum at universities. The identified courses are instead mostly offered in other disciplines. The identified CPD programs generally dealt with key aspects, such as climate change, and not specifically with solar energy in urban planning.

The gaps and barriers in existing courses and pedagogy that are identified in this study provide knowledge that can be implemented in relevant seminars, lectures and tools for educating the next generation of architects, urban planners and specialist planners.

Executive Summary

In the context of the IEA SHC Task 51, an international survey was carried out in order to investigate how educational courses and CPD programs are dealing with the topic of solar energy in urban planning.

The objectives of the survey were to:

- identify existing courses on solar energy in urban planning in higher education as well as existing CPD programs; and
- identify needs and gaps in order to improve teaching methods at a later stage.

The results of the surveys and interviews will be used to generate an e-learning platform.

Approach and Methodology

The modus operandi of how to find and evaluate existing teaching material was based on internet research, surveys and interviews. Each participating country—Australia, Austria, Canada, France, Germany, Italy, Norway, Sweden and Switzerland—performed online preliminary research to gather and create a list of current courses within the tertiary educational system that address to some degree the topic of solar energy in the urban context.

The gathering process focused on courses that are taught in the architectural, engineering and urban planning disciplines. Any available information was collected for each course, including the disciplines, the work effort in the form of credit points and the software used. After generating the list of solar energy courses, each responsible person was contacted and asked to take part in a personal interview in order to seek more detailed information about the respective course. The results of this research are compiled by each country and compared in a matrix and assessed by the editors.

Results

Courses in higher education
In total, 284 courses dealing with solar energy could be identified in the various countries. Most of these courses were found to be located in Italy, followed by France and Germany, whereby the Italian courses mainly address the technical aspects of solar energy and not the implementation in the urban context. The difference between courses taught at the undergraduate and postgraduate level is marginal. However, it is important to note that the quantity of courses is not representative, because some countries only focused their research on one region due to limited resources. Despite this limitation, a clear trend is visible. Currently, there are very few existing courses that specifically focus on solar energy in urban planning. Most of the courses are taught in the disciplines of architecture and environmental science, which are using the principle of solar energy for technical and design purposes. The surveys and interviews demonstrate a comprehensive overview of the content and methodology of the seminars and lectures in each country.

CPD - Continuing Professional Development Courses

Varied approaches for continuing professional development exist in different countries. Binding and optional procedures are present in the participating countries. Through the architectural chamber in Australia, Austria, Canada and Germany, CPD courses are binding. In France, Norway, Sweden and Switzerland the participation in CPD programs is optional and self-motivated. The required hours of attendance in these courses varies from 8 to 20 hours per year. Most CPD courses are addressing relevant key aspects and current issues of architectural planning in the broader consideration of climate change and not specifically solar energy in urban planning.

Software Tools

Software is an important component of university courses, as it facilitates the planning and use of active and passive solar energy and helps to make design decisions during the planning process. In this part of the report, the software tools that are used are only mentioned and not described and evaluated in detail. The second part of the D.D1 report (D.D1 Part II "Solar Irradiation Potential Tools in Education") discusses these tools and how they were used by students in realistic case studies. On the basis of a generated evaluation sheet, the strengths and weaknesses of the individual tools will be examined and evaluated in the second part of the D.D1 report.

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List of Abbreviations

CPD	continuing professional development
PV	photovoltaic
ECTS	The ECTS System (European Credit Transfer System) is a European measurement system which describes the students´ work effort in educational courses. The measuring unit are credit points.
SWS	German: Semesterwochenstunden (Semester periods per week) The number of taught sessions in one week during a semester.

Introduction

1. Introduction

1.1. Background of SHC Task 51

The main objective of the IEA SHC Task 51 is to provide a framework of support for urban planners, authorities and architects to achieve integrated solar energy solutions within urban areas and eventually entire cities and a substantial level of renewable energy for the future. This includes the aim to develop processes, methods and tools capable of assisting cities in developing a long-term urban energy strategy. The scope of the Task includes solar energy issues related to new and existing urban area development and sensitive/protected landscapes (solar fields).

To achieve these objectives, work is carried out in four main areas (Subtasks):

A: Legal framework, barriers and opportunities for solar energy implementation
(lead: Mark Snow, University of NSW, Australia)

B: Development of processes, methods and tools
(lead: Johan Dahlberg & Marja Lundgren, White Arkitekter, Sweden)

C: Case studies and action research
(lead: Annemie Wyckmans, Carmel Lindkvist & Gabriele Lobaccaro, NTNU, Norway)

D: Education and dissemination
(lead: Tanja Siems & Katharina Simon, Wuppertal University, Germany)

The overall lead of the Task is carried out by Maria Wall, Lund University, Sweden.

1.2. Research Approach and Methodology: Current Situation

Universities and colleges are responsible for educating the next generation of architects, urban planners, and specialist planners, etc. Several studies emphasise the important role that education and training play in the field of energy (Brunsgaard et al., 2014; Kandpal & Broman, 2014; Navarro et al., 2014; Otis, 2011). Embedding courses in students' curriculum that mirror reality are of key importance. An example of such a multidisciplinary approach is the Solar Decathlon, where architecture and engineering students work together (Navarro et al., 2014). Another approach was the IDES-EDU project, where several European universities created teaching material together to train and educate future architectural and engineering professionals (Brunsgaard et al., 2014).

The most important factor involved in this education process is the ability to present and describe a wide-breadth of knowledge for students during their studies, so that they can then utilise this later in their practical day-to-day duties. While research and development within technological subjects is finding its way to the market, teaching programs are not always up-to-date. In particular, the short five-year timespan of a Bachelor and Master program is not sufficient to convey the necessary knowledge required for professional practice. This is the reason why certain professions, such as architecture or urban planning, must be supported with additional occupational education often referred to as Continuing Professional Development (CPD).

The research project "Solar Energy in Urban Planning" addresses knowledge gaps that currently exist in teaching. Knowledge within the specific field of solar energy utilisation and explanations of the existing deficiencies in teaching are conveyed. Solution strategies are developed which should remedy these gaps in the study programs.

1.3. Motivation

Teaching at universities and colleges cannot be considered separate from research or practice. Creating a connection between the areas of ‘research and teaching’, as well as between ‘research and practice’ is an essential integral objective for research projects. Therefore, research is used as a connective link between teaching and practice and/or the public with far-reaching impacts. Researching new insights is not the only important factor here, but also information exchange and dissemination.

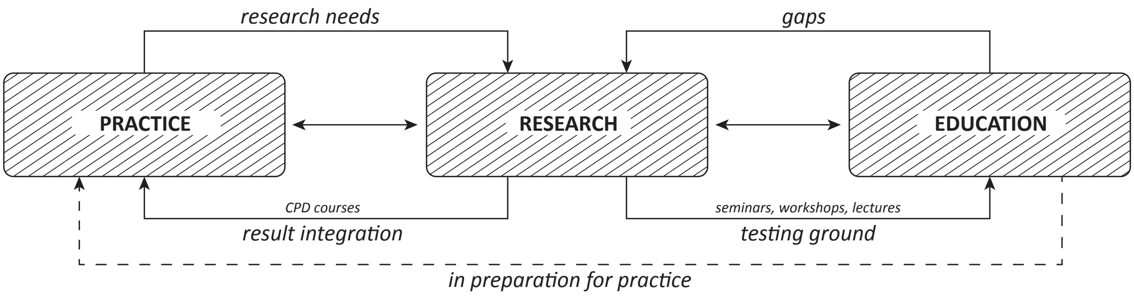


Figure 1: Interrelationships and dependencies of practice, research and teaching (K. Simon, 2014)

Figure 1 illustrates the interrelationships and dependencies of the three aforementioned areas. The ideal case would be where research results would be presented to the students in university or college seminars, workshops or lectures and thereby tested in this environment. The evaluation from the students would draw attention to existing limitations and additional research requirements. If the students are involved in current research projects and, where applicable, can have some impact on them, then they will be able to prepare themselves for their future working environment, as well as entering practice with an up-to-date knowledge standard. Practical environments can also profit from research as the current research results can be introduced into administrative bodies and offices, thereby having a considerable influence on working practices, methodologies and technology. Research questions and existing limitations that have not been fully clarified, or are still completely open, will be returned to the research facilities.

1.4. Objectives

The aim of the SHC Task 51 research project is to investigate the inter-relationships between research, praxis and education. Based on the fact that the current teaching content influences the next generation of architects and urban planners, it is of prime importance to research which challenges and barriers exist in teaching in order to be able to provide targeted teaching content, methods and tools in the future. If solar energy is not a topic within urban planning, then it must be clarified what the reasoning is behind this and which barriers are responsible. The lack of knowledge of planners who are long-serving employees must be remedied by sourcing additional education programs and special events.

1.5. Procedure and Applied Methodology

The following section describes the discrete steps of the procedure that provided the basis for this report. A common methodology was used, although certain country-related differences may occur. Deviations are documented per country.

a) Internet research according to universities and colleges with urban planning institutes
A first step was to focus on universities and colleges with a specialist area for architecture and/or urban

planning. It was important, in this instance, to cover a wide range of universities and technical colleges with the aim of ensuring a countrywide distribution.

b) Generating a survey in order to get an overview about existing courses in solar energy
The next step was to create a survey which would provide a generalised overview with regard to the integration of solar energy in the teaching content. Alongside general information relating to the university or college, questions were also asked about the final examinations, types of events, educational credits as well as a brief description of available courses. An example of the survey can be found in the attachment to this document.

c) Evaluation of the survey
Once the survey had been sent to the responsible teaching staff of the institute by email, an evaluation and categorisation of the results was performed.

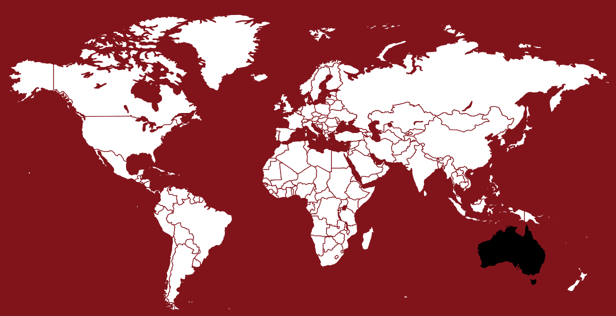
d) Carrying out interviews
Interviews with the educators were conducted to provide an insight in the teaching methods for solar energy.

e) Gathering continuing professional development programs in various countries (CPD)
An evaluation of the offered courses for working professionals was also carried out in the participating countries.

The international results are presented by country in alphabetical order and evaluated in the following chapters. Experts from the following countries have participated in this work:

- Australia
- Austria
- Canada
- France
- Germany
- Italy
- Norway
- Sweden
- Switzerland


Charles Darwin
University
James Cook University
University of the Sunshine Coast
Griffith University
Queensland University
of Technology
University of Queensland
Bond University
Southern Cross University
University of New England
University of Adelaide
University of South Australia
University of Western Australia
Murdoch University
Curtin University
University of Newcastle
University of Sydney
University of Technology Sydney
University of New South Wales
Macquarie University
University of Western Sydney
Australian National University
University of Canberra
University of Melbourne
Deakin University
Monash University
RMIT University
La Trobe University
University of Tasmania



Australia

2. Australia

The aim of this report is to provide an overview of the state of education in the field of solar energy and more especially in the application of solar principles in urban planning. Australia has had a strong background of over 40 years in academic research in the field of solar energy, dominated by PV device research and development engineering at University of New South Wales (NSW). The application of solar energy in the built environment has been dominated by the fields of architecture and planning through the study of daylight, energy-efficient design of buildings and urban environments. Active solar energy considerations for urban areas is less well covered in the education offerings from a review of current courses. However, cross faculty studies on sustainability have stimulated a broader interest in this important field.

This section overviews the current status of Australian solar energy education in the tertiary sector in the context of national university programs with a focus on Schools of Architecture, Planning and Engineering. Continuing Professional Development (CPD) courses are also investigated for the three major corresponding institutions—Australian Institute of Architects (AIA), Planning Institute of Australia (PIA) and Engineering Australia.

Solar energy installation qualifications required for Clean Energy Council (CEC) accreditation of PV roof applications are serviced by a range of trade certificate courses offered by private and public vocational education and training providers industry and TAFE (Technical & Further Education) institutions. These are specific to the electrical engineering design and installation of PV roof applications.

The initial findings for Australia are:

- Solar energy and engineering are strong educational offerings at a range of Australian universities;
- Architecture and Planning undergraduate course material provide cursory consideration of solar energy as a sustainable approach to buildings and the built environment from primarily an energy efficiency and daylighting provision perspective;
- Masters courses have more specific content on active solar applications, but are limited in terms of details;
- Continuing professional development (CPD) courses are also limited in terms of detail;
- The typical staged learning approach is the lecture and tutorial environment;
- Architecture and Planning disciplines lend themselves to student workshop/studio-scenario based solution learning complimented by computer lab simulation modelling and formal presentation work;
- Increasingly, a number of cross-faculty learning opportunities are being offered for different student practitioners (architects, engineers, urban planners, economists, and lawyers) to solve city scenarios in lecture and studio environments. This is effective in that it drives team building, communication, identification of skill sets, use of decision support tools and delivery of project outcomes.

2.1. Selection of the Academic Institutes' Part of the Analysis Sample

Australian tertiary courses of specific relevance to solar energy in urban environments fall predominantly within the disciplines of:

- Architecture;
- Urban design and Urban Planning; and
- Electrical Engineering.

Preliminary enquiries into the detail of courses that have relevance to solar energy in urban planning have been conducted for University of NSW and Australian National University (ANU). The majority of course information has currently been derived from available websites from different institutions and also course accreditation from the core professional organisations of the Australian Institute of Architects (AIA), the Planning Institute of Australia (PIA) and Engineers Australia.

From 43 Australian universities as depicted in the Australian map below, there are:

- 19 Schools of Architecture;
- 24 Urban Planning/Design Schools; and
- 32 Engineering Schools.

Table 1: List of Architecture Schools in Australia

STATE	UNIVERSITY	FACULTY	WEBSITE
ACT	University of Canberra	Faculty of Arts & Design	www.canberra.edu.au/faculties/arts-design
NSW	University of Newcastle	Faculty of Engineering & Built Environment	www.newcastle.edu.au
NSW	University of New South Wales	Faculty of the Built Environment	www.be.unsw.edu.au
NSW	University of Sydney	Faculty of Architecture, Design & Planning	http://sydney.edu.au/architecture
NSW	University of Technology Sydney	Faculty of Design, Architecture & Building	www.uts.edu.au
QLD	Griffith University	Environment, Planning & Architecture	www.griffith.edu.au/environment-planning-architecture
QLD	Queensland University of Technology	School of Design	www.qut.edu.au
QLD	University of Queensland	School of Architecture	www.architecture.uq.edu.au
QLD	Bond University	Abedian School of Architecture	http://architecture.bond.edu.au/
NT	Charles Darwin University	School of Creative Arts & Humanities	www.cdu.edu.au/creative-arts-humanities
WA	Curtin University	School of Built Environment	http://humanities.curtin.edu.au/schools/BE
WA	University of Western Australia	Faculty of Architecture, Landscape & Visual Arts	www.alva.uwa.edu.au
SA	University of Adelaide	School of Architecture & Built Environment	https://architecture.adelaide.edu.au
SA	University of South Australia	School of Art, Architecture & Design	www.unisa.edu.au/study/art-architecture-design
VIC	Deakin University	School of Architecture & Building	www.deakin.edu.au/architecture-built-environment
VIC	Monash University	Faculty of Art & Design	http://monash.edu/mada
VIC	RMIT University	School of Architecture & Design	www1.rmit.edu.au/architecturedesign
VIC	University of Melbourne	Faculty of Architecture, Building & Planning	https://msd.unimelb.edu.au
TAS	University of Tasmania	School of Architecture & Design	www.utas.edu.au/architecture-design

Table 2: List of Urban Planning Schools and Courses in Australia

LOCATION	UNIVERSITY	COURSE	WEBSITE
ACT	University of Canberra	Urban & Regional Planning (BPlan, MPlan)	www.canberra.edu.au/faculties /arts-design
NSW	University of NSW Faculty of the Built Environment	Planning (BPlan, MPlan) Masters in Sustainable Built Environment	www.be.unsw.edu.au
NSW	University of Sydney Faculty of Architecture, Design & Planning	Urban and Regional Planning (MPlan) Urban Design (Urban Design & Planning) (MPlan)	http://sydney.edu.au/architecture
NSW	University of Technology Sydney Planning School of the Built Environment Design, Architecture & Building	Master of Planning	www.uts.edu.au

LOCATION	UNIVERSITY	COURSE	WEBSITE
NSW	Macquarie University Dept. of Environment & Geography	Planning (BPlan) Master of Environmental Planning	www.gse.mq.edu.au
NSW	University of New England School of Behaviour, Cognitive & Social Science	Urban and Regional Planning (GDip, BPlan, MPlan)	www.une.edu.au
NSW	University of Western Sydney School of Social Sciences	Bachelor of Social Science Master of Urban Management & Planning	www.uws.edu.au
NSW	Southern Cross University School of Environment, Science & Eng.	Regional and Urban Planning (BPlan)	http://scu.edu.au
QLD	University of Queensland School of Geography Planning & Architecture	Bachelor of Regional & Town Planning Master of Urban & Regional Planning	www.gpa.uq.edu.au
QLD	Griffith University School of Environmental Planning	Urban & Environmental Planning (BPlan, MPlan)	www.gu.edu.au
QLD	Queensland University of Technology School of Urban Development	Urban Development (Urban and Regional Planning) (BPlan)	www.qut.edu.au
QLD	James Cook University School of Earth & Environmental Sciences	Bachelor of Planning (BPlan) Masters of Tropical Urban & Regional Planning	www.jcu.edu.au
QLD	University of the Sunshine Coast Faculty of Arts & Social Sciences	Regional & Urban Planning (BPlan, MPlan)	www.usc.edu.au
QLD	Bond University Urban Planning, Faculty of Society& Design	Sustainable Environments & Planning (GDip, BPlan, MPlan)	www.bond.edu.au
SA	University of Adelaide School of Architecture &BuiltEnvironment	Master of Planning Master of Planning (Urban Design)	www.hss.adelaide.edu.au/pg
SA	University of South Australia School of Natural & Built Environments	Urban&Regional Planning (BPlan, MPlan)	www.unisa.edu.au
TAS	University of Tasmania School of Geography & Environmental Studies	Environmental Planning (G.Dip, MPlan)	www.utas.edu.au
VIC	Deakin University School of Architecture & Built Environment	Planning (BPlan, MPlan)	http://www.deakin.edu.au/scitech/ab
VIC	Latrobe University Humanities and Social Sciences	Urban, Rural & Environmental Planning (BPlan) Community Planning and Development (MPlan) Spatial Planning, Management & Design (MPlan)	www.latrobe.edu.au/courses/planning [MPlan linked with University of Moratuwa, Sri Lanka]
VIC	Melbourne University Faculty of Architecture, Building and Planning	Master of Urban Planning Master of Urban Design Bachelor of Environments	https://msd.unimelb.edu.au http://benvs.unimelb.edu.au
VIC	RMIT School of Global, Urban and Social Studies	Urban & Regional Planning (BPlan) Urban Planning and Environment (MPlan) International Urban & Environmental Management	www.rmit.edu.au
WA	Curtin University School of Built Environment	Urban & Regional Planning (BPlan, MPlan)	www.curtin.edu.au
VIC	University of Western Australia School of Earth & Environment	Urban Planning (GDip, BPlan, MPlan)	www.see.uwa.edu.au
WA	University of Western Australia School of Earth & Environment	Urban Planning (GDip, BPlan, MPlan)	www.see.uwa.edu.au

Table 3: List of Specific Solar Energy Related Courses in Australia

STATE	INSTITUTION	CODE	COURSE	DURATION	DEGREE
ACT	Australian National University	830820	Master of Engineering in Solar Energy Technologies	2 years	Masters (campus)
ACT	Australian National University	830436	Master of Laws in Environmental Law	3 years	Masters (campus)
NSW	University of NSW	NA	Applied Photovoltaics	12 weeks	Online
NSW	University of NSW	425200	Renewable Energy Engineering	4 years	B.Eng (campus)

STATE	INSTITUTION	CODE	COURSE	DURATION	DEGREE
NSW	University of NSW	425200	PV and Solar Energy Engineering	4 years	B.Eng (campus)
NSW	University of NSW	SOLACS8338	Masters of Engineering Science (PV & Solar Energy)	2 years	Masters (campus)
NSW	University of NSW	8134	Masters of Sustainable Built Environments	2 years	Masters (campus)
NSW	University of NSW	SOLAES5341	Graduate Diploma of Engineering Science (PV & Solar Energy)	1 year	Diploma (campus)
NSW	University Technology Sydney	607059	B Advanced Science (Advanced Materials)	4 years	B.Eng (campus)
NSW	University Technology Sydney	603035	B Engineering (Hons) Electrical	4 years	B.Eng (campus)
QLD	University of Sunshine Coast	ENS281	Introduction to Sustainable Energy Systems	1 semester	B.Eng Science (campus)
VIC	RMIT	BH076	Sustainable Systems Engineering	4 years	B.Eng (campus)
VIC	RMIT	MC229	Master of Engineering (Sustainable Energy)	2 years	Masters (campus)
VIC	RMIT	MC229	Master of Engineering (Solar Energy)	2 years	Masters (campus)
TAS	University of Tasmania	N5B	Graduate Certificate in Renewable Energy Power Systems	1 year	Grad Dip.
WA	Murdoch University	B1320	Renewable Energy Engineering	4 years	B.Eng (campus)
WA	Murdoch University	M1218	Master of Renewable Energy	1 year	Masters (campus)
WA	Murdoch University	G1062	Graduate Diploma in Energy and the Environment	1 year	Diploma (campus/online)
WA	Murdoch University	G1065	Graduate Diploma in Energy Studies	1 year	Diploma (campus/online)

2.2. Existing Courses in Non-Academic Institutions (Continuing Professional Development)

Australian Institute of Architects (AIA)
AIA Institute members are required by a Code of Professional Conduct to provide professional services conscientiously and competently, and are encouraged to improve their professional knowledge and competence through participation in CPD activities. The AIA currently offers CPD opportunities delivered across Australia from capital cities to regional areas through National Seminar Series, online continuum learning resources and Practice of Architecture Learning Series (PALS), which is a 15-module online course combined with face-to-face tutorials for people preparing for the registration examination.

In 2010-11, Dr. Mark Snow on behalf of the Australian PV Institute (formally Australian PV Association) and University of NSW completed a national seminar series in major cities and regional AIA chapters and an online continuum course on Integrating Solar Technology, see webpage http://www.continuum.com.au/courses.php?o=view&sco=2723405&c=1.

Learning outcomes from the CPD course focused on architects being able to:

- outline the importance of solar technologies in achieving zero-emission buildings;
- explain the opportunities and barriers impacting solar technology uptake;
- apply integrated systems approaches to building design;
- argue the added value of solar applications to clients; and
- evaluate the use of solar integration in commercial buildings.

Planning Institute of Australia (PIA)

Certified Practicing Planner or CPP is the accreditation awarded to planning professionals who have demonstrated a commitment to continued learning through the undertaking of the CPP course. The course is a professional development program for practitioners within planning-related fields. The course is nationally consistent and focuses on areas of key competencies for planning practitioners. It is designed for professionals with several years' experience and provides an opportunity for planners to update the skills and knowledge they have gained through planning practice.

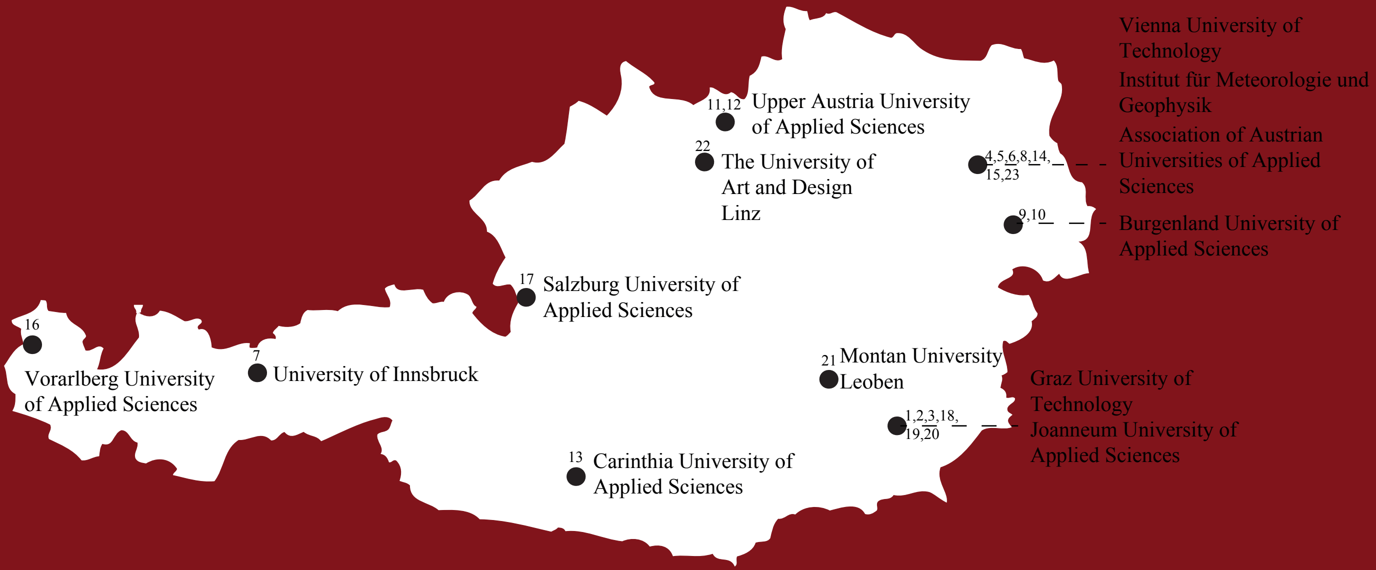
Climate Change CPD and Urban Design CPD units are the most relevant content to solar energy currently offered. On completion of the climate change unit, participants will have acquired an understanding of:

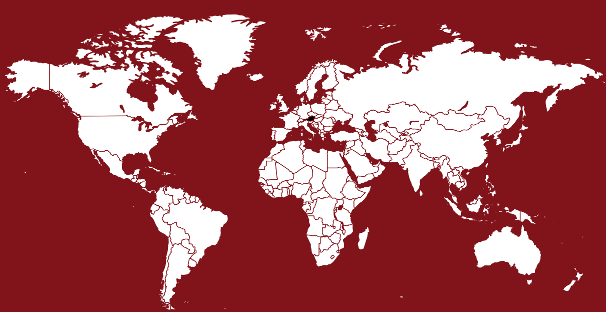
- The science and consequences of climate change;
- The principles and procedures of climate change risk management and adaptive planning;
- How land use planning can make a positive impact in terms of developing more resilient and adaptive urban systems;
- How land use planning can make a positive impact in reducing greenhouse gas emissions;
- The strategic and statutory tools that can embed climate change adaptation and greenhouse gas mitigation into planning policy and practice; and
- The existing and evolving policy and legislative initiatives that will shape a planner's response to climate change.

The Urban Design unit includes field activities but excludes drawing or detailed design activities.

On completion of the urban design unit, participants will have:

- An understanding of urban design and the delivery of quality places within our urban, regional and rural communities;
- Related theory, leading concepts and principles of urban design to their work environment;
- Awareness of a range of practical tools and techniques to 'hit the ground running'; and
- Access to national and international best practice.


Vienna University of Technology
Institut für Meteorologie und Geophysik
Association of Austrian Universities of Applied Sciences
4,5,6,8,14, 15,23
11,12 Upper Austria University of Applied Sciences
22 The University of Art and Design Linz
9,10
Burgenland University of Applied Sciences
17 Salzburg University of Applied Sciences
16
Vorarlberg University of Applied Sciences
7 University of Innsbruck
21 Montan University Leoben
Graz University of Technology
Joanneum University of Applied Sciences
1,2,3,18, 19,20
13 Carinthia University of Applied Sciences



Austria

3. Austria

3.1. Evaluation of Existing Courses in Tertiary Education

The majority of the Austrian IEA SHC Task 51 partners are representing tertiary educational facilities: Graz University of Technology, Institute of Thermal Engineering and Institute of Urbanism as well as Salzburg University of Applied Sciences. The given constellation of Austrian partners is compiled of an interdisciplinary team, capable of depicting the perspectives typical to each field of study in regards to the utilisation of solar energy in cities (e.g. Engineering, Urbanism, Smart Building, Applied Research and Practice/Implementation). Thus, the first method the Austrian team used in the given task setting, was to draw from their ‘own’ experience of each partner.

The second method used was investigation of the existing courses in tertiary education that would entail the topic of solar energy. Here, responsible persons were contacted and interviewed. The interviews were performed with reference to the following key points:

- Information of the course;
- Practical experience during the extent of the course;
- Teaching methods and applied tools;
- Challenges faced;
- Cooperation with other education institutes; and
- Working scale: buildings/neighbourhoods/cities.

The key outcomes resulting from the interviews are outlined in the summary section of this chapter.

3.2. General Status Quo on Solar Energy in Tertiary Education in Austria

The utilisation of solar radiation for various functions has a long history in the scientific tradition in Austria. Solar radiation, as a scientific phenomenon, has been the object of research for several years in various scientific disciplines. Meteorologists are analysing the intensity and the effect of turbidity on incident solar radiation. Architects and civil engineers take advantage of the knowledge of the sun path to create efficient heating and cooling performance within buildings. Besides this so-called "passive’ use, ”active“ solar systems have also been developed. The utilisation of solar energy for thermal processes is primarily represented by the discipline of mechanical engineering. Engineers are developing solar thermal systems for the use of solar radiation for heating or cooling purposes or for the use in industrial processes. On the other hand, physicists and electrical engineers are working on systems for generating electricity from solar radiation.

The investigation and utilisation of solar radiation in the field of natural sciences has been part of numerous research projects in the past and present. Sufficient knowledge has been accumulated over a significant period of time, enabling the transmission of knowledge from research into teaching and learning activities at universities. This effect was strengthened by the typical tri-section of the university assignments in research, teaching and administration. Consequently, the same faculty that were engaged in solar research activities were also responsible for developing teaching curricula. In addition, this effect was reinforced by so-called "academic freedom". Lecturers had, therefore, far-reaching autonomy regarding the choice of the teaching content. Thus, teaching in the field of natural science and technology in relation to the utilisation of solar energy has formed an integral part of education at universities for quite some time.

A depiction of courses is provided in Table 4 and Table 5, presenting some examples of the existing courses, entailing content related to solar energy.

Table 4: Examples of Courses, Containing the Topic of Solar Energy in Austria

Institution		Department		Code	Title	Semester	ECTS/SWS
1	TUG	Graz University of Technology Institute of Thermal Engineering	Solar Energy	307.041	Solar Building Technology	Spring	2 SWS
2	TUG	Graz University of Technology Institute of Thermal Engineering	Solar Energy	307.036	Solar Energy Use	Autumn	2 SWS
3	TUG	Graz University of Technology Institute of Buildings and Energy	Solar Energy	159.803	Urban design and energy	Spring	2 SWS
4	TUW	Vienna University of Technology Institute of Architecture and Design	Solar Energy	270.079	Solar Construction *"Solares Bauen"*	Autumn	2 SWS
5	TUW	Vienna University of Technology Inst. of Energy Systems & Electric Drives	Solar Energy	372.383	Solar Energy Use *"Nutzung der Sonnenenergie"*	Spring	3 ECTS
6	BOKU	Vienna University of Natural Resources and Life Sciences Institute of Meteorology (BOKU-Met)	Solar Energy	814051	Solar radiation and biosphere	Autumn	2 SWS
7	TUI	University of Innsbruck Institute of Construction and Material Science	Solar Energy	846188	Architectural integration of photovoltaic systems *"Architektonische Integration von Photovoltaikanlagen"*	Spring	2,5 ECTS
8	TUI	Institut für Meteorologie und Geophysik Institute of Meteorology and Geophysics	Solar Energy	707620	Meteorological: radiation *"Allgemeine Meteorologie: Strahlung"*	Autumn	2 ECTS
9	FHB	Burgenland University of Applied Sciences Building Technologies and Management	Solar Energy	-	Solar Thermal Systems *"Solarthermie"*	Spring	2ECTS
10	FHB	Burgenland University of Applied Sciences Building Technologies and Management	Solar Energy	-	Photovoltaics *"Photovoltaik"*	Spring	2ECTS

Institution		Department		Code	Title	Semester	ECTS/SWS
11	FH OÖ	Upper Austria University of Applied Sciences Ecological Energy Technologies	Solar Energy		Solar thermal energy systems / power plants *“Solarthermische Energieversorungs-systeme / Kraftwerke”*	Spring	3,5 ECTS
12	FH OÖ	Upper Austria University of Applied Sciences Ecological Energy Technologies	Solar Energy		Photovoltaics *“Vertiefung Photovoltaik”*	Spring	3,5 ECTS
13	FHK	Carinthia University of Applied Sciences Engineering & IT	Renewables including Solar Energy	RES	Renewable Energy Systems	Autumn	2 ECTS
14	FHT	Vienna University of Applied Sciences Urban Energy Systems	Renewables including Solar Energy		Process Optimization *“Prozessoptimierung”*	Spring	4.50 ECTS
15	FHK	Association of Austrian Universities of Applied Sciences Bauingenieurwesen & Architektur, Bionik Structural Engineering & Architecture, Bionics	Renewables including Solar Energy	M1.06230.20.231	Biomimetics in Energy Systems	Spring	2 SWS
16	FHV	Vorarlberg University of Applied Sciences - Energy Technologies and Energy Economics	Renewables including Solar Energy	07272015	Thermal energy technology *“Thermische Energietechnik”*	Spring	4 SWS
17	FHS	Salzburg University of Applied Sciences Smart Building	Renewables including Solar Energy	SMBB3EEEVO	Energy Technologies “*Energietechnologien (Erneuerbare Energien)”*	Autumn	2 ECTS
18	FHJ	Joanneum University of Applied Sciences Advanced Electronic Engineering	Renewables including Solar Energy	130592103	Renewable Energy	Autumn	4 ECTS
19	FHJ	Joanneum University of Applied Sciences Energy and Transport Management	Renewables including Solar Energy	TMT4285	Integration of Renewable Energy Sources (W)	Spring	2 ECTS
20	FHJ	Joanneum University of Applied Sciences Architecture	Renewables including Solar Energy	100235111	Energetics in design *“Energetik im Entwurf”*	Autumn	1 ECTS
21	MOL	Montan University Leoben Institute of Physics	Renewables including Solar Energy	460.070	solar cells *“Solarzellen”*	Autumn	2 ECTS

Institution		Department		Code	Title	Semester	ECTS/SWS
22	UFG	The University of Art and Design Linz Architecture	Renewables including Solar Energy	AAR4926	Solar Construction *"Vertiefung Solarbau"*	Autumn	1 ECTS
23	BOKU	Vienna University of Natural Resources and Life Sciences Institute for Spatial Planning and Rural Development	Renewables including Solar Energy	855321	Energy Planning *"Energieraumplanung"*	Autumn	2 SWS

Table 5: Selected exemplary courses including a brief on their goals and expected learning outcomes of different respondents

Institute	Course goals	Expected learning outcomes
Graz University of Technology Course: Solar Building Technology	Energy performance of the Austrian building stock Principles of sustainable buildings Planning of energy efficient buildings Thermal Building Simulation Verification of the energy performance of buildings Examples of energy efficient buildings	• Students are able to: - understand the basic principles of planning energy efficient buildings - analyse the thermal behaviour of buildings
Graz University of Technology Course: Solar Energy Use	Physical and meteorological basics on solar radiation, measurements and estimations, calculation of direction and intensity of radiation, theory and practice on solar collectors and other related components, hydraulic layout and dimensioning of solar thermal plants for heating of tap-water, dwellings and swimming pools, passive solar heating, photovoltaics.	• After successful completion of the course, the students have acquired a deeper knowledge in theoretical basics and in practical methods for harnessing solar energy. They are capable to calculate and design plants for active and passive solar energy use.
Graz University of Technology Course: Urban design and energy	Development of master plans for sustainable, energy-efficient urban design projects.	• After successfully completion of the course, students will be able to develop master plans for sustainable energy-efficient urban design projects.
Vienna University of Technology Course: Solar Construction	Priorities are set on the optimization of forms for maximum energy performance and ecological design, building with the sun, recycling-friendly design, reuse, monitoring, evaluation and improvement of building construction, as well as Life Cycle Assessment. Introduction to passive house technology and methods of renewable energy use.	• Designing including the consideration of ecological, social and economic principles
Vienna University of Technology Course: Solar Energy Use	Uses the sun's energy: sun as an energy source (solar radiation, calculation of irradiation conditions, meteorological data, etc.); the basic elements for the use of solar energy (collectors, storage systems, heat pumps, etc.); production of drinking water and extraction of salt: methods for thermal use of solar energy in the residential sector (domestic hot water, heating, cooling, pool heating); solar homes; solar furnaces; conversion of photovoltaic energy; solar thermal power plants	• Providing an overview and the basics of the entire field of solar energy utilisation, including its possibilities and limitations. A range of possibilities are discussed, concluded by the definition of practical solutions.
University of Innsbruck Course: Architectural integration of photovoltaic systems	Proposals for innovative building integration of photovoltaics are developed. Latest simulation and design tools are used employed in this course	• Innovative integration solutions for integration of photovoltaics in buildings are developed. Latest simulation and design tools are trained in this course.
BOKU University of Natural Resources and Life Sciences, Vienna Institute of Meteorology and Geophysics Course: Solar radiation and biosphere	Basics of solar radiation; radiation laws; Plants, humans and animals in the radiation field; Radiation in canopies; radiation climate in housing; spectral radiation; actual problems in the domain of UV radiation; biological function of UV radiation; ozone hole; longwave radiation; radiation balance; greenhouse effect	• Understanding of radiation transfer. Knowledge about application of radiation laws in practical applications.

Institute	Course goals	Expected learning outcomes
BOKU University of Natural Resources and Life Sciences, Vienna Course: Energy Planning „VS Energieraumplanung“	Spatial planning decisions have a significant impact on how energy consumption, efficiency measures and renewable energy supply can take place. The seminar appropriate planning methodologies for energy planning, especially energy zone planning are being taught.	• Students can assess, the systemic relationships between land use planning and energy supply. They acquire knowledge of methods to render these relationships for planning decision-making processes.

3.3. Identification of the Challenges for the Integration of Solar Energy in Urban Planning

Urban planning represents a well-established discipline in Austrian universities. So far and in principle, the urban planning study field in Austria is focused on the spatial development at an urban and regional scale, more specifically meaning the planning, design and organisation of space, people and their environment within a given legislative framework and regulations. This includes spatial planning, regional planning, framework planning, urban design, master planning, landscape design, and modelling, etc.

The official description of the educational curricula at the Institute of Urbanism, Technical University Graz, illustrates the extent of educational content:

“The department’s task is to educate students of architecture in all fields of urban and regional planning. The main focus is put on teaching and the preparation of necessary data and materials. Moreover, practice-oriented projects for students are organised, executed and presented. The relation to the practice is assured by embedding these projects in real situations and problems. Accordingly, the field of research of the department’s members is practice- and region-oriented as well. The theoretical scientific work is mainly focused on processes in urban development and on the exploration of settlement’s structures in the context of architecture within a particular culture” (https://online.tugraz.at/tug_online/webnav.ini).

Within the context of education in urban planning, solar energy cannot be contemplated as an independent element. It rather represents one secondary aspect of many aspects under consideration, particularly when looking at the entire and complex chain of the spatial planning processes. Thus, solar energy is clearly not the main focus of this field of studies, research and education. This means that urban planning is concerned with numerous priorities, for instance - definition of spatial parameters, urban structure and configuration, social parameters, historical parameters, parameters regarding orientation (at this point, solar energy plays an important role), transportation and mobility, infrastructure and climate sensory/noise parameters, etc. All of these criteria form an integral part of one complex process — the “urban development process”. Jointly, they contribute to a holistic sum of a complex urban system. This leads to the fact that the discourse and examination of the field of urban planning cannot be led in a meaningful manner by isolating one area from another since the nature of urban development, in itself, is inherently complex and reliant on many interdependent factors of influence as well as risks.

It has to be said that the educational/teaching dynamics in the field of urban planning still follow long-established and well-accepted local traditions, whereas the research activities are of a different character in this regard. This makes the integration between teaching and research a challenging undertaking. Most often, research projects follow actual global tendencies and trends, featuring the sustainable development processes and entering the discourse on “Smart Energies”, “Renewable Energy Sources”, “Solar”, etc. In recent years, these important subjects moved to the forefront of interdisciplinary research.

The key question at this point is whether, how far, and in what format the technical knowledge of solar radiation, as derived from natural and engineering sciences, should be implemented in the teaching discipline of urban planning. Furthermore, it is not yet clear what the implications in terms of the impact of this knowledge on the teaching and research methods would be. Numerous research projects are investigating these questions and discussing the use of solar energy in urban environment at present. A majority of these projects are integrated in the context of Smart City discourse, including:

- **CityCalc** – Development of a tool for the purpose of calculation of Energy-Efficiency in Urban Planning and Design
- **ERP_hoch3** – EnergieRaumPlanung für Smart City Quartiere und Smart City Regionen
- **SCP** – Smart City Project Graz Mitte
- **Smart Mürz** – Development of the Smart City Region Mürz
- **Smart Service** – Smart Services for resource efficient City quarters
- **EnergySimCity** – Ganzheitliche Analyse und Simulation von Energiesystemen und Ressourcenverbünden in Städten und Stadtquartieren
- **TRANSFORM** – Development of Transformation Agendas for six European Smart Energy Cities and Implementation Plans for local Smart Urban Labs on the scale of urban districts. Development of a Decision Support Tool.
- **TRANSFORM+** – Development of an implementation and replication strategy for the city of Vienna, based on the outcomes of Transform project.

3.4. Summary – Key Findings

In the consideration of an adequate integration of the topic "solar urban design" in the teaching curricula of tertiary education, the following are the key considerations relevant in Austria:

- At present, master and doctoral theses are frequently connected to a specific research project or can even be completely executed as part of a research project in conjunction with academic education. In this respect, a link between research and teaching already exists, at least on an individual level. However, the situation contains some space for further synergistic improvements, since, only a small number of the master and doctoral students enter university teaching occupations after graduation.

- Through a continuous increase of the third-party funds at Austrian universities, the traditional "unity of research and teaching" cannot be sustained in a consistent manner any longer. Those staff members of universities, who are being funded through research projects are in most cases not involved in the teaching activities and, thus, have no opportunity to provide an adequate transfer of knowledge from research into education.

- The inherently interdisciplinary and complex nature of solar urban planning and design is often perceived as a barrier in itself, demanding a cooperative attitude and open mindset from multiple parties, involved in the task. The processing of the natural scientific and technical tasks is usually carried out by individuals, with an engineering and/or natural science background, while the tasks related to spatial/urban development are carried out by architects and/or spatial planners/urban designers. Both groups are indispensable for achieving convincing and sustainable outcomes. However, adequate methods for successful interdisciplinary integration of dominating disciplinary perceptions, established 'languages' and working methodologies are still very deficient and in some cases also non-existent.

- Another challenge lies in different methods and approaches applied by involved disciplines. In engineering, "analysis" on the level of single parameters and components is common, while urbanists usually approach the same topic from a "multi-criteria, macro-systemic" perspective, based on "synthesis" methodology of problem solving. A satisfactory integration is presently one of the biggest challenges: in education as well as in the research and implementation projects.

- Diverse knowledge regarding the potentials and application of solar in urban areas is still segregated in sectorial, disciplinary silos. This situation is an obstacle to the needed integration of solar energy in urban environment, which requires new, innovative approaches to problem solving and demands stepping out of the comfort zone of each discipline.

- In order to overcome this situation, development of integrative approaches, establishing an overarching and holistic 'platform' for experimentation, testing, and application of solar solutions in urban environment is required.

- The tertiary education is confronted with the rapidly changing requirements, framework conditions and dynamics, taking place in urban development globally and locally. The current educational system has yet to catch up with these changes and move beyond traditional educational methods. This process—matching of the educational curricula and teaching methodologies with rapidly changing market and development requirements is ongoing and demands more creativity to go beyond conventional teaching methods.

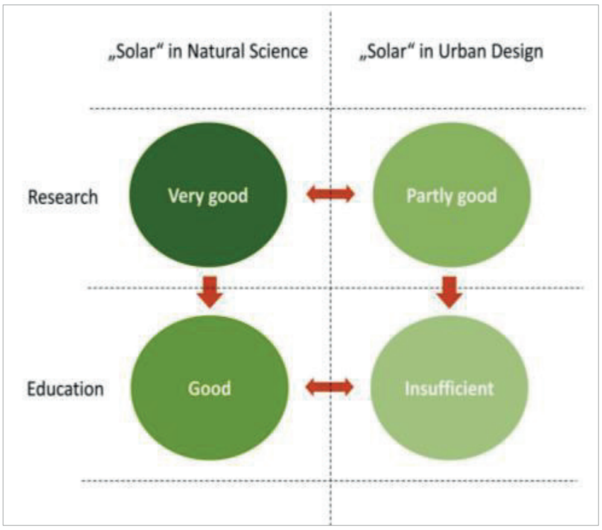


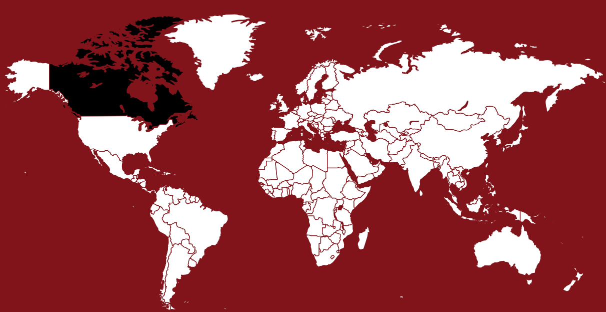
Figure 2: Graphic Summarizing the Degree of Integration of the Solar Energy Topic in the Field of Natural Science versus Urban Design

3.5. Common Solar Analysis Methods and Tools in Urban Design

It can be concluded that lacking integration of solar energy use in urban planning and development processes, as well as in education, can hardly be based on a shortage of tools. Numerous tools, providing adequate information on the solar irradiation in various urban contexts are being used, equipping the design professionals with the required information.

The shortcomings for an adequate integration of solar energy topic in urban planning and design are rather based on the limited capacity of involved stakeholders to consider this topic from an urban energy system perspective. An isolated consideration of solar energy use in an urban planning context cannot be sustained in the long term. In order to achieve better levels of solar integration in urban environment, an evaluation of solar energy production potentials has to be considered in connection with the patterns of the local energy demand, energy storage and grid feed-in capacity.


University of Calgary
Université Laval
University of Toronto
University of Waterloo
Université York
Ryerson University



Canada

4. Canada

4.1. Interviews - Evaluation of Existing Courses in Tertiary Education

To start the process, preliminary research was performed online to create a list of current programs within the Canadian educational system that may offer insight into solar energy to some degree. This research focused on gathering courses from Architecture, Engineering and Urban Planning disciplines. Any available information was gathered for each course, including the teaching professors' name and contact information. We then contacted each professor via email asking them to partake in a phone interview to discuss their respective course – alternatively, the interview questions were provided in the email and they could respond via email at their convenience.

There was a good response rate from the universities, with five of the seven professors responding to our questionnaire. Information for the remaining courses and all college courses were found on their respective websites. Once the information was gathered, a brief description of each course was created based on the available content. Relevant courses were then used to create a summary document on the current status of state-of-the-art of education on solar energy in Canada.

It was found that there currently are no courses that are specifically geared toward solar energy in urban planning schools. However, there are courses being taught in the disciplines of architecture and environmental science that use the principle of solar energy for technical and design purposes. The information for these courses has been collected by combining the interview questionnaire responses and the information on the webpage of each course.

Table 6: Courses on Solar Energy at Laval University, Canada

Respondent 1	**Université Laval** **Laval University**
Education institute and faculty	Laval University, School of Architecture, Faculty of Architecture, Art and Design
Respondent Position	Professor
Name of course	Architecture and Environment
Course level	Bachelor
Total credits	3
Course code	ARC 2001
Course category	Solar energy, architecture
Student background	Students are in their first term of their architecture degree.
Recommended prerequisites	none
How old is the course?	Several years
Teaching language	French
Mandatory/Optional	Mandatory
Average no. of students	-
Reference	(Laval University, 2015)

Respondent 2	**Université Laval** **Laval University**
Education institute and faculty	Laval University, School of Architecture, Faculty of Architecture, Art and Design
Respondent Position	Professor
Name of course	Ambiances physiques architecturales et urbaines
Course level	Master, PhD
Total credits	3
Course code	ARC 6044
Course category	Passive and active solar, lighting, acoustics; urban, architectural and detail scale
Student background	Created for architecture students, as a complementary course to their studio at this level; however, also available to urban design and engineering students
Recommended prerequisites	Recommended to be taken with ARC 6037 (studio)
How old is the course?	-
Teaching language	French
Mandatory/Optional	Optional
Average no. of students	-
Reference	(Laval University, 2015)

Table 7: Courses on Solar Energy at York University, Canada

Respondent 3	**Université York** **York University**
Education institute and faculty	York University, Faculty of Environmental Studies
Respondent Position	Professor
Name of course	Fundamentals of Renewable Energy
Course level	Bachelor
Total credits	3
Course code	ENVS 4400
Course category	Renewable energy for electricity generation, heating and cooling of buildings, and transportation
Student background	Urban design and environmental studies third and fourth year students
Recommended prerequisites	ENVS 3130
How old is the course?	-
Teaching language	English
Mandatory/Optional	Optional
Average no. of students	-
Reference	(York University, 2015)

Table 8: Courses on Solar Energy at Waterloo University, Canada

Respondent 4	University of Waterloo
Education institute and faculty	University of Waterloo, Faculty of Engineering, School of Architecture
Respondent Position	Professor
Name of course	Principles of Environmental Design
Course level	Bachelor
Total credits	0.5
Course code	ARCH 125
Course category	Influence of environment on design, sustainability, solar energy
Student background	Architecture undergraduate students
Recommended prerequisites	None
How old is the course?	-
Teaching language	English
Mandatory/Optional	Mandatory
Average no. of students	-
Reference	(University of Waterloo, 2015)
Respondent 5	University of Waterloo
Education institute and faculty	University of Waterloo, Faculty of Engineering, School of Architecture
Respondent Position	Professor
Name of course	Environmental Building Design
Course level	Bachelor
Total credits	0.5
Course code	ARCH 226
Course category	Daylighting, photovoltaics, carbon neutral strategies
Student background	Architecture undergraduate students
Recommended prerequisites	None
How old is the course?	-
Teaching language	English
Mandatory/Optional	Mandatory
Average no. of students	-
Reference	(University of Waterloo, 2015)

Table 9: Courses on Solar Energy at the University of Calgary, Canada

Respondent 6	University of Calgary
Education institute and faculty	University of Calgary, Faculty of Environmental Design
Respondent Position	Professor
Name of course	Special Topic: Solar Energy and High Performance Buildings
Course level	Masters, PhD
Total credits	3
Course code	EVDS 597.54
Course category	Solar energy, architecture
Student background	Master and PhD students in architecture, urban planning and engineering
Recommended prerequisites	None
How old is the course?	Only held one year
Teaching language	English
Mandatory/Optional	Optional
Average no. of students	-
Reference	(University of Calgary, 2014)
Respondent 7	University of Calgary
Education institute and faculty	University of Calgary, Faculty of Environmental Design
Respondent Position	Professor
Name of course	Special Topic: Solar Energy and High Performance Buildings
Course level	Masters, PhD
Total credits	3
Course code	EVDS 597.54
Course category	Solar energy, architecture
Student background	Master and PhD students in architecture, urban planning and engineering
Recommended prerequisites	None
How old is the course?	Only held one year
Teaching language	English
Mandatory/Optional	Optional
Average no. of students	-
Reference	(University of Calgary, 2014)
Respondent 8	University of Calgary
Education institute and faculty	University of Calgary, Faculty of Environmental Design
Respondent Position	Assistant Professor
Name of course	Special Topic: Solar Building Envelope
Course level	Masters, PhD
Total credits	3
Course code	EVDS 683.6
Course category	Building performance, solar communities, solar generation
Student background	Architecture, engineering
Recommended prerequisites	None

Recommended prerequisites	None
How old is the course?	-
Teaching language	English
Mandatory/Optional	Optional
Average no. of students	-
Reference	(University of Calgary, 2015)

Table 10: Courses on Solar Energy at the University of Toronto, Canada

Respondent 9	**University of Toronto** University of Toronto
Education institute and faculty	University of Toronto, John H. Daniels Faculty of Architecture, Landscape and Design
Respondent Position	Professor
Name of course	Sustainable Architecture
Course level	Master
Total credits	-
Course code	ARC3042
Course category	Solar energy is often incorporated, topic changes each semester
Student background	Background in building science, math and physics
Recommended prerequisites	ARC2043 and ARC2045
How old is the course?	-
Teaching language	English
Mandatory/Optional	Optional
Average no. of students	-
Reference	(University of Toronto, 2015)
Respondent 10	**University of Toronto** University of Toronto
Education institute and faculty	University of Toronto, Faculty of Applied Science and Engineering, Institute for Sustainable Energy
Respondent Position	Professor
Name of course	Efficient use of energy
Course level	Master
Total credits	-
Course code	JPG 1407
Course category	Energy use in buildings, transportation, industry and agriculture
Student background	Urban design/geography; also, available to architecture students
Recommended prerequisites	-
How old is the course?	-
Teaching language	English
Mandatory/Optional	-
Average no. of students	-
Reference	(University of Toronto, 2015)

Table 11: Courses on Solar Energy at Ryerson University

Respondent 12	**Ryerson University** **Ryerson University**
Education institute and faculty	Ryerson University, Faculty of Engineering and Architectural Science, Department of Architectural Science
Respondent Position	Industry professional, guest lecturer
Name of course	Renewable Energy Systems for Buildings
Course level	Master
Total credits	1
Course code	BL8212
Course category	Integration of renewable energy systems in buildings, special focus on PV
Student background	Building science, some engineering and architecture
Recommended prerequisites	None
How old is the course?	New
Teaching language	English
Mandatory/Optional	Optional
Average no. of students	20-30
Reference	(Ryerson University, 2015)
Respondent 13	**Ryerson University** **Ryerson University**
Education institute and faculty	Ryerson University, Faculty of Engineering and Architectural Science, Department of Architectural Science
Respondent Position	Professor
Name of course	Building Performance Simulation/Modelling
Course level	Master
Total credits	1
Course code	BL8204
Course category	Simulation tools for hygrothermal, energy performance and solar potential
Student background	Building science, some engineering and architecture
Recommended prerequisites	None
How old is the course?	-
Teaching language	English
Mandatory/Optional	Optional
Average no. of students	20-30
Reference	(Ryerson University, 2015)

4.2. Findings Related to Solar Energy in Urban Planning at Universities in Canada

Our findings have shown that there are currently 7 universities across Canada teaching a total of 13 courses that integrate some aspect of solar design and/or solar technology. Of these courses, half are for undergraduate students and the other half are for graduate level and PhD students. The majority of the courses offered are within the discipline of Architecture. However, a few are offered by Geography, Environmental Design and Urban Design programs. It was found that currently none of the courses are officially offered or being taught within the discipline of urban planning. However, there are courses that are offered to urban planning students from other departments.

Architecture

Courses offered within the architectural discipline seem to be mostly design-based concepts with occasionally some technical aspect. At the undergraduate level, students learn the fundamentals of solar energy and the built environment. Topics include site planning, solar geometry, sun angles and solar penetration, passive solar heating and cooling, daylighting and carbon-neutral design basics including an introduction to technologies such as photovoltaics.

At the graduate level, students are encouraged to examine the link between ecology, culture and technology in the built environment within the context of passive solar design. One course emphasizes the importance of the integrated design approach in passive and active solar design. For example, in one course students are asked to investigate an existing building and its potential for solar integration. At several institutions, graduate level students research international and local strategies for low-energy building and evaluate codes and rating systems such as LEED. A couple of programs in Canada offer energy simulation software training integrated within their courses, such as EnergyPlus, Hot2000, and mainly Autodesk Ecotect. Otherwise, often students are encouraged to self-train and use these (and other) software tools on their assigned projects.

Urban Design/Environmental Design/Geography

Courses offered out of these interrelated disciplines cover topics such as renewable energy, carbon-free energy concepts, and efficient use of primary energy. Focus is placed on the reduction of primary energy, specifically the reduction of energy use in buildings as well as industry and agriculture, and the potential for renewable energy technologies for electrical generation, heating, cooling and transportation. Students are encouraged to consider the social and economic aspect of the implementation of these technologies to mitigate climate change. Constraining factors are discussed such as basic feasibility, physical/biophysical limits, application and cost.

Table 12: Course goals and learning outcomes of different respondents in Canada

Institute	Course goals	Learning outcomes
Laval University Course: Architecture and Environment	Optimizing building geometry for solar potential, specifically looking at solar radiation and daylighting.	• Use Ecotect and heliodon to model a cube form with windows, to illuminate a specific area at certain times of day • Build a solar oven with maximum temperature • Evaluate solar energy potential • Explore architectural integration of solar building materials
Laval University Course: Ambiances physiques architecturales et urbaines	Understanding the thermal (passive and active solar), lighting and acoustic ambiances at three scales; urban, architectural and detail.	• Ability to apply knowledge of these principles into design studio projects • Ability to integrate thermal, lighting and acoustic strategies that are compatible at all three scales
University of Calgary Course: Solar Energy and High Performance Buildings	Understanding the importance of integrating solar components into the architectural design.	• Students will learn the principles for the integration of solar components into the design as part of the aesthetic and function • Students will learn to evaluate the solar potential of buildings • Students will learn the potential for energy upgrades

Institute	Course goals	Learning outcomes
University of Waterloo Course: Principles of Environmental Design	Understanding the effect of various environmental conditions on building performance.	• Enable students to understand the influence of environmental factors on design, site planning, sustainability, solar geometry, climate and passive and active solar systems • Emphasis is placed on passive heating and cooling, including sun angles and solar penetration
University of Toronto Course: Sustainable Architecture	Enable students to critically examine the intersection between ecology, culture, and technology within the context of the built environment.	• Enable students to establish appropriate criteria and metrics to argue the veracity of 'green design' ideas and their applicability to design interventions • Students will develop their own means of engaging complex intersections where design culture must grapple with significant social, environmental and economic issues.
University of Toronto Course: Efficient Use of Energy	Examines the options available for dramatically reducing our use of primary energy with no reduction in meaningful energy services, through efficient use of energy at the scale of energy devices and systems.	• Topics covered: energy use in buildings, transportation, industry and agriculture • Students will evaluate the underlying principles that determine the potential of and limits to energy efficiency, the difference in potential savings of individual energy devices compared to energy systems, and the cost and financing of energy efficiency improvements
University of Toronto Course: Carbon-free Energy	Examines the options available for providing energy from the major carbon-free energy sources: solar, wind, biomass and nuclear; as well as sequestration of carbon from fossil fuel sources.	• Students will evaluate the physical principles, efficiencies and constraining factors of each technology • Students will learn current applications, current and projected future costs, and possible future scenarios
University of Calgary Course: Special Topics: Solar Building Envelope	Understanding the characteristics of energy performance of existing and prospective envelope/curtain wall systems.	• Students will evaluate the effect of building geometry on solar potential • Students will evaluate the performance of building integrated photovoltaics on various geometries
Ryerson University Course: Building Performance Simulation/Modelling	Understanding the capabilities of various simulation tools for hygrothermal and energy performance of buildings, as well as effect of building parameters on solar potential.	• Students will learn how to evaluate hygrothermal performance of building envelope assemblies • Students will learn to create building models to evaluate energy performance and the effect of energy efficiency measures on performance • Students will learn to evaluate solar potential of buildings
Ryerson University Course: Renewable Energy Systems for Buildings	Understanding the integration of renewable energy systems into buildings, with a special focus on photovoltaics and solar thermal.	• Students will learn the basics of effectively integrating and optimizing the use of renewables in building design • Students will learn how to prepare a financial analysis for the cost/benefit of photovoltaic integration in buildings

More information about the courses are available under the link:
https://www.google.com/maps/d/viewer?mid=zwO1nQaLivM0.ktj1hGnhbqho

4.3. Used Sources in Education

Most professors tend to use a lecture-style format. Some opt to carry out hour long seminars each week after class for tutoring and hands-on application of material taught in class. Often, case studies (varying from local, Canada-wide and international projects) are used in class to demonstrate successful application of the integrated solar design process. Some professors organise field trips to local sustainable and solar integrated projects.

Most professors are using some form of software tool to evaluate parameters of solar energy in design, such as daylighting, solar potential and solar heating. Table 13 lists the courses that offered a response to the questionnaire, describing the process, methods and tools used in their course.

Table 13: Course goals and learning outcomes of different respondents

Institute	Process tools	Digital tools	Experiment and practical measurements
Laval University Course: Architecture and Environment	No	Ecotect, Heliodon	/
Laval University Course: Ambiances physiques architecturales et urbaines	No	Vasari, Revit, Ecotect, CFD, Radiance, Excel, LUMcalcul	/
University of Calgary Course: Solar Energy and High Performance Buildings	Field trips to solar projects	F-chart	/
University of Waterloo Course: Principles of Environmental Design	No	Climate Consultant, HEED	/
University of Toronto Course: Sustainable Architecture	No	HOT2000, Ecotect	/
University of Toronto Course: Efficient Use of Energy	No	Excel	/
University of Toronto Course: Carbon-free Energy	No	Excel	/
University of Calgary Course: Special Topics: Solar Building Envelope	No	EnergyPlus, OpenStudio for Sketchup	/
Ryerson University Course: Renewable Energy Systems for Buildings	No	RETScreen 4, Excel	/
Ryerson University Course: Building Performance Simulation/Modelling	No	EnergyPlus, OpenStudio for Sketchup, WUFI, eQuest	/

4.4. Description of Existing Courses in Tertiary Education

Essentially, solar energy focused education programs are limited to colleges or private classes. These courses are often focused on the component level, design and installation of systems. Universities and/or bigger institutions are focused on general guiding principles of sustainable design and renewable technologies at the building scale. These programs are offered mainly within the architecture, but crossover to engineering and urban design.

Within Canadian universities, plenty of courses are offered within architecture that teach passive solar principles for daylighting and heating, and some active solar integration at the building scale. Some specialized courses are teaching students to utilize software to calculate solar potential. Most architectural programs within Canada offer courses (some required) related to energy use in buildings, energy efficiency, sustainable design, renewable energy, integration of solar technologies in buildings, etc., to some degree. Courses focusing on solar energy are often offered as electives and are not yet core (required) courses. Because of this, there is often overlap between the disciplines. For example, a course that is offered in the department of architecture will often open the course to engineering and/or urban planning students, and vice versa, depending on the content. Environmental Design programs are offered at some universities, which cover some form of site planning consideration for solar energy.

Within Canadian colleges, there are several programs available to students interested in joining the growing solar industry. These programs are job-specific and prepare students for work straight out of their programs. Some examples of this include training for solar system designers and solar photovoltaic installers, feasibility studies for renewable energy systems, etc.

4.5. Used Tools and Instruments

- Most courses use reports, assigned textbooks, etc. as required and/or supplementary reading material related to the course content.
- Often, case studies (varying from local, national and international projects) are used in class to demonstrate successful application of the integrated solar design process.
- Some professors organise field trips to local sustainable and solar integrated projects.
- Simulation tools are being used include:

- Autodesk Suite – VASARI, REVIT, Ecotect, CFD, Radiance (multiple institutions)
- Hot2000 (University of Toronto, Ryerson)
- EnergyPlus (Ryerson, grad level)
- Climate Consultant (Waterloo)
- HEED (Waterloo)
- Microsoft EXCEL-based computational models (multiple institutions)
- Heliodon (Laval)
- AGI-32 (Ryerson)

Most professors tend to use lecture-style format. Some opt to carry out hour-long seminars each week after class for tutoring and hands-on application of material taught in class.

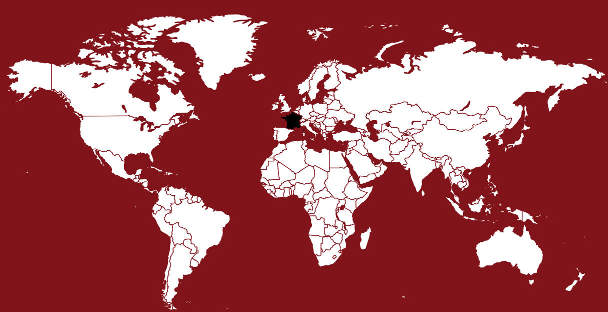
4.6. Evaluation of Existing CPD Courses

In Ontario, architects are required to collect continuing education credits in order to maintain their status as a licensed architect under the Ontario Association of Architects (OAA). These credits can be obtained in various ways. One way architects can obtain them is to attend seminars that can be viewed as expanding their knowledge within the architectural discipline or broadening their knowledge of related industries. These seminars and/or courses will specify how many credits are available for attending prior to registration.

There are also a variety of certificate courses offered for working professionals to expand their credentials, and increase their knowledge base within their discipline. For example, Ryerson University (Toronto, Canada) offers a Certificate in Energy Management and Innovation program that focuses on renewable energy and green technology.


Lille
A5,U5,U6,E8
Amiens
E1
Caen
E3
Normandie
A11
Compiegne
E5
Reims
U13
Nancy
A9
Bretagne
A2
Brest
U2
Rennes
U14,E14
Sceaux
E18
Paris
A6,A12,A13,A14,A15,A19
U9,U10,U11,U12,E12
Strasbourg
A17,U15
Tours
E19
Nantes
A10,U8,E10,E11
La Rochelle
E6
Clermont-
Ferrand
A3,U3
Lyon
U7,E9
Chambéry
E4
Saint-Etienne
A16,E15,
E16
Grenoble
A4,U4
Bordeaux
A1,U1
Montpellier
A8
Bayonne
E2
Toulouse
A18
Marseille
A7
Perpignan
E13


LA REUNION
Le Tampon
E7
Saint-Pierre
E17



France

5. France

5.1. Selection of the Analysis Sample

5.1.1. Academic Institutes

The first method used for investigating the existing courses in tertiary education in terms of solar energy and its implications in the urban design process was to directly contact the person in charge of the course and to conduct an interview based on the most important points of the teaching material and the organisation of the course. The main areas of investigation were:

- Information about the course;
- Time spent on teaching method;
- Value put on method;
- Pedagogical methods;
- Digital tools;
- Involvement of practicing professionals;
- Principles of teaching;
- Legal regulations;
- Teaching sources;
- Cooperation with other education institutes;
- Consideration for buildings/neighbourhoods/cities; and
- Requested report.

The French academic network is built around several study domains, 4 of which are related to the topic of solar energy integration in urban areas:

- Architecture;
- Urban design;
- Building engineering and
- Energy engineering.

Since there was no currently available list focusing on solar energy, several databases/lists were used to identify the academic institutes and teaching materials potentially related to the theme of solar energy in an urban context. Through the institutes' websites visits and the first negative answers to our questionnaire, multiple individuals were removed from the analysis sample. At the time of redaction of this report, 53 institutes are part of the analysis sample:

- 19 Architecture Schools;
- 15 Urban Planning/Design Schools and
- 19 Engineering Schools.

Table 14: List of the identified Architecture Schools in France

ID	LOCATION	INSTITUTE	MASTER CODE	TITLE
A1	Bordeaux	ENSAP Bordeaux	M2 ACAU	Environment and Comfort for Architecture and Urban Planning
A2	Bretagne	ENSA Bretagne	M TPCAU	Urban and Architectural Design Theories and Practice
A3	Clermont-Ferrand	ENSA Clermont-Ferrand	M DD	Sustainable Development
A4	Grenoble	ENSA Grenoble	M UPU	Urban Planning and Projects
A5	Lille	ENSAP Lille	M DEA	Architecture and Landscape
A6	Marne-La Vallee	School of Architecture for Cities and Territories of Marne-la-Vallee	M DEA	Architecture City and Territories
A7	Marseille	ENSA Marseille	M DU	Urban Design
A8	Montpellier	ENSA Montpellier - La Reunion	M CAU	Architectural and Urban Design
A9	Nancy	ENSA Nancy	M2 IU-VTT	Urban Engineering - Evolving Cities and Territories
A10	Nantes	ENSA Nantes	M2 AFU	Ambiances and Urban Form
A11	Normandie	ENSA Normandie	M DEA	Architecture
A12	Paris-Belleville	ENSA Paris-Belleville	M DEA	Architecture
A13	Paris-La Villette	ENSA Paris-La Vilette	M DEA	Architecture
A14	Paris-Malaquais	ENSA Paris-Malaquais	M2 UT	Urban Planning
A15	Paris-Val de Seine	ENSA Paris-Val de Seine	M DEA	Architecture
A16	Saint-Etienne	ENSA Saint-Etienne	M DEA	Architecture
A17	Strasbourg	ENSA Strasbourg	M2 ASPU	Architecture, Structures, Urban Projects
A18	Toulouse	ENSA Toulouse	M DEA	Architecture
A19	Versailles	ENSA Versailles	M DEA	Architecture

Table 15: List of the identified Urban Planning/Design Schools in France

ID	LOCATION	INSTITUTE	MASTER CODE	TITLE
U1	Bordeaux	Planning, Tourism and Urban Planning Institute (University of Michel de Montaigne Bordeaux 3)	M PEEPUT	Landscape and Environmental Assessment of urban and spatial …
U2	Brest	Geoarchitecture Institute (University of Western Brittany)	M AUDE	Sustainable Urban Design and Planning, Environment
U3	Clermont-Ferrand	Auvergne Institute of Territorial Development (AgroParisTech, Auvergne Clermont-Ferrand 1 University, Blaise Pascal Clermont-Ferrand 2 University, Vetagro Sup)	M SAVPMT	Urban Planning Strategies for Small and Middle Towns and Territories
U4	Grenoble	Urban Planning Institute of Grenoble (Pierre Mendès-France Grenoble 2 University)	M UPU	Urban Planning and Projects
U5	Lille	Urban Design and Planning Institute of Lille (Science and Tech University, Lille 1)	M CAD / M2 ENVIE	Sustainable Planning and Construction / Environment and Sustainable City
U6	Lille	Construction, Environment and Urban Planning Institute (Law and Health Faculty, Lille 2 University)	M2 UAU	Urban Planning and Sustainable Development

ID	LOCATION	INSTITUTE	MASTER CODE	TITLE
U7	Lyon	Urban Planning Institute (Lumière Lyon 2 University)	M2 UAU	Urban Planning and Sustainable Development
U8	Nantes	Geography and Regional Planning Institute (Nantes University)	M2 VTPPU	Cities and Territories: Politics and Planning Practice
U9	Paris	City, Environment, Transport Department (Ecole des ponts ParisTech)	M IU	Urban Planner Engineer
U10	Paris	Sciences Po's Urban Planning Cycle (Sciences Po)	M U	Urban Planning
U11	Paris	Urban Planning and Development Institute (Paris-Sorbonne University)	M AUDP	Urban Planning, Design, Development and Prospective
U12	Paris	Paris School of Urban Planning	M2 EUSPS	Urban Environments: Strategies, Projects, Services
U13	Reims	Spatial Planning, Environment and Urban Planning Institute (Reims Champagne-Ardenne University)	M UDA	Sustainable Urban Planning and Design
U14	Rennes	Urban Development and Planning Institute (Brittany School of Architecture, National Institute of Applied Sciences of Rennes, Sciences Po Rennes, Rennes 2 University)	M2 DYATER / M2 AUDIT	Spatial Dynamics and Planning, Territoriality / Urban Planning, Design, Diagnostic and Territories Intervention
U15	Strasbourg	Institute of Land Planning and Urban Design of Strasbourg University	M2 PSAUME	Projects and Sociology of Urban Planning, Mediations and Environment

Table 16: List of the identified Engineering Schools in France

ID	LOCATION	INSTITUTE	MASTER CODE	TITLE
E1	Amiens	EISIEE Amiens	M GEB	Building Energy Engineering
E2	Bayonne	ISA-BTP Bayonne	M EH	Energy and Housing
E3	Caen	ESITC Caen	M BU	Building and Urban Planning
E4	Chambery	Polytech Chambery	M EBE	Environment Building Energy
E5	Compiegne	Compiegne University of Technology	M GSU	Urban Systems Engineering
E6	La Rochelle	EIGSI La Rochelle	M EEB	Energy and Environment - Building major
E7	Le Tampon	University of La Reunion	M SBE	Building and Environment Sciences
E8	Lille	HEI Lille	M EHE	Energy Housing and Environment
E9	Lyon	INSA Lyon	M GEE	Energy and Environment Engineering
E10	Nantes	Centrale Nantes	M HEU	Housing and Urban Environment Science
E11	Nantes	Mines Nantes	M STEU - City and Energy specialty	Science and Techniques of Urban Environment
E12	Paris	ESIEE Paris	M EE	Energy Efficiency
E13	Perpignan	University of Perpignan	M SPI-ES	Solar Energy Science and Techniques
E14	Rennes	INSA Rennes	M GCU	Civil and Urban Engineering
E15	Saint-Etienne	ENISE	M GC	Civil Engineering
E16	Saint-Etienne	Ecole des Mines de Saint-Etienne	M EEB	Building Energy Efficiency
E17	Saint-Pierre	ESIROI	M BE	Building and Energy

ID	LOCATION	INSTITUTE	MASTER CODE	TITLE
E18	Sceaux	EPF	M UOBD	Urban Planning - Sustainable Building Design major
E19	Tours	Polytech Tours	M DAE - RESEAU	Urban Development and Environment - Urban Engineering, Climate and Energy major
E20	Sophia-Antipolis	Mines Paris Tech	M ENR-EUREC	European Master in Renewable Energy

At the time this report was written, it was only possible to collect information from individuals teaching 15 courses. For the rest of the courses, information was gathered from public websites. For this reason, information from all areas throughout the country are not available. From the information that was obtained, it is possible to have a preliminary overview of state-of-the-art educational programs on solar energy and solar urban/building design in France.

5.1.2. Non-academic Institutes

Continuing Professional Development courses proposed by mostly non-academic institutes have also been considered as solar training providers for professionals and practitioners, and content on those programs has been reviewed and presented in section 5.3.

Table 17: Examples of Continuing Professional Development courses proposed by Non-academic French Institutes

ID	Location	Institute	Title
P1	Bourget-du-Lac	INES	National Institute of Energy
P2	Saint-Denis de La Réunion	CAUE Reunion	Architecture Urbanism and Environment Council of La Reunion
P3	Paris	Pole Formation IDF	Training, Environment, City and Territory centre of the Ile de France region
P4	Paris	CSTB	Training Department of the Scientific and Technical Centre for Building

In order to present all the collected data in a more user-friendly manner, an interactive map was generated and posted online. This map allows users to explore solar energy course information but also to click on the institutes' website links in order to get extra details or contacts.
More information about the courses are available under the link: https://goo.gl/1NfvDm

Additional Reference: The Renewable Energy Observatory publishes each year a comprehensive guide of available trainings in France. It is a valuable complementary source of information (chargeable). The 2017-2018 guide is available at:
http://librairie-energies-renouvelables.org/les-ouvrages/322-guide-des-formations-2017-2018.html

5.2. Interviews - Evaluation of Existing Courses in Tertiary Education

The following material was produced through the collection of online data and interviews with the 15 course instructors. The results of the courses have more applications and implications in solar energy in urban planning and are presented in the following pages.

For each course, tables referring to the course goals, expected learning outcomes, as well as the tools and methods used are presented in addition to administrative and identification details.

Table 18: Courses on Solar Energy at architectural departments in France, Bordeaux

Respondent A1	**Ecole nationale supérieure d'architecture et de paysage de Bordeaux** **National Superior School Architecture And Landscape of Bordeaux**
Education institute and faculty	ENSAP Bordeaux
Respondent Position	Professor
Name of course	Simulation and Assessment Tools for Ambiances and Structures course Ambiances Urban Approach: Ecodistricts and Sustainable Public Spaces course
Course level	Master 2
Total credits	
Course code	
Course category	Solar energy
Student background	M1 level
Recommended prerequisites	
How old is the course?	
Teaching language	French
Mandatory/Optional	Optional
Average no. of students	
Reference	http://www.bordeaux.archi.fr/formations/etudes-darchitecture/programmes/2e-cycle.html

Courses	**Process tools**	**Digital tools**	**Experiment and practical measurements**	**Course goals**	**Learning outcomes**
ENSAP Bordeaux Simulation and Assessment Tools for Ambiances and Structures	Daylight Factor tables, Sun charts, Audience website (http://audience.cerma.archi.fr/index.html)	Girasol, Gnomon, Dialux, Dial Europe, Solène, Audience website		Building solar use optimization is mandatory for all studied projects	
Ambiances Urban Approach: Ecodistricts and Sustainable Public Spaces			Site measurements Pyranometer Soundmeter	Building solar use optimization is mandatory for all studied projects	Overall environmental study (microclimate, daylighting, urban noise)

At ENSAP Bordeaux, the solar energy topic is addressed in class from Semester 2 with the use of simple solar tools (Girasol, Gnomon, Daylight Factor tables, etc.) based on the sun path. In the following seminar "Environment and Comfort for Architecture and Urban Planning" (M2 ACAU) the students learn how to use more evolved software such as Dialux. In the "Ambiances Urban Approach: Ecodistricts and Sustainable Public Spaces" course, students have the opportunity to conduct site visits for various measurements with the aim to produce a global environmental study of their project. For each of their final projects, students have to optimize the building's solar use.

Table 19: Courses on Solar Energy at architectural departments in France, Nancy

Respondent A9	**Ecole nationale supérieure d'art et de design Nancy** **School of architecture of Nancy**
Education institute and faculty	ENSA Nancy
Respondent Position	Professor
Name of course	Environmental Simulation (I and II) and Prospective Urban Design courses
Course level	Master 2
Total credits	21 = 3+3 and 15
Course code	
Course category	Solar energy
Student background	M1 level
Recommended prerequisites	
How old is the course?	
Teaching language	French
Mandatory/Optional	Optional
Average no. of students	
Reference	http://www.nancy.archi.fr/fr/enseignements-de-master.html

Courses	Process tools	Digital tools	Experiment and practical measurements	Course goals	Learning outcomes
ENSA Nancy Environmental Simulation				Exploring, studying and using existing models and tools for architecture and urban planning.	
Prospective Urbanism				Exploring spatial organisations in terms of social and physics phenomena.	Ability to propose a prospective and practical transformation process for cities.

At ENSA Nancy, the solar energy topic is of particular interest, particularly with respect to buildings and urban environments.

In the “Environmental Simulation” course, the aim is for students to explore the characteristics and capabilities of several existing models, simulation and visualization tools on architectural and urban projects. The focus is put on thermal and daylighting studies. The solar energy is used as a passive strategy for daylighting buildings and as part of an energy exchange system.

In the “Prospective Urbanism” course, the focus is placed primarily on the spatial evolution of the city (i.e. urban design) more than on its organisation (i.e. urban planning). The aim of this course is to explore the territorial organisations with equal attention to physical and social phenomena in order to offer prospective and pragmatic solutions. At the heart of this problem lie issues of sustainability, energy and energy self-sufficiency. Again, solar energy is treated as a component of a system.

Table 20: Courses on Solar Energy at architectural departments in France, Nantes

Respondent A10	École Nationale Supérieure d'Architecture Nantes School of architecture of Nantes
Education institute and faculty	ENSA Nantes
Respondent Position	Professor
Name of course	Solar Irradiance, Daylighting and Urban Form course Microclimate and Urban Form course
Course level	Master 2
Total credits	
Course code	
Course category	Solar energy
Student background	M1 level
Recommended prerequisites	
How old is the course?	
Teaching language	French
Mandatory/Optional	Optional
Average no. of students	
Reference	http://www.crenau.archi.fr/sites/default/files/Brochure_M2STEU_2015-2016.pdf

Table 21: Courses on Solar Energy at urban planning/design departments in France, Strasbourg

Respondent U15	Institut d'Urbanisme et d'Aménagement Régional Institute of Land Planning and Urban Design of Strasbourg University
Education institute and faculty	Institute of Land Planning and Urban Design of Strasbourg University
Respondent Position	Professor
Name of course	Projects and Sociology of Urban Planning, Mediations and Environment
Course level	Master 2
Total credits	
Course code	
Course category	Sociology
Student background	M1 level
Recommended prerequisites	Sociology, Urban Design and Planning
How old is the course?	
Teaching language	French
Mandatory/Optional	Mandatory
Average no. of students	
Reference	https://sciences-sociales.unistra.fr/formation/master/urbanisme-amenagement/ http://sspsd.u-strasbg.fr/IMG/pdf/4_p._M2_PSAUME_2015-2016.pdf

Courses	Process tools	Digital tools	Experiment and practical measurements	Course goals	Learning outcomes
Institute of Land Planning and Urban Design of Strasbourg University Projects and Sociology of Urban Planning, Mediations and Environment		Plan EE: a GIS tool for renewable energies integration (www.plan-ee.eu)	Research Project: CIMBEES, High Energy, Sustainability and Social Performance Dwellings (http://vertigo.revues.org/15018)	Analyse the urban areas in terms of public policies, sociology, social design acceptance; all supported by demographical projections	

At IUAR, solar energy in urban planning topics is studied in terms of public policy, sociology and social acceptability. The aspect of demographic projection comes also in support of the previous aspects. Several research projects, such as CIMBEES or Plan EE, are related to this topic.

Table 22: Courses on Solar Energy at engineering departments in France, Amiens

Respondent E1	**École supérieure d'ingénieurs en électronique et électrotechnique d'Amiens** School of electronic and electrical engineering Amiens
Education institute and faculty	ESIEE Amiens
Respondent Position	Professor
Name of course	Building Energy Systems Sizing and Design
Course level	Bachelor 3, Master 1 and 2
Total credits	
Course code	
Course category	
Student background	
Recommended prerequisites	
How old is the course?	
Teaching language	
Mandatory/Optional	
Average no. of students	
Reference	

Courses	Process tools	Digital tools	Experiment and practical measurements	Course goals	Learning outcomes
ESIEE Amiens Building Energy Systems Sizing and Design	Fundamental principles and equations	None in order to avoid the 'black-box' effect of commercial software		Solar Thermal study: conduction, convection and internal pipe radiation PV study at the building scale (goals will be redefined soon)	Overall understanding of energy systems and their integration to the building Assessment of building energy use
				PV study at the building scale (goals will be redefined soon)	Assessment of building energy use

At ESIEE Amiens, future engineers are trained to have an overview of all the issues pertaining to energy. Objectives of the training are currently evolving for the future years. The current training provided incorporates modules on building energy use assessment and energy systems sizing tools, as well as their integration within buildings. The design of solar modules is also explored during the students training. This area remains an extensive research field, including photovoltaics.
In the field of solar thermal technologies, teachers do not use any specific software, but prefer to deal with fundamental problems (e.g. heat transfer by conduction, convection and radiation in a pipe) in order to avoid the 'black-box' effect for students. PV systems are also studied but only at the building scale.

Table 23: Courses on Solar Energy at engineering departments in La Réunion

Respondent E7	**Université de La Réunion** **University of La Reunion**
Education institute and faculty	Civil Engineering Master, Building and Energy Sciences Department, University of La Reunion
Respondent Position	Professor
Name of course	Energetics; Building and Energy Systems; Analysis and Modelling Tools
Course level	Master 1 and 2
Total credits	25 = 9 + 3 + 5 + 8
Course code	M1 UE4 and UE8; M2 UE2 and UE4
Course category	Solar energy
Student background	Bachelors in Science
Recommended prerequisites	
How old is the course?	
Teaching language	French
Mandatory/Optional	Mandatory
Average no. of students	
Reference	http://ufr-she.univ-reunion.fr/departements/sciences-du-batiment-et-de-lenvironnement-sbe/formations/

Courses	Process tools	Digital tools	Experiment and practical measurements	Course goals	Learning outcomes
Building and Energy Sciences department, University of La Reunion Energetics		SketchUp OpenStudio EnergyPlus Fluent			Thermal transfers Energy balance Climatology and comfort Flow analysis Renewables Open systems thermodynamics Energy systems Building monitoring and management
Building and Energy Systems Analysis and Modelling Tools					Renewable energy Comfort and urban context Sustainable design in tropical climate Energy storage Ambiances control Holistic approach and complex systems modelling Building physics modelling Environmental modelling CFD Sensitivity analysis methods

Table 24: Courses on Solar Energy at engineering departments in France, Nantes

Respondent E10	**École Centrale de Nantes** **Central School of engineering Nantes**
Education institute and faculty	Institute of Land Planning and Urban Design of Strasbourg University
Respondent Position	Professor
Name of course	Projects and Sociology of Urban Planning, Mediations and Environment
Course level	Master 2
Total credits	
Course code	
Course category	Sociology
Student background	M1 level
Recommended prerequisites	Sociology, Urban Design and Planning
How old is the course?	
Teaching language	French
Mandatory/Optional	Mandatory
Average no. of students	
Reference	https://sciences-sociales.unistra.fr/formation/master/urbanisme-amenagement/ http://sspsd.u-strasbg.fr/IMG/pdf/4_p._M2_PSAUME_2015-2016.pdf

Courses	Process tools	Digital tools	Experiment and practical measurements	Course goals	Learning outcomes
Centrale Nantes Acoustics, Artificial Lighting and Daylighting course		SOLENE		Solve environmental and energy issues through an integrated approach, combining technological development together with the consideration of human, social and urban constraints.	
Building Thermodynamics and Ambiences course		TRNSYS			
Urban Scale Energy course	Local Urban Planning				

Respondent E11	**École des Mines de Nantes** **Grande School of Mining Studies of Nantes**
Education institute and faculty	Mines Nantes
Respondent Position	Professor
Name of course	Urban Energy Management course Energy Demand Management course Energy Production and Distribution course
Course level	Master 2

Total credits	
Course code	
Course category	Solar energy
Student background	M1 level
Recommended prerequisites	Master 1 level
How old is the course?	
Teaching language	French
Mandatory/Optional	Optional
Average no. of students	
Reference	http://www.emn.fr/z-ener/ville-energie/index.html http://www.crenau.archi.fr/sites/default/files/Brochure_M2STEU_2015-2016.pdf

Table 25: Courses on Solar Energy at engineering departments in France, Perpignan

Respondent E13	**Université de Perpignan** **University of Perpignan**
Education institute and faculty	University of Perpignan
Respondent Position	
Name of course	Energy UE
Course level	Master 1 and 2
Total credits	60
Course code	M ES
Course category	Solar energy
Student background	
Recommended prerequisites	Bachelor level
How old is the course?	
Teaching language	French
Mandatory/Optional	Mandatory
Average no. of students	
Reference	

Courses	Process tools	Digital tools	Experiment and practical measurements	Course goals	Learning outcomes
University of Perpignan Solar Energy		Coolpack, Thermoptim, EES		- Understanding of thermodynamic principles for solar energy systems design and optimization - Energy optimisation for residential and commercial buildings.	- Thermodynamic optimization of solar energy systems - Solar captor selection (concentrated or non-concentrated) according to solar resource and site characteristics - Solar-electric or solar-thermal energy convertor sizing - Design, use and optimization of industrial solar plants - Integration of passive and active solar energy strategies to bioclimatic architecture for building energy consumption reduction - Assessment of building energy use

The solar energy specialised training proposed at the University of Perpignan focuses on the study of solar-energy systems. Students learn how to use, size and optimise energy systems at both the building and urban scales.

Table 26: Courses on Solar Energy at engineering departments in La Réunion

Respondent E17	**Ecole Superieure d'Ingenieurs Reunion Ocean Indien** **Reunion Island and Indian Ocean Engineering School**
Education institute and faculty	ESIROI
Respondent Position	Professor
Name of course	Energy production and distribution; Solar resource; Building Thermal loads; Comfort and design in tropical climate; Lighting; Renewables; Energy simulation I and II; NZEB; Urban planning
Course level	Bachelor 3, Master 1 and 2
Total credits	18 = 1 + 0.5+ 0.5 + 0.5 + 1 + 0.5 + 4.5 + 2 + 1.5 + 3 + 3
Course code	
Course category	
Student background	Bachelors in Science
Recommended prerequisites	
How old is the course?	5 years
Teaching language	French
Mandatory/Optional	Mandatory
Average no. of students	20
Reference	http://esiroi.univ-reunion.fr/fileadmin/Fichiers/Esiroi/RUBRIQUES/3FORMATIONS/Batiment/programme_batiment_ESIROI_2015.pdf

The Building and Energy Department in the Engineering School at the University of La Réunion, aims to train students on a wide range of building-related topics, with a focus on tropical climate. Several courses explore the theme of solar energy and its integration into urban planning and passive building design in tropical climates. The following table presents the solar-energy related courses.

Courses	Process tools	Digital tools	Experiment and practical measurements	Course goals	Learning outcomes
ESIROI Solar Energy		EES Sketchup/open studio Daysim Fluent PV Syst Solo			.
Energy production and distribution				Production and distribution energy systems; Management of the systems according to the context	Basic knowledge on energy production and mass distribution systems
Solar resource	Solar irradiation calculus			Designing energy systems such as solar renewable energy systems in building requires advanced knowledge on solar resource	Calculate solar coordinates and determinate solar irradiation on surfaces

Courses	Process tools	Digital tools	Experiment and practical measurements	Course goals	Learning outcomes
Building thermal loads	Solar path			Study of the thermal behaviour and aerodynamics of zones; Hygrothermal comfort; Calc related to the French Thermal Regulation	Climatology: solar irradiation study (global, diffuse, direct) Solar protections sizing
Comfort and design in tropical climate		SketchUp, EnergyPlus		Study thermal comfort in a tropical environment and main principles for tropical design (sun protections and natural ventilation)	Design passive buildings in tropical climate. Being able to make an energy diagnosis
Lighting	Rules of thumb; UDI; Daylight factor; Sky luminance	Daysim	Lux levels inside outside; case study	Visual comfort for users; Daylighting; Artificial lighting	Advanced knowledge for manual illuminance calculations and daylight simulation analysis
Solar Renewables		PVSyst		Using the most important resource in the tropics, i.e. the sun; Mastering the solar energy conversion systems	Mastering technical, environmental and regulatory features of solar PV and thermal systems
Energy simulation I and II		EnergyPlus		Know how to interpret the results obtained with an energy building digital simulation software. Complementary use of both simulation and regulations / labels	Running a building energy simulation and present results in a report in relation with regulatory aspects.
NZEB				Know the design principle of NZEB. Make the students study on real NZEB case study projects	Calculate energy and environmental loads of a NZEB; Set up a post-occupancy audit; Develop energy management strategies for NZEB in tropical climate
Urban planning	Urban planning local documents; Holistic approach of urban planning; Integration of aerodynamics in planning		Site visits; Legal documents and laws	Know the basic of urban planning in tropical climate	Understand the challenges of urban planning in tropical climate. Identify the priorities of development

Table 27: Courses on solar Energy at engineering departments in France, Sceaux

Respondent E18	**Ecole d'ingénieurs** **School of engineering**
Education institute and faculty	EPF
Respondent Position	Professor
Name of course	Renewable Energy, Building Energy and Building Physics courses
Course level	Master 1 and 2
Total credits	16 = 6 + 6 + 4
Course code	
Course category	
Student background	Bachelor level
Recommended prerequisites	
How old is the course?	
Teaching language	English and French
Mandatory/Optional	Optional
Average no. of students	
Reference	http://www.epf.fr/fr/formations/filieres/filiere-urbanisme

At EPF, the engineers are trained to work in diverse and varied sectors in the field of urban planning (i.e. planning, development, programming, etc.) and construction (i.e. site supervision, energy efficiency, environmental quality, etc.). The theme of solar energy is discussed in the course "Renewable Energy" and occasionally in projects during the students' fifth year. Energy integration is one of the challenges explored during this training.

Table 28: Courses on Solar Energy at engineering departments in France, Tours

Respondent E19	**Polytech'Tours - Université François Rabelais** **Polytech Tours- François Rabelais University**
Education institute and faculty	Polytech Tours
Respondent Position	Professor
Name of course	Advanced Urban Energy and Sustainable Design courses
Course level	Master 1 and 2
Total credits	
Course code	
Course category	Solar energy
Student background	
Recommended prerequisites	Bachelor level
How old is the course?	
Teaching language	French
Mandatory/Optional	Optional
Average no. of students	
Reference	http://polytech.univ-tours.fr/formations/genie-de-l-amenagement-et-de-l-environnement-405799.kjsp

Respondent E19	Process tools	Digital tools	Experiment and practical measurements	Course goals	Learning outcomes
Polytech Tours				Train future engineers to analyse: - Dynamic loads of the energy demand of the building and transport sectors; - Dynamic load supply (biomass, wind, solar).	- Urban energy demand dynamic load assessment; - Distribution and renewable energy production systems sizing; - Energy efficient solutions design; - Storage system sizing.
Advanced Urban Energy				Train engineers to find optimal problem solutions.	
Urban Sustainable Design		Toaster (Maths solver under MatLab)		Train future engineers to master plan urban design from a real project: - Make models (digital and physical models); - Model a system; - Organise a project schedule (Gantt).	- Reformulate and model a problem given by a client; - Explore multiple solutions scenarios; - Design spatial and technical solutions; - Design a scale model; - Integrate environmental constraints in the design process.

At Polytech Tours, the RESEAU training focuses on the understanding of the fundamentals of energy at the urban scale and their relationship. The teaching strategy is called ‘inversed pedagogy’, where problems are given to students as a project. Students have to solve the given problems by themselves or in a group with the proposed resources. The teacher supervises the ongoing progress of the student projects and intervenes only in the case of obstacles, which are then contextualised to the student groups.

In the “Advanced Urban Energy” and “Urban Sustainable Design” courses, no specific commercial tools or software is used. A home-developed tool called Toaster uses the fundamental thermal and energy equations taught throughout the course to analyse building and urban energy uses, but also to optimize them via mathematical objective functions (i.e. the tool is run under MatLab).

5.3. Evaluation of Existing CPD Courses

In addition to the previously presented training courses, some of the non-academic institutes (i.e. governmental departments, research institutes, etc.) which offer instruction in solar technology are presented below.

INES, the National Institute of Solar Energy, carries on solar and building R&D activities, but has also set up a Training & Evaluation Division. It provides a wide range of initial and continuing training courses on thermal and photovoltaic solar energy and building efficiency with respect to academics and the industry. The department also carries out monitoring of solar installations and buildings and offers its expertise to professionals in the sector.

INES offers courses in partnership with several academic institutes, such as the University of Savoy, ENSAM Chambery and Grenoble INP, to provide its expertise on renewable energy and buildings. INES also offers continuing trainings and made-to-measure training courses to professionals in the building sector (i.e. projects managers, architects, engineers, etc.) from 1 to 5 day courses depending on the level of instruction. The institute is also preparing soon-to-be-published e-learning courses via an educational web platform hosting various francophone videos related to solar energy and building efficiency. Finally, a particular focus is made on disseminating knowledge of quality throughout the country via technical training for teachers.

The following table presents the course catalogue proposed by INES. It must be noted that all these training courses are proposed by INES out of any academic framework and, therefore, require students to pay additional fees.

Table 29a: CPD courses catalogue proposed by INES

BUILDING ENERGY PERFORMANCE	**Course Code**
NZEB Objective: Towards a general adoption of the Net Zero Energy Building concept	PEB1
Building energy systems	PEB2
TH-BCE method for the French Thermal Regulation (RT2012)	PEB3
Application of the French Thermal Regulation (RT2012) to secondary and tertiary buildings	PEB4
Building thermal simulation tools	PEB5
Introduction to principles and methods for BIM	PEB6
Energy efficient envelope design	PEB7
Energy efficient ventilation installation design	PEB8
Low energy building refurbishment	PEB9
LCA eco-building design	PEB10
European Passive House Certification (CEPH) design	PEB11
Daylighting and artificial lighting	PEB12
Building energy audit	PEB13
SOLAR THERMAL	
Solar thermal project principles	TH1
Collective DHW design	TH2
Solar thermal integration into heating networks and processes	TH3
Ultramarines specialty: solar heating and cooling	TH4
Collective DHW maintenance	TH5
Collective DHW management	TH6
CESI-Qualisol accreditation according to the quality referential EnR	TH7
COMBI-Qualisol accreditation according to the quality referential EnR	TH8
COLLECTIF-Qualisol accreditation according to the quality referential EnR	TH9
Solar heating engineer	TH10
Teaching training for COMBI-Qualisol accreditation according to the quality referential EnR	TH12
PHOTOVOLTAICS	
Thermal and solar PV for NZEB	PV1
Network-connected PV system design	PV2
Norms and maintenance of network-connected PV systems	PV3
Design and sizing of PV systems for isolated site	PV4
Norms and implementation of PV systems for isolated site	PV5
Monitoring and maintenance of network-connected PV systems	PV6
Monitoring and maintenance of PV systems in isolated site	PV7
Off-grid PV systems: hybrid system and micro-network	PV8
Security and risks of PV installations	PV9
Security for interventions on connected PV installations	PV10
Electric auto-consumption of PV systems and batteries	PV11
Electrochemical storage for intermittent energy	PV12
PV energy for mobility	PV13
PV energy for lighting	PV14
Solar pumping	PV15
PV production systems engineering	PV16

QualiPV-Electricity accreditation according to the quality referential EnR	PV17
Auto-consumption - QualiPV-Electricity accreditation option	PV18
QualiPV-Building Integration accreditation according to the quality referential EnR	PV19
PV systems installer and maintainer	PV20
Teaching training for QualiPV-Electricity, Renewables specialty accreditation according to the quality referential EnR	PV21/22

Table 29b: Example for CPD program in La Réunion

Respondent	**Conseil d'architecture d'urbanisme et d'environnement La Reunion** School of architecture of town planning and of environment La Reunion
Education institute and faculty	CAUE Reunion, Architecture Urbanism and Environment Council of La Reunion
Respondent Position	
Name of course	Cf. following table
Course level	Multiple
Total credits	
Course code	
Course category	Solar energy
Student background	
Recommended prerequisites	
How old is the course?	
Teaching language	French
Mandatory/Optional	
Average no. of students	
Reference	http://www.caue974.com/fr/

The Architecture Urbanism and Environment Council of La Réunion offers different training, which is open to building sector professionals, regarding building environmental quality for architectural and urban planning projects. This year, the program is built around 7 modules from 'Eco-management in tropical climate' to 'Environmental urban policy'. Regarding the challenges imposed by harsh climate conditions and the building challenges related to air conditioning and lighting uses in Réunion, all of the modules take into account various scales of solar energy application.

Table 29c: Example for CPD courses offered by the Architecture Urbanism and Environment Council of La Reunion

2015 CAUE courses	Course Code
Eco-management in tropical climate	M1
Construction in tropical climate, tools	M2
Building environmental design, a holistic approach; Aero-thermal principles for building and urban design	M3
Environmental issues of urbanism	M4
Eco-conception trade-offs; Project management method	M5
Architecture, construction and health	M6
Environmental urban policy	M7

The courses offered by the partnership Rhino Training / LesEnR, combines the teaching skills of Rhino Training and the technical support of LesEnR (not longer existing, status as of December 2015).

The courses are provided to building professionals, striving to implement the High Environmental Quality certification (HQE), energy performance professionals (i.e. architects, builders, etc.), but also to urban planners.

Table 30: Example for CPD courses offered by the partnership Rhino Training / LesEnR (Status as of December 2015)

Les EnR courses	Objectives
Module E1 - Building energy efficiency	Knowing the global challenges and goals from the Grenelle, understanding energy issues in the building, using methods for the design of low energy buildings
Module E2 - Renewable energy in building	Knowing the context related to renewables in France, understanding the different types of renewable energy, advantages and disadvantages, performing a preliminary design for key renewable energy systems
Module E3 - Building energy refurbishment	Knowing the state of the existing building stock in France, assimilating regulatory constraints, identifying over-consumption sectors and proposing appropriate solutions
Module E4 - Renewables and urbanism	Knowing global issues and energy constraints resulting from the Grenelle for urban redevelopment, understanding the link between energy issues and urban planning, knowing the principle of a heat network, i.e. making a preliminary design of the key renewable energy systems
Module H1 - Management of the High Environmental Quality (HQE) certification	Understanding the fundamentals of the HQE
Module H2 - Initiation to the High Environmental Quality (HQE) certification	Acquiring the operations management methods HQE
Module H3 - HQE specialization Eco-Management	Following this training, students will be able to master the technical requirements of ECO-management HQE by the provision of design and management tools
Module H4 - Products environmentally	Designing a sustainable and environmental-friendly building
Module H5 - HQE Comfort and Health	Integrating the criteria of comfort and health in a building based on the HQE
Module H6 - HQE Exploitation	Mastering the methods of achieving the sustainable use of a building according to the HQE Exploitation referential
Module H7 - HQE Refurbishment	Understanding the fundamentals of the HQE® Refurbishment
Module H8 - HQE Planning approach	Knowing the contribution of the HQE Planning and be able to implement a sustainable development project
Module H9 - Mastering the Habitat & Environment referential	Understanding the fundamentals of the H & E process
Module U1 - Issues, goals and feedback on sustainable neighbourhoods	Knowing the issues and sustainable management approaches for urban planning
Module U2 - Eco-neighbourhoods and sustainable neighbourhoods: Methodologies and Tools	Knowing the sustainable management approaches; Acquiring steering methods for a sustainable development project
Module U3 - The Environmental Approach of Urbanism (AEU)	Knowing the contribution of the AEU approach and being able to implement a sustainable development project
Module U4 - The HQE Planning	Knowing the contributions of the HQE Planning and being able to implement a sustainable development project
Module U5 - Towards Sustainable Cities - How to integrate environmental issues at every scale of urban development?	Knowing the different actions and approaches according to the project scale in order to plan and build a sustainable city

Respondent	**Pôle régional de formation Environnement, Ville & Architecture en Île-de-France** **Regional training centre of Environment, City and Architecture in Île-de-France**
Education institute and faculty	Training, Environment, City and Territory Centre of the Ile de France region
Respondent Position	
Name of course	Cf. following table
Course level	Multiple
Total credits	
Course code	
Course category	Solar energy
Student background	
Recommended prerequisites	
How old is the course?	
Teaching language	French
Mandatory/Optional	
Average no. of students	
Reference	http://www.poleformation-idf.org/

The Ile de France regional Training, Environment, City and Territory Centre aims to promote continuing education for architects and all building sector professionals. We have selected courses from the online catalogue that are related to solar energy at different levels.

Table 31: Example for CPD courses offered by Ile de France regional Training in France

DIPLOMA TRAINING in 2015	**Objectives**	**Tools & Methods**
Project management and environmental quality project management: architecture and planning - 20 days	Eco-management of energy, transports, water, air and sanitation	
TECHNICAL EXPERTISE FOR ENVIRONMENTAL QUALITY	**Objectives**	**Tools & Methods**
Passive summer comfort - 1 day	Adapt design standards to climate change; Master the rules and tools of passive summer comfort	Dynamic Thermal Simulation; Simplified calc for wind and ventilation; ABC bioclimatic diagram; Givoni diagram
Architecture and Thermal Regulations - 1 day	Know the applicable French thermal regulation (RT) according to the project (RT2005ex, RT2012, Feasibility Study); Identify the main changes compared to the RT2005; Know the requirements and application principles of the RT2012 and its labels and certifications; Understand the basics of thermal for buildings; Knowing how to implement thermal regulation in design projects, renovation or rehabilitation	Various administrative, regulatory and practical exercises
Daylighting, artificial and mixed lighting - 1 day	Acquire technical knowledge on lighting natural and understand its necessity; Design an artificial lighting project quality; Know the regulations	Daylight Factor; Daylighting indices; daylight comfort criteria
Energy and building ... efficient buildings - 2 days	Know the physical processes that generate heat in a building; Master the bioclimatic design approach; Deduct architectural design principles from the heat transfer modes; Know the architectural responses related to energy issues	Climate analysis; thermal transfers

TECHNICAL EXPERTISE FOR ENVIRONMENTAL QUALITY	**Objectives**	**Tools & Methods**
Rehabilitation and efficient renovation of buildings - 4 1/2 days	Understanding the challenges of high environmental quality rehabilitation of heritage architecture; Putting in synergy all aspects contributing to the functional quality, environmental quality (HQE), high health quality, comfort and energy savings; Acquire the necessary technical knowledge; Manage the complexity of the rehabilitation and preservation of heritage buildings, and integrate alternatives to radical solutions	Identify the different technical elements to renovate; Know the available tools to renovate; Know how to exploit the BMS (Building Management System); Use the tool "Baby Papoose"; Case studies, workshop + a site visit (½ day)
Integrate air, sunshine, light, water and vegetation in the architectural project an enlarged bioclimatic - 2 days	Know how to design, build and develop an architectural project taking into account the natural resources; Learn how to make trade-offs based on owners' objectives and expectations of future users; Define an expanded bioclimatic strategy	Solar, wind, microclimate analysis in urban area; Strategies to face UHI; Integration of vegetation at the urban scale; Management of rain, grey and black water; Building morphology; Building mass; Insulation; Air tightness; Solarisation, transparency and porosity of facades; Sensitivity analysis and case studies
Understand and discuss the Dynamic Thermal Simulation - 2 days	Consolidate knowledge of building thermal principles; Apply these principles in building design to optimize energy performance and comfort; Evaluate Thermal Dynamic Simulation outcomes in architectural design from early stages	Thermal Dynamic Simulation; Simulation scenarios
Sustainable urban project: the design and implementation - 2 days	Analyse the new urban challenges; Acquire the knowledge necessary to face these challenges thanks to objective and comparative analysis of experiences from existing urban projects; Take into account the social, environmental, economic and cultural aspects of sustainable cities	Design urban strategies from diagnosis; Evaluate performance and define a sustainable urban project; Case study and workshop

Respondent	**Centre Scientifique et Technique du Bâtiment** Training Department of the Scientific and Technical Centre for Building
Education institute and faculty	Training Department of the Scientific and Technical Centre for Building
Respondent Position	
Name of course	Cf. following table
Course level	Multiple
Total credits	
Course code	
Course category	Solar energy
Student background	
Recommended prerequisites	
How old is the course?	
Teaching language	French
Mandatory/Optional	
Average no. of students	
Reference	http://formation.cstb.fr/

The Scientific and Technical Centre for Building offers a wide range of chargeable training for the building sector professionals. As the main French national organisation in the building sector, the CSTB, provides research and innovation, consultancy, testing, training and certification services in the construction industry. All these fields are available in the range of training offered, with a focus made on the application of the environmental certification label HQE (High Environmental Quality), which takes into account daylighting, visual and thermal comfort in relation to the solar theme (i.e. within its scoring criteria).

Table 32: Example for CPD courses offered by the Scientific and Technical Centre for Building in France

SUSTAINABLE CITIES	Objectives	Tools & Methods	Course code
Sustainable management approaches: comparison of tools and methods	Identify the challenges of sustainable development in a planning project; Know the tools, methods and certification labels, their structure, their application field, their evolution, their advantages, and drawbacks	HQE, LEED, BREEAMB	DEDU11
Network optimization strategies: transport, energy, water, waste	Analyse concrete projects; Identify alternative management, architectural or technology for transportation, energy, water and waste	Energy provision management; renewable energy production	M10
SUSTAINABLE BUILDINGS	**Objectives**	**Tools & Methods**	**Course code**
Building environmental performance indexes : HQE Performance test	Measure the stakes and objectives of the HQE Performance label and its articulation with the HQE approach; Know the main principles of this multi-criteria approach and the environmental performance indicators; Analyse feedback from test operations	Eco-design tools; Multi-criteria approach	ENV46
Overview of thermal in buildings: equipment, envelope	Understand the principles and thermal phenomena in buildings; Advanced knowledge on materials, processes and thermal systems; Knowledge of HVAC systems and their operating principles	Conduction, convection, radiation; Solar gains; Thermal comfort; Climatic loads	ENR17
Design high energy performance buildings (French Thermal Regulation RT2012)	Integrate via a holistic approach, bioclimatic architecture principles and innovative technology	Dynamic Simulation tools for design; Electricity use management; Renewable energy; NZEB; PassivHaus; Minergie; Case Study	ENR8
Optimization of lighting for buildings	Understand the general principles of indoor lighting; Optimize the overall performance of indoor lighting equipment; Optimize daylighting in buildings	Daylighting characteristics; Luminous climate; Daylighting indexes; Daylighting assessment tools; On-site measurement; Case studies	ENR22
Optimization of summer comfort	Understand the principles of hygrothermal comfort in summer; Advanced knowledge of technical, architectural and behavioural solutions to improve summer comfort by limiting the impact on the environment and the risks of heat exposure for health	Human comfort parameters; Comfort models; Bioclimatic approach: UHI, master plan, building form, solar shadings; green roofs; Natural cooling systems; Simulation tools	CONF1
Dynamic Thermal Simulation of buildings with TRNSYS	Discover the software and its capabilities	TRNSYS; TRNBuild; Simulation Studio: building environment modelling (climate, solar masks…); TRNSYS3D (SketchUp plugin)	TRN6
Optimization of solar thermal performance with TRANSOL	Know the basics in the field of application of solar thermal related to the manipulation and use of TRANSOL 3 software; Take over the tool through TRANSOL simple exercises and understand its operation	TRANSOL: thermal cooling and heating systems modelling	TRANS3

5.4. Solar Analysis Methods and Tools in Urban Planning

Through the analysis of the answers provided by the surveyed institutions, it appears that the methods and the tools used to teach solar-related courses vary significantly between different disciplines and also the specialties of the degrees offered in France.

For a first solar approach and basic solar potential analyses of projects, simple process tools such as daylight factor tables or sun charts are used across the disciplines. For more evolved analyses, design concepts and optimization problems, dynamic simulation tools such as Daysim or EnergyPlus, are used in tandem with 3D modellers to explore the solar performance of various design scenarios.

Regarding software and digital tools in general, it appears that their selection depends on the discipline, the course goals and expected learning outcomes, but also the teacher's preferences and teaching methodology with some teachers even developing specific tools. Since solar urban planning deals with the integration of solar energy at different scales, the range of tools is broad, from GIS tools to system specific tools.

The following software is currently used and taught in the identified courses:

- Coolpack
- Dialux
- Girasol
- Gnomon
- Daysim
- EES
- OpenStudio
- EnergyPlus
- PV Syst
- Solene
- Thermoptim
- TRNSYS
- TRANSOL
- Various GIS tools

5.5. Findings Related to Solar Energy in Urban Planning in French Education

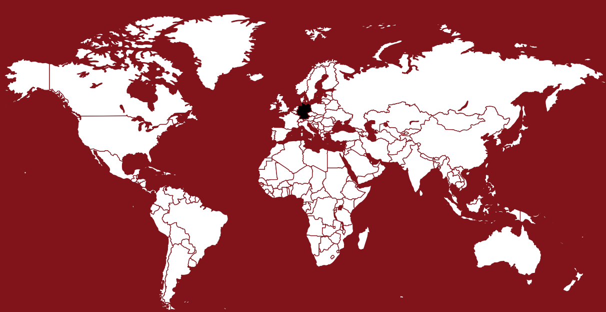
Formerly a topic restricted to building science courses taught in engineering schools, the solar energy topic is becoming a much more multi-disciplinary and transversal theme in the French educational system, with about fifteen identified institutions in the engineering, architecture and urban planning/design fields. The solar energy topic is of course addressed in these disciplines at various levels of difficulty and integration: from simple introductory lectures to more advanced training for others.

The courses offered by the educational institutions remain mostly discipline-specific with only few shared courses between the main study domains, even if some programs offer cross-discipline courses like the Master 2 in Science and Techniques of Urban Environment co-organised by ENSA, Centrale and Mines schools in Nantes.

Regarding the educational level of the proposed trainings in France, it appears that solar-related courses are mostly taught at the Master's level. The Master's level seems to be more adapted to this kind of complex topic, especially in the Architecture and Urban Design trainings where science related lectures are approached only in more advanced classes, within specialty or optional courses.

Finally, regarding CPD, several non-academic institutions with different backgrounds, offer a wide range of continuing studies and made-to-measure training courses for building sector professions (i.e. projects managers, architects, engineers, urban planners, etc.) in relation to solar energy within urban planning topics. The themes addressed range from regulatory assessment to active solar energy system related courses.


7,8
HCU Hamburg
9
Hildesheim
2
TU Cottbus
4
TU Dortmund
11,12
Uni Kassel
26
Bauhaus Universität
Weimar
13
HS Koblenz
3
TU Darmstadt
5,6
FH Frankfurt am Main
14
FH Mainz
10
TU Kaiserslautern
17,18
Technische
Hochschule Nürnberg
20
HTW Saar
21,22,23,24,25
Stuttgart
19
Hochschule
Nürtingen- Geislingen
1
HS Augsburg
15,16
TU München



Germany

6. Germany

6.1. Description of the Existing Courses at German Universities

Across Germany, 26 courses were evaluated that deal with the topic of solar energy or at least renewable energy and had published online descriptions of their teaching modules. Due to data protection legislation it was only possible to research the information online, as contacted institutions such as DIFU or the Chamber of Architects were not able to give information about existing academic programs or continued professional development seminars.

Within the international context it is important to mention that in Germany, universities of applied science as well as general universities and academies are responsible for higher education and therefore are included in this evaluation. The researched modules do not claim to be comprehensive. The aim of this project is rather to capture a differentiated impression of the subjects and methods currently taught within the field.

Table 33: Courses that were found on solar energy in Germany

	Institution	Faculty, Department	Degree course	Module code	Module name	Sem.	Type	ECTS
1	HS Augsburg	Architektur und Bauwesen	M.Eng. Energie Effizienz Design E2D	M7/ UFP	Umfeldplanung	in 2nd Sem.	Full time	5
2	TU Cottbus-Senftenberg	Architektur, Bauingenieur-wesen und Stadtplanung	M. Architektur	24503	Stadttechnik und Verkehr	Summer term	Full time	6
3	TU Darmstadt	Architektur	B.ScArchitektur	344	Smart Building	Summer term	Full time	5
4	TU Dortmund	Raumplanung	M.Sc. Raumplanung	7	Erneuerbare Energien	-	Full time	-
5	Fachhoch-schule Frankfurt am Main	Architektur, Bauingenieur-wesen, Geomatik	M.A. Architektur	WP M G4	(WPF) Stadtentwicklung und Quartiersplanung	in 3rd Sem.	Full time	5
6	Fachhoch-schule Frankfurt am Main	Architektur, Bauingenieur-wesen, Geomatik	M.Sc. Urban Agglomerations	UA 8	(PF) Urban Ecology and Environment	in 2nd Sem.	Full time	5
7	HCU Hamburg	Architektur	M.Sc. Resource Efficiency in Architecture and Planning	REAP_M020 2	Urban Energy Flows	in 1st Sem.	Full time	5
8	HCU Hamburg	Städtebau und Quartiersplanung	M.Sc Stadt- und Regionalentwicklung	SP_M0201	Städtebauliche Entwurfsprojekte	in 2nd Sem.	Full time	8
9	HAWK Hildesheim Holzminden Göttingen	Bauen und Erhalten	M.A Architektur	MAV-64	Nachhaltigkeit im Bauwesen	Winter term	Full time	6
10	TU Kaisers-lautern	Raum- und Umweltplanung	M.Sc Stadt- und Regionalentwicklung	M-IÖK-1	Nachhaltiges Bau- und Siedlungsflächen-management und Quartiersentwicklung (Stand 2014)	-	Full time	3
11	Uni Kassel	Architektur, Stadtplanung, Landschafts-planung	M.A Architektur	D-2.0-43	(PF) Städtebauliches Entwerfen und Stadtplanung	Winter term	Full time	6

	Institution	Faculty, Department	Degree course	Module code	Module name	Sem.	Type	ECTS
12	Uni Kassel	Architektur, Stadtplanung, Landschafts-planung	M.A Landschafts-architektur	D-2.0-40	(WPF) Ländlicher Raum und neue Kulturlandschaften	Winter term	Full time	6
13	Hochschule Koblenz	Bauwesen	B.A Architektur	B-EP2 -	(WPF) Entwurfsprojekt: Architectural Building Design 1	in 2nd Sem.	Full time	8
14	FH Mainz	Technik	M.A Architektur: Integrierte Wohnungsbau-entwicklung	220	Wohnbau: Stadtentwicklung		Full time	-
15	TU München	Architektur	B.A Architektur	BV620007	Grundlagen des nachhaltigen Bauens	Summer term	Full time	3
16	Hochschule München	Technik	M.A. Architektur	MA_13 DU	(WPF) Fachprojekt 3-Vertiefung Urban Design	Summer term	Full time	5
17	Technische Hochschule Nürnberg	Architektur	B.A Architektur	B5300	(PF) Entwerfen + PlanenStadt	Winter term	Full time	10
18	Technische Hochschule Nürnberg	Architektur	B.A Architektur	B3600	(PF) Modul 6 im AR 3: Professionalisierung / Vertiefung	in 3rd Sem.	Full time	5
19	Hochschule Nürtingen-Geislingen	Landschafts-architektur, Umwelt- und Stadtplanung	B.Eng. Stadtplanung	2.4	Städtebauliches Entwerfen IV	in 4th Sem.	Full time	5
20	HTW Saar	Architektur und Bauingenier-wesen	B.A. Architektur	B-A-1.6	(PF) Klimagerechtes Entwerfen	in 5th Sem.	Full time	6
21	ABK Stuttgart	Architektur	M.A Architektur		Urban Sustainability	in 1st Sem.	Full time	5
22	Uni Stuttgart	Architektur und Stadtplanung	M.Sc Architektur und Stadtplanung	48250	Werkzeuge der räumlichen Planung	unregel-mäßg	Full time	6
23	Uni Stuttgart	Architektur und Stadtplanung	M.Sc Integrated Urbanism and Sustainable Design (IUSD)	51200	Sustainable Architecture I	Winter term	Full time	6
24	HfT Stuttgart	Architektur und Gestaltung, Studiengang Klima Engineering	Bachelor of Engineering (B.Eng.)	M 25- ES	Energetische Stadtplanung und Infrastruktur	in 6th Sem.	Full time	6
25	HfT Stuttgart	Architektur und Gestaltung, Studiengang Stadtplanung	Master of Engineering (M.Eng.)	Teilmodul EST von ISP2 Städtebau	Stadtplanung im Klimawandel- EST Energieeffizienter Städtebau	Winter term	Full time, part time possible	2 von 8
26	Bauhaus Universität Weimar	Architektur und Urbanistik	Urbanistik Bachelor of Science B.Sc.	Planungs-projekt	Entwurfsprojekt zur energetischen Modernisierung	5th oder 7th Sem.	Full time	12

The modules represented in Table 33 are consecutive as well as postgraduate degree courses. In principle, we can determine that the topic of renewable energy is taught both within Bachelor- as well as Master-level courses with varying degrees of intensity. In regards to the distribution of the credit points, independent from the specific degree course, a wide range between 3 and 12 ECTS is available. The methodical approach of the module and therefore the set requirements for the students is the decisive factor for the distribution of the credit points. In case of mere lecture series, the number of credit points is lower than, for example, in seminars or for urban and architectural projects, as the individual contribution of students for this type of work is significantly higher.

It is important to note that a mere numerical comparison cannot be used to evaluate the depth of the subjects that are taught on solar energy, as all listed modules not solely deal with the specific topic of solar energy but always look as well at the wider urban range and context. For example, within a design project, emphasis will be placed on the conceptual idea as well as the evaluation of necessary criteria and parameters in regards to urban design, rather than the specific topic of energy supply. The incorporation of solar energy, however, would be required as an additional layer from the outset. Based on the given examples, it can be concluded that the shown credit points have to be viewed on a percentage basis.

6.2. Description and Evaluation of Specific Modules

Every institution listed in Table 33 has been contacted with a request to participate in the survey regarding the significance of the topic of solar energy within the urban design context. Unfortunately, despite of repeated personal calls as well as emails, the response to the survey was minimal. Of all contacted institutions across Germany only eleven instructors from ten higher education institutions could be identified that where happy to have a further exchange for example in form of an interview.

On basis of the returned surveys one can generally conclude that the topic of renewable energy is taught at the German institutes of higher education, however, in contrast to the specific education in solar energy, especially urban design and planning, is only taking place in a few cases. If the topic is considered it is usually only part of the overall context of the design concept. To a substantial degree solar energy is mostly covered within the areas of building physics and technical building services. Modules concerned with building physics, which where explicitly excluded from this survey, specifically look at PV and solar thermal plants within a building and their architectural integration.

In the following overview, the content and methods of an exemplary module will be demonstrated (see respondent 1, Table 34).

In principle, the evaluated courses can be separated into two categories: either the integration of solar energy is seen as a secondary topic of the wider education on renewable energy and climate protection and is therefore mostly taught in secondary modules that are irregular and non-mandatory. Or the specific topic is allocated to a design project. In this case, solar energy is mostly one of many urban design and planning aspects that has to be considered as part of the design brief.

More information about the courses are available under the link:
https://www.google.com/maps/d/edit?mid=zwO1nQaLivM0.kURr7ejWyJ9c&usp=sharing

Table 34: Courses on Solar Energy at the University of Braunschweig

Respondent 1 "building physics"	**Technische Universität Braunschweig** University of Braunschweig
Education institute	University of Braunschweig
Faculty	Architecture, Civil Engineering and Environmental Sciences
Respondent position	Professor
Name of course	Building Technology
Course level	Bachelor
Total credits	6
Course code	ARC-IGS-01 (C5)
Type of course	Lecture
Description module handbook	The students are able to plan technical building systems, to design them and lay out dimensions accordingly. They possess the relevant knowledge required to illustrate specific technical methods and technical vocabulary in order to be able to communicate with other engineering disciplines. Conventional systems for generating and distributing thermal heating and hot water. Alternative technologies such as co-generation CHP and solar technology. The students understand conventional systems for generating and distributing thermal heating and hot water, but also alternative technologies such as co-generation CHP and solar technology.
Used tools	TRNSYS

Table 35: Courses on Solar Energy at the University of Cottbus

Respondent 2	**Brandenburgische Technische Universität** Brandenburg University of Technology
Education institute	Brandenburg University of Technology Cottbus-Senftenberg
Faculty	Architecture, civil engineering and urban planning
Respondent Position	Research fellow
Name of course	Urban Technical Infrastructure and Transport
Course level	Master
Total credits	6
Course code	24503
Type of course	Seminar
Description module handbook	The courses teach students to identify the importance of orientation and design systems of solar technologies for the sustainable development of urban spaces, but also for individual projects. Analysis, evaluation and representations of economical, ecological and social interactions between premises and buildings (i.e. building services), town and city structures and technical town and city systems.
Used tools	-

Table 36: Courses on Solar Energy at the University of Dortmund

Respondent 3	**Technische Universität Dortmund** TU Dortmund University
Education institute	TU Dortmund University
Faculty	Spatial planning
Respondent Position	Information from the module handbook
Name of course	Renewable energies
Course level	Master
Total credits	4
Course code	Module 3
Type of course	Seminar

Description module handbook	The focal points of this institution are, on the one hand, the spatial planning processes at community and regional levels for evaluating and implementing the required areas, locations and routes. On the other hand, the focus of the institution is on the design and implementation of integrated development plans as determination processes between the various participants from the fields of technical energy planning as well as the complete spatial planning. , which includes an understanding of the various parties involved in the process such as technical energy and spatial planning professionals.
Used tools	-

Table 37: Courses on Solar Energy at the University of Hamburg

Respondent 4	**HafenCity Universität Hamburg** **HafenCity University Hamburg**
Education institute	HafenCity University Hamburg
Faculty	architecture
Respondent Position	Professor
Name of course	Urban Energy Flows
Course level	Master (Postgraduate)
Total credits	5
Course code	REAP_M0202
Type of course	Lectures, tutorials
Description	Resource Efficiency in Architecture and Planning The Master of Science Degree Program REAP – "Resource Efficiency in Architecture and Planning" is an international and interdisciplinary program at HafenCity University Hamburg that is concerned with sustainable planning at different scales. It aims to enable participants to promote sustainable architecture and urban development in different geographical and cultural settings. The REAP program consists of 17 study modules taught over 2 academic years. During their studies, REAP students will obtain knowledge and skills within the following areas: - Sustainability - Water, Material and Energy Cycles in the city - Resource efficient urban technologies and infrastructure - Economics and administration of buildings and urban services - Legal and policy instruments - Urban Planning on different scales - Skills development: dimensioning, perception, assessment and decision making in the field of sustainable resource technologies - Research methods and decision support techniques
Used tools	-

Table 38: Courses on Solar Energy at the University of Kaiserslautern

Respondent 5	**Technische Universität Kaiserslautern** **University of Kaiserslautern**
Education institute	University of Kaiserslautern
Faculty	Department of Regional and Environmental Planning
Respondent Position	Professor
Name of course	Urban Development and Planning 2
Course level	Master
Total credits	9

Course code	M-IÖK-1
Type of course	Lectures, Seminar
Description	The subject of renewable energy (i.e. solar energy, geothermal energy, etc.) and its relevance to urban design and development as well as planning processes will be covered in the lectures.
Used tools	GoSol

Table 39: Courses on Solar Energy at the University of Munich

Respondent 6	**Technische Universität München** **Technical University of Munich**
Education institute	Technical University of Munich
Faculty	Engineering and Architecture
Respondent Position	Professor
Name of course	building physics and building services + energy supply systems
Course level	Bachelor
Total credits	3+3
Course code	-
Type of course	Lectures and Workshops
Description	In addition to the theoretical component of the courses (i.e. lectures and workshops), this program also offers a combined design studio with the department for Building Constructions. The challenge is to fill knowledge gaps in the urban or suburban context. For the analyses, we always use a solar potential analysis.
Used tools	Autodesk Ecotect

Table 40: Courses on Solar Energy at the University of Nuernberg

Respondent 7	**Technische Hochschule Nürnberg** **Nuernberg Institute of Technology**
Education institute	Nuernberg Institute of Technology NIT
Faculty	Architecture and Urban Planning
Respondent Position	Professor
Name of course	Designing and Planning: Urban Design
Course level	Bachelor
Total credits	10
Course code	B5300
Type of course	Lectures, Seminar
Description	Students acquire basic theoretical and practical knowledge of urban planning and urban development with a focus on integrative design using a holistic design approach, which also includes all aspects of solar energy design.
Used Tools	Students individual choice.

Table 41: Courses on Solar Energy at the University of Nuernberg

Respondent 8	**Technische Hochschule Nürnberg** **Nuernberg Institute of Technology**
Education institute	Nuernberg Institute of Technology NIT
Faculty	Architecture and urban planning
Respondent Position	Professor
Name of course	Digital form and design
Course level	Master
Total credits	5
Course code	-
Type of course	Seminar, Workshops
Description	The course focuses on geometrical development of solar shading modules for varying exploitation of solar radiation and resp. levels of shading. Analysis of site conditions regarding prevailing winds, natural lighting, and shadow casting is conducted. The course is not obligatory and is offered based on faculty schedules (i.e. it is not offered regularly).
Used Tools	Autodesk Ecotect, McNeal Rhinoceros 5s (with Grasshopper extension)

Table 42: Courses on Solar Energy at the University of Saarbruecken

Respondent 9	**Hochschule für Technik und Wirtschaft des Saarlandes** **University of Applied Sciences School**
Education institute	University of Applied Sciences Saarland
faculty	Architecture and civil engineering
Respondent Position	Professor
Name of course	Climate-Adapted Design
Course level	Bachelor
Total credits	6
Course code	B-A-1.6
Type of course	Seminar
Description module handbook	The module develops a competence in integrated design with a focus on "Climate effective planning and construction". The stages of superstructure planning will be taught integrally and practised. The course concentrates on the entire draft and design process. The process commences with urban planning analysis, it includes the processing of draft variants through to detail planning and complex representations, and personal presentations of building designs.
Used Tools	-

Table 43: Courses on Solar Energy at the University of Stuttgart

Respondent 10	**Universität Stuttgart** **University of Stuttgart**
Education institute	University of Stuttgart
Faculty	Architecture and urban planning
Respondent Position	Research assistant
Name of course	Urban Design Lab I+II
Course level	Diploma
Total credits	6+3
Course code	-

Type of course	Lecture, Seminar, Workshops
Description	Seminar (SS 2007 + WS 2007/08) Content: The students are given a (small) urban planning site and are asked to iteratively optimize energy efficiency and noise protection of their urban design concepts, with the help of digital simulation tools.
Used Tools	GoSol, CADNA-A

Table 44: Courses on Solar Energy at the University of Applied Sciences Stuttgart

Respondent 11	**Hochschule für Technik Stuttgart** **University of Applied Sciences Stuttgart**
Education institute	University of Applied Sciences Stuttgart
Faculty	Architecture and Design
Respondent Position	Professor
Name of course	Energetic urban planning and infrastructure
Course level	Bachelor
Total credits	6
Course code	M 24- ES
Type of course	Lecture, Seminar
Description module handbook	• Urban planning and town and/or city planning-related parameters and basic terminology (e.g. building density) • Planning instruments and their importance (State Building Regulations, Article 34) • Public vs. private building regulations • Sustainable town planning – sustainable districts • Supply infrastructure, local and district heating networks • Aspects and concepts for handling building stock in urban development benchmarks • Certification systems at town district levels (e.g. DGNB - German Sustainable Building Council) • Interests and perspectives from the various process participants
Used Tools	-

Table 45: Courses on Solar Energy at the University of Applied Sciences Stuttgart

Respondent 12	**Hochschule für Technik Stuttgart** **University of Applied Sciences Stuttgart**
Education institute	University of Applied Sciences Stuttgart
Faculty	Architecture and Design
Respondent Position	Professor
Name of course	Urban planning in climate change- EST energy efficient urban development
Course level	Master
Total credits	2/8
Course code	EST as part of ISP2 (urban design)
Type of course	Lecture, seminar
Description	• Energy saving and urban optimization • Energy supply • Implementation strategies
Used Tools	-

After surveying all the instructors from various institutions who could speak to the status and the value of solar energy in education, we have summarised the following comments:

“The topic of renewable energy and its relevance for urban design is covered in lectures and extended within workshops. The focus is generally on the reduction of the demand of energy (i.e. building typology, building techniques, etc.), the use of renewable sources of energy (i.e. solar energy, geothermal, etc.), and an efficient supply (technique).”

“During design projects, students apply the use of solar energy during their design process within a larger urban area.”

“Solar energy is lectured within basic studies during seminars and tutorials as well as workshops, within the framework of the project studies. Connections with discipline-bridging topics such as climate-optimized construction and climate-optimized urban design are made.”

“The topic of ‘energy efficient building’ and ‘solar urban design’ is an integral part of urban design for us and is, therefore, not an independent teaching module.”

6.3. Bachelor and Master’s Degrees or Diplomas

A survey of the modules that were examined in this study reveals no difference between Bachelor and Master consecutive degree courses. The modules on solar energy generally take place within a design project, whereas solar energy is only part of the overall design and planning study. Often, these courses are offered and taught through an interdisciplinary collaboration between institutes or other faculties.

The content of the studies is often the design of an urban area, which should not only hold a certain design quality, but as well achieve energy efficient requirements. An iterative process is applied to achieve an optimised solution. In regards to energy simulations mostly software-based tools are used. In relation to solar energy integration and usage of solar energy, ‘Autodesk Ecotect’, ‘Rhino3D’ with extensions and ‘GoSol’ are frequently used.

6.4. Non-Consecutive (Post-Graduate) Courses

Within non-consecutive postgraduate courses, which are considered as further education, many programs allow students to become specialized within a specific field of studies. More often these programs focus on broader topics rather than specifically focusing on solar energy within the urban context. The program aims to educate, e.g. experts in climate protection and energy advisers.

In addition to the survey, general research in regards to the requirements for an urban planner has been undertaken. The ‘guideline professional qualification of urban planners’, published by the federal architects’ chamber, show which qualifications have to be achieved in order to be admitted to this architectural and urban planning chamber. It is apparent that within the disciplines, specific aspects of energy planning are not taught. Rather, the technical and environmental details are covered in a general manner. Therefore, it is understandable that the topic is infrequently taught in higher-educational urban planning programs.

6.5. Doctoral Dissertations

Doctoral dissertations cannot be evaluated within this context, as they depend on a very specific interest of the doctoral researcher. Mostly these are linked to a current research project of the institution. Therefore, doctoral studies will not be considered in this report.

6.6. Further Education Programs - CPD (Continuing Professional Development Programs)

In Germany, continued professional development programs for practicing architects and urban planners are mandatory. They aim to fill existing knowledge gaps with current research and thus link the research to the practice.

Every German federal state has an individual chamber of architects. Practicing architects, interior designers, urban planners, and landscape architects must be admitted to these state chambers. For example, in North Rhine Westphalia a minimum of four year of studies is required. In addition, work experience in all phases of the discipline services (HOAI) in a timeframe of no less than two years are necessary.

This time of 'internship or assistantship' is supported by a program of further education with a minimum of 80 hours of lessons, which should provide an inside into the architectural and urban discipline. The strict guidelines of each federal state for the topics of applied further education programs can be found in respect to the further education directives of the respective chamber. In addition, further educational programs are offered to already practicing members by the chambers. For this specific intuitions, academies were established which offer and administer and coordinate these various programs. According to §5 of the Chamber of Architecture in North Rhine-Westphalia (AKNW), at least 8 lessons per annum are required.

For urban planners (AKNW) the following topics for further education are offered:

- Planning and Design
- Technique and Execution
- Planning- and Project Management
- Planning Economy
- Planning and Building Legislation
- Organisation and Office Management
- Communication

As apparent from the topics above, the thematic area that needs to be covered is vast. For the research on solar energy in urban planning the existing category of 'Technique and Execution' is of interest, as the topic of energy in planning and construction is discussed in more detail. Unfortunately, because of data protection issues from the institution, there is no public record of all offered courses of recent years which would allow for a retrospective evaluation of topics relevant for the area of solar energy. Current German continued professional development courses can be found on the following webpage: http://www.architekten-fortbildung.de

6.7. Further Educational Programs

In the following section, a few exemplary modules for further education programs are listed. These four further education CPD programs are focusing in on a broader sense on the subject of renewable energy and three of the modules focus on specific areas of solar energy. It is notable that the selection is aimed mainly at practicing architects (i.e. see example 1 and 4), as most problems of building physics and techniques for buildings are discussed in these examples. The case is different for urban planners and landscape architects, as documented in examples 2 and 3, where the focus is mostly on the planning process and different planning instruments. Generally, it should be noted that very few courses are offered for urban planners that engage in the overlap of information between urban environments and energy.

Table 46: Example 1: „Akademie der AKNW- Regenerative Energy“

Akademie der Architektenkammer Nordrhein-Westfalen GmbH	**Regenerative Energy**
Number	15 001 197
Hours	8 hours
Field	architects
Objective	Qualification to "Energy efficiency expert for funding programs from the Association for Energy Efficient Construction and Refurbishing" (KfW - DLC)
Content	"The seminar will provide an overview relating to the spectrum of regenerative energy from solar-thermal to wood pellets, and up to and including heat pumps. The objective of the seminar is to provide information on the basic principles and the necessary framework conditions of technology, as well as on efficiency and profitability by utilising examples from practical situations."

Table 47: Example 2: Akademie der AKNW- „Energy transition and landscape architecture“

Akademie der Architektenkammer Nordrhein-Westfalen GmbH	**Energy transition and landscape architecture — Task fields in climate protection and with climate adjustment**
Number	15 001 214
Hours	8 hours
Field	Landscape architects
Objective	Dealing with climate change, pointing out conflicts and developing plan-related strategies for designing and managing energy transition
Content	"The seminar concentrates on the needs of landscape architects, who are involved in developing objective concepts for future environmental and landscaping developments which have to consider energy transition. For all those who are confronted on a daily basis in practice with the challenges of climate change, examples from planning and practice should clearly indicate which contribution the landscape architects should provide and control in the future, within the framework of the process for energy transition."

Table 48: Example 3: ifbau der AKBW- „Energy efficient town planning“

Institut Fortbildung Bau Architektenkammer Baden-Württemberg	**Energy efficient town planning – The way to a CO2- neutral town**
Number	15 122
Hours	8 hours
Field	Architects, Landscape Architects, Urban Planners
Objective	Gaining knowledge about climate protection objectives and their consequences for urban planning
Content	• Framework conditions for energy efficient urban development • Sustainability and climate protection: Objective and trends • Efficiency technology for new housing, old buildings, strategies for energy efficiency

Table 49: Example 4: Akademie der AKH- „Basic knowledge: The way to energy efficient construction“

Architekten- und Stadtplanerkammer Hessen	**Basic knowledge: The way to energy efficient construction**
Number	215-K36
Hours	8 hours
Field	Architects, Landscape Architects, Urban Planners The objective of the seminar is to present the important components for a comprehensive building concept which sustainably considers the economic as well as energy-saving aspects when planning and constructing buildings.
Content	• Basic principles for balancing energy • Important correlations with the EnEV - Energy Saving Ordinance 2014 • Economics and expenses-utilisation-ratio from energy saving measures • Basic principles and collection of ideas about passive houses • Example of a solar-active concept and regenerative system technology

6.8. Survey on Further Educational Programs

Within the framework of our survey, 90 urban planning and environmental departments have been contacted across Germany. The selection of the surveyed cities we took into consideration represents cities with a varying size of inhabitants (less than 100 000; 100 000 to 250 000; 250 000 to 500 000; more than 500 000 inhabitants). Furthermore, an important criterion was to include all 16 federal states of Germany. Finally, twelve cities participated in the non-representative survey from seven federal states.

On these responses the following opinion in regards to the current situation of further education programs can be captured:

Of the twelve interviewed individuals seven took part in a further educational program 1 to 3 times per year. Four declared to even take part in 3 to 5 further education programs per year. One person abstained.

The following six categories, which are often recommended by the chambers for further education, were surveyed:

- Urban planning
- Planning and project management
- Planning and building legislation
- Communication
- Energy planning within the urban context
- Climate protection
- Others

The most common topics related to climate protection and the application of renewable energy and its economy for a project, building legislation, energy optimisation or energy controlling. It is apparent that most seminars and lectures were valued as ‘helpful’ and even as ‘very helpful’. It was noted that there should be more seminars, lectures or symposia covering the basics of the specific topic of urban planning as legislative steering possibilities in relation to solar energy. Further the interviewees considered documented, exemplary urban design strategies and concepts as examples of ‘best practice’ approaches as desirable.

6.9. Software Tools

To evaluate if the integration of solar energy is efficient or not for planners, the incident solar radiation value on roof-, façade, and urban open spaces are of upmost interest. To be able to make statements in regards to shading, especially within dense urban areas, planners often use supporting instruments such as software tools. At the surveyed German institutions of higher education, instruction on these software packages is also taught through the use of realistic case studies within design projects. There is no general software that can answer all energy-related questions. Rather, it depends on the general brief and at least the preferences of the tutors which software is taught and applied within the courses. The following software tools are currently used within education in Germany:
- DIVA for Rhino
- Autodesk Ecotect
- ArchiWizard
- OpenStudio
- Solene
- TownScope
- GoSol
- CitySim

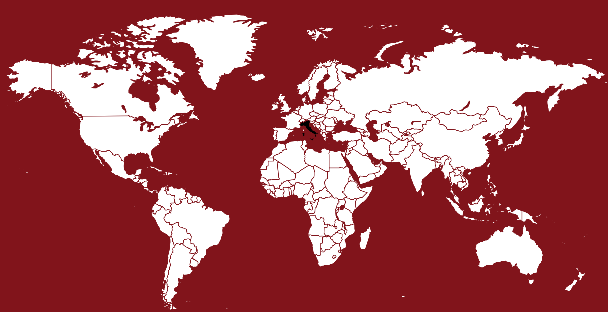
A detailed evaluation of the first four software tools used by the students at the institutions of higher education will be described separately in the second part of this report (see report D.D1 Part II).

6.10. Remarks about Software Tools in Practice

In advance of the evaluation of the software tools at universities, here is a short note on the software that is used in planning and environmental departments.
The results are generated by using a survey in regards to applied software tools. Notably the majority of interviewed individuals work with GISystems of various producers. In this context, eleven interviewed individuals mentioned six different GISystems. These are the following:
- WS Landcad (Widemann)
- AutoCad Map3D
- ArcGIS
- MapInfo
- PromegisWeb.GIS
- InfographGISMobil

For the tools related to CO_2 accounting, the software ECOregion was mentioned. Applied software explicitly for solar irradiation was only mentioned once in form of GoSol, however, with the remark that the tool GoSol is not used, as most tasks in the area of simulation or accounting are commissioned to outside offices or institutions.

[1]http://diva4rhino.com
[2]http://www.autodesk.de
[3]http://www.graitec.com/fr/archiwizard.asp
[4]https://www.openstudio.net
[5]http://www.crenau.archi.fr/
[6]http://www.townscope.com
[7]http://www.gosol.de
[8]http://citysim.epfl.ch
[9]http://www.widemann.de/produkte/wslandcad
[10]http://www.autodesk.de/products/autocad-map-3d/overview
[11]https://www.arcgis.com/features/
[12]http://www.pitneybowes.com/
[13]http://www.promegis.de/news.html
[14]http://www.gismobil.com/infograph/



Italy

7. Italy

7.1. Evaluation of Existing Courses in Tertiary Education

The Italian investigation has been conducted in two steps. Initially, it was carried out considering only university courses in the Northern Italian Universities using interviews, because of the high number of courses altogether in Italy. In detail, such investigation was conducted considering urban planning courses within architectural engineering (University of Padua, University of Trento), architecture (Politecnico of Milano, Politecnico of Torino, University IUAV of Venice), environmental and land engineering (University of Trento) and civil engineering (University of Padua, University of Trento) degree courses. The method that was used was first to identify the departments and the courses, as well as their instructors. The teachers were contacted directly by e-mail, explaining the objectives of the task and of the survey. Unfortunately, not many shared information. Despite this, the teachers' answers have been collected and processed and generally it became clear that solar energy was not the main topic of any urban planning courses. This is because teachers tend to survey several topics in their courses in order to provide students with a preliminary holistic understanding of the urban planning discipline. As a matter of fact, the urban planning discipline ranges from environmental to socio-economic aspects, as well as infrastructural topics.

As a consequence, urban planning students are provided with basic knowledge about solar energy in regard to:
- optimal building orientation in order to take advantages of the local climate by passive solar radiation;
- distance between buildings in order to prevent relative shading effects.

In some urban planning courses, students are required to design urban areas in order to reach sustainability and energy saving goals by the use of passive solar energy, even though the integration of active solar energy (PV or ST systems) is generally not required. In order to reach the goals mentioned above, students participate in excursions to areas subjected to urban planning in order to analyse existing obstacles (e.g. buildings or vegetation) that should be considered in designing the urban areas. In addition to this, another possible reason for the limited integration of solar energy in urban planning courses can be identified in the lack of free simulation software, as well as the lack of well-documented case studies. To summarize, solar energy is generally discussed in urban planning courses, but only the basics of passive solar energy are covered and required when students design urban areas.

At a later stage, given the scarce teachers' participation and the small number of replies received with the interview method, it was chosen to change the investigation method and use the data source available in the portal of the Ministry of Education, Universities and Research (MIUR), set up specifically to guide the students in their study course. The website Universitaly[15] provides information on the degree courses of tertiary education in Italy and contains official data made available directly by the Ministry of Education, Universities and Research.
Altogether, the Italian University System[16] includes:
- Sixty-seven (67) State Universities;
- Twenty-nine (29) non State Universities legally recognized;
- Six (6) Institutes of Higher Education with a special system;
- Eleven (11) online Universities.

Around 92% of the students enrol to State Universities while around 2.6% enrol to online universities.[17]

[15]http://www.universitaly.it
[16]Rapporto sullo stato del sistema universitario e della ricerca 2013. National Agency for the Evaluation of Universities and Research Institutes (http://www.anvur.org/attachments/article/644/Rapporto%20ANVUR%202013_UNIVERSITA%20e%20RICERCA_ integrale.pdf)
[17]http://attiministeriali.miur.it/media/211300/the_italian_university_system.pdf

The university system is regulated by the law of the 30th of December 2010, n. 240, which states: "Norms in subject of organisation of the universities, of academic personnel and recruitment, as well as delegation to the Government to stimulate the quality and the efficiency of the University System."
The Italian university system is organised in three cycles, according to the Bologna structure: the main academic degrees are the Bachelor of Science (1st cycle), the Master of Science (2nd cycle) and the Research Doctorate or PhD (3rd cycle). The system also offers other study programs and related qualifications (see Table 50).

Table 50: The Italian University System[18]

	Italian qualifications	Qualifications	ECTS	years
First Cycle	Laurea	Bachelor of science	180	3
Second Cycle	Laurea magistrale	Master of Science	120	2
	Master universitario di 1° livello	Specialist Bachelor	≥ 60	
	Laurea magistrale ciclo unico	Master of Science	300-360	5-6
Third Cycle	Dottorato di ricerca	Research Doctorate -PhD		3
	Specializzazione di 2° livello	Postgraduate diploma course		2
	Master universitario di 2° livello	Specialist Master's Degree	≥60	

The first cycle consists exclusively of degree courses and lasts three years. The Bachelor of Science is awarded to students who have gained 180 ECTS credits (i.e. 60 for each year of the course) equivalent to credits ECTS (European Credit Transfer System) and who have satisfied all curricular requirements, including the production of a final written paper or equivalent final project. The Bachelor of Science qualification gives access to the courses of second cycle degree as well as to other second-cycle study programs.

The main degree programs in the second cycle are the Master's Degree. These studies take two years to complete. The Master of Science qualification is awarded to students who have gained 120 ECTS credits and who have satisfied all curricular requirements, including the production and public presentation of an original thesis. Some programs, as is the case in construction engineering/architecture are defined as "single-cycle programs", where admission is based on entrance exams. These studies require five years to complete. A Master of Science degree is awarded to students who have gained 300 ECTS credits and who have satisfied all curricular requirements, including the production and public exposition of an original thesis. A Master of Science qualification gives access to PhD courses, third-cycle study programs.

The main degree programs in the third-cycle are research doctorate programs, where admission is based on a competitive exam, studies last at least three years and include the completion and public presentation of an original research project.

The Italian system also offers other academic courses with the relative qualifications such as:

Specialist Master's Degree. Admission requires a Master of Science degree (or a comparable foreign degree) and it is based on a competitive exam; studies may last from two (120 ECTS credits) to six years (360 ECTS/CFU credits) depending on the discipline. The final degree awarded is a specialization;

First Level Master Degree is a second-cycle program intended to provide students with further specialisation or higher continuing education after completion of the first cycle. Access requires a Bachelor of Science degree (or a comparable foreign degree); admission may be subject to additional requirements. Studies last at least one year (60 ECTS credits). The qualification awarded does not give access to doctorate courses or to any

[18] UNI-Italia "Centre for the academic promotion of and orientation of study in Italy" DGSP -
Ministero degli Affari Esteri P.le della Farnesina 1 - 00136 Roma (http://www.uni-italia.it/it/sistema-universitario)

other third-cycle program, since this type of course does not belong to the general requirements established at national level, but is instead offered under the autonomous responsibility of each university.

Second Level Master Degree is a third-cycle program intended to provide students with further specialisation or higher, continuing education studies after completion of the second-cycle. Access requires a Master of Science degree (or a comparable foreign degree), and admission may be subject to additional requirements. Studies last at least one year (60 ECTS credits). The qualification awarded does not give access to doctorate courses or to any other third-cycle programs, since this type of course does not belong to the general requirements established at national level, but it is offered under the autonomous responsibility of each university.

All degree programs of Bachelor of Science and Master of Science sharing general educational objectives, which are grouped into "classes". In developing the specific learning outcomes of single programs, Universities have to include some national requirements for each class concerning the types (i.e. and the corresponding amount of credits) of teaching-learning activities to be included. Degrees belonging to the same class have the same legal value.

The investigation was carried out in the period of October to December, 2015, and it concerned the universities located in the geographical area of the north of Italy in the regions of Veneto, Friuli Venezia Giulia, Trentino and Bolzano, Lombardia, Piemonte, Liguria and Emilia Romagna.

The locations of the universities taken into consideration are shown in the map in according to the numeration exposed in Table 51:

No.	City	University
1	**Bergamo**	*Università degli studi di Bergamo*
2	**Bologna**	*Università di Bologna*
3	**Bolzano**	*Libera Università di Bolzano*
4	**Brescia**	*Università degli studi di Brescia*
5	**Cesena**	*Università di Bologna - Sede di Cesena*
6	**Cremona**	*Politecnico di Milano - Sede di Cremona*
7	**Como**	*Politecnico di Milano*
8	**Ferrara**	*Università degli studi di Ferrara*
9	**Genova**	*Università degli studi di Genova*
10	**Gorizia**	*Università degli studi di Trieste - Polo universitario di Gorizia*
11	**Lecco**	*Politecnico di Milano - Polo territoriale di Lecco*
12	**La Spezia**	*Università degli studi di Genova - Polo Universitario della Spezial*
13	**Milano**	*Politecnico di Milano*
14	**Modena**	*Università degli studi di Modena*
15	**Padova**	*Università degli studi di Padova*
16	**Parma**	*Università degli studi di Parma*
17	**Pavia**	*Università di Pavia*
18	**Piacenza**	*Politecnico di Milano*
19	**Ravenna**	*Università degli studi di Bologna*
20	**Reggio Emilia**	*Università degli studi di Modena e Reggio Emilia*
21	**Savona**	*Università degli studi di Genova - Polo di Savona*

No.	City	University
22	**Torino**	*Politecnico di Torino*
23	**Trento**	*Università degli studi di Trento*
24	**Trieste**	*Università degli studi di Trieste*
25	**Udine**	*Università degli studi di Udine*
26	**Varese**	*Università degli studi dell'Insubria*
27	**Venezia**	*Università IUAV di Venezia*
28	**Vicenza**	*Università degli studi di Padova - Sede di Vicenza*

The research has been developed according to the following method: for every university and for the classes L-7, L-9, L-17, L-21, L-23 belonging to the first-cycle degrees, LM-3, LM-23, LM-24, LM-30, LM-35 belonging to the second-cycle degrees and LM-4 belonging to single-cycle degree, the respective manifestos of the degree courses have been analysed.

The choice of the classes was made on the bases of the experience and it was directed towards those degree classes that contents had a great probability to have courses related with the objectives declared in the present work. Table 52 shows the denomination of every degree class. The classes of degree taken into consideration are respectively divided for the first cycle, the second cycle and the single cycle degree.

Table 52: List of the Classes of Degree Courses for cycle of study

Cycle Degrees analysed Web References: http://www.universitaly.it	
FIRST CYCLE DEGREES	
CODE	NAME OF THE CYCLE DEGREE
L - 7	Civil and Environmental Engineering
L - 9	Industrial Engineering
L - 17	Architecture
L - 21	Town, Regional and Environmental Planning
L - 23	Building Sciences
SECOND CYCLE DEGREES	
CODE	NAME OF THE CYCLE DEGREE
LM - 3	Landscape architecture
LM - 23	Civil Engineering
LM - 24	Construction Engineering
LM - 30	Energy and Nuclear Engineering
LM - 35	Environmental Engineering
SINGLE CYCLE DEGREES	
CODE	NAME OF THE CYCLE DEGREE
LM - 4	Architecture and Architectural Engineering

Table 53 shows quantitative data related to the number of degree courses for each delivered class for the total number of universities on a national level. The last two columns contain the quantitative data of the survey related to the number of degree courses for the total number of universities in the studied geographical area.

Table 53: Comparison of the number of Degree courses and Provider University in Italy and in geographical area object of investigation

CODE	NAME OF THE CYCLE DEGREE	*Number Degree Course*	*Number of Provider University*	*Number Degree Course survey object*	*Number of Provider University survey object*
FIRST CYCLE DEGREES					
L -7	Civil and Environmental Engineering	60	43	22	15
L -9	Industrial Engineering	130	46	63	17
L -17	Architecture	15	14	5	5
L -21	Town, Regional and Environmental Planning	11	11	4	4
L -23	Building Sciences	15	14	5	4
SECOND CYCLE DEGREES					
LM -3	Landscape architecture	3	3	1	1
LM -23	Civil Engineering	49	42	15	13
LM -24	Construction Engineering	16	14	6	4
LM -30	Energy and Nuclear Engineering	17	15	7	6
LM -35	Environmental Engineering	30	26	14	11
SINGLE CYCLE DEGREES					
LM -4	Architecture and Architectural Engineering	32	26	9	8

Inside the manifestos of the studies for every course of degree related to the classes taken into consideration, the courses belonging to the following Scientific Disciplinary Sectors[19]: ICAR/10, ICAR/11, ICAR/12, ICAR 13, ICAR/20 e ICAR/21, ING-IND/09, ING-IND/10, ING-IND/11, ING-IND/19, ING-IND/25, ING-IND/27, ING-IND/31, ING-IND /32, ING-IND/33, ING-INF/04, FIS/06 (Table 54). The Scientific Disciplinary Sectors4 have been individualized both on the base of the experience of the authors and from the analysis of their "declaratorie"[20] coherent with the objectives of this report.

Table 54: Academic Disciplines List for Italian university research and teaching

Scientific Disciplinary Sector Web References: http://www.universitaly.it	
CODE	***NAME OF THE CYCLE DEGREE***
ICAR/10	Building design
ICAR/11	Building production
ICAR/12	Architectural technology
ICAR/13	Design
ICAR/20	Urban and regional planning
ICAR/21	Urban and landscape planning

[19]Annex A to D.M. 4th October 2000. List of Scientific Disciplinary Sectors
[20]Annex B to D.M. 4th october 2000. Declaratorie: Description of contents of Scientific Disciplinary Sectors. Art. 1 D.M. 23th December 1999.

CODE	*NAME OF THE CYCLE DEGREE*
ING-IND/09	Energy systems and power generation
ING-IND/10	Thermal engineering and industrial energy systems
ING-IND/11	Building physics and building energy systems
ING-IND/19	Nuclear power plants
ING-IND/25	Chemical plants
ING-IND/27	Chemical technologies
ING-IND/31	Electrical engineering
ING-IND/32	Power electronic converters, electrical machines and drives
ING-IND/33	Electrical power systems
ING-INF/04	Systems and control engineering
FIS/06	Physics of the Earth and of the circum terrestrial medium

Finally, for every course, the available programs listed on the websites of the athenaeums have been analysed. Within the programs, contents connected to the theme of solar energy were looked at. The analysis made it possible for each university and for each university centre to compile Table 55 with a list of the courses delivering the afore-mentioned contents. Table 55 shows the class of degree course, the degree course, the course unit name, the code of the scientific disciplinary sector, the typology (i.e. A-base, B-characterising, C-similar integrative, D-choice of the student), and the number of ECTS credits.

Table 55: List Courses having inside the program the matter of the solar energy

Location: ***BERGAMO (1)***		**University of Bergamo** Università degli studi di Bergamo			
		Education institute and faculty: ***Università degli studi di Bergamo***			
		Web References: ***http://www.unibg.it***			
CYCLE DEGREE	***DEGREE COURSE***	***COURSE UNIT NAME***	***CODE***	***TIPOLOGY***	***ECTS***
L-9	Industrial engineering	Renewable Energy Technologies	ING-IND/09	D	6
LM- 24	Construction Engineering	Energy saving techniques in buildings	ING-IND/11	n.d.	9

Location: ***BOLOGNA (2)***		**University of Bologna** Università di Bologna			
		Education institute and faculty: ***Università di Bologna***			
		Web References: ***http://www.unibo.it***			
CYCLE DEGREE	***DEGREE COURSE***	***COURSE UNIT NAME***	***CODE***	***TIPOLOGY***	***ECTS***
L-9	Industrial Engineering	Energy Management	ING-IND/10	C	9
L-9	Industrial engineering	Placing of Energy Systems	ING-IND/19	D	6
LM -30	Energy and Nuclear Engineering	Solar and Geothermal System	ING-IND/10	B	6
LM -30	Energy and Nuclear Engineering	Innovative Technologies for Electric Energy Production, Transfer and Storage	ING-IND/33	B	6

Location: ***CESENA (5)***	**University of Bologna- Cesena Campus** Università di Bologna-Sede di Cesena				
		Education institute and faculty: ***Università di Bologna***			
		Web References: ***http://www.unibo.it***			
CYCLE DEGREE	***DEGREE COURSE***	***COURSE UNIT NAME***	***CODE***	***TIPOLOGY***	***ECTS***
LM -4	Architecture and Architectural Engineering	Environmental Planning	ICAR/12	D	5
LM -4	Architecture and Architectural Engineering	Modelling of Energy-Consumption Behaviours	ING-IND/11	n.d.	4

Location: ***COMO (7)***	**Polytechnic University of Milan- Como Campus** Politecnico di Milano - Polo di Como				
		Education institute and faculty: ***Politecnico di Milano***			
		Web References: ***http://www.polimi.it***			
CYCLE DEGREE	***DEGREE COURSE***	***COURSE UNIT NAME***	***CODE***	***TIPOLOGY***	***ECTS***
LM -35	Environmental Engineering	Energy for sustainable development	ING-IND/10	C	6

Location: ***FERRARA (8)***	**University of Ferrara** Università degli studi di Ferrara				
		Education institute and faculty: ***Università degli studi di Ferrara***			
		Web References: ***http://www.unife.it***			
CYCLE DEGREE	***DEGREE COURSE***	***COURSE UNIT NAME***	***CODE***	***TIPOLOGY***	***ECTS***
L-9	Industrial engineering	Energy systems	ING-IND/09	B	6

Location: ***GENOVA (9)***	**University of Genoa** Università degli studi di Genova				
		Education institute and faculty: ***Università degli studi di Genova***			
		Web References: ***http://www.unige.it***			
CYCLE DEGREE	***DEGREE COURSE***	***COURSE UNIT NAME***	***CODE***	***TIPOLOGY***	***ECTS***
LM-23	Civil Engineering	Environmental Energetics	ING-IND/10	C/D	5
LM -35	Environmental E.	Environmental Energetics	ING-IND/10	C/D	5

Location: ***MILANO (13)***	**Polytechnic University of Milan** Politecnico di Milano				
		Education institute and faculty: ***Politecnico di Milano***			
		Web References: ***http://www.polimi.it***			
CYCLE DEGREE	***DEGREE COURSE***	***COURSE UNIT NAME***	***CODE***	***TIPOLOGY***	***ECTS***
L-17	Architecture	Technological systems for buildings	ING-IND/11	A	4
LM -24	Construction Engineering	Mechanical technical equipment for buildings	ING-IND/11	B/C	6
LM -30	Energy and Nuclear Engineering	Power production from renewable energy	ING-IND/09	B	8
LM -30	Energy and Nuclear Engineering	Power Production from renewable energy	ING-IND/09	B/C	8

LM -30	Energy and Nuclear Engineering	Engineering of solar thermal processes	ING-IND/11	B/C	8
LM -30	Energy and Nuclear Engineering	Heating and cooling systems	ING-IND/11	B/C	10
LM -30	Energy and Nuclear Engineering	Energy savings and renewable energies in buildings	ING-IND/11	B/C	8
LM -35	Environmental Engineering	Processes for energy and environment	ING-IND/27	B	10
LM -4	Architecture and Architectural Engineering	Energy Efficient Buildings	ICAR/10	B/C	6
LM -4	Architecture and Architectural Engineering	Building Elements Design and Laboratory	ICAR/10-11	B/C	12
LM -4	Architecture and Architectural Engineering	Sustainable Building Technologies and Studio	ICAR/11	B	12
LM -4	Architecture and Architectural Engineering	Environmental physics	ING-IND/11	A	9

Location: ***PADOVA (15)***

University of Padova
Università degli studi di Padova

Education institute and faculty: ***Università degli studi di Padova***

Web References: ***http://www.unipd.it***

CYCLE DEGREE	*DEGREE COURSE*	*COURSE UNIT NAME*	*CODE*	*TIPOLOGY*	*ECTS*
LM -30	Energy and Nuclear Engineering	Renewable energy sources	ING-IND/10	B	9
LM -30	Energy and Nuclear Engineering	Energy and buildings	ING-IND/10	B	6
LM -30	Energy and Nuclear Engineering	Photovoltaic Science and technology	ING-IND/31	Affine/ integrativa	6
LM -30	Energy and Nuclear Engineering	Electrical energy conversion equipment for renewable sources	ING-IND/32	B	6

Location: ***PAVIA (17)***

University of Pavia
Università degli studi di Pavia

Education institute and faculty: ***Università di Pavia***

Web References: ***http://www.unipv.it***

CYCLE DEGREE	*DEGREE COURSE*	*COURSE UNIT NAME*	*CODE*	*TIPOLOGY*	*ECTS*
L-9	Industrial engineering	Energy conversion and renewable energy sources	ING-IND/33	n.d.	6
LM -35	Environmental Engineering	mod. Environmental Physics in Environmental Physics and Hydraulic Systems	ING-IND/11	n.d.	6
LM -35	Environmental Engineering	Energy conversion and renewable energy sources	ING-IND/33	n.d.	6
LM -35	Environmental Engineering	*	ING-IND/32	n.d.	6
LM -35	Environmental Engineering	mod. Environmental Physics in Environmental Physics and Hydraulic Systems	ING-IND/11	n.d.	6
LM -4	Architecture and Architectural Engineering	Building Technologies for sustainable architecture	ICAR/10	n.d.	9

Location: ***SAVONA (21)***	**University of Genoa- Campus Savona** Università degli studi di Genova -Polo di Savona			
	Education institute and faculty: ***Università degli studi di Genova***			
	Web References: ***http://www.unige.it***			

CYCLE DEGREE	*DEGREE COURSE*	*COURSE UNIT NAME*	*CODE*	*TIPOLOGY*	*ECTS*
L-9	Industrial engineering	Systems for energy and environment	ING-IND/09	B	6
L-9	Industrial engineering	Power System Control and Optimization	ING-IND/33	B	6
L-9	Industrial engineering	Systems for energy and environment	ING-INF/04	B	6

Location: ***TORINO (22)***	**University of Turin** Politecnico di Torino			
	Education institute and faculty: ***Politecnico di Torino***			
	Web References: ***http://www.polito.it***			

CYCLE DEGREE	*DEGREE COURSE*	*COURSE UNIT NAME*	*CODE*	*TIPOLOGY*	*ECTS*
L-7	Civil and Environmental Engineering	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L-7	Civil and Environmental Engineering	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L-9	Industrial engineering	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L-9	Industrial engineering	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L-9	Industrial engineering	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L-9	Industrial engineering	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L-9	Industrial engineering	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L-9	Industrial engineering	Applied energy and renewable sources	ING-IND/10	B	10
L-9	Industrial engineering	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L -17	Architecture	Combined Heat and Power (CHP) Plants	ING-IND/09	D	6
L -17	Architecture	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L -21	Town, Regional and Environmental Planning	Energetic efficiency of the built environments	ING-IND/11	C	6
L -21	Town, Regional and Environmental Planning	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L -21	Town, Regional and Environmental Planning	Combined Heat and Power (CHP) Plants	ING-IND/09	D	6
L -21	Town, Regional and Environmental Planning	Introduction to Sustainable Engineering	ING-IND/25	D	6
L -23	Building Sciences	Introduction to Sustainable Engineering	ING-IND/25	D	6
L -23	Building Sciences	Photovoltaic and wind systems for electricity production	ING-IND/33	D	6
L -23	Building Sciences	Combined Heat and Power (CHP) Plants	ING-IND/09	D	6
LM -30	Energy and Nuclear Engineering	Energy savings and comfort in buildings	ING-IND/11	B	8
LM -30	Energy and Nuclear Engineering	Power generation from renewable sources	ING-IND/33	D	6
LM -30	Energy and Nuclear Engineering	Technology for renewable energy sources	ING-IND/11	B	8

Location: ***TRENTO (23)***		University of Trento Università degli studi di Trento			
		Education institute and faculty: ***Università degli studi di Trento***			
		Web References: ***http://www.unitn.it***			
CYCLE DEGREE	***DEGREE COURSE***	***COURSE UNIT NAME***	***CODE***	***TIPOLOGY***	***ECTS***
LM -30	Energy and Nuclear Engineering	Renewable Energy and Meteorology	FIS/06	D	6
LM -30	Energy and Nuclear Engineering	Solarenergiesystem	ING-IND/11	D	6

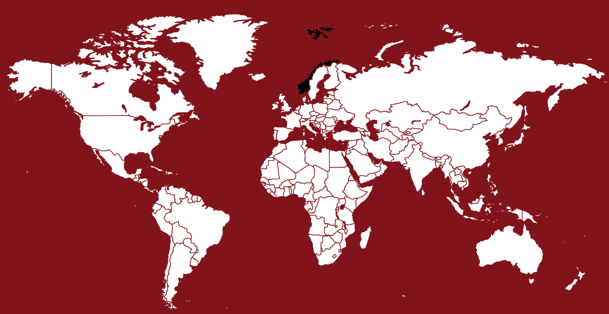
The last column of Table 56 shows the number of courses for each university that apply to the criterion outlined for the survey.

Table 56: Number of courses related to solar subject in every university

N.	City	University	N. of Courses
1	**Bergamo**	*Università degli studi di Bergamo*	2
2	**Bologna**	*Università di Bologna*	4
3	**Bolzano**	*Libera Università di Bolzano*	-
4	**Brescia**	*Università degli studi di Brescia*	-
5	**Cesena**	*Università di Bologna - Sede di Cesena*	2
6	**Cremona**	*Politecnico di Milano - Sede di Cremona*	-
7	**Como**	*Politecnico di Milano*	1
8	**Ferrara**	*Università degli studi di Ferrara*	1
9	**Genova**	*Università degli studi di Genova*	2
10	**Gorizia**	*Università degli studi di Trieste - Polo universitario di Gorizia*	-
11	**Lecco**	*Politecnico di Milano - Polo territoriale di Lecco*	-
12	**La Spezia**	*Università degli studi di Genova – Polo Universitario della Spezia*	-
13	**Milano**	*Politecnico di Milano*	12
14	**Modena**	*Università degli studi di Modena*	-
15	**Padova**	*Università degli studi di Padova*	4
16	**Parma**	*Università degli studi di Parma*	-
17	**Pavia**	*Università di Pavia*	6
18	**Piacenza**	*Politecnico di Milano*	-
19	**Ravenna**	*Università degli studi di Bologna*	-
20	**Reggio Emilia**	*Università degli studi di Modena e Reggio Emilia*	-
21	**Savona**	*Università degli studi di Genova - Polo di Savona*	3
22	**Torino**	*Politecnico di Torino*	23
23	**Trento**	*Università degli studi di Trento*	2
24	**Trieste**	*Università degli studi di Trieste*	-
25	**Udine**	*Università degli studi di Udine*	-

N.	City	University	N. of Courses
26	**Varese**	*Università degli studi dell'Insubria*	-
27	**Venezia**	*Università IUAV di Venezia*	-
28	**Vicenza**	*Università degli studi di Padova - Sede di Vicenza*	-


14,15,16
17,18,19
Norwegian University of Science and Technology
1,2,3,4,5,6,7
8,9,10,11
University of Oslo
12,13
Norwegian University of Life Science (nmbu)



Norway

8. Norway

8.1. Interviews - Evaluation of Existing Courses in Tertiary Education

The first method used for investigating the existing courses in tertiary education in terms of solar energy and its implications in the design process has been to directly contact the responsible person of the course and conduct an interview based on the most important points of the teaching principles and the organisation of the course. The areas of investigation were:

- Information of the course;
- Time spent on teaching method;
- Value put on method;
- Pedagogic methods;
- Process tools;
- Digital tools;
- Involvement of practicing professionals;
- Student background;
- Principles of teaching;
- Legal regulations;
- Teaching sources;
- Cooperation with other education institutes;
- Consideration for buildings/neighbourhoods/Cities; and
- Request report

It was possible to get information only from coordinators of four courses. For the rest of the courses, the information has been taken from each course website. For this reason, not all information areas are available. However, the results show that it is possible to get an overview of the state of the art of education on solar energy and solar urban/building design in Norway.

Most of the courses on the energy topics active in Norway have been collected by the NorRen – The Norwegian Research School in Renewable Energy (NorRen - The Norwegian Research School in Renewable Energy, 2014).

The courses are divided in 11 categories: bioenergy, economics, energy, geothermal energy, hydropower, law, ocean energy, political science, solar energy, smart grid, and wind energy. In Table 57, all of the operative courses in Solar Energy are listed. There are a total of 14 courses on the topic of solar energy. Through this classification, it was revealed that only three universities in Norway have courses on solar energy (Nokut - Norwegian Agency for Quality Assurance in Education, 2010). These are the University of Oslo (UiO), Norges miljø- og biovitenskapelige universitet (NMBU) and the Norwegian University of Science and technology (NTNU).

Table 57: List of the courses in solar energy in Norway (NorRen - The Norwegian Research School in Renewable Energy, 2014)

Institute		Department	Category	PhD code	Master code	Title	Semester	Type	ECTS
1	UiO	Physics	Solar energy	MENA9010	MENA5010	Nanophysics	Spring	Intensive	10
2	UiO	Physics	Solar energy	MENA9510		Advanced Characterization methods	Autumn	Intensive	5
3	UiO	Physics	Solar energy	MENA9520		Ab initio modelling of solar cell materials	Spring	Intensive	5
4	UiO	Physics	Solar energy	FYS9310	FYS4310	Material science of semiconductors	Spring	Intensive	10
5	UiO	Physics	Solar energy	FYS9540	FYS4540	Energifysikk-solenergi	Autumn	Intensive	10
6	UiO	Physics	Solar energy	UNIK9450	UNIK4450	Solceller	Autumn		10
7	UiO	Physics	Solar energy	UNIK9460	UNIK4460	Photovoltaic devices, technology and system	Spring		10
8	UiO	Chemistry	Solar energy		KJM5100	Uorganiskmaterialsyntese	Autumn		10
9	UiO	Chemistry	Solar energy		KJM5120	Defektkjemiogreaksjoner	Autumn		10
10	UiO	UiO Energy	Solar energy	MILEN9020		Technology and ethnographic methods, in the context of implementing new technology on household level	Spring	Intensive	5
11	UiO	UiO Energy	Solar energy	MILEN9102		Development and implementation of technology, a focus on solar energy	Spring		2
12	UMB	Mathematical Sciences and Technology	Solar energy		FYS372	Solcelleteknologi	Autumn		5
13	UMB	Mathematical Sciences and Technology	Solar energy		FYS376	Solenergi	Autumn		10
14	NTNU	Material Science and Engineering	Solar energy	MT8214		Advanced Silicon - Solar Cells	Spring		7,5
15	NTNU	Material Science and Engineering	Solar energy		TMT4285	Hydrogen Technology, Fuel Cells and Solar Cells	Spring		7,5
16	NTNU	Material Science and Engineering	Solar energy		TMT4322	Solar Cells and Photovoltaic Nanostructures	Autumn		7,5
17	NTNU	Faculty of Architecture and Fine Arts	Solar energy design		AAR4532 AAR4832	Climate and built forms (Design and Theory)	Autumn		15+ 7.5
18	NTNU	Faculty of Architecture and Fine Arts	Solar energy design		AAR4926	Integrated Energy Design	Autumn		15+ 7.5
19	NTNU	Faculty of Architecture and Fine Arts	Solar energy		AAR4845	Landscape Analysis	Autumn		7.5

However, some courses that use the principle of solar energy for technical and design purposes have not yet been listed in the NorRen database. The missing courses have been collected and analysed in the following pages. Actually some courses, especially the ones that use solar energy for architectural and design scopes, could never be included in the NorRen database. Despite this, these courses have to be included in this review considering the importance of solar energy in affecting the design, technical and architecture choices. The most important features of the courses related to solar energy in Norway are summarized below. The information has been collected combining the interviews of the course coordinator and the information on the webpage of each course. The results of the courses with more applications and implications in solar energy in urban planning are presented in the following pages.

Table 58: Some of the courses on solar energy at the University of Tromsø (University of Tromsø, 2015)

Respondent 1	**Universitetet i Tromsø** University of Tromsø
Education institute and faculty	University of Tromsø, Faculty of Science and Technology
Respondent Position	Professor
Name of course	Solar energy and energy storage
Course level	Masters
Total credits	10
Course code	FYS 3028\8028
Course category	Solar energy
Student background	Students must have a degree in physics/engineering and recommended to have quantum physics
Recommended prerequisites	FYS-2000 Quantum mechanics, MAT-2200 Differential Equations, MAT-2201 Numerical Methods
How old is the course?	New (Not started)
Teaching language	English
Mandatory/Optional	Both 50/50
Average no. of students	Expected 20
Reference	(University of Tromsø, 2015)

Table 59: Some of the courses on solar energy at Norwegian University of Science and Technology – Trondheim (Norwegian University of Science and Technology, 2010b)

Respondent 2	**Norges teknisk-naturvitenskapelige universitet** Norwegian University of Science and Technology
Education institute and faculty	Norwegian University of Science and Technology (NTNU), Department of Architectural Design, History and Technology - Faculty of Architecture and Fine Arts
Respondent Position	Associate Professor
Name of course	Climate and built forms (Design and Theory)
Course level	Masters
Total credits	15+7.5
Course code	AAR4532 and AAR4832
Course category	Solar energy
Student background	Architecture or different kinds of engineering

Recommended prerequisites	Completed three years, basic courses in architecture, engineering or urban planning; bachelor in architecture, engineering or urban planning; or equivalent. Semester programme is coordinated with AAR4833 - Concepts and Strategies in Sustainable Architecture and AAR4532 - Climate and Built form Design Project.
How old is the course?	3 years
Teaching language	English
Mandatory/Optional	Mandatory
Average no. of students	20-30
Reference	(Norwegian University of Science and Technology, 2010a)
Respondent 3	**Norges teknisk-naturvitenskapelige universitet** Norwegian University of Science and Technology
Education institute and faculty	Norwegian University of Science and Technology (NTNU), Department of Architectural Design, History and Technology - Faculty of Architecture and Fine Arts
Respondent Position	Associate Professor (Course); Postdoctoral Research Fellow (Module)
Name of course	Module on Parametric design & Solar analysis within the course of Integrated Energy Design
Course level	Masters
Total credits	15+7.5
Course code	AAR4926
Course category	Parametric modelling & Solar design; Architecture; Energy and Indoor Environment; Building Science
Student background	Architecture or different kinds of engineering
Recommended prerequisites	Completed three years, basic courses in architecture, engineering or urban planning; bachelor in architecture, engineering or urban planning; or equivalent. Students following AAR4616 Integrated Energy Design Project must also follow AAR4626. The semester programmes for courses AAR4907, AAR4616 and AAR4926 are coordinated to match.
How old is the course?	1 year
Teaching language	English
Mandatory/Optional	Mandatory
Average no. of students	20-30
Reference	(Norwegian University of Science and Technology, 2010b)
Respondent 4	**Norges teknisk-naturvitenskapelige universitet** Norwegian University of Science and Technology
Education institute and faculty	Norwegian University of Science and Technology (NTNU), Department of Urban Design and Planning- Faculty of Architecture and Fine Arts
Respondent Position	Adjunct Professor (Course); Professor (Module)
Name of course	Landscape analysis
Course level	Masters
Total credits	7.5
Course code	AAR4845
Course category	Parametric modelling & Solar design; Architecture; Energy and Indoor Environment; Building Science, Architecture, Information Systems, Landscape Planning, Planfag
Student background	Bachelor in geography, civil engineering, urban planning, architecture

Recommended prerequisites	None
How old is the course?	More than 10 years
Teaching language	Norwegian
Mandatory/Optional	Mandatory
Average no. of students	20-30
Reference	(Norwegian University of Science and Technology, 2010b)

Regarding the "Norges miljø – og biovitenskapelige universitet" (NMBU), two courses on solar energy have been detected. The first one is in the Solar Technology course (FYS372) that is not currently operative and the second entitled Solar Energy (FYS376) that is focused on the principles, theory and application of photovoltaic solar cells in the construction and design systems.

Table 60: Some of the courses on Solar Energy at Norges miljø- og biovitenskapelige universitet – Oslo (Norges miljø og biovitenskapelige universitet, 2012)

Respondent 4	**Norges miljø- og biovitenskapelige universitet** **Norwegian University of Life Sciences**
Education institute and faculty	Norgesmiljø- ogbiovitenskapeligeuniversitet (NMBU), Department of Mathematical Sciences and Technology (IMT)
Respondent Position	Associate Professor
Name of course	Solar energy
Course level	PhD/ Masters
Total credits	10
Course code	FYS376
Course category	Solar energy
Student background	MSc/Engineering/Physics
Recommended prerequisites	FYS 271, FYS 251, KJM 100
How old is the course?	20-30 years
Teaching language	Norwegian
Mandatory/Optional	Optional
Average no. of students	5 students minimum
Reference	(Norges miljø og biovitenskapelige universitet, 2012)

Table 61: Some of the courses on Solar Energy at Norges miljø- og biovitenskapelige universitet – Oslo (Norges miljø og biovitenskapelige universitet, 2012)

Respondent 5	**Universitetet i Oslo** **University of Oslo**
Education institute and faculty	University of Oslo (UiO), Department of Physics
Respondent Position	/ (Information from the website of UiO)
Name of course	Energy Physics - Solar Energy
Course level	PhD
Total credits	10
Course code	FYS9540
Course category	Solar energy

Student background	MSc/Engineering/Physics and energy resources
Recommended prerequisites	FYS3320 - Physics and energy resources
How old is the course?	4 years (but the course is discontinued)
Teaching language	Norwegian (English on demand)
Mandatory/Optional	Optional
Average no. of students	Minimum number of students for activing the course is 4
Reference	(University of Oslo, 2014b)
Respondent 6	Universitetet i Oslo University of Oslo
Education institute and faculty	University of Oslo (UiO), Department of Physics
Respondent Position	/ (Information from the website of UiO)
Name of course	Energy physics - Solar energy
Course level	Masters
Total credits	10
Course code	FYS4540
Course category	Solar energy
Student background	/ (Bachelor course)
Recommended prerequisites	FYS3320 - Physics and energy resources
How old is the course?	10 years (but the course is discontinued)
Teaching language	Norwegian (English on demand)
Mandatory/Optional	Optional
Average no. of students	Minimum number of students for activing the course is 4
Reference	(University of Oslo, 2014a)
Respondent 7	Universitetet i Oslo University of Oslo
Education institute and faculty	University of Oslo (UiO), Interdisciplinary courses within Social Sciences
Respondent Position	/ (Information from the website of UiO)
Name of course	Development and implementation of technology, a focus on solar energy
Course level	PhD
Total credits	2
Course code	MILEN9102
Course category	Solar energy
Student background	No obligatory prerequisites beyond the minimum requirements for entrance to higher education in Norway.
How old is the course?	1 year
Teaching language	English
Mandatory/Optional	Optional
Average no. of students	N/A
Reference	(University of Oslo, 2013)

According to UiO, the two courses of FYS9540 and FYS4540 were given for the last time at the department of physics in the autumn of 2013. Also the course MILEN9102 was taught only once in the spring 2013 in the University of Oslo and the course MILEN9020 has not been offered either since 2013. There has been some discussion, however, about offering the course for a second time after 2016, but this decision has not yet been finalised.[21]

[21] University of Oslo

8.2. Which are the Principles that You are Teaching Related to Solar Energy in Urban Planning?

The contents of the NMBU course are organised in several topics. After a general introduction, the course focuses on the sun as energy source and the principles of photovoltaic solar cells from sand to solar cells and PV systems, solar heat absorbers, and solar heat systems. In the last part, it analyses environmental aspects of solar technologies and their integration in the buildings.

At the NTNU, in the course of Climate and Built Forms (Design and Theory), the students learn to analyse local site and climate and their consequences for the built form. Particular attention is dedicated to daylight, solar access and shading principles, ventilation, wind and precipitation and climate-adapted design of outdoor-indoor areas. The contents of the Integrated Energy Design course are energy systems and services and their integration in architecture, solar energy and challenges related to the renovation of existing buildings and cultural heritage, design and evaluation tools in the Integrated design methodology. Also the course Landscape analysis AAR4845 at NTNU provides an introduction to landscape theory and landscape history, landscape analysis, analysis of possibilities and limitations in the landscape and natural environment on the basis of ecological, resource and visual conditions. It focuses on the use of GIS (Geographical Information System) as a tool in landscape analysis. Lectures for GIS cover terrain analysis, including view shed analysis, solar/shading analysis and similar topics. The exercises comprise the building of digital terrain models (TIN and raster models), and the utilisation of them (together with building volumes and other solid objects), for visibility analysis, sun-shadow maps etc.

In the University of Oslo, the FYS9540 and FYS4540 course topics are energy needs, energy consumption and energy conservation from a physics perspective, as well as solar energy, energy density, availability, time and angle dependency, spectral characteristics. The methods are used for solar energy exploitation, including the absorption and emission of electromagnetic radiation from different materials, as well as technical design and construction of devices for solar energy exploitation (University of Oslo, 2014b) (University of Oslo, 2014a). The MILEN9102 course focuses on the implementation of solar energy technology for provision of electricity in developing countries. The successful introduction and use of a technology depends on paying close attention to both the social and the technical side in a coherent manner (University of Oslo, 2013).

All respondents referred to pedagogic methods as involving solar energy practices but none related to urban planning practices. However, some courses have specific application of solar technologies in developing the building's design based on solar principles.

Students are examined either once or twice a year as well as with compulsory assignments. Unlike the other courses, the NTNU courses involve interdisciplinary cooperation with other courses, offering some work experience with industry. The NTNU course as well as that offered by the University of Tromsø, have students conducting presentations and doing individual and group projects. Student group projects were also done at NMBU.

The course goals indicated in Table 62 are related to the learning outcomes and diverged whether the course emphasized solar energy in renewable energy or in architectural design.

Table 62: Course goals and learning outcomes of different respondents.

Institute	Course goals	Learning outcomes
University of TromsøUiT Course: Solar energy and energy storage	Understanding conversion of solar energy into electricity and heat; principle of PV conversion in solar cells; harvesting and storing of energy and solar cell technology	• Convert solar energy into electricity and heat; harvesting and storing solar energy; • Explain the physical working principles of photovoltaic conversion in solar cell; • Analyse the performance of solar cells and modules; • Obtain knowledge about the research and development progress of solar energy applications and how to critically assess new scientific findings within the area; • Communicate solar energy theories, problem descriptions and solutions
Norwegian University of Science and Technology NTNU Course: Climate and built forms	Understanding architectural design of sustainable buildings as a meaningful process based on the understanding of the external environment resources.	• Ability read and use climatic chart as basis for design. • Ability to use energy simulation models, understanding their basic principles and assume a critical approach towards their outcome. • Ability to define an entire design process on the basis of the climate analysis. • Ability to develop a climate adapted concept from early stage to detail.
Norwegian University of Science and Technology NTNU Course: Integrated Energy Design Module of Parametric Modelling Design & Solar analysis	Understanding the defined problems of complex geometric form in architecture developing the ability in conducting solar analysis in the design processes through parametric and generative design tools combined by energy simulation analysis software.	• The students will learn the principles for the integration of energy systems in new and existing buildings. • Tools and methods for practical use by the participants involved in a design process (building owners, architects, consulting engineers). • Students will gain competence in models for interdisciplinary design processes that facilitate their successful functioning.
Norwegian University of Science and Technology (NTNU), Department of Urban Design and Planning-Faculty of Architecture and Fine Arts Course: Landscape analysis	The course will also focus on design of the landscape with an emphasis on the design of urban spaces and landscape elements in cities and towns.	• KNOWLEDGE: Introduction to ecologically based landscape planning in a detailed as well as a broad scale, with weight on analysis methods. • SKILLS: Use of advanced analysis tool in land use planning and landscape planning. • GENERAL COMPETENCE: Understanding of the importance of landscape in all land use planning.
Norges miljø- og biovitenskapelige universitet NMBU	Enable the student to understand: Principles, construction and design of systems for conversion of solar energy to heat and electricity.	• Enable the student to understand: Principles, construction and design of systems for conversion of solar energy to heat and electricity.
University of Oslo (UiO) Course: Energy Physics - Solar Energy	The course will give an understanding of basic principles of energy consumption and energy conservation, from both a physical and a social perspective.	• It will give skills and understanding about how solar energy can be exploited, with emphasis on the physical processes and limitations or/and possibilities. • Emphasis will be placed on the experimental and technical measurement aspects of the characterization and evaluation of solar energy as well as various other types of energy systems.

Institute	Course goals	Learning outcomes
University of Oslo (UiO) Course: Development and implementation of technology, a focus on solar energy	The course will give increased knowledge on how solar energy technology can best be implemented, used and adapted to local contexts.	The students will learn about: • Solar energy in the North and the South - now and in the future. • How to create viable models for local solar power supply that can be replicated in a large number of villages.

8.3. Used Sources for Education

NTNU courses had a range of practicing professionals with municipal experts, designers and architects. The involvement of municipal experts may indicate some involvement of urban planning. The University of Tromsø course is new but the respondent considered that the course may involve urban planners, architects and other different scientists. NMBU did not mention the involvement of practicing professionals.

Other text-based teaching resources were based on policy reports, such as that used by IPCC in the course at the University of Tromsø. In the courses at NTNU, standards books such as Heating, Cooling and Lighting (N. Lechner) and Introduction to Architectural Science (S. Szokolay) were used. NMBU referred to use policy reports, standards, books and journal articles.

Table 63 indicates tools and instruments used during the courses. The NTNU courses were the only ones that refer to process tools. This may be because this course is focusing on architectural design which is in direct contrast to the other two focused on renewable energy. Digital tools are also quite different across the university courses involved. While the University of Tromsø and NMBU courses do have different experiments and measurements, the NTNU respondent believed that this was a weak area in their courses.

Table 63: Course goals and learning outcomes of different respondents

Institute	Process tools	Digital tools	Experiment and practical measurements
University of TromsøUiT Course: Solar energy and energy storage	No	Pvsyst, Polysun	Pyranometer
Norwegian University of Science and Technology NTNU Course: Climate and built forms	Transition pathways, Stakeholder involvement, Building information modelling, Life-cycle assessment	PvsystDayism, Ecotect,	/
Norwegian University of Science and Technology NTNU Course: Integrated Energy Design Module of Parametric Modeling Design & Solar analysis	Analysis and replicability of symbolic architectures, Solar potential analysis.	DIVA for Rhino DIVA for Grasshopper Grasshopper & Rhinoceros	/
Norwegian University of Science and Technology (NTNU), Department of Urban Design and Planning- Faculty of Architecture and Fine Arts Course: Landscape analysis	Land suitability analysis	ArcGIS. Web based solar angle calculator	building of digital terrain models (TIN and raster models)
Norges miljø- og biovitenskapelige universitet NMBU	No	Simulation programs, GIS, E-Learning platforms	Modelling and testing of PV array and 2 solar heat systems
University of Oslo	No		

8.4. Description of Taught Principles Related to Solar Energy in Urban Planning

a) Legislations

At NTNU, there are four different standards offered and taught to students for applying, calculating energy demand and ranking the level of sustainability according to various standards. These standards include:

- **TEK 10:** Guidance on technical requirements for buildings: Regulation on technical requirements for buildings pulls up limit for the minimum features an edifice must have to be constructed legally in Norway. This guide explaining regulations elaborates contents and provides guidance on how the requirements can be met within practice. The guide also includes a portion advising how buildings can exceed minimum standards. It is permissible and often wise to design and build structures that exceed minimum legal requirements.[22]

- **Norwegian Standards (NS 3031, NS 3700 and NS 3701)**: includes the entire standard prepared in Standard Norway committee SN/K 34 Energy performance of buildings. The standard is adapted to document the energy requirements of the Regulation on technical requirements for construction works (TEK) and to calculate the energy performance against regulations on energy labelling of buildings.[23]

- **SINTEF Byggforskserien (SINTEF Building Research Design Guides):** 'The SINTEF Building Research Design Guides consists of about 760 design guides. It is a complete source to technical solutions for buildings, and the three sub-series (Architectural Planning, Building Details and Building Management and Maintenance) present experience and solutions from both research and practice.' [24]

- **Passivhaus Standard**

- **BREEAM (Building Research Establishment Environmental Assessment Methodology):** 'BREEAM NOR is operated in Norway since 20 October 2011 by the Norwegian Green Building Council (NGBC) under licence from BRE Global.' [25]

Each one of these standards has chapters and sections for rules and regulation of building specification to optimize using renewable energy in buildings. Some of these regulations are listed in below:

- According to TEK 10
    - Energy needs for heating and hot water should wherever possible be covered with different energy than electricity and/or fossil fuels.
- According to NS 3031(Norwegian standards)
    - In cases where parts of the building are largely exposed by solar and other parts of the building are averagely exposed, it will be necessary to computationally divide the building into zones.
    When the area proportion of windows, doors and glass and total solar factor for window and shading exceeds 5%, the building is divided into at least three zones calculation as follows:
        - One zone with sun exposed facade (south, southeast and southwest orientation);
        - One zone with little sun exposed façade (north, northeast, northwest);
        - One middle zone of the building;

[22] http://dibk.no/no/BYGGEREGLER/Gjeldende-byggeregler/Veiledning-om-tekniske-krav-til-byggverk/ - TEK10
[23] Norwegian standards: NS 3031:2014
[24] http://bks.byggforsk.no/OtherLanguages.aspx?sectionId=0&language=en
[25] http://ngbc.no/breeam-nor - http://www.breeam.org/podpage.jsp?id=364

- Depth of zones with sun exposed and little sun exposed facades can be set to between 4 meters to 5 meters.
- Sunroom, atriums, glass farms or similar virtually all glass facades shall be considered as a separate zone.

• According to BREEAM-NOR[26]
  - To reduce greenhouse gas emissions, the organisation that occupies the building has in place a contract with an energy supplier to provide electricity for the assessed building/development from a 100% renewable energy source. This supply must be delivered by an accredited external renewable source. The contract must be valid for a minimum of 3 years from the date the assessed building becomes occupied.
  - To recognize and encourage the use of the building and site as a learning resource for demonstrating environmental awareness by working renewable energy source such as PV’s or wind turbines with a description of the technology and live data on energy generated and subsequent CO2 emissions prevented.
  - Solar hot water and Photovoltaics are recognised as low or zero carbon technologies (LZC)

b) Planning Processes
No information on the planning processes is currently available.

8.5. Explanation of Used Sources

a) References like reports, documentations, etc.
Each course has a dedicated bibliography or literature list with the most preparatory and useful publications and books suggested by the instructor.
All the teaching material, such as power point presentations, reports, exercitations and communications to the students are most of the time collected or posted on a web platform. At NTNU the “Itslearning” is NTNU's Internet-based system for teaching and learning, while at UiT and the University of Oslo (UiO) the Fronter is an online system used for virtual classrooms at the university. The students can also access the virtual classrooms through web browsers like Internet Explorer, Firefox, Safari etc.

Table 64: Summary of some used sources in the Norwegian Institutes.

University of Tromsø (UiT)	University of Oslo (UiO)	Norwegian University of Science and Technology (NTNU)	Norges miljø- og biovitenskapelige universitet (NMBU)
		N. Lechner, Heating, Cooling, Lighting: Sustainable Design Methods for Architects Hardcover, November 24, 2008	
/	/	Steven V. Szokolay, Introduction to Architectural science: the basis of sustainable design, Architectural Press, Elsevier Science, 2004.	Yes - Lectures, Examples, Discussions,
		Case studies; research articles and other literature; lecture notes; site visits, workshops and tutorials.	
		Compendium, composed of various method handbooks and articles	
Fronter	Fronter	Itslearning	Fronter

[26]http://ngbc.no/sites/default/files/BREEAM-NOR%20Engl%20ver%201.1_0.pdf

b) Case Studies (studying realized projects);
In collaboration with NTNU campus, ØvreRotvoll.

c) Field studies linked with excursions
Students go for a study trip in an emblematic city or site. In 2014 the NTNU students went to London during the course of the Integrated Energy Design (fall semester) to have meetings and lectures from Mott MacDonald and Laing O'Rourke.

8.6. Evaluation of the course methodology in relation to the teaching approach and success

At the University of Tromsø, for the course mentioned previously, 40 hours have to be spent on lectures and 24 hours on exercises with an unspecified amount of time for guest teachers, seminars and workshops. In the course at NTNU, 40% of the time is spent on lectures, 40% of teaching time on tutorials and the design studio with the rest of the time is divided up by guest lectures, workshops and seminars. At NTNU students are provided with both theoretical lectures and computer-based workshops where they learn different computer tools related to the courses. While in the NMBU is tentatively 2x2 weekly lecture hours with additional training that are usually arranged directly by teacher depending on the students' needs.

NTNU and NMBU's respondents commented on the value of their teaching methods with most value being placed on lectures and tutorials and NTNU respondents also rating the value of the design studio highly.

8.7. Evaluation of Existing CPD Courses

In Norway, University of Oslo (UiO) and NTNU offer continuing professional development courses and programs for their employees.[27] An extensive list of courses in different fields is available at NTNU Centre for continuing and professional development, which was established to offer both open and in-house courses.

Topics and course content
NTNU offers many courses in five different fields: technology and science, social, language and humanities, management and organisation, health and teaching.[28]

Teaching methods and instruments
According to the University of Oslo (UiO), employees are allowed to attend courses during their working hours.[29] UiO employees have right to:[30]

- develop their competencies relevant for their position;
- attend courses during working hours;
- leave with pay if they take a course (internal or external) that takes place during working hours;
- apply to participate in any course that is arranged by UiO;
- apply for financial support for further education.

[27]http://www.uio.no/english/for-employees/competence/
[28]http://videre.ntnu.no/pages/enkeltkurs/vaare_kurstilbud/
[29]http://www.uio.no/english/for-employees/competence/rights-obligations/
[30]http://www.uio.no/english/for-employees/competence/rights-obligations/

Motivation and organisation
NTNU Centre for Continuing and Professional Development organises NTNU's further and continuing education which has:[31]

- 9450 participants in further and continuing education;
- 5385 participants at conferences;
- 213 credit-based courses completed.

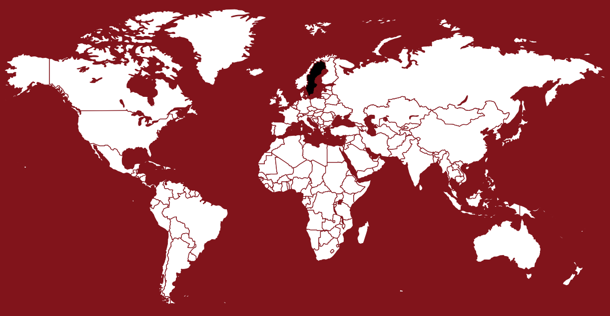
This Centre helps employees to achieve:

- Flexible post-experience master's programs;
- Tailored courses and programs to meet industry's needs; and
- Provides NTNU with valuable expertise and industrial contacts.

Continuing and professional development programs and courses at UiO focus on the importance of developing competencies so that they:[32]

- give each employee a chance to perform given work tasks in an effective and better way;
- prepare employees for mastering reorganisation; and
- make the individual employee more competitive regarding internal advancement.

[31]http://www.ntnu.edu/continuing-education
[32]http://www.uio.no/english/for-employees/competence/rights-obligations/



Sweden

9. Sweden

9.1. Selection of Study Domains in Relation to Urban Planning

In order to find out to what extent solar energy is taught in relation to urban planning, we have conducted this inquiry in two ways:

- by searching through the national database for courses with the key words “solar energy”; and
- by using the key word “sustainability” within some of the study domains where spatial planning and design is a major part of the education.

In this way, we address the four study domains where we expect urban planning and solar energy to meet:

- Architecture and urban design
- Urban and specifically spatial planning
- Civil and Energy Engineering

Within the study domains of spatial planning and design, the tradition is an educational method with a project-based approach grounded in real-world situations and problems, addressing a complex situation where the subjects (such as sustainability and solar) are intertwined into the program of the different design studios. This means that single courses focusing on one subject at a time, such as “solar energy”, is not that common. To find out whether solar energy is part of the curriculum the search for “sustainability” and experience from two exemplary schools of architecture has been used.

By searching for courses using the key words “solar energy,” we hope to cover Civil and Energy Engineering.

9.2. Spatial Planning and Design Education in Sweden

In Sweden, architecture is taught at nine architecture schools, including architecture and urban design, interior design, landscape design and urban planning. The Swedish Association of Architects is a professional organisation for architects, interior architects, landscape architects and spatial planners in 2015 with 12,300 members (including 2,600 students). The following educations (not mentioning interior design) are supported by a title from the Swedish Association of Architects:

- Schools of Architecture at KTH Royal Institute of Technology, Lund University and the Faculty of Engineering, Chalmers and Umeå University.
- Landscaping architecture at SLU Alnarp or SLU Ultuna.
- Education in Spatial Planning at Blekinge Tekniska Högskola (BTH).

KTH, Chalmers, LTH, and Umeå University have collaborated since 2009 within the platform Swedish Schools of Architecture. Urban planning is taught at BTH, with the following programs: Bachelor of Science in Spatial Planning, Master of Science in Spatial Planning, Master of Science in European Spatial Planning and Regional Development. Other university colleges and universities also offer education that contains architecture and urban design but are not assessed by the Swedish Association of Architects as full architectural educations.

Within the curriculum of these educations the triple bottom line of sustainability is mentioned but it is hard to detect to what extent active solar and passive solar (including daylight and micro-climate) is included.

The first section that follows will focus on solar energy courses, whereas the second section will focus on some examples of active and passive solar included into the curriculum of sustainability at the architectural educations in Sweden.

9.3. Evaluation of Existing Courses in Tertiary Education

In Sweden, almost all existing courses at university colleges and universities are available through a national database, accessible via a website (antagning.se). A search was performed with the key words “solar energy” and resulted only in a small amount of courses that dealt solely with solar energy.

Table 65: Existing courses in Sweden

Course name	Level	School	ECTS
Passive solar energy technology	Master	Högskolan Dalarna	5
Master Program in solar energy technology	Master	Högskolan Dalarna	60
SwB - Solar Energy 1 and 2 Technology, Economics and System Design	Master	Högskolan Dalarna	60
Solar radiation and other energy sources	Master	Högskolan Dalarna	2.5
Solar Heating Technology, Basic Course	Master	Högskolan Dalarna	7.5
Project course in solar energy systems or energy efficient buildings	Master	Högskolan Dalarna	7.5
Thermal solar power	Master	Högskolan Dalarna	5
Solar energy economy	Master	Högskolan Dalarna	5
Solar energy	Master	Högskolan i Halmstad	7.5
Solar Heating Technology, Basic Course	Master	Lunds Universitet	7.5
Photovoltaic Systems, Basic Course	Master	Lunds Universitet	7.5
Building Integrated Solar Energy Systems	Master	Lunds Universitet	7.5
Public Building - Integrating Solar Energy, Costs and Environmental Issues	Master	Lunds Universitet	15
Climate Smart Architecture and Urban Design	Master	Lunds Universitet	7.5

None of these courses was specifically called ‘solar energy in urban planning’. It should be kept in mind there is not one single education program for the profession of urban planner, since urban planners can have studied other programs, like architecture. There were many courses where solar energy was only a small part of the course. Also, there are master programs which focus on ‘sustainable urban planning’ but they hardly ever include technical aspects of (solar) energy. The national database also provided course goals and documents that were studied.

9.4. Description of Taught Principles Related to Solar Energy in Urban Planning

The following sections are focused on the solar energy courses at Lund University. The instructors of these courses were interviewed and asked to describe the principles that were taught related to solar energy in urban planning. The following table shows the aims and learning outcomes of the courses at Lund University.

Table 66: Table describing the learning outcomes

	Aim	Learning Outcomes
Lund University, Photovoltaic Systems, Basic Course	It is necessary from a national and global point of view to develop renewable energy technologies for generating electric energy. In the future, PV-system will be one of the most important technologies for producing electricity. The course aims to teach basic knowledge of how solar cells and solar cell systems work in different applications. In Sweden. building integrated PV-systems are most interesting. In the developing countries where many people live outside the electric grid, stand-alone PV systems are of great interest. The ability to simulate the performance of PV-systems is an important part of the course. After the course the student should be able to perform a prestudy of the installation of a new PV-system	*For a passing grade, the student must* • be able to estimate and describe the use of energy in a building; • be able to characterize a PV-module, i.e. measure the IV-curve; • be able to use a simulation program for estimation of the energy delivered from a PV-system; • be able to construct a stand-alone or a grid connected PV system and describe how its components work; • be able to use a simulation program for estimation of the solar irradiance towards surfaces in different geometries; and • be able to calculate the cost for PV-electricity using different methods and competing technologies.
Lund University, Solar Heating Technology, Basic Course	The aim of the course is to show how solar heating systems can be integrated in and co-operate with the buildings main energy system. An important part of the course is for the students to use simulation programs for investigating the performance of the solar system. After the course is completed the student should be able to perform a pre-study of the installation of a solar thermal system in a building or in a larger system.	*Competences and skills* For a passing grade the student must: • be able to estimate and describe the use of heat and hot water in a building; • be able to characterize a solar collector, i.e. measure the efficiency-curve; • be able to use a simulation program for estimation of the energy delivered from a solar thermal-system; • be able to design a solar thermal system and describe how its components work and adapt it to a given building; • be able to use a calculation program for estimation of the solar irradiance towards surfaces in different geometries; • be able to calculate the cost for solar thermal and competing technologies using different methods; and • understand how a solar thermal system can be designed so it interacts with other energy systems like electric heating, heat pumps, district heating and bio fuel system.
Lund University, Building Integrated Solar Energy Systems	The aim of the course is to show how active solar energy systems can be integrated in and co-operate with the main energy system of buildings.	*Competences and skills* For a passing grade the student must: • Show the ability to communicate verbally and graphically an architectural solar concept, using the appropriate vocabulary concerning the basic design of solar energy systems, the main components and connection to the existing energy system of the building; • Show the ability to carry out basic hand estimates and use basic simulation tools for both solar thermal and electrical systems and to estimate solar energy potential on building facades and roof for solar thermal and electrical systems;

		• Show the ability to perform a basic pre-study of the installation of a solar thermal or electrical system in a building; and • Be able to make a principal design for a solar thermal system and a solar electricity system.
Lund University, Public Building - Integrating Solar Energy, Costs and Environmental Issues	In this course, the students will explore innovative solar energy systems and concepts (active and passive) and test, through computer simulations and calculations, the integration of these systems in a case study project (a public building).	*Competences and skills* For a passing grade, the student must: • Be able to select an adequate, wisely integrated solution leading to cost-effective energy production, while demonstrating that the other performances of the building (i.e. low energy use, adequate thermal comfort, indoor air quality and visual comfort) are maintained; • Be able to develop and graphically present a solar energy building concept suitable for the cold or temperate climatic context; • Demonstrate skills to use tools, energy simulations or hand calculations in a productive way as a support for analysing solar energy effects of own propositions and guide design decisions; • Show ease in the verbal and graphical communication of solar building concepts and systems, using the appropriate vocabulary and fact-based arguments; • Be able to predict life-cycle costs and environmental impact to reach a certain goal for active solar energy systems in the studied case and similar building with its envelope performance and normal building services; and • Show ease in the verbal and graphical communication of the lifecycle costs and the environmental impact.
Climate Smart Architecture and Urban Design	The aim of the course is to give students the possibility to explore how an adequate building and urban design can minimize negative impact on the climate. It also aims at supporting students' learning on how the built environment in different climates is affected by the microclimate, vegetation, orientation etc. Moreover, the aim is to support the students' learning on how building and urban design affect energy use and daylight in buildings. Moreover, the aim is to highlight the impact of people's attitude and behaviour towards climate and energy issues.	*Competences and skills* For a passing grade the student must show the ability to transform knowledge about climate smart architecture and urban design into creative architectonic and urban design, which results in a reduction in negative environmental impact; show the ability to use tools and models for climate conscious urban design as well as to achieve thermal comfort, low energy use and adequate daylight conditions indoors; and show the ability to formulate criteria for a climate conscious and sustainable architectonic and urban design.

Interviews with course teachers and course documents from other courses has made it clear that the focus of the courses is mainly on three aspects of solar energy:

Technical aspects

- What is the output of a solar energy system, either PV or Solar Thermal systems? Students had to work with assignment and simulation programs to study the output of PV/ST systems.
- In two courses, the impact of shading was assessed. This was studied through simulation software. In the future, a lab is planned to study the effect of shading on the output of a whole system.

- The technical layout of systems is also studied in one course; what happens if PV modules are parallel or series connected? The effect of this is studied with a computer program.

Architectural aspects
- In one course—even though this is not fully developed yet—there is a focus on how to integrate solar energy systems in architecture (colour, material, form, etc.). Students have to design a building and in the assignment, the architectural integration will be assessed.
- In one course, students have to design a new (small) urban district. With help by using a simulation program, they will study how well their design performs for solar energy. Since all students have the same site, students will discover and discuss differences between the different designs.

Financial aspects
- Financial feasibility studies are performed based on the output of a PV/ST system and its revenue.

In one course at Lund University, students first had lectures about the theory of solar energy (including technical, architectural and financial aspects), while in the second part of the semester, they had to apply this knowledge into a design studio project.

9.5. Explanation of Used Sources

Much of the course literature is based on our own research of the involved instructors. This partly covers the outcome of IEA SHC Task 41 "Solar Energy and Architecture." The available reports of Task 41 as well as the website are frequently used as a source. For more technical aspects, relevant books and articles are used as study material.
Instructors experienced it hard to work with case studies. There is normally not enough material to support the whole story of a case study, since the process of a case study is often unclear. By only showing the end results, any encountered problems will not be highlighted. Relevant case studies, like the Task 41 cases where more material is available, are used within some courses.
Normally, students enrolled in the courses will go on study trips where they visit examples of buildings with solar energy installed, however, the amount of good case studies is very limited.

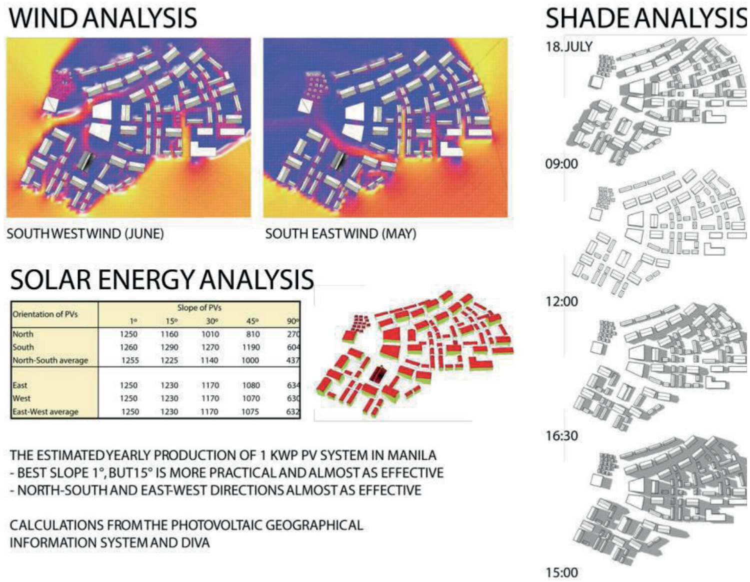
9.6. Tools and Instruments

In some courses, students perform lab exercises in a solar lab to learn the basic principles of solar thermal and PV systems. The lab also has a lamp resembling the conditions of a full bright sun. This lamp is also used to study the output of mainly solar thermal systems.

In many courses, different software is used to support the knowledge-building in the courses. In the courses at Lund University, the following programs are used:

- SAM (System Advisory Model), developed by US DOE. Free program based on TRNSYS and very extended. With this program, the output of a PV and ST system are simulated. Also, the effect of shading on the system is studied with this program.
- Students are also working with Rhino, Grasshopper and DIVA to assess the solar potential of their own building/urban district.

Below are two examples of how students performed shading studies and simulation of the solar energy potential with help of Sketchup and DIVA4RHINO.



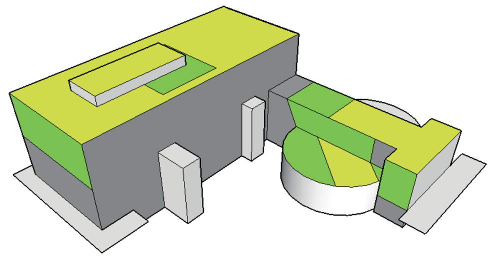


Figure 3: Results of simulations in the course Climate Smart Architecture and Urban planning

Figure 4: Results of simulations the solar energy potential in the course Public Building

9.7. Teaching Methods

Some courses are divided into two parts: first part consists of mainly lectures, while the second part consists of a studio project. In such a way, students gain knowledge before applying that knowledge in practice. Besides lectures, the first part also consists of lab exercises and exercises with computer simulation programs. In the second part, there are hardly any lectures planned and instructors go around the class and function as tutors; discussing issues with the students. The project ends with a final presentation by the students.

9.8. Sustainability Courses at Architectural Department Incorporating Solar

Sustainability including Solar at Architectural Schools at KTH

Since 2008, the School of Architecture at KTH Royal Institute of Technology has had a professor in Sustainable Design. Architect Sara Grahn, artistic professor and part time practitioner, has had the position since 2008. She has, together with colleagues, led a design studio at the master's level called Sustainable Design studio ranging from the Urban Design stages to the Building Design stages, incorporating the triple bottom line of sustainability and within this also incorporated the knowledge on active solar and in recent years also daylighting, very closely connected to the "Solelprogrammet" by Elforsk and to IEA SHC Task 41 and 51.

The students work with traditional architectural methods and tools as well as simulation tool such as Ecotecht, Vasari, Sefaira Architecture and in recent years daylighting simulation programs. During the years tools have been used such as; Ecotect (wind, solar, energy), Velux daylight Visualizer, Sunscape Index (Swedish method from IEA SHC Task 41), Swedish Solar Cadastre and Solekonomi (a Swedish tool on building level but useful, available at http://www.solelprogrammet.se/projekteringsverktyg/berakningsverktyg/).

Sustainability including Solar in Architectural Schools at Chalmers

At the architectural department at Chalmers there have been courses in sustainability where active solar has been a part of education at some level. The sustainability courses started in the late 90s on an urban level. In additional to the Architectural and Urban Design Bachelor and Master's training, Chalmers has started a new five-year MSc program in Engineering and Architecture. There are several courses within the curriculum that deal with the triple bottom line of sustainability. In what degree they teach energy efficiency, or active and passive solar is hard to read from the information provided on the home page.

In 2011, the Sustainable Building class at Chalmers, launched Chalmers participation in the Solar Decathlon China, 2013. The education received over the course of two years focused on the challenge to design, build and operate solar-powered houses that are cost-effective, energy-efficient and attractive, evolving collaboration between students, faculty, and industry partners. The team consisted of a diverse group of 26 master's students and three faculty advisors; all with varying backgrounds, from architecture to structural engineering, building physics to project management, among others; http://www.halosweden.com/en/category/detail/video/1074. It was carried out within collaborations of different studios, such as:

- Sustainable Building that "integrates the environmental issues of sustainable building into an architectural project, combining functional and aesthetical qualities with low environmental impact". This studio was a part of Chalmers' commitment to participate in the international competition Solar Decathlon.
- Sustainable Building Competition, where the "aim was to practice design for sustainable building, to introduce findings from design for energy and environmental efficiency, to promote cooperation between architects and engineers and to implement this knowledge into a competition". This studio was part of Chalmers' commitment to participate in the international competition Solar Decathlon.

9.9. Description of the Seminars and Education Available for Professionals

Courses and seminars for practitioners, either urban planners, urban designers or architects are given by private educational organisations or by associations of the professionals, such as "Föreningen för Samhällsplanering" (FFS, in English: Association for Community Planning), or Sveriges Arkitekter (SA, Swedish Association of Architects) or Building Sector NGO´s such as Sweden Green Building Council. Workshop series are arranged by the Swedish Energy Agency towards the municipalities on Energy Planning, a broad target group that includes urban planners from strategical/comprehensive planning to a detailed-planning level.

Example of existing courses towards these target groups – urban planners, urban designers and architects within active and passive solar energy are:

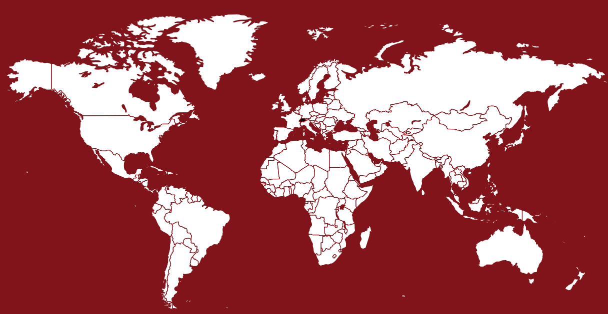
- building codes, including how active solar and daylight is treated;
- daylighting;
- certification systems (BREEAM, LEED, Miljöbyggnad – the Swedish assessment on building level);
- active solar (Photovoltaics and solar thermal), IEA SHC Task 41 has been widely disseminated; and
- City Lab action on sustainable cities: www.sgbc.se/citylab.

During 2015, a collaboration between FFS and IEA SHC Task 51 educated members of FFS, mainly within the target groups in daylight and active solar (Feb. 2015). The four-hour course was included in a longer course on the relation of energy and urban planning.

IEA SHC Task 41 was widely disseminated though different Energy Conferences during 2009-2014. IEA SHC Task 41 also held a symposium for the whole building and planning sector.

Through many different seminars, and the yearly Swedish Energy Agency Seminar, the active solar subject is presented for practitioners.

Within active solar "Solenergiprogrammet" at Elforsk, a research body financed equally by the Swedish Energy Agency and private interests has disseminated active solar information to architects and planners for at least 10 to 15 years by presenting projects like EU POLIS and local research projects. The "Solenergiprogrammet" has also developed an educational kit and sent it out together in 2005 with 10 000 prints of the book Aktivsolenergi i hus- och stadsbyggnad – samtida perspektiv och framtida möjligheter (Active solar energy in building construction and urban development – contemporary perspectives and future potential), by M. Lundgren and F. Wallin.



Switzerland

10. Switzerland

10.1. Educational Structure and Selected Institution

In Switzerland, the main institutions in charge of tertiary education in architecture and engineering are the Swiss Federal Institutes of Technology in Lausanne (EPFL, French-speaking part of the country) and Zürich (ETHZ, German speaking part of the country). Together with other research bodies they form the "ETH Board," which includes the Swiss Federal Laboratory for Materials Science and Technology (EMPA). The EMPA is particularly relevant for educational support, technology transfer and advanced training courses in the building technology domain. From the ETH Board are the Universities and the Universities of Applied Sciences, of which the cantonal governments are in charge. There are seven regional associations of Universities for Applied Sciences (Fachhochschulen, KFH) or SUP (Scuole Universitarie professionali), today integrated in the common Swiss universities system. Universities and Universities of Applied Sciences are vocational institutions that provide a broad range of educational programs in the field of engineering, architecture and planning. Universities do not generally offer courses in architecture and engineering, with the exception of the Università della Svizzera Italiana USI, in the Italian-speaking canton of Ticino which has a school of architecture (Accademia di Architettura) and the University of Applied Sciences and Arts of Southern Switzerland, SUPSI (Scuola Universitaria Professionale della Svizzera Italiana). Both of these institutions offer bachelor-level courses in Architecture and Civil Engineer together with other specialization training programs for continuous training that are focused in environment construction and design (Certificate of Advanced Studies, CAS, 10 ECTS; Diploma of Advanced Studies, DAS, 30 ECTS). In this case, the research and development activities constitute one of the main characteristics of the formation activities, which aims to prepare specialists in their respective fields of activity. However, many university courses in geography provide a specific curriculum in urban planning. Similarly, many Universities of Applied Sciences provide specific courses related to energy in buildings in the framework of CPD programs, such as Certificates of Advanced Studies (CAS) or Masters of Advanced Studies (MAS), and especially the SUPSI (Scuola Universitaria Professionale della Svizzera Italiana) has developed a CAS program in "Design of photovoltaic systems" (10 ECTS, 150 hours).

For the purpose of this report, the teaching activities offered by EPFL and SUPSI are summarised below.
Related Teaching Activities

Table 67: List of teaching activities related to solar energy and urban planning / design at EPFL, by type of program.

	Faculty, Department	Degree course	Module code	Module name	Sem.	ECTS
1	ENAC, LESO-PB	B. Sc. Architecture	PHYS-335	Building Physics V	5th B. Sc.	2
2	ENAC, LAST	B. Sc. Architecture	AR-331	Construction and Sustainability V	5th B. Sc.	3
3	ENAC, LESO-PB	• B. Sc. Architecture, • B. Sc. Civil Eng., • B. Sc. Environmental Eng.	PENS-301	Architecture & Solar Energy - Toward Solar decathlon	5th B. Sc.	4
4	ENAC, LESO-PB	• B. Sc. Architecture, • B. Sc. Civil Eng., • B. Sc. Environmental Eng.	PENS-309	Neighbourhoods, infrastructure and sustainable planning	5th B. Sc.	4
5	ENAC, LIPID; CRYOS	• B. Sc. Architecture, • B. Sc. Civil Eng., • B. Sc. Environmental Eng.	PENS-210	Renewable energy and solar architecture in Davos	4th B. Sc.	4
6	ENAC	M.Sc. Architecture	AR-401(u)	Studio MA 1	1st M.Sc.	13

	Faculty, Department	Degree course	Module code	Module name	Sem.	ECTS
7	ENAC, LESO-PB	M.Sc. Architecture	AR-449	Solar energy and architecture	2nd M.Sc.	3
8	ENAC, LIPID; LAST	• M.Sc. Architecture • Minor in Integrated Design, Architecture and Sustainability • Ph. D. Architecture and Sciences of the City	AR-440	Architecture and Sustainability: performance studies	1st M.Sc.	4
9	STI, LRESE	• M.Sc. Mechanical Eng. • M.Sc. Energy Management and Sustainability • Minor in Integrated Design, Architecture and Sustainability • Minor in Energy	ME-460	Renewable Energy	2nd / 4th M.Sc.	4
10	ENAC, GR-GN	• M.Sc. Civil Eng. • M.Sc. Energy Management and Sustainability • Minor in Integrated Design, Architecture and Sustainability • Minor in Urban Planning and Territorial Development • Minor in Energy	CIVIL-442	Integrated planning of energy infrastructures	2nd / 4th M.Sc.	3
11	ENAC, LAC	Minor in Urban Planning and Territorial Development	ENV-493	Sustainable territorial development	2nd / 4th M.Sc.	4
12	ENAC, GR-GN	Ph.D. Energy	CIVIL-603	Energy planning: modelling and decision support systems	/	3
13	STI, IPESE	Ph.D. Energy	ME-602	Modelling, optimization, design and analysis of integrated energy systems	/	2
14	ENAC, LIPID; LAST	Ph. D. Architecture and Sciences of the City	AR-616	Architecture and sustainability: critical approaches	/	2
15	ENAC, CEAT with UNIL, UNIGE, UNINE	CPD	CAS	Sustainable urbanism: Methodologies for territorial analysis, information management and envisioning	/	20

Table 68: List of teaching activities related to solar energy, energy efficiency and urban development at SUPSI, by type of program.

	Faculty, Department	Degree course	Module code	Module name	Sem.	ECTS
1	SUPSI, DACD	B. Sc. Architecture B. Sc. Civil Eng	R132.01 G131.01	Building Physics I	1st B. Sc.	1
2	SUPSI, DACD	B. Sc. Architecture B. Sc. Civil Eng	R233.01 G252.01	Building Physics II	2nd B. Sc.	1
3	SUPSI, DACD	B. Sc. Architecture	R343.01	Building Physics III	3rd B. Sc.	1
4	SUPSI, DACD	B. Sc. Architecture	R440	Building plants and systems	4th B. Sc.	3
5	SUPSI, DACD	B. Sc. Architecture	R506.03	Integrated planning	5th B. Sc.	1
6	SUPSI, DACD	B. Sc. Architecture	R540	Energy and environment	5th B. Sc.	2
7	SUPSI, DACD	B. Sc. Architecture B. Sc. Civil Eng	D000.30	Law and planning I	5th B. Sc.	1

	Faculty, Department	Degree course	Module code	Module name	Sem.	ECTS
8	SUPSI, DACD	B. Sc. Architecture B. Sc. Civil Eng	D000.31	Law and planning II	6th B. Sc.	1
9	SUPSI, DACD	B. Sc. Architecture	R608	VI project: Architecture and Sustainability (elective course)	6th B. Sc.	7
10	SUPSI, DACD	B. Sc. Architecture	R631	Insights on sustainability (elective course/obligatory to R608)	6th B. Sc.	2
11	SUPSI, DACD	B. Sc. Architecture	R655	Sustainable campus (elective course)	6th B. Sc.	2
12	SUPSI, DACD	B. Sc. Architecture	R655	Architecture and solar energy (elective course)	6th B. Sc.	2
13	SUPSI, DACD	B. Sc. Architecture	R700.02	Architecture and Sustainability (Thesis)	6th B. Sc.	4
14	SUPSI, DACD	B. Sc. Civil Eng.	G445.01	Environment and territorial development	4th B. Sc.	2
15	SUPSI, DACD	B. Sc. Civil Eng.	G445.03	GIS (geographic information system)	4th B. Sc.	1
16	SUPSI, DACD	B. Sc. Civil Eng.	G480	The "building system": HVAC plants and energy efficiency in buildings (elective course)	4th B. Sc.	2
17	SUPSI, DACD	CPD	CAS PV	Design of photovoltaic systems	/	10
18	SUPSI, DACD	CPD	CAS SIA-1	SIA standards in the field of physics, energy and building technique - Part 1	/	10
19	SUPSI, DACD	CPD	CAS SIA-2	SIA standards in the field of physics, energy and building technique - Part 2	/	10
20	SUPSI, DACD	CPD	CAS GE	Restoration and Management of Real Estate	/	10

10.2. Advanced Courses Specifically Addressing Sustainable Urban Planning

Table 69: Advanced courses specifically addressing sustainable urban planning at EPFL, by type of program

Module 4	**Swiss Federal Institute of Technology in Lausanne** **École polytechnique fédérale de Lausanne**
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Neighbourhoods, infrastructure and sustainable planning
Course level	Bachelor (multidisciplinary): Architecture; Civil Engineering; Environmental Engineering
Total credits	4
Course code	PENS-309
Type of course	Lectures, Seminars, Practical work
Description module handbook	Principles of sustainable urban planning; urban planning and design; water management; landscape ecology; energy needs reduction; urban transports; energy storage and supply; waste management
Notes	Option among different courses

Module 6	**Swiss Federal Institute of Technology in Lausanne** École polytechnique fédérale de Lausanne
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Studio Master 1 – Solar Urban Infrastructures
Course level	Master: Architecture
Total credits	13
Course code	AR-401(u)
Type of course	Practical work
Description module handbook	Which form, which materials to collect and supply energy in the future? This design studio focuses on new relations among countryside and urban density, assuming the complete extinction of fossil fuels. Discover constructive autonomy and energy resilience for 2050 term.
Notes	Option among different courses

Module 11	**Swiss Federal Institute of Technology in Lausanne** École polytechnique fédérale de Lausanne
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Sustainable territorial development
Course level	Minor: Urban Planning and Territorial Development
Total credits	4
Course code	ENV-493
Type of course	Practical work
Description module handbook	This project addresses spatial questions related to energy, environment and urban context. Which tools allow the impact estimation of renewable energy production, distribution and supply on environment and cities? What are the challenges, who are the stakeholders?
Notes	Option among different courses

Module 15	**Swiss Federal Institute of Technology in Lausanne** École polytechnique fédérale de Lausanne **University of Geneva** Université de Genève **University of Neuchatel** Université de Neuchâtel **University of Lausanne** Université de Lausanne
Institutions	University of Lausanne (UNIL), University of Geneva (UNIGE), University of Neuchatel (UNINE), Swiss Federal Institute of Technology (EPFL)
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Sustainable urbanism: Methodologies for territorial analysis, information management and envisioning
Course level	CPD
Total credits	20
Course code	CAS-2
Type of course	Lectures, Practical work
Description module handbook	Analyse and understand the state and evolution of a territory, evaluate the impact of a public policy with a territorial intent; identify strategic principles of sustainable urbanism and project follow-up; Propose methodologies of analysis and assessment of urban spaces, and development of multi-criteria decisional tools; understand methodologies of territorial perspective processes (expert, participative, strategic), envision evolutionary scenarios and master operational conditions for a perspective process; master geographic information and geodatabases and learn how to use them for project follow-up; master the operational methodologies to trigger sustainable urban projects

Table 70: Advanced courses specifically addressing sustainable urban planning at SUPSI, by type of program

Module 5	University of Applied Sciences and Arts of Southern Switzerland
faculty	University of applied sciences and arts of southern Switzerland (SUPSI), Department for environment construction and design (DACD)
Name of course	Integrated planning
Course level	Bachelor: Architecture
Total credits	1
Course code	R506.03
Type of course	Lectures, Seminars, Practical work
Description module handbook	Planning strategies at different scales of territory. Development of a methodological and instrumental base of knowledge to argue the measures, actions and decisions of the planning.
Notes	Mandatory course

Module 7/8	University of Applied Sciences and Arts of Southern Switzerland
faculty	University of applied sciences and arts of southern Switzerland (SUPSI), Department for environment construction and design (DACD)
Name of course	Law and planning I / Law and planning II
Course level	Bachelor (multidisciplinary): Architecture; Civil Engineering
Total credits	1/1
Course code	D000.30/D000.31
Type of course	Lectures, Seminars, Practical work
Description module handbook	Know the main tools of spatial planning and building law and the concepts that are behind them. Express a comprehensive evaluation in this complex field concerning the evaluation of public law related to construction problems.
Notes	Mandatory course

10.3. Advanced courses specifically addressing solar buildings design

Table 71: Advanced courses specifically addressing solar buildings design at EPFL, by type of program

Module 3	**Swiss Federal Institute of Technology in Lausanne** **École polytechnique fédérale de Lausanne**
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Architecture & Solar Energy – Toward Solar Decathlon
Course level	Bachelor (multidisciplinary): Architecture; Civil Engineering; Environmental Engineering
Total credits	4
Course code	PENS-301
Type of course	Lectures, Seminars, Practical work
Description module handbook	This interdisciplinary course is designed to allow an optimised use of solar energy in high quality architecture. To this end it provides the knowledge needed one hand to maximise the contribution of the various solar technologies in covering building's energy needs, on the other hand to master the architectural issues related to their integration into the building envelope.
Notes	Option among different courses

Module 5	Swiss Federal Institute of Technology in Lausanne École polytechnique fédérale de Lausanne
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Renewable energy and solar architecture in Davos
Course level	Bachelor (multidisciplinary): Architecture; Civil Engineering; Environmental Engineering
Total credits	4
Course code	PENS-210
Type of course	Lectures, Seminars, Practical work
Description module handbook	Renewable energy production in mountain areas; Sustainable Building Infrastructure; Landscape Development
Notes	Option among different courses

Module 7	Swiss Federal Institute of Technology in Lausanne École polytechnique fédérale de Lausanne
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Solar Energy and Architecture
Course level	Master: Architecture
Total credits	3
Course code	AR-449
Type of course	Lectures, Seminars
Description module handbook	This course aims at giving architects the needed skills to select, pre-size and position the different types of solar systems and products (solar thermal / photovoltaics / passive solar) in a comprehensive approach that considers the same time energy constraints and architectural composition issues. A practical implementation of the theoretical knowledge is proposed taking as a base a real design studio project.
Notes	Option among different courses

Table 72: Advanced courses specifically addressing solar buildings design at SUPSI, by type of program

Module 12	University of Applied Sciences and Arts of Southern Switzerland
faculty	University of applied sciences and arts of southern Switzerland (SUPSI), Department for environment construction and design (DACD)
Name of course	Architecture and solar energy
Course level	Bachelor: Architecture
Total credits	2
Course code	R655
Type of course	Lectures and exercises
Description module handbook	The goal of the course is to provide participants with the knowledge necessary for the design and architectural integration of solar systems, with particular reference to the photovoltaic and solar thermal technologies. It will study the concept of BIPV (Building Integrated PhotoVoltaics).
Notes	Option among different courses

Module 17	University of Applied Sciences and Arts of Southern Switzerland
faculty	University of applied sciences and arts of southern Switzerland (SUPSI), Department for environment construction and design (DACD)
Name of course	Design of photovoltaic systems
Course level	CPD
Total credits	10
Course code	Lectures, practical work and exercises
Type of course	The Swiss Society of Engineers and Architects SIA is the professional association of reference. The SIA standards constitute the working tool in professional practice to ensure quality services provided knowledge and belief in the field of physics, energy and building technology.
Description module handbook	The course provides in-depth knowledge bases, tools of analysis, the practical and theoretical skills for the proper design and installation of photovoltaic systems.

10.4. Other Courses Addressing Solar Energy Issues as Part of a Broader Topic

Table 73: Other courses addressing solar energy issues as part of a wider topic at EPFL, by type of program

Module 1	**Swiss Federal Institute of Technology in Lausanne** **École polytechnique fédérale de Lausanne**
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Building Physics V
Course level	Bachelor: Architecture
Total credits	2
Course code	PHYS-335
Type of course	Lectures and exercises
Description module handbook	Smart management of energy in buildings; Heat recovery techniques; Renewable sources of heat and electricity; Passive and active exploitation of solar energy; principles of heat and electricity storage; Energy management techniques
Notes	Mandatory course

Module 2	**Swiss Federal Institute of Technology in Lausanne** **École polytechnique fédérale de Lausanne**
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Construction and sustainability V
Course level	Bachelor: Architecture
Total credits	3
Course code	AR-331
Type of course	Lectures and exercises
Description module handbook	Heating systems: design principles, system choice, renewable energies; Ventilation: design principles, air exchange, heating recovery; DHW: design of a solar collectors' plant; Electricity: artificial lighting dimensioning and design; Principles of integration of technical equipment into an architectural concept
Notes	Mandatory course

Module 9	**Swiss Federal Institute of Technology in Lausanne** **École polytechnique fédérale de Lausanne**
faculty	School of Engineering
Name of course	Renewable Energy
Course level	Master: Mechanical Engineering; Energy Management and Sustainability Minor: Integrated Design, Architecture and Sustainability; Energy
Total credits	4
Course code	ME-460
Type of course	Lectures, Practical work
Description module handbook	Explain and apply the concepts of thermodynamic efficiency; Explain the principles and limitations of the main energy conversion technologies; Characterise fossil and renewable energy resources and their corresponding conversion technologies; Understand the challenges related to energy: resources, energy services, economic and environmental impacts; Calculate and design hydraulic machines; Calculate and design solar collectors and receivers; Calculate and design wind power plants
Notes	Option among different courses

Table 74: Other courses addressing solar energy issues as part of a wider topic at SUPSI, by type of program

Module 2	University of Applied Sciences and Arts of Southern Switzerland
faculty	University of applied sciences and arts of southern Switzerland (SUPSI), Department for environment construction and design (DACD)
Name of course	Building Physics II
Course level	Bachelor (interdisciplinary): Architecture; Civil Engineering
Total credits	1
Course code	R233.01/ G252.01
Type of course	Lectures, Practical work
Description module handbook	Ensure the quality of the built environment and meet the needs of comfort and energy in buildings. Main topics: global energy policy, and Swiss; climate and energy (physics of the sun); thermal comfort; heat transfer through opaque and transparent elements; thermal bridges; energy balance in buildings.
Notes	Mandatory course

Module 6	University of Applied Sciences and Arts of Southern Switzerland
faculty	University of applied sciences and arts of southern Switzerland (SUPSI), Department for environment construction and design (DACD)
Name of course	Energy and environment
Course level	Bachelor: Architecture
Total credits	2
Course code	R540
Type of course	Lectures, Practical work
Description module handbook	Knowing how to apply the laws, ordinances and regulations on energy (at international, national and local level) in the context of project development.
Notes	Mandatory course

Module 9	University of Applied Sciences and Arts of Southern Switzerland
faculty	University of applied sciences and arts of southern Switzerland (SUPSI), Department for environment construction and design (DACD)
Name of course	VI project: Architecture and Sustainability
Course level	Bachelor: Architecture
Total credits	7
Course code	R608
Type of course	Lectures, Seminars, Practical work
Description module handbook	"Architecture and Sustainability" elective course aims to provide the tools for the implementation of an architectural design project oriented on sustainable development as a whole. The architectural quality requirements are linked to the site (accessibility by transport), the need for economic optimization (use of space) and energy (eco-labels such as Minergie), the integration of renewable technologies in design, and the choice of sustainable materials.
Notes	Option among different courses

10.5. Other Courses Addressing Sustainable Urban Planning Issues as Part of a Wider Topic

Table 75: Other courses addressing sustainable urban planning issues as part of a wider topic at EPFL, by type of program

Module 10	Swiss Federal Institute of Technology in Lausanne École polytechnique fédérale de Lausanne
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Integrated planning of energy infrastructure
Course level	Master: Civil Engineering; Energy Management and Sustainability Minor: Integrated Design, Architecture and Sustainability; Urban Planning and Territorial Development; Energy
Total credits	3
Course code	CIVIL-442
Type of course	Lectures, Practical work
Description module handbook	Principles of strategies of energy supply; model electricity demand and its spatial variability; model electricity supply and its spatial variability; model the matching between electricity demand and supply; compare different means of electricity production; evaluate energy infrastructure projects
Notes	Option among different courses

Module 12	Swiss Federal Institute of Technology in Lausanne École polytechnique fédérale de Lausanne
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Energy Planning: modelling and decision-support system
Course level	PhD: Energy
Total credits	3
Course code	CIVIL-603
Type of course	Lectures, Practical work
Description module handbook	Solving the problems of energy planning: demand forecasting, evaluation of supply matrixes, probabilistic evaluation of demand/supply adequacy, multi-criteria assessment of medium and long term energy strategies, risk assessment of energy supply portfolios.
Notes	Option among different courses

Module 14	**Swiss Federal Institute of Technology in Lausanne** **École polytechnique fédérale de Lausanne**
faculty	School of Architecture, Civil and Environmental Engineering
Name of course	Architecture and sustainability: critical approaches
Course level	PhD: Architecture and Science of the City
Total credits	2
Course code	AR-616
Type of course	Lectures, Practical work
Description module handbook	This course responds to a growing integration of sustainable architecture through an interdisciplinary approach (multi-criteria process) on a building /neighbourhood.
Notes	Option among different courses

Table 76: Other courses addressing sustainable urban planning issues as part of a wider topic at SUPSI, by type of program

Module 15	University of Applied Sciences and Arts of Southern Switzerland
faculty	University of applied sciences and arts of southern Switzerland (SUPSI), Department for environment construction and design (DACD)
Name of course	GIS (geographic information system)
Course level	Bachelor: Civil Engineering
Total credits	1
Course code	G445.03
Type of course	Lectures, Seminars, Practical work
Description module handbook	Learn the basic knowledge to use GIS tools to analyse all the aspects related to the territorial planning.
Notes	Mandatory course

10.6. Summary of Findings

It is evident from the reported teaching activities how all the disciplines related to spatial planning are involved in a broad inclusion of renewable energy sources demand, dispatch and supply characterization within their educational curriculum. A focus on the territorial scale enhances the need of a qualified expert to address different spatial planning issues, from energy management to transport infrastructure and land use. Currently, a tailored educational program for this specific profile is lacking in Switzerland. Nevertheless, the creation of new interdisciplinary study plans covering geographical, technical, environmental and urban planning aspects partially tackles this challenge. It is worth mentioning:

- The Master in Energy Management and Sustainability at EPFL, which includes many modules mentioned above, intends to address critical issues such as climate change, enhanced urbanization, growing energy demand, distributed energy production, wind and water use, etc. A similar axis of interest is covered by the Master in Integrated Building Systems at ETHZ, with a strong emphasis on the integration of sustainable energy technologies at building and urban levels.

- The CPD Sustainable Urbanism (Module 15) organised together with other institutional partners in the field of geography, political sciences, environmental sciences, territorial planning. As part of a Master of Advanced Studies (MAS), a specific course comprehensive of multiple disciplines and focused on decisional methodologies is addressed to geographers, urban planners and designers, engineers, political scientists, public administration personnel, public or private enterprises related to environmental management.

- The course on Solar energy and Architecture and the teaching unit on the same topics (Module 7 and Module 3), initiated in 2010, also as a result of IEA SHC Task 41 Solar energy and Architecture (AA. VV., 2012). The content has been recently introduced in the University IUAV of Venice as a guest course.

Another important initiative is the participation to Solar Decathlon 2017, an interdisciplinary design competition for students envisioning future urban scenarios implementing renewable energy and promoting sustainable way of living. EPFL has formed a student team with the School of Engineering and Architecture of Fribourg (HEIA-FR), the University of Fribourg (UNIFR) and the Geneva University of Art and Design (HEAD). Instructors from environmental sciences, architectural and urban design, energy engineering and structural design have gathered together to offer specific courses and lectures and assist the students in the design process.

Within this framework some of the most innovative teaching activities have been developed. Instructors empower student through early interactions between those with different backgrounds so as to foster the use of innovative tools for envisioning urban scenarios.

Regarding the teaching activities at SUPSI Campus, not many courses related specifically solar energy in buildings and solar urban planning are considered in the basic educational programs. Only these topics are included as part of mandatory courses considering a wide concept including aspects related to environmental, sustainable and energy efficiency in the building sector. A singular elective course is being development since 2012 on the topic “Solar Energy in Architecture,” but at the moment this course does not consider solar urban approaches.

ISAAC Institute of SUPSI has extensive experience in applied research in the field of photovoltaic systems and in recent years has developed the Swiss PV Module Test Centre, a testing laboratory for photovoltaic modules, IECEE accredited Test and Certification Body. For this reason, it was possible to develop a specific CAS, (Certificated Advances Studies) on the topic “Design of photovoltaic systems” available since 2015. ISAAC hosted also the Swiss BIPV Competence Centre active for the dissemination of relevant information on photovoltaic elements integrated in buildings through a specific web page, for specialist and general public (www.bipv.ch). Furthermore, different workshops and conferences have been organised on this topic in the recent years in order to better understand how the solar market is evolving, its potential and recent developments.

[33] June 22, 2012 Workshop: “The integrated photovoltaic systems: towards a zero energy balance buildings”, SUPSI, Lugano (CH).
October 3, 2014 Workshop: “Photovoltaic in Buildings. Challenges, innovation, visions for solar architecture”, SUPSI, Lugano (CH) <http://www.bipv.ch/index.php/it/links-news>
October 19, 2015 Interactive webinar and lecture: “Solar architecture: product development, innovation in design and building process. Experiences of the ConstructPV research project” <http://www.constructpv.eu/workshop-solar-architecture-product-development-innovation-in-design-and-building-process-experiences-of-the-constructpv-research-project/>

Conclusion & Prospects

11. Conclusion and Prospects

Conclusion

Institutions and universities in higher education are educating and forming the next generation of architects, urban planners and experts. The study on the state-of-the-art of education on solar energy in urban planning underlines the hypothesis that the importance of teaching solar energy at an earlier stage of the educational training in universities is necessary for the future practice.

A deep comprehensive knowledge in all relevant areas of the profession during students' studies can help them to apply this advanced knowledge in order to plan and build sustainable architectural and design projects. That is one of the reasons why this evaluation of university courses and their research is of utmost importance.

The next chapters compare the current situation of solar education at various universities in different countries.

Identified Courses in Tertiary Education

In total, 284 courses dealing with solar energy could be identified in the various countries examined in this review. The majority of these courses were taught in Italy followed by France and Germany, however, the Italian courses mainly addressed the technical aspects of solar energy and not their implementation in an urban context. The difference between courses taught at the undergraduate and graduate level is marginal. It is important to remember that the quantity of courses is not necessarily representative because some countries were only able to conduct research in one region due to limitation in work load. Despite this, a clear trend is visible.

Currently, there are not many existing courses that specifically focus on teaching solar energy in urban planning at universities. Most of the courses are taught in other disciplines, such as architecture, engineering, or environmental science, which teach the principles of solar energy for technical and design purposes. The surveys and interviews conducted for this project demonstrate a concrete overview of the content and methodology of the seminars and lectures that are offered in different countries.

The matrix, “study modules classification in categories” (see Figure 5), clarifies the study modules and variety in the different disciplines and summarizes the data that was collected for this study by combining the interview questionnaire responses and the information from the webpage of each course in the participating countries. Most of the courses that were taught concentrated on technical specifications such as material, system studies as well as the construction of solar integration systems. These were typically provided in engineering and architectural programs at the undergraduate and graduate university level.

In regards to education at an earlier stage of the studies, the matrix shows that various courses exist at the bachelor's level for urban solar integration in design and planning. Courses offered within the architectural discipline seem to be mostly design-based concepts with occasionally some technical aspects. At the undergraduate level, students learn the fundamentals of solar energy and the built environment. Topics are including site planning, solar geometry, sun angles and solar penetration, passive solar heating and cooling, daylighting and carbon-neutral design basics including an introduction to technologies such as photovoltaics. Architectural and urban planning undergraduate courses provide solar energy as a sustainable approach to buildings and the built environment from primarily an energy efficiency and daylighting provision perspective. The investigation revealed that various courses on solar energy also exist in the field of urban and regional planning, economic science and legal studies.

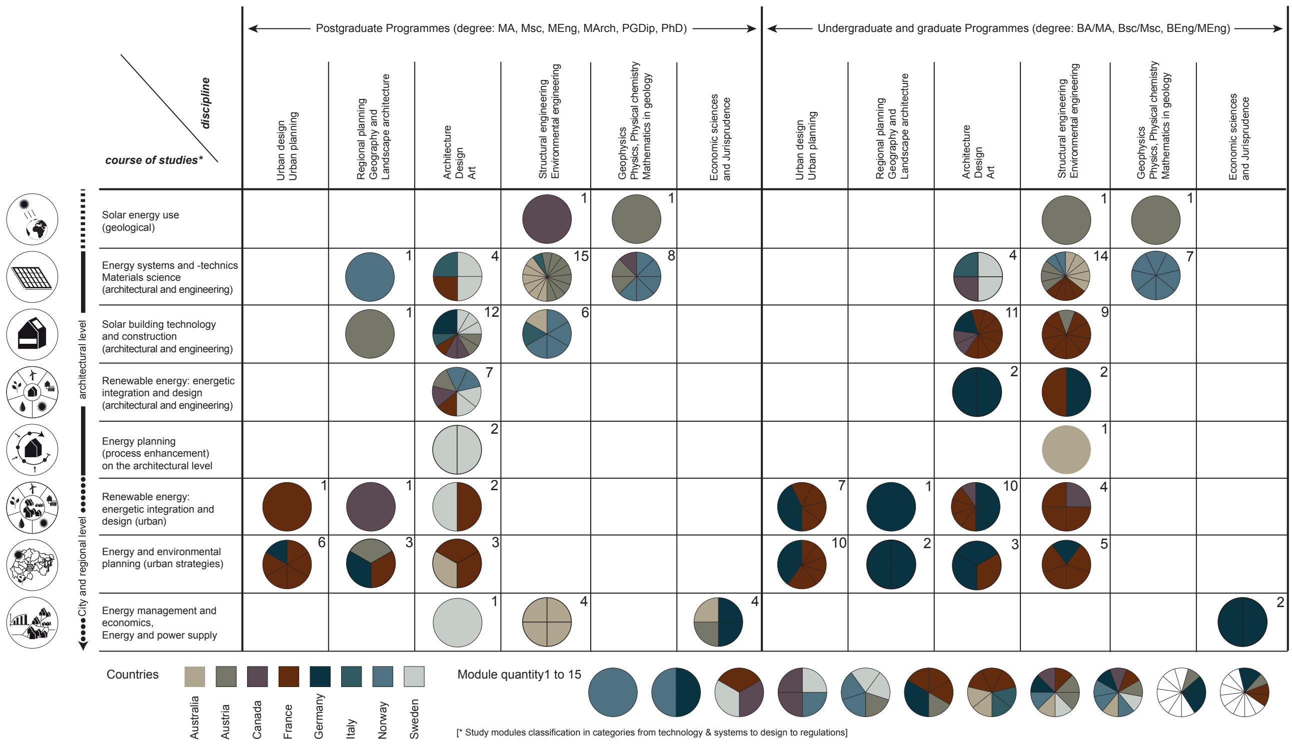


Figure 5: Matrix “Study modules classification in categories”. Each pie shows the number of identified and investigated courses in each country in relation to educational program and course category (T. Siems, K. Simon).

All in all, it can be determined that the principles on how to implement solar energy are taught by various universities. The technical aspects, especially on the architectural level, are taught in most of the courses, particularly in the undergraduate level. The knowledge of how to integrate solar energy in urban areas is mostly taught as one key factor of the whole design process of an urban settlement.

Teaching Methodology

Through the analysis of the answers given by the surveyed institutions, it appears that the methods and tools used to teach solar-related courses vary greatly throughout the different disciplines and also the specialties of the degree programs. For example, the topic on solar integration is taught during student workshops, seminars and lectures. During studio-based research, the learning process is complimented by computer simulation and modelling.

The challenge lies in the fact that different methods and approaches are taught in each discipline. In engineering, the method of analysis on the level of single parameters and components is common, while urban planners usually approach the same topic from a more multi-criteria perspective, based on a synthesis of problem solving. A satisfactory integration in education as well as in the research is currently one of the biggest challenges. In order to overcome this situation, the development of integrative approaches that establish an overarching and holistic ‘platform’ for experimentation, testing, and application of solar solutions in urban environment are required.

Comparing the CPD Systems in Each Country

Different approaches for continuing professional development exist in various countries. Binding and optional systems are present in the participating countries. Through the architectural chamber in Australia, Austria, Canada and Germany, CPD courses are binding. In France, Norway, Sweden and Switzerland, the participation in CPD programs is optional and self-motivated. The range of presence in these courses varies between 8 and 20 hours per year. Most CPD courses address relevant key aspects and current issues discussed in the public, e.g. climate change and not specifically solar energy in urban planning.

CPD arch. & eng. / countries	Australia	Austria	Canada	France	Germany	Italy	Norway	Sweden
OPTIONAL				n.s		n.s	●	●
OBLIGATORY	●	●	●	n.s	●	n.s		
Architectural and engineering chamber	- AIA - Australien Institute for Architects	Austria chamber civil engineer and architects	- OAA - Ontario Association of Architects		- AKNW - Chamber for Architects NRW			
CP crediot points and/or hours per year	20 hours (20 CP)	n.s	70 h (in 3 years) pre-registration 35 h (in 3 years) registration		80 hours pre-registration 8 hour registration			

Figure 6: CPD matrix (T. Siems)

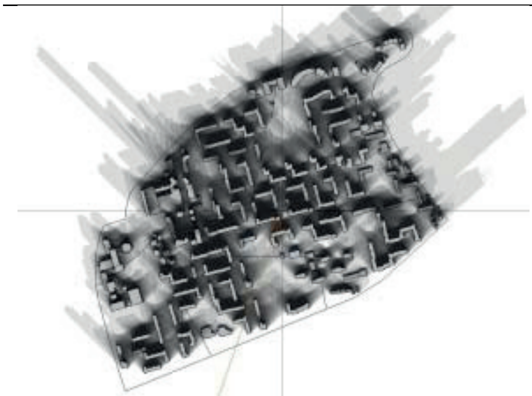
The Use of Software Tools

Software tools are an important component of university courses as they concern the planning and use of active and passive solar energy. At different stages of the planning process, software tools can help students to make design decisions. For each relevant aspect, like solar irradiation, solar access, shading, energy consumption, micro climate etc. the students can utilize specific software tools.

Table 77 shows an overview of software tools used at the universities and research institutions mentioned by educators in this research project. The software tools are categorized by solar energy relevant aspects showing a short description of the scope of function and the usability for urban planners.

Table 77: Software tools dealing with solar energy sorted by relevant aspects for using solar energy

Solar Access Analysis / Shading Analysis / Daylight Hours



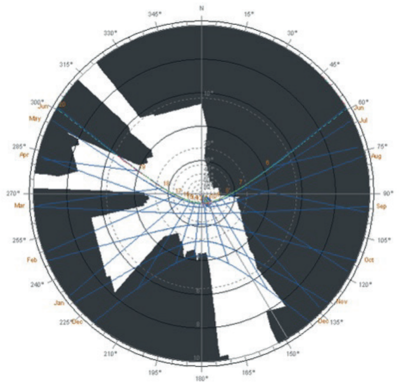
Source: BUW, Katharina Simon
Used software tool: Autodesk Ecotect

ASPECT:
Solar accessibility maps of urban areas through hourly shadow maps. Number of hours of direct sun on open areas, or roofs.
Quantification of surfaces by direct sun or shadow (areas of interest).

USE FOR URBAN PLANNERS: Evaluation of solar accessibility conditions, e.g. shading situation of urban design projects.

TOOLS: Autodesk Ecotect; DIVA for Rhino 3D

Sky View Factor



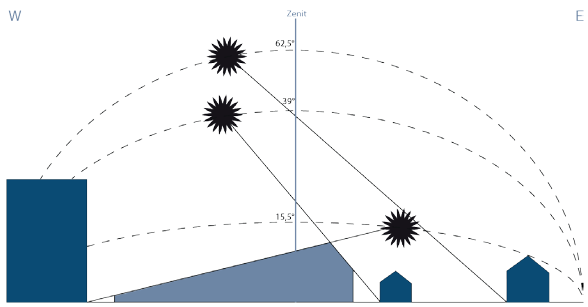
Source: BUW, Student Eva Hagen
Used software tool: Autodesk Ecotect

ASPECT:
Quantification of sky view factor on the ground, on roofs, on the entire urban area.

USE FOR URBAN PLANNERS: Evaluation of sky openness conditions of urban form in design projects

TOOLS: ArcGIS, Autodesk Ecotect

Solar Envelope



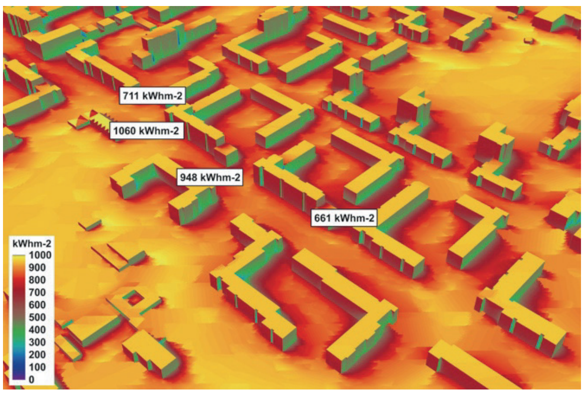
Source: BUW, Student Jana Schendekehl

ASPECT:
The solar envelope presents the maximum heights of buildings that do not violate the solar access of any existing buildings during a given period of the year. Buildings within this container will not overshadow their surroundings during critical periods of the day and year.
Verification if design projects exceed the envelope and thus the solar rights of the existing fabric.

USE FOR URBAN PLANNERS: Verification of solar rights conditions of design projects.

TOOLS: Autodesk Ecotect, any CAD Program

Solar Radiation Analysis



Source: BUW, Katharina Simon
Used software tool: DIVA for Rhino3D

ASPECT:
Calculates the amount of radiation falling on selected surfaces on a specific time period.
Geometric overshadowing and reflective effects are also taken into account.

USE FOR URBAN PLANNERS: Assessment of solar irradiance on roofs for the estimation of solar energy production.

TOOLS: Autodesk Ecotect, DIVA4Rhino3D, ArcGIS

Building Energy Consumption Plans

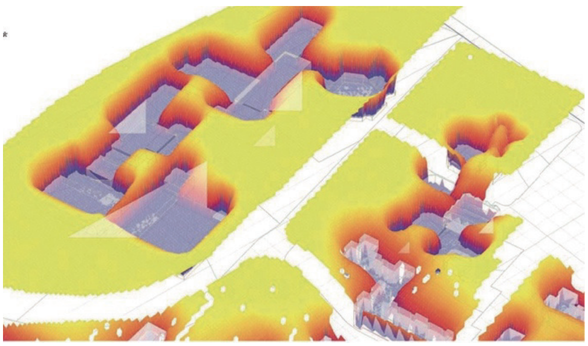
Source: BUW, Students David, Schütt
Used software tool: DECA, Adobe Illustrator

ASPECT:
Estimation of energy consumption and heating demand of the urban fabric, Quantification (estimation) of energy demand.

USE FOR URBAN PLANNERS: As a support for energy action plans.

TOOLS: GIS, local cadastral plans combined with building energy performance certificates, calculated in DECA and depicted in Adobe Illustrator

Thermal Discomfort / HeatMaps



Source: BUW, Student Eva Hagen
Used software tool: unknown

ASPECT:
Simulation showing potential thermal discomfort on open areas.
The computation takes into account the solar irradiation on site, vegetation, albedo of urban materials and urban geometry.

USE FOR URBAN PLANNERS: For programming punctual interventions in urban areas and spaces.

TOOLS: e.g. CFD Simulation Tools, ENVI-met, RayMan

In this part of the report, the software tools that are used are not described and evaluated in detail, as the second part of the D.D1 report "Solar Irradiation Potential Tools in Education" discusses the software tools focusing on solar irradiation. The evaluated software tools were used by students in order to assess realistic case studies. The main assessment criteria focuses on the functionality and the handling of these tools. On the basis of a generated evaluation sheet, the deficits and opportunities of the individual tools will be examined and evaluated by the students.

Prospects

This study identified that one of the core problems associated with solar energy education is the accessibility of relevant teaching material. Within this framework, it is our goal to strengthen education at universities on the topic of solar energy in urban planning, by testing relevant software tools, generating an e-learning platform called "EnOB Lernnetz" and developing teaching material in form of a web-based platform for life-long learning. This web-based platform should include a knowledge base of available digital and analogue tools, teaching methodologies as well as samples of "best practice" in regards to the integration of solar energy in an early phase of the planning process. During the development of the life-long learning platform, an evaluation will take into account existing educational material as well as possible deficits in regards to its usability and accessibility. The material that will be developed will be useful for tertiary educational courses and continuing professional development.

Regarding barriers in the educational sector, two relevant issues need to be mentioned. Barriers have been identified, e.g. in the existing separation of research and teaching in universities and outside institutions. This is the result after changing the funding strategies and structures in some of the studied countries. A change is needed in future research programs to generate a more sustainable and integrated research process that will link research and education together in a better way.

12. Acknowledgements

First of all, we would like to thank all the educators for their availability in providing the information related to their courses as well as all the students for helping us to collect information through the survey of the tool evaluation.

This report is a collaborative project between participants from Australia, Austria, Canada, France, Germany, Italy, Norway, Sweden and Switzerland. We are very grateful for the fruitful international cooperation between researchers, teachers and practitioners that is possible within the International Energy Agency and the Solar Heating and Cooling Programme.

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- University of La Réunion, France
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- Projektträger Jülich PtJ
- Energieoptimiertes Bauen (EnOB)
- Forschung für die energieeffiziente Stadt (EnEff:Stadt)
- University of Padua, Italy
- Norwegian University of Science and Technology (NTNU)
- Research Council Norway
- The Swedish Energy Agency
- ARQ, Sweden
- Swiss Federal Office for Energy
- EuroTech Universities Alliance
- Competence Center Energy and Mobility (CCEM), Switzerland
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14. Appendix

Appendix 1:
Example of a survey used by experts in order to get a first overview on solar energy courses in the different countries.

Task 51 Solar Energy in Urban Planning

Subtask D Education and Dissemination

Introduction: This survey belongs to the Task 51 „Solar Energy in Urban Planning". The goal of Subtask D „Education and Dissemination" is to communicate new research results and to develop teaching material for tertiary education.

The first step is to screen the state-of-the-art in higher education regarding solar energy in urban planning in the participating countries and to collect courses including any relevant software tools from bachelor/master (in under-grad and post-grad level) to PhD level.

Please fill out this survey to give a first overview about your known contact details regarding teachers and their courses and return until the **9th of September** by e-mail to *ksimon@uni-wuppertal.de*.

Educational institution

Contact details: contact name, address, phone number, e-mail

Faculty: ☐ Architecture ☐ Engineering (environmental, civil, etc.) ☐ Urban design ☐ other:

Name of course

Level: ☐ Bachelor ☐ Master ☐ PhD ☐ other:

Type of course: ☐ Lecture ☐ Tutorial ☐ Workshop ☐ other:

Interval of course (e.g. weekly)

Topic of course: Please give a short description about content and collaborations (e.g. Only concerning solar energy in urban planning or concerning energy efficiency in urban and landscape context).

Which software tools do you use in education to simulate solar energy in the urban context?

Do you have already any experiences with the software tools?

TS, KS | 2013

15. Annex - IEA Solar Heating and Cooling Programme

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives („Implementing Agreements") of the International Energy Agency. Its mission is "to enhance collective knowledge and application of solar heating and cooling through international collaboration to reach the goal set in the vision of solar thermal energy meeting 50% of low temperature heating and cooling demand by 2050.

The members of the IEA SHC collaborate on projects (referred to as "Tasks") in the field of research, development, demonstration (RD&D), and test methods for solar thermal energy and solar buildings.

A total of 59 projects have been initiated, 50 of which have been completed. Research topics include:
- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54)
- Solar Cooling (Tasks 25, 38, 48, 53)
- Solar Heat or Industrial or Agricultural Processes (Tasks 29, 33, 49)
- Solar District Heating (Tasks 7, 45, 55)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59)
- Solar Thermal & PV (Tasks 16, 35)
- Daylighting/Lighting (Tasks 21, 31, 50)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58)

In addition to the project work, there are special activities:
- SHC International Conference on Solar Heating and Cooling for Buildings and Industry
- Solar Heat Worldwide – annual statistics publication
- Memorandum of Understanding – working agreement with solar thermal trade organizations
- Workshops and seminars

Country Members

Australia	France	South Africa
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