Approaches, Methods and Tools for Solar Energy in Urban Planning

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IEA SHC Task 51 Solar Energy in Urban Planning

Task 51/Report B2

Approaches, Methods and Tools for Solar Energy in Urban Planning

Editors:
Marja Lundgren (White arkitekter)
Johan Dahlberg (White arkitekter)

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EDITORS

Johan Dahlberg & Marja Lundgren
White arkitekter, Sweden

AUTHORS

Olaf Bruun Jørgensen
Danish Energy Management & Esbensen, Denmark
Johan Dahlberg
White arkitekter, Sweden
Laurent Deschamps
Ecole Polytechnique Fédérale de Lausanne (EPFL)
Switzerland
Aymeric Delmas
University of La Réunion & IMAGEEN, France
Pietro Florio
Ecole Polytechnique Fédérale de Lausanne (EPFL)
Switzerland
Francesco Frontini
University of Applied Sciences and Arts of Southern
Switzerland (SUPSI), Switzerland
Francois Garde
University of La Réunion, France
Simone Giostra
DAStU, Politecnico Milan, Italy
Jouri Kanters
Energy and Building Design Lund University, Sweden
Karin Kappel
Solar City Denmark, Denmark
Margarethe Korolkow
IBUS GmbH, Germany
Tilmann Kuhn
Fraunhofer Institute for Solar Energy Systems ISE, Germany
Marja Lundgren
White arkitekter, Sweden
Christoph Maurer
Fraunhofer Institute for Solar Energy Systems ISE, Germany
Maria Cristina Munari Probst
Ecole Polytechnique Fédérale de Lausanne (EPFL)
Switzerland
Emilie Nault
Ecole Polytechnique Fédérale de Lausanne (EPFL)
Switzerland
Romain Nouvel
Hochschule für Technik Stuttgart, Germany
Giuseppe Peronato
Ecole Polytechnique Fédérale de Lausanne (EPFL)
Switzerland
Cristina S. Polo López
University of Applied Sciences and Arts of Southern
Switzerland (SUPSI), Switzerland
Cristian Roecker
Ecole Polytechnique Fédérale de Lausanne (EPFL)
Switzerland
Alessandra Scognamiglio
Photovoltaic Technologies Unit (UTTP-FOTO) ENEA, Italy
Simon Stendorf Sørensen
PlanEnergi, Denmark
Tanja Siems
Bergische Universität Wuppertal, Germany
Katharina Simon
Bergische Universität Wuppertal, Germany
Daniele Vettorato
European Academy EURAC Bozen/Bolzano, Italy
Karsten Voss
Bergische Universität Wuppertal, Germany

REVIEWED BY

Maria Wall
Energy and Building Design Lund University, Sweden

CONTENTS

EXCECUTIVE SUMMARY

This report gathers and presents approaches, methods and tools that can support and facilitate daylight and solar energy considerations within urban planning processes. Future cities and landscapes will not only use energy but will also locally generate renewable energy, often by means of solar energy. Therefore, this report presents different ways to address existing building stock, new urban environments and landscape environments in relation to use of daylight and active solar. This report addresses the need for spatial and energy planning that enhances solar energy while respecting cultural and historical heritage values in urban and landscape contexts.

The multi-layered challenge that urban and energy planning stands before has engaged both practice and research communities. We report on how internationally acknowledged methodologies, such as the Environmental Impact Assessment common for the EU Member states, can support actions addressing this complex context, and how some countries have worked with governance, regulatory or procurement approaches in order to enhance solar. From the northern to the southern hemisphere the issues of creating outdoor and indoor comfort by designing urban areas that utilises daylight, sunlight and wind through interdisciplinary work is presented by work from both practice and academia. The report includes different methods of reaching new and project specific knowledge supported by developments in computational modelling and combined approaches from the design and engineering communities. The possibility to show real estate owners and professionals how much solar radiation that reaches buildings has been available for many years now through solar maps that more and more cities have developed. At the same time knowledge is needed to interpret this quantitative knowledge in relation to the architectural prerequisites in existing urban environments as well as harmonising with the architectural ambitions when planning new urban environments.

Combining solar assessment methods and tools with other more qualitative assessments approaches, methods and tools on how to integrate solar in urban areas have been developed within *IEA SHC Task 51 - Solar Energy in Urban Planning* and is presented in this report. The content of the report spans from the strategic comprehensive scales of planning through the urban design and detailed development planning scale, to the scale of building materials.

In the later chapters of the report awareness and consultations methods for public, professionals and decision makers on the building level are addressed. The last chapter introduces the field of combining photovoltaics and solar thermal in a landscape setting with other cultural, agricultural or touristic functions - a more novel research field than existing and new urban areas. The design of solar systems in landscape settings demands delicacy and an interdisciplinary approach combining sustainability aspects relating to ecology, social and economic aspects in a very concrete and direct way. More research is required in this field of active solar implementations in sensitive landscape areas based on knowledge from practice in order to create standard processes with awareness of and in dialogue with solar approaches, methods and tools sensitive for environmental, heritage, aesthetic and other cultural values.

Why Solar Energy in Urban Planning?

The urban planning process is a political and technical process that balances different needs of society within a physical and spatial environment. Decisions need to be taken during the process in regard to spatial, social, environmental, economical, technical and political aspirations and goals. Strategies are needed to support and facilitate these decisions and to enhance solar energy considerations within the existing urban planning processes. Future cities will not only use energy but will also locally generate renewable energy, mostly by means of solar energy.

The aims of this report are to:

- provide a theoretical background to the complex decision-making context in urban planning,
- present ways on how to inform and support decision-making in urban planning regarding solar energy,
- orientate on existing approaches, methods, and tools for active and passive (daylight) solar measures,
- present new or further developed approaches, methods and tools for active and passive solar measures.

Today, different strategies are practiced in different countries, regions and local planning offices regarding solar and energy integration in urban planning. In this report the focus is on approaches, methods and tools that can be generalized and help decision making in different planning contexts. These are illustrated by local examples.

Today decisions are made that have an effect on solar energy implementation. This report aims to introduce approaches, methods and tools to support decision-makers in making relevant decisions. This report addresses three main environments of planning: *1. existing urban areas, 2. new urban areas and, 3. sensitive and protected landscapes.*

Supportive Planning Instruments | AMT:s

One of the objectives of this report is to position approaches, methods and tools (also referred to as AMT:s in this report) relevant to the fields within planning research and planning praxis. The following short definitions of AMT's have been used in this report:

Approaches: means of incorporating solar methods and tools into regular planning processes, e.g. policies, community engagement etc.

Methods: planned procedures to assess and evaluate solar in relation to other aspects in urban planning (including landscape planning).

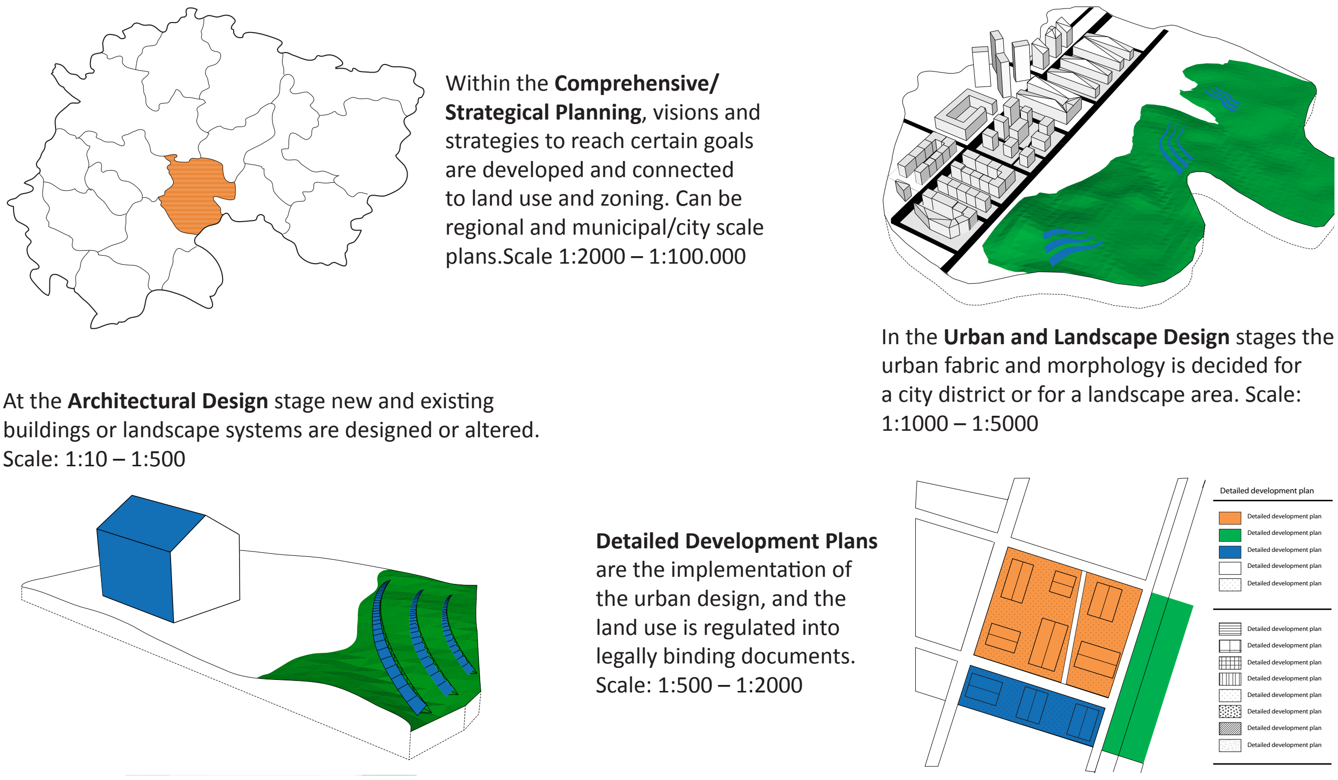
Tool: a rule of thumb, a calculation or a modelling software that mainly gives geometrical or numerical results; e.g. solar maps, solar potential software, GIS software, etc. GIS can also be used to visualize qualitative data.

This definition also implies a hierarchy between the three terms where approaches can incorporate methods and tools into regular planning processes; methods can apply tools to do multi-criteria assessments and evaluations while tools can be used more stand-alone and as a knowledge base.

In urban planning processes both quantitative and qualitative aspects are relevant. Therefore the AMT:s described relate to natural science, social science, humanistic and interdisciplinary forms of science as well as professional expertise.

Within this report the following categories of approaches, methods and tools will be presented:

- Regulatory, policy and governance approaches
- Integrated design and planning support
- Assessment methods and tools
- Awareness and consultation methods



Within the **Comprehensive/ Strategical Planning**, visions and strategies to reach certain goals are developed and connected to land use and zoning. Can be regional and municipal/city scale plans.Scale 1:2000 – 1:100.000

In the **Urban and Landscape Design** stages the urban fabric and morphology is decided for a city district or for a landscape area. Scale: 1:1000 – 1:5000

At the **Architectural Design** stage new and existing buildings or landscape systems are designed or altered. Scale: 1:10 – 1:500

Detailed Development Plans are the implementation of the urban design, and the land use is regulated into legally binding documents. Scale: 1:500 – 1:2000

Figure 1: Illustration of the 'Generic Planning Process' developed in IEA SHC Task 51 - Solar Energy in Urban Planning. Illustrations by Amanda Fröler, White arkitekter

Spatial Scales Within Planning

Through the generalization of knowledge from experts from 12 countries and three continents, a common description of the scales addressed within planning processes has been developed. The report revolves around an illustration of the *Generic Planning Process* relating to the spatial scale. A complement to this report, "Illustrative Prospective of Solar Energy in Urban Planning: Collection of International Case Studies" relates to administrative planning dependent on the local context, such as law and regulations.

Existing urban environments
In most developed countries, urban areas are already consolidated and have the highest share of energy consumption* with the building sector accounting for the majority of the existing stock. Considering the substantial benefits of integrating energy savings measures into existing buildings, an enormous effort is attributed to modifying the built environment. Currently, most of the attention is devoted to the reduction of energy needs, but in the future a more comprehensive effort includes envisioning localized renewable energy generation.

New urban environments
Planning new urban environments in the 21st century requires addressing the need for energy efficient design and an energy-generating built environment. Urban planning is complex, and there is a need to bring in the relevant aspects at stake at the right stages of the planning process in order to support spatial planning and energy production. In future buildings and urban environments, this concerns free energies such as daylight as well as active solar in the form of solar thermal systems and electricity production from photovoltaics (PV).

Sensitive landscape environments
The urban planning context is not independent from the surrounding landscape. Urban areas need to be supported by the surrounding land for production of food, energy, water and waste management, materials and much more. Hence, a greater demand for energy in urban areas also puts strain on the surrounding land. When solar strategies are incorporated in sensitive landscapes, the balance between relevant spatial, environmental, social, cultural and economical aspects is at its most delicate and most critical level. Here, spatial and energy planning meets agricultural and landscape ecology.

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* Energy consumption refers to energy use during operation in buildings, not to embodied energy in materials or energy from production of buildings.

Scope and Limitations

In order to achieve a substantial contribution regarding the increase of the use of solar energy, the focus in this report is on how to improve and accelerate the integration of solar energy in urban planning while respecting the quality of the urban context. The main work is on passive (daylight and solar gains) and active solar (solar thermal and photovoltaic) strategies due to a significant need for development in these areas within the complex context of urban planning.

This report will cover a sample of approaches, methods or tools available for solar energy integration in urban planning practices and serve as an inspiration of what is possible and how urban planners can reach a deeper understanding of the role of solar energy in different planning contexts.

In relation to active solar strategies there are obvious conflicts with cultural and historical heritage values of buildings and urban contexts if not carried out with great care. New approaches, methods and tools with special relevance for enhancing solar and dealing with this conflict in existing urban areas and sensitive landscapes will be presented. As urban planning documents are long lasting documents, the plans will determine the possibility in the future regarding building integrated or building added solar. In order to prepare for possible surfaces of urban solar energy generation it is important to act now. As solar energy can function as a building material, substituting traditional materials, aesthetics is of vital concern for solar thermal and photovoltaics to be accepted and implemented. The focus in this report will therefore support decision making dealing with the intersection between urban planning concerns due to spatial, heritage, aesthetics, and solar energy.

The need to change from fossil fuel solutions to renewable solutions is at the same time apparent. In 2012 the estimation was that without decisive action towards a change into renewables the energy-related emissions of carbon dioxide would more than double by 2050 (IEA, 2012). The solar heating and cooling (SHC) roadmap envisages how active solar could account for 16 % of the total final annual low temperature heating, and 17 % of total energy use for cooling by 2050 (IEA, 2012). In 2050 solar power is expected to account for 16 % of the world’s electricity production (IEA, 2014). At the same time 19 % of the world’s electricity use today is estimated to be used for lighting, which implies that there is a great potential for harvesting daylight for energy efficiency reasons (OECD/IEA, 2006). Daylight access is also important for health reasons. This development (urbanisation, densification and an increased share of solar energy in the global energy mix) will have a great effect on urban planning practices, especially when planning new areas in an era of intense urbanisation and increased urban density. The relation between urban planning, density, daylight and active solar needs to be addressed in very early planning process stages in order to seize opportunities for both saving energy through passive measures and preparing for possible generation of renewable energy.

Building on Earlier IEA SHC Tasks

Between 2009-2013 an International Energy Agency Solar Heating and Cooling Task 41 - Solar Energy and Architecture focused on research helpful in achieving high quality energy efficient architecture through building integration or building application of active solar. The vision (and the opportunity) was to make architectural design a driving force for the use of solar energy. The task resulted in publications and websites supporting a deeper knowledge in high quality architecture combined with solar thermal and photovoltaics (ST and PV). Part of the result is a collection of case study reference projects.

Task 51 Solar Energy in Urban Planning originated from the group of experts and the task operating agent of the earlier task, Task 41 Solar Energy in Architecture, whose members have since been accompanied by new experts with backgrounds in e.g. urban planning. The earlier task focused on building level and architectural quality. Task 51 focuses on planning from comprehensive (or strategical planning) stages to urban and landscape design stages and to detailed development plans into the architectural design stage dealt with in Task 41.

During the earlier IEA SHC Task 41 Solar Energy and Architecture, substantial work was done on architectural aspects regarding solar on the building level, targeting building integrated and building added active solar (BIPV/BAPV, BIST/BAST). When dealing with urban planning processes of existing and new urban areas, it is based on the knowledge of the work done in Task 41.

The knowledge on planning processes relating to sensitive landscape were not included in Task 41. There was a need to define and elaborate on the architectural aspects regarding active solar in sensitive landscape in Task 51 (similar to the work on buildings carried out in Task 41).

When dealing with the urban scale it is even more important to address other aspects of solar, such as solar gains, solar impact in urban outdoor areas and the risks of overheating indoors. Within the ambitions to reach low carbon cities it is important to build on the knowledge of IEA SHC Task 40/ EBC Annex 52 Towards Net Zero Energy Solar Buildings as Net Zero buildings will be an important strategic part of striving towards energy efficiency and renwables within urban areas. An important ambition in that work on the building scale as well as this report addressing a greater spatial scale is the hierarchy aiming first at passive measures (spatial and form-related energy minimizing tactics), followed by active measures (planning for active solar).

In Task 51 the spatial planning impact on passive and active solar is acknowledged and the planner's position as enabler is in focus. Harvesting the sun's potential in daylight and micro-climate is fundamentally connected to design. On this highly populated planet, a relevant focus for Task 51 is using active solar systems in building construction, which saves energy through material choice while simultaneously saving space.

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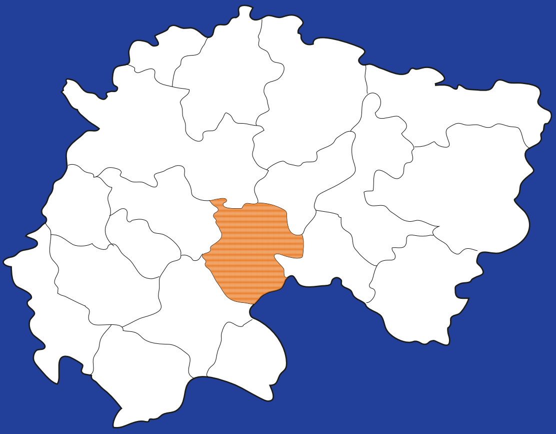
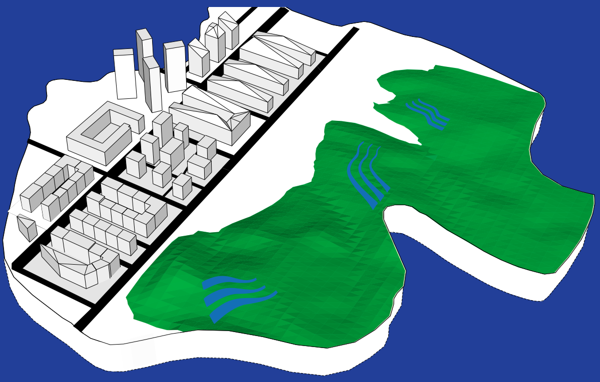
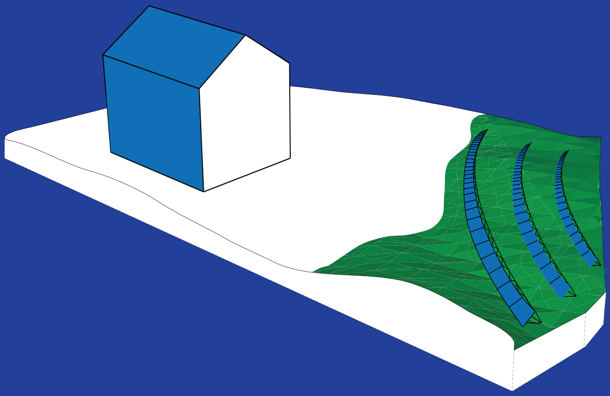
THE NEED FOR APPROACHES, METHODS AND TOOLS







Urban planning usually consists of both formal and informal processes. The formal planning process relates directly to the legal framework in the local context while the informal process relates planning traditions, land ownership and the division of power between private and public stakeholders. At the same time a lot of different criteria need to be fulfilled in order for the spatial environment to function. Urban planning is by nature a inter-disciplinary process which requires complex decision making weighing different aspects - a balancing act. Within the spatial planning and architectural professions interdisciplinarity is the basis for the complex solution-finding process. The professional training for urban planners, urban designers and architects usually consists of project-based approaches grounded in real-world situations and problems using mapping, drawing and other tools to iteratively test solutions to complex problems. This report relates to both practice and research dealing with complex spatial planning and design from the pragmatic focus to find approaches, methods and tools that will help enhancing solar in the urban planning process. The approaches, methods and tools presented in relation to urban environments in this report are relevant for:

- Urban and specifically spatial planning
- Architecture and urban design
- Civil- and energy engineering
- Legislators dealing with building and planning

In the coming chapters approaches, methods and tools are presented that support policy and design decisions on solar energy and daylight access in the design stages, relevant when designing existing and new urban environments as well as dealing with sensitive landscapes. Focus is on approaches, methods and tools that give visual or technical information directly to the problem-solving aspects when passive and active solar meets spatial planning and design. In the first chapter, the complexity of dealing with solar aspects in regard to these three focus environments, existing and new urban environments and sensitive landscape environments, is highlighted. There is also a need for a closer relation between the traditional urban planning and energy planning, and a general focus on synergies instead of conflicts when dealing with the challenges at stake when planning an increase of renewable energy systems, as in this report with focus on energy efficiency, daylight harvesting and use of active solar energy.

Marja Lundgren & Johan Dahlberg

1.1. EXISTING URBAN ENVIRONMENTS

Pietro Florio, Giuseppe Peronato & Maria Cristina Munari Probst

Existing building gross floor area in the EU27, Switzerland and Norway could be concentrated in a land area equivalent to that of Belgium (30,528 km^2). This building stock consists to 75 % of residential buildings, a quite homogenous group from an energy perspective, whereas the other 25 % consists of a quite heterogeneous group of services from retail and offices to hospitals and sports areas with different usage patterns, energy intensity and building construction (BPIE,2011). More than an one third of the European buildings were built before 1960. Almost half of the building stock was built between the 60’s and 90’s and less than a fifth was built between the 90’s and 2010 (BPIE, 2011). Much of the effort, especially in Europe, has been concentrated on renovating the whole building stock which accounts for almost 40 % of total energy use (including new buildings) (Nolt & Strong 2011). Benefits coming from the urgent retrofit of this amount are remarkable, even if the decrease of energy needs should be coupled with a diffuse renewable energy generation. The 27 EU Member States have set an energy savings target of 30 % by 2030, mainly through energy efficiency measures also implemented in a building code directive from 2002 and reacted in 2010. This aims at both new buildings and buildings that undergo substantial refurbishments (EPBD, 2010). A report from 2002 highlights how solar power production potential from photovoltaic roofs and façades could cover between 15-60 % of electricity consumptions in IEA countries (IEA PVPS T7-4, 2002). It is foreseen that more than half of the global PV capacity from now to 2050 will be installed on buildings, producing a little less than half the total PV electricity needed (IEA, 2014). This is also enhanced by a continuous decrease in prices for solar technologies (Zang et al., 2014).

Nevertheless, this process remains quite challenging: as a consequence of the above-mentioned cost reduction, public incitation like feed-in-tariffs or fiscal deductions are diminishing (Zang et al., 2014) and the entire financial burden (and risk) is shifted more to private initiatives. This encompasses a "renewable refurbishment expenditure" that in some occasions translates into higher rents for tenants or a filtering-up of wealthier households in freshly solar-equipped buildings, or sometimes even discourages potential investors. One general effect is the critical optimization of energy generation to cover the investment, which probably becomes more dramatic on existing buildings than for new urban developments, where solar design can be implemented from the beginning in the overall design process.

As a result, most solar energy installations in existing urban areas are realised on roofs where the prevalent amount of solar irradiation is available, targeting the highest generation and often disregarding the architectural integration quality of the system and the effect on the urban context. Public institutions and local authorities, on the other hand, have to balance the will to add more solar systems on buildings with protection of socio-cultural values and cultural heritage concerns. This can sometimes be contradictory and raise conflicts between energy planning and historical identity preservation.

Approaches, Methods and Tools for Solar energy in Existing Urban Areas

In order to deal with local energy generation, new methods and tools have been introduced into urban planning, such as assessment methods aiding urban planners and property owners in estimating the potential of existing built surfaces in regards to solar energy. One of the main challenges is related to covering the solar potential in existing urban areas over large areas. To deal with this, several approaches, methods and tools are linked to the recent advancements in rmote-sensing and city 3D-modeling as well as the integration of such data in complex spatial decision support systems, often based on GIS platforms. Several cities have used these technologies to create 2D or 3D solar maps together with energy maps for assessing the potentials of active solar and energy conservation. Even though there has been a rapid increase in software tools where solar insolation on existing surfaces can be calculated or measured, there is a lack of approaches and methods to integrate the results into traditional planning processes.

Due to the sometimes conflicting responsibilities of municipalities, to develop and preserve the physical environment with its architectural, cultural and heritage assets as well as promoting and enhancing renewable energy sources, new approaches, methods and tools are also needed to visualize these aspects of planning criteria. In the chapter on *Integrated urban design and planning support* different tools are presented that can be used in a combined fashion in order to support design solutions that weighs several aspects, often environmentally related, such as daylight, solar gains, energy efficiency and active solar at the same time. In the chapter on *Assessment methods and tools* several new approaches are presented that address the complex decision-making by weighing several aspects such as energy, spatial, aesthetical and heritage concerns at the same time. In the chapter on *Awareness and consultation methods in urban planning,* guidelines of different sorts for the public and real estate holders as well as the consultants are presented, which are useful especially in the detailed development plan and architectural design stages.

1.2. NEW URBAN ENVIRONMENTS

Marja Lundgren & Johan Dahlberg

The global phenomenon of urbanisation has recently developed along a steep curve. In the early 20th century 14 % of the population living in urban areas whereas in 2007 50 % of the population lived in urban areas. This increase is expected to continue and in 2050 around 65 % of the world's population will live in urban areas (UN, 2014). At the same time urban areas only account for 1-3 % of the total land area of Earth (Liu et al, 2014) although a far greater surrounding land area is needed to support urban populations with food and other necessities (Gunnartz, 2017).

The driving forces for urbanisation are often summarised as: economic, social, resource and environmental (Gunnartz, 2017). In many cities the urbanisation leads to densification which, in many ways, is positive. It can enhance the possibility to create attractive cultural and business areas, high quality education, public transport etc. However, there are also limits to how dense a city can be from sustainability perspective. Research back in 2003 showed that more dense urban development saves energy up to a certain limit and after that increased density starts to conflict with energy savings (Steamers, 2003). The findings were that although urban density has positive effects on transport emissions and heat conservation, shading in the urban morphology can create raised electricity consumption in buildings as a consequence of reduced daylight. Recent research show that the impact of spatial design of the same floor area ratio* in an urban development shows very different daylight conditions (Baek Pedersen, 2011). A too dense or too poorly designed density can also create heat island effects with an increased cooling demand and poor prerequisites for natural night cooling.

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*Floor Area Ratio is the ratio of a building's total floor area (zoning floor area) to the size of the piece of land upon which it is built, https://en.wikipedia.org/wiki/Floor_area_ratio

Other effects can be less sunlit surfaces to be used for active solar, urban farming or outdoor activities. Direct solar radiation (sunlight) has been shown by research to be absolutely necessary for healthy environments. A lack of sunlight can lead to irregularities in the circadian rhythm necessary for mental and physical well-being (Kongebro et al*,* 2012).

In the coming chapters different approaches, methods and tools for enhancing either passive solar (daylight, solar gains and thermal comfort) or active solar (photovoltaics or thermal solar heating) is presented as it has become an urban design concern.

Approaches, Methods and Tools for Solar Energy in New Urban Areas

Solar Approaches

Solar rights is a concept that several countries, regions or cities use within regulation (Capeluto et al., 2006). The reasons for regulating according to solar rights can both be related to public goals of ensuring sunny and daylit outdoor environments and to protect active solar potential. The latter both protect private property and enable legislative aims to reach environmental goals within renewable energy. Cities like New York, San Francisco, Toronto and Tel Aviv all use solar rights to protect public places like sidewalks (Capeluto et al., 2006). Two main approaches have been found by Capeluto et al, defined as a performance method defining functional requirements, such as hours of insolation or a descriptive method by geometric rules, regulating heights or street widths or their relation. As several countries, especially in the south of Europe has made solar heating mandatory, the active solar potential needs to be considered in urban planning.

A method developed in the 70's that has influenced legislation in several countries towards solar rights, both performance based and descriptive based, is the solar envelope originally defined as "the volumetric limits of buildings that will not shadow surroundings" for a minimum number of hour (Knowles, 1981). In chapter 5 on *Integrated urban design and planning support* the development of both new parametric tools that facilitates working with the solar envelope is presented as well as a simple geometrical section method based on solar envelope, easily carried out by architects and assessed by authorities.

Daylight Approaches

Urban development from the mid 19th century and onwards used geometrical guidelines in legislation making sure that light, air, fire protection and other civic functions were designed and paid for. Guidelines were often placed into building acts regulating distances and building heights, often making it possible to add an extra floor when broadening the streets, i.e. increasing density and floor area ratio and by this improving the land use economy for both the city and real estate developer (Rådberg, 2014). For cities, this created an economic foundation for common infrastructure. The geometric regulations starting off with Hausmann in Paris and spreading to several other countries resulted in architecture and city planning with common features in European cities in the late 19th century, where geometric regulation of street widths and building heights where adjusted after the latitude and solar prerequisites (Rådberg, 2014; Ngo et al., 2016).

In the 60's and 70's ways to assess daylight through the indicator daylight factor, a physical model of assessing daylight on a cloudy day originating from UK, entered several building codes. There are interesting relationships between the regulative approaches, standards and rules of thumb developed empirically throughout architectural history (Reinhart & LoVerso, 2010). A lot of national legislations and international standards today, as well as international voluntary certification systems, are based on the daylight factor and therefore a fair amount of research has been devoted to daylight factor methodology. In the chapter on *Integrated urban design and planning support* a short referee of an exhibition addressing the relationship between Building Code demands on daylight to Swedish multi-storey dwellings from 1920 until 2010 addresses how the use of a quick test of geometrical rules can give very relevant knowledge on the challenges regarding daylight that the urban design will create.

Within practice, easy methods and rules of thumb and conventional simulation tools complemented with Climate Based Daylight Modelling (CBDM) can lead the design from very early crude stages to the more detailed phases. New knowledge can also be developed from simulations into new rules of thumb and create a deeper shared knowledge between the designer world and the engineering world. In the chapter on *Integrated urban design and planning suppor*t the development of several approaches of using a combination of different simulation tools to inform urban design is presented.

Planning Acts to Guide Solar Enhancement

Urban planning has throughout history been guided by regulation and tradition. Regulation is related to the organisation, health aspects and the functions of the city. Policy and regulatory approaches can help balancing the common good and individual investments on all scales, from a national level to a regional and city level for both infills in existing areas as well as developments of new areas. In chapter 2; *Regulatory, Policy and Governance Approaches* different illustrative examples are given on how to use regulation and voluntary approaches to enhance solar energy within planning.

Trüby (Ngo et al., 2016) differentiates between rules dealing with safety (as building code) and those dealing with design and the regulation of visual appearance (design codes). There are different traditions within different countries and regions, when it comes to how far the visual appearance is regulated by planning acts or building acts and codes and through the regulated planning process. In chapter 4; *Assessment Methods and Tools* new approaches, methods and tools are presented on how to use modelling tools to support decisions relating to visual aspects in new dense urban fabrics taking into account cultural heritage. Chapter 5; *Awareness and Consultation Methods in Urban Planning* presents guidelines for active solar on an architectural design level addressing the aesthetics and technical aspects of building integration.

Building regulation on conservation and active solar

On the building level the EU directive of Nearly Zero Energy Buildings regulates the heating demand, summer comfort, and solar energy generation toward nearly zero energy building and relies on renewable energy to lower energy demands. This has made it necessary to quantify the solar potential and solar energy generation in the building design phase (Voss & Musall, 2011). In densely built urban areas, considering the new building together with its neighbourhood and modelling the interactions between both is essential and addressed in chapter 3; *Integrated Urban Design and Planning Support.* In chapter 4; *Assessment Methods and Tools* different approaches, methods and tools are presented that support planning and design decisions when striving for low energy demand and high solar heat and power production.

With the 2015 Paris commitment in mind it is even more important to make sure that energy generation is renewable. Since solar energy systems can replace other building materials they have additional advantages compared to other heat and power production solutions. In order to enhance solar considerations within the planning process, there is a great need for knowledge from different disciplines to reach the planning practice and the public. In chapter 5; *Awareness and Consultation Methods in Urban Planning*, guidelines for both daylight and active solar are presented.

1.3 LANDSCAPE ENVIRONMENTS

Alessandra Scognamiglio

The concept of landscape is very wide, and its meaning and wording can vary depending on the context in which the concept is used and according to different disciplines (Kapetanakis et al., 2014).

According to the European Landscape Convention “Landscape” means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors. ‘Landscape quality objective’ means, for a specific landscape, the formulation by the competent public authorities of the aspirations of the public with regard to the landscape features of their surroundings (Council of Europe, 2000).

The interrelation between energy systems and physical environments exists since energy generation needs space as a resource, a site of production, a transportation channel, and there is a receiver with an energy need and this also creates an economic transaction somewhere down the line. Traditional energy sources and the creation of value in energy regimes has internalized benefits and accrued them to the urban centre, while “externalizing” costs, sliding them to the periphery, out of sight (Ghosn, 2009). In contrast to traditional fossil fuels, the use of renewable energy sources (RES), and large-scale solar arrays in particular, makes new energy-oriented land uses and landscape transformations visible because the energy generators are visually exposed and are close to the places where people live. The landscape turns into the spatial and cultural medium through which the perception of the energy generation by RES, specifically solar energy generation, happens. When this is done in a way where social acceptance of RES passes it also results into an acceptance of a certain modified landscape.

Land use represents a major human effect on natural systems; the energy sector affects and limits alternative uses of land; in the future the assimilation, conversion, storage, and transport of renewable energy will be one of the most important land uses of the twenty-first century (Stremke & van den Dobbelsteen, 2013). PV arrays are beneficial regarding CO_2 emissions mitigation but it is only recently, with the increase of the number and size of the installations that the attention towards their impacts in terms of land use and land transformation has been growing (Chiabrando et al., 2009). In fact, in contrast to systems in which solar technology is integrated in buildings or infrastructures, which do not impact on land use, the realisation of ground mounted solar arrays requires suitable space, land conversion and management practices that can produce dramatic land use changes (Lakhani et al., 2014; Pasimeni et al., 2014; Mc Donald et al., 2009). These changes may counteract other sustainability goals, such as preserving biodiversity and ecosystem services, conflicting with related legislation (Prados, 2010; Pang et al., 2014), such as the European Landscape Convention (Council of Europe, 2000).

Society is facing new challenges regarding energy generation from RES, and only focusing on energy objectives does not ensure that the sustainability challenges as a whole will be met. Design plays a key role as an enabler for the transition from fossil fuels to RES. To exploit design potentialities new approaches are needed, since in the current practice energy and space design are treated in separate domains, if at all.

Different ways of addressing the relation between energy generation and land use can be detected in the concepts of “energy landscape”, “energyscapes” and “sustainable energy landscapes". The concept of an "energy landscape" is useful when dealing with these new challenges. The connection between geography and energy is clear when looking at maps (Pasqualetti, 2013). Energy landscapes establish a link between physics-based views on energy commodities and their spatial footprints on one hand, and the perception of citizens about geographic space on the other. Such energy landscapes can be a valid intuitive concept for spatial planning and may provide spatial analysis capabilities and methods with which to plan future courses of action (Blaschke et al., 2013, Stremke, 2013). "Energyscapes" defines the complex spatial and temporal combination of the supply, demand and infrastructure for energy within a landscape (Howard et al., 2013). "Sustainable energy landscapes" are energy landscapes that can evolve on the basis of locally available renewable energy sources without compromising landscape quality, biodiversity, food production and other life-supporting ecosystem services (Stremke, 2013). The attribute "sustainable" for an energy landscape changes with regard to time and specific local conditions. Such energy landscapes do not necessarily represent a distinct spatial entity but can be conceptualized as a layer or subsystem of the larger physical environment (Stremke, 2014). There is also a concept of landscape ecology, where a "landscape" is described as a mosaic where the mix of local ecosystems or land uses is repeated in similar form over a kilometre-wide area. This concept, now widely used, integrates a focus on (a) spatial pattern, (b) the area viewed in an aerial photograph or from a high point of the land, and (c) unity provided by repeated pattern (Forman, 1995).

While energy targets are set at national or on an EU-level or levels alike, the application is realized in specific geographical areas where an energy-spatial planning process is necessary to be carried out by local authorities. Utilities should set energy targets based on the use of RES, and local authorities should propose specific sites, or protect others (Voivontas et al., 1998). In a post-carbon world, spatial planning and design must facilitate the utilisation of local energy potentials and account for the optimum size of each energy carrier (Stremke & Koh, 2010).

Approaches, Methods and Tools for Solar Energy in Landscapes

Energy mapping can help in identifying renewable energy sources in a region (van den Dobbelsteen et al., 2007). Criteria for an energy landscape should require location where optimal site parameters, such as natural vegetation and human oriented landscape services offer the best solution for the available options (Blaschke et al., 2013; Calvert et al., 2013). Modelling of energy resources and demand should not involve just a simple juxtaposition of energy supply potential and energy demand, but should also consider the spatial and temporal characteristics of each energy carrier and the characteristics of each individual subset of a region at the appropriate scale (Blaschke et al., 2013). The ability to realize renewable energy objectives is constrained by a range of geographic factors related to resource potential, the distribution of resources, land availability/suitability, land-costs, the absorptive capacity of proximal infrastructure, and local socio-political acceptance (Calvert et al., 2013).

Site characteristics are crucial for understanding what the suitable sites for the introduction of photovoltaic solar cell (PV) or solar thermal (ST) systems are, and many different layers of information are needed. The solar potential has to be verified in terms of real available potential, by overlapping many layers of information, and in particular, site features (such as solar energy availability, solar access, orography, or landscape sensitivity) that influence the implementation. Geographical Information System (GIS) technology has been acknowledged as an indispensable tool for energy management, thanks to its flexibility in handling data available on different levels of spatial analysis and its ability to highlight the spatial interrelations between data sets. Multi Criteria Decision-Supporting (MCDS) systems can be developed based on GIS technology, which help local authorities in setting design guidelines and criteria for installing renewable energy systems (RES). The weight given to each single indicator depends on the specific features and conditions of the installation site. The optimal site selection for installing large-scale PV arrays can be governed by means of a carrying capacity model, which combines Multi Criteria Decision Analysis (MCDA) as well as the Analytic Hierarchy Process (AHP) with GIS technology (Arán Carrión et al, 2008).

It has been acknowledged that in many cases renewable energy systems do not require the exclusive use of land, and they can be designed so as to extract multiple sources of energy from the same land-base. Algorithms to produce multiple maps of shared potentials have been proposed (Calvert et al., 2013). The optimal site selection for RES happens through an evaluation based on resource inventories and spatial restriction criteria. Resource inventories allow for mapping the theoretical potential for each renewable energy source. Restriction criteria refer to dimensions such as: environmental/ecological; technical/ economic (proximity to water, proximity to airport); social/political. A hierarchy can be set among restrictions: hard restrictions automatically eliminate a site in the analysis; soft restrictions can be overcome through technical innovation, infrastructural development or changes to legislation, land-use patterns, and cultural attitudes (Calvert et al., 2013). Existing energy models and research have low concerns on land use, landscapes and biodiversity. Consequently, it would be difficult to provide comprehensive decision support by using only these tools. However, suitable energy models, ecological assessment models and multi-criteria approaches exist with great potential for interlinking (Pang et al., 2014).

1.4 COLLABORATION BETWEEN SPATIAL AND ENERGY PLANNING

Marja Lundgren, Karsten Voss

As renewables take a greater share of the total energy generation on the national and transnational levels, it is relevant to address renewables early when planning for active solar energy. Focus needs to be on balancing energy needs, energy efficiency measures and local as well as district energy generation. On one hand there are issues in predicting or measuring energy use related to energy building design, energy conservation, in existing building areas and daylight access; and, on the other hand, there are also difficulties predicting the energy harvesting and storage potential. The grid interaction might also consider advanced concepts for demand site management as well as concepts for future electric mobility as part of the energy needs and storage capacity within a district.

The energy needs and the generation profiles are different for different countries and, as such, the answers regarding efficiency, balancing or storage will differ quite a lot between the countries. This report will only deal with the generic level and how tools can help in this balance between planning the built fabric, the transformation of built fabric or the landscape transformation in relation to energy conservation and use of passive and active solar systems; technical solutions for distribution or storage are excluded from this report. In this report, focus is on approaches, methods and tools aimed at supporting the spatial planning and design by predicting the active solar energy generation potential, the daylight potential, micro-climate aspects and the urban and building design in relation to energy needs. The relation between load match on district and building design level and other ways of balancing solar to energy needs is of relevance.

On a building and energy system level, the IEA SHC Task 40/ EBC Annex 52 Towards Net Zero Energy Solar Buildings dealt with studies of grid interaction (power/heating/cooling) and time dependent energy load match analysis. The development of a harmonized international definition framework for the Net Zero Energy Building (NZEB) concept will be useful as a basis for further developments regarding large-scale implications. In this task, this was referred to as Net Zero Energy Clusters (NZEC). As the NZEB level is extremely challenging to achieve with high density individual buildings (decreasing solar roof area per m² floor area while increasing energy demand with every additional floor), strategies must be developed by clustering buildings of various types within net zero energy city quarters or cities. Different building uses have different energy profiling, which makes it possible for an exchange; for example, offices and retail buildings have an excess of internal heat which can be shared with dwellings needing heat during the cold periods of the year.

In the positioning paper for Net Zero Energy Solar Buildings, the concept of Net Zero Buildings is elaborated upon.The need for suitable architectural design and improved building envelopes through the use of upgraded thermal envelopes, daylighting and energy efficient ventilation is presented. For better efficiency, these are combined with energy systems and services for heating and cooling on the demand side along with the utilization of a renewable solar energy concept: solar heating, solar cooling, solar electricity and other renewable energy generation sources. As the concept of NZEB has a longer tradition in the “autonomous building energy option”, the novelty in the research of Task 40 was the development of a robust net-zero energy regulatory framework for policy makers – something missing in most countries. Together with case studies, this was applied and presented in concrete terms. Furthermore, the net zero approach permits an annual, monthly or hourly balance between energy demand and energy supply in contrast to the autonomous building and creates the need for grid interaction and additionally introduces the concepts of load match and grid connectivity, smart controls, load management and on-site solar energy utilization. Annex 67 “Energy Flexible Buildings” within the EBC programme, consequently addresses these questions as a follow up activity to Task 40.

Scaling up NZEB to an Urban Planning Level?

At an urban planning scale, the relationship between on-site solar availability and off-site availability is determined by the urban design planning. Presented in this report in the chapter on *Assessment Methods and Tool*s, the section on Sunscape Index; the Case Årstafältet shows the impact of urban design on a south-facing, geologically flat area and the need for collaboration between the functions of municipalities, in this case the Offices for city planning, environment and land development (the latter in charge of the civil contracts of land owned by the Municipality of Stockholm).

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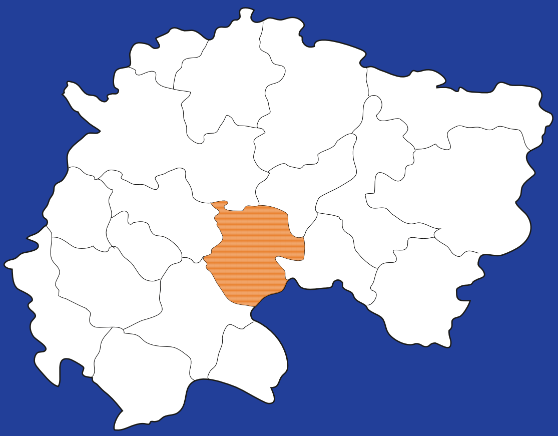
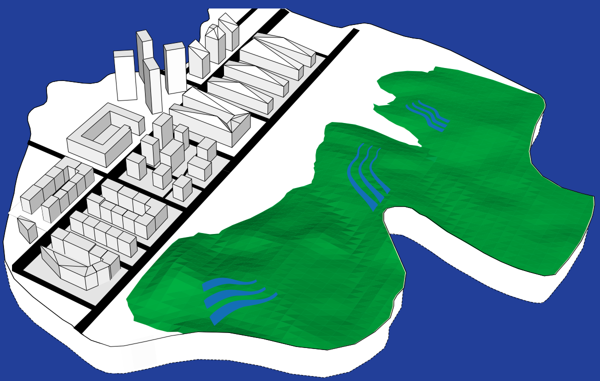
REGULATORY, POLICY AND GOVERNANCE APPROACHES





In this chapter some examples of regulatory measures as well as policy and governance approaches to enhance active and passive solar will be presented. Some of these approaches and methods are already in use in some countries or regions and some are developed and discussed within a research discourse.

Building codes differ from local to national and depend on whether or not a region or city can set higher requirements than national minimum standards.

Within comprehensive/strategical planning, visions and strategies to reach certain goals are developed and connected to land use and zoning. This can be on a regional, municipal or city scale plan (1:2000 – 1:100 000). On this level, policy and regulatory approaches can be very effective. In this section we introduce a number of existing approaches, methods and tools that are relevant for enhancing implementation of active solar (i.e. solar thermal and photovoltaics) and passive solar (daylight and solar gains).

Also, in the urban and landscape design stages (1:1000-1:5000) – where the land use is developed often in a collaboration between public and private interests – legislation as well as policies and governance can guide: surpassing the national goals can have a great effect on speeding up solar enhancement.

During detailed development planning, the land ownership is one of the more important aspects. Therefore different forms of governance and innovative use of land procurement agreements have proven to give positive effects creating drivers for active solar.

Marja Lundgren and Johan Dahlberg.

2.1. REGULATION LEADING THE WAY

Marja Lundgren

Environmental Impact Assessment (EIA) has become a natural part of planning through regulation in the EU Member states. In the report *Illustrative Prospective of Solar Energy in Urban Planning: Collection of International Case Studies*, several examples show how existing regulation – in combination with financial incentives and political decisions – can lead the way to solar implementation. In the Austrian Cases, Aspern + Die Seestadt Wiens and Stadwerk Lehen, legislative framework in combination with research projects (contributing interdisciplinary processes and platforms for testing ambitions goals) led to an enhancement of energy efficiency and energy generation (including geothermal, solar thermal and photovoltaics). In Aspern, the consequential use of EIA in early urban planning stages (Master and Zoning Plans) – as a strategic EIA in 2003 and a second EIA in 2010 and a final EIA in 2015 – led to a development in accordance to its guiding principles. One of the main challenges mentioned in the case study description is the timely integration of energy planning and urban planning concepts within the realm of existing regulatory and legal frameworks. A variety of approaches and methods were used in order to plan for a balance of energy need and use of renewable resources. The success factors of this case study refer to the collaboration between all concerned parties: municipalities, utility companies, energy suppliers, developers, civil engineers, experts. By 2006 two main pillars of the Stadtwerk Lehen master plan were formed through the guidance of national and local goals and regulations and led towards the use of mainly renewable energy systems: high performance buildings and extended use of solar thermal and photovoltaics. This master plan was developed from a collaboration of energy and urban planning by the leading municipality of Salburg, the energy supplier Salzburg Ag and the scientific institutions SIR and Steinbeis. The master plan was then divided between four developers and ten teams of architects. Extended simulation and monitoring of the solar installations were founded by the EU programme Concerto “Green Solar Cities”. The energy concept was successfully based on solar thermal collectors and a renewable district heating system for high energy performance of buildings.

2.2. GOVERNANCE IN URBAN PLANNING – LEARNING FROM THE NORDIC COUNTRIES

Johan Dahlberg, Karin Kappel, Marja Lundgren & Simon Stendorf Sørensen

Scandinavian planning tradition emphasises the role of local authorities and, in Sweden, is referred to as the ‘municipal planning monopoly’. In theory this means that municipalities have full control over both strategic planning and detailed development plans.

However, in practice the opportunity for municipal urban planners to promote solar energy in urban planning is often limited by both the lack of available and relevant legislative framework and the will of individual developers (J. Matzen, personal communication, 2015). These circumstances, as well as land ownership, attractiveness of land and resources in municipal planning organisations (amongst others), constitute a narrow ‘space’ in which the planner struggles to navigate in different ways to assist and encourage the integration of solar energy in urban development.

From a planner’s perspective, it could be seen as if the fate of solar energy lies in the hands of regulators and developers (J. Matzen, personal communication, 2015). However, the de-centralised legislative approach to urban planning gives planners in Scandinavia the tools to initiate a balanced negotiation between public and private interests with developers and the possibility to expose unknown potentials for integration of solar energy in early stages of the planning process.

Solar energy as a technology has grown rapidly over the last few years and a new generation of solar panels offers, with its new colours, styles, structures and texture, another aesthetic than previously available. Solar panels were formerly an application, but now they are a construction material with a distinct intrinsic value that opens up new architectural possibilities. In urban planning and building design, solar energy is still often seen as a novelty and legally, local authorities have difficulties enforcing specific technologies in detailed development plans partly to remain ‘technology neutral’ and partly because a basic principle is to ‘not include more than what is needed’ in a plan.

In general, this means that a detailed development plan cannot entail tougher requirements on buildings than what is stated in the national building code. At the same time, larger cities in Scandinavia have a long tradition of owning a large share of the land. Stockholm, for example, owns 70 % of the land within its’ borders (City of Stockholm, 2017). There is also a trend where smaller municipalities are buying back land to gain more control over plans. When the municipality owns the land they can act as a land owner and not as a public authority; as a land owner they can place extra requirements on developers through land procurement agreements. This is the key to sustainable urban development. Examples in Scandinavia include Hammarby Sjöstad (Stockholm), Bo01 (Malmö), Ørestad (Copenhagen) and Stockholm Royal Seaport. It is also important to understand that, generally, land of a larger urban district is not sold to a single developer, rather districts are sold as individual plots where architectural competitions and bidding processes are used to raise sustainability aspects at an early phase.

Thus, when discussing solar energy in urban planning, the cases available represent a situation where cities or local authorities have used their land ownership to place tough requirements in land procurement agreements or have developed the land themselves. These requirements encompass a variety of sustainability aspects; but when looking at solar energy specifically, it is often stated as a quantitative demand. Since there exist little precedence detailing reasonable requirements, different types of requirements have been tested. In Stockholm at a large new urban development, Stockholm Royal Seaport, the requirements where initially stated as “30 % of the building energy needs (excluding household or business energy) are to be supplied by locally generated energy” (City of Stockholm, 2012). Today, the requirement is to generate “2 kWh/m^2 (floor area) PV annually or 6 kWh/m^2 (floor area) Solar Thermal annually or a combination of both” (City of Stockholm, 2015).

The requirements were changed in dialogue with private developers as they proved infeasible early on. The capacity and will to amend requirements in dialogue with private developers has been a learning process for the City of Stockholm starting with the development of Hammarby Sjöstad in the late 90’s and 00’s. Hammarby Sjöstad was an early attempt to push through tough requirements. As a result, the area contains some of the first solar energy installations in dense urban areas in Sweden. Although Hammarby Sjöstad is a good example resulting from high ambitions, the outcome is somewhat unclear. When targets, goals and requirements were set, there was no stated procedure to make sure they were implemented. Later evaluations of the area have proven difficult as a lot of data is lacking (Pandis & Brandt, 2009).

In Ørestad, a new urban area in Copenhagen, the municipality itself has been directly involved in developing some of the plots as owner or as a subsidising body, while several plots have also been developed by private developers. This mix was used by the municipal planners as leverage to exercise what could be termed as governance by the form of ‘story-telling’ (Sørensen, 2006). They developed a scheme of guiding

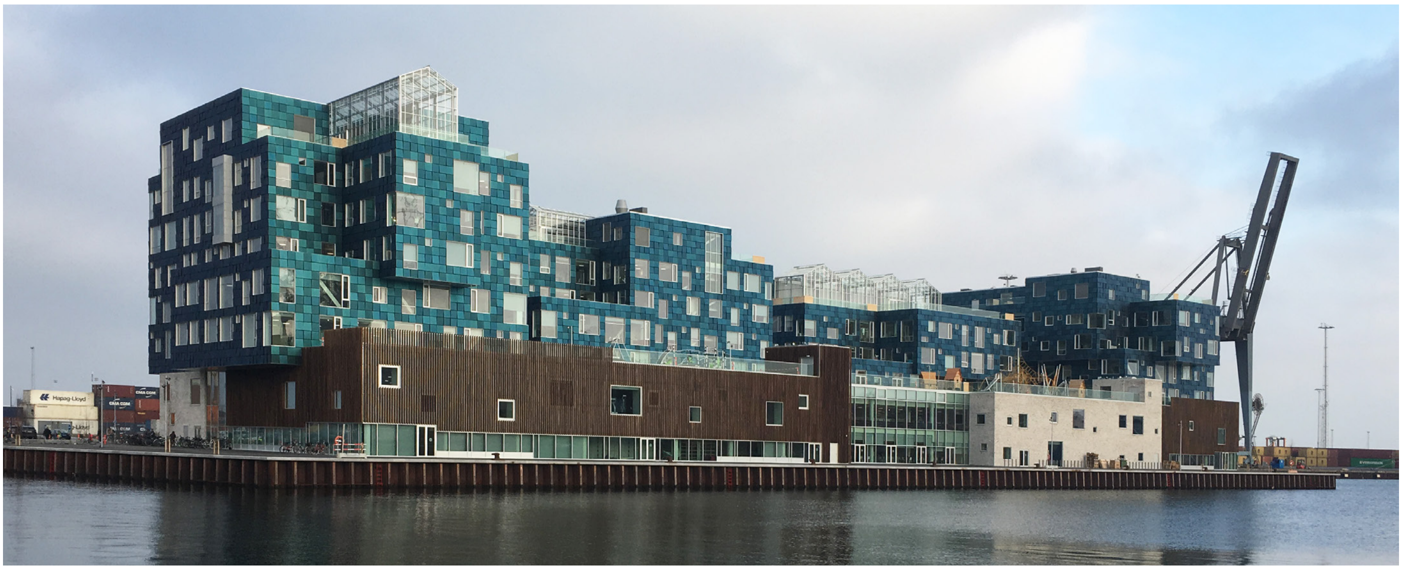


Figure 2: Copenhagen International School: façade with green PV panels mounted in different angles

principles to ensure environmentally friendly construction, which stated that utilising suitable solar energy potentials was obligated in all developments subsidised by the municipality.

This demonstrated the municipality's willingness to be a front-runner, and when engaging with private developers it served to inspire the use of storytelling, by creating interests, images and visions among other stakeholders in an attempt to steer more private developers towards solar energy integration. This approach has contributed to a trend in Ørestad, where solar energy in some cases has been an integrated part of urban planning and development (also due to the need of meeting high energy standards for new buildings, where active solar energy is deducted from the energy consumption of the building).

Carlsberg is another case in Copenhagen. The master plan included an analysis of optimal integration of solar energy in the dense urban area and showed how shadow effects from planned high rise buildings should be taken into account. However, recent development plans for plots in the Carlsberg area consider little if any integration of solar energy. Unlike Ørestad, the area contains several existing buildings with some of them of heritage value, which complicates integration of solar energy compared to new buildings. Another difference is that the municipal involvement as plot developer is limited, as the plots are developed by private developers. This has narrowed the governing 'space' for local planners to promote solar energy integration in the urban development.

Experiences from Scandinavian cities show that taking control of the urban development process through land ownership, requirements and guiding principles is essential but usually not enough. Developers may be new to solar energy technologies and the people that sign the land procurement agreements are not always the same people that have to implement them. Local authorities need to be at the forefront showcasing the potential with inspirational examples, while at the same time ensuring that targets, goals, visions and requirements are implemented. This can be summarised as an approach that involves one or more of the following:

- *Storytelling.* Making a district known for its sustainability ambitions is important for attracting developers interested in e.g. solar energy.
- *Capacity building.* The local authority needs to supply developers with information and knowledge on what solar energy technology entails, what products are available and what benefits come with it.
- *Follow up requirements.* If requirements are not clearly set and there is no formal process of checking that they are actually being implemented, they tend to be lost along the way.

One noteworthy experience to be shared is that when there are many developers in the same district and all have the same requirements, a sense of competition arises where no one wants to be the one that did not fulfil the requirements. Therefore, it is important to facilitate active collaboration between developers to ensure they know if they are on par with each other.

The approach to utilise public land ownership to set tough requirements has proven to be an effective way of showcasing to the building sector what is possible; in the long term attitudes change and eventually lead to solar energy becoming a common aspect in the urban planning processes.

2.3. SOLAR FRACTION AS AN INDICATOR FOR DETAILED PLANNING

Jouri Kanters

In the Swedish context, urban planners are not allowed to set any specifications regarding the supply of heat and electricity of buildings in the detailed development plan. It might, however, be possible to set indicators in the detailed development plan for solar energy that are not directly related to the energy generation of active solar systems but have an indirect relationship.

An example of such an indirect-related indicator is the SAFAR$_n$ (Suitable Area to Floor Area Ratio) as described by Kanters et al. (2014). This indicator describes the relationship between the 'Suitable Area' (Area receiving an amount of solar radiation greater than or equal to a predefined threshold *n*) and the Floor Area of the considered building. The 'suitable area' could provide a rough estimation of the possible production by means of a solar energy system, while the floor area can provide a maximum required energy used as specified by the national building code.

2.4. PROCUREMENT AS A STRATEGY FOR SOLAR

Margarethe Korolkow

When it is not possible to implement specific requirements for energy efficiency or utilisation of renewable energies towards urban planning, other ways can be found to promote these goals, especially when municipalities have ownership of the land. For example, in Adlershof, the City of Berlin established a local developer that is in charge of marketing and selling plots. First, an independent professional determines the value of a plot. Then, the plot is offered at the given price and different investors can apply to purchase the plot. The developer's priority as a trustee of the Federal State of Berlin is not to find the best offer in terms of profit, but to find the best concept and match for the development of the entire urban area. This encourages investors to be innovative and to include renewable energies in their concepts. This approach also works well for the implementation of solar systems. In 2017, there were more than 2 MW$_{peak}$ of installed PV power. Several building integrated systems exist as well as building added systems. Since there is a district heating network with a very low primary energy factor, solar thermal systems are not common. (Senatsverwaltung für Stadtentwicklung und Umwelt, 2007 & 2013).

Figure 3: Impressions of solar systems in Berlin Adlershof (photos: Margarethe Korolkow).

2.5. METHODS INTEGRATED IN THE GERMAN PLANNING PROCESS

Katharina Simon

The urban planning and design process is very complex. Especially when the goal is the development of a sustainable neighbourhood, the planers need to deal with many aspects and criteria in parallel. In Germany, it is usual to carry out the planning after the following seven main planning phases:

1. Situation evaluation
2. Problem detection
3. Goal setting
4. Determination of planning scope
5. Plan development
6. Realisation
7. Monitoring and evaluation

Figure 4, on the following page, shows the planning phase in detail. Red marked are the relevant phases for making energy decisions.

The phases can neither be considered separately, nor is the goal to work through them step by step. All phases should mesh and support each other. As different disciplines can be involved in each phase, the communication between the inter-disciplinary planners should work. In general, the sooner the interdisciplinary planning is started, the better the expected results are.

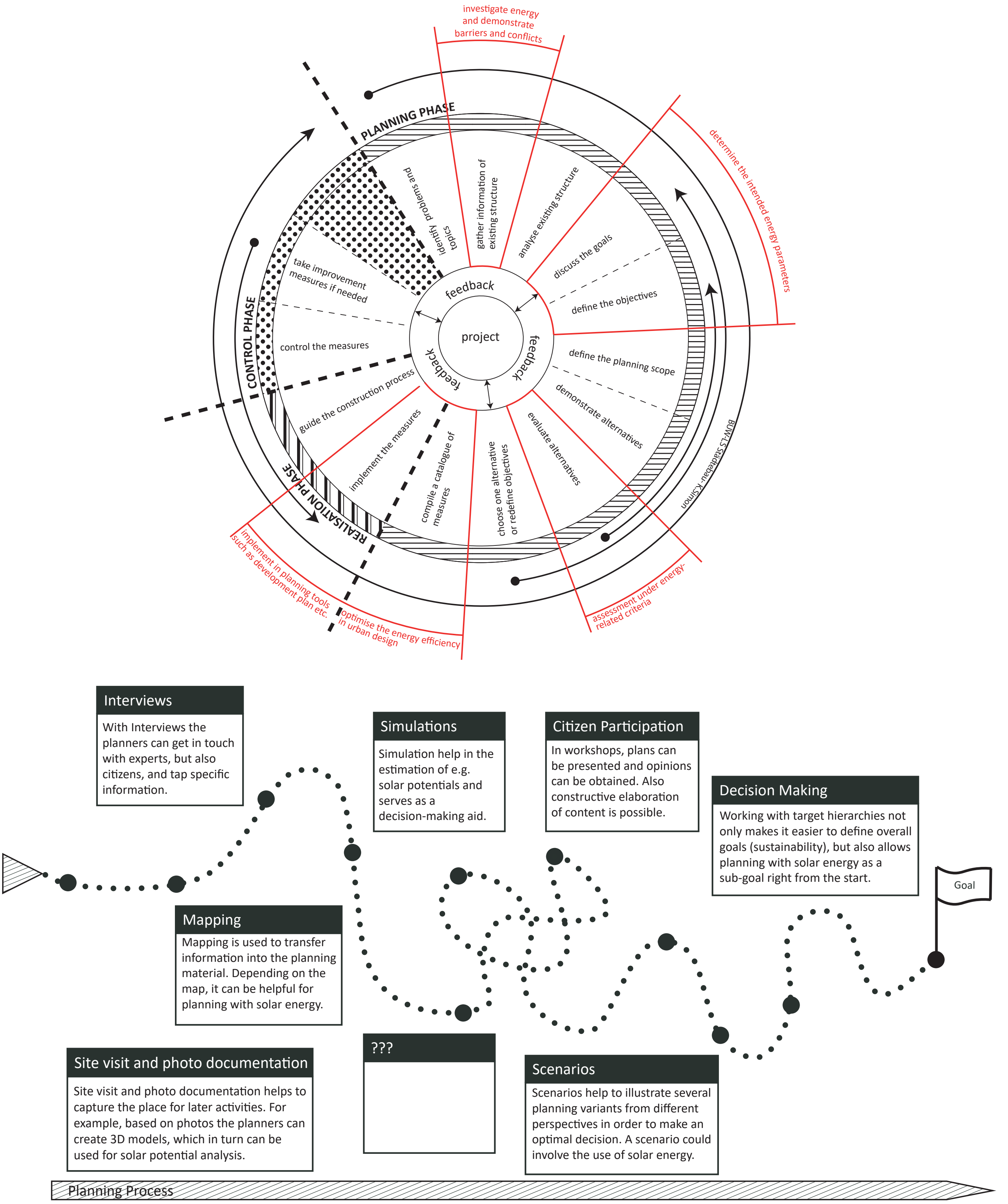
Methods and tools are able to support the planning process, but it is necessary that the planners have got the knowledge on how to use them. In Germany, the planners have a well-filled methodology kit available. The methods in this kit are divided into formal and non-formal methods. Formal methods are set by the German legislation and need to be implemented in any case. Furthermore, there is a variety of methods that can be used depending on the situation, but there is no legal requirement.

One formal method which must be used several times in the planning process is citizen participation. With the legally anchored method, the legislator wants to ensure that any planning cannot be realised without asking the citizens. At certain times in the planning process, such as during the goal setting or plan development phases, the citizens get the opportunity to express their opinions and actively intervene in the planning process. They can do this e.g. through workshops and working groups. This approach promotes the acceptance of planning in general and also the acceptance for solar energy planning.

Other non-formal methods which can support the planning process are divided into the following categories:

- Information collection and evaluation
- Objective and problem structuring methods
- Decision making and evaluation method
- Mapping methods
- Scenarios
- Planning and project management

They can be assigned to every planning phase, when needed. Figure 4 explain shortly some methods, which can support solar development at an early planning stage. Methods such as site visit, photo documentation, interviews, mapping etc. are easy to handle but generate a huge benefit for the planning (Simon, 2017).



Interviews

With Interviews the planners can get in touch with experts, but also citizens, and tap specific information.

Simulations

Simulation help in the estimation of e.g. solar potentials and serves as a decision-making aid.

Citizen Participation

In workshops, plans can be presented and opinions can be obtained. Also constructive elaboration of content is possible.

Decision Making

Working with target hierarchies not only makes it easier to define overall goals (sustainability), but also allows planning with solar energy as a sub-goal right from the start.

Mapping

Mapping is used to transfer information into the planning material. Depending on the map, it can be helpful for planning with solar energy.

Site visit and photo documentation

Site visit and photo documentation helps to capture the place for later activities. For example, based on photos the planners can create 3D models, which in turn can be used for solar potential analysis.

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Scenarios

Scenarios help to illustrate several planning variants from different perspectives in order to make an optimal decision. A scenario could involve the use of solar energy.

Figure 4: Top: German planning process. (Source: BUW, Katharina Simon) Bottom: Solar supported methods in the planning process. (Source: BUW, Katharina Simon)

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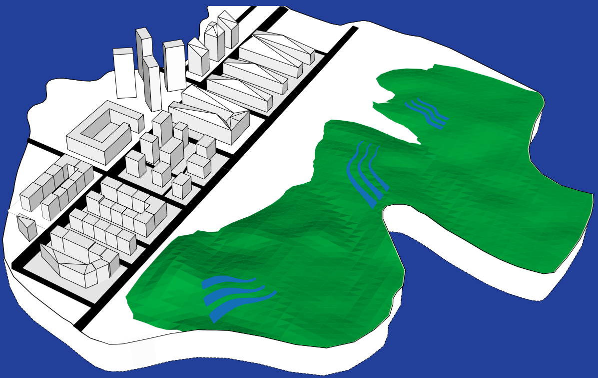
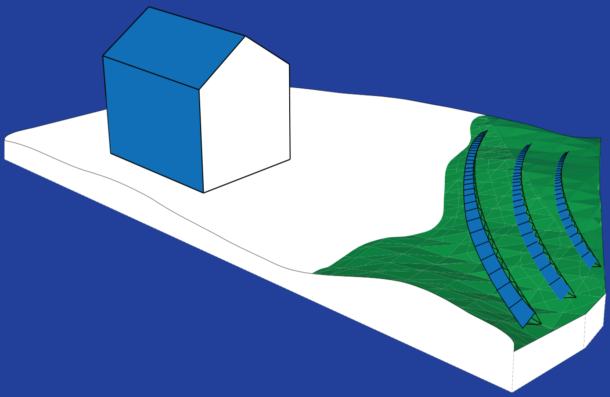
3

INTEGRATED URBAN DESIGN AND PLANNING SUPPORT





Urban planning determines the prerequisites of urban morphologies and of possible use and impact of free energy resources such as wind, daylight and solar gains. The city plan and the built environment will also impact air temperatures and consequently outdoor comfort and health but also the needs for energy within a building.

The relation of individual buildings to their surroundings and their orientation is important for shading. Ratti et al. (2005) presents and quantifies the form-energy dependency within the sequence 1) urban geometry in relation to operational energy, 2) building geometry, 3) system efficiency and 4) occupant behaviour. Very early design decisions, even on an urban scale, will at certain city density rates start 'boxing-in' the possibilities of energy efficiency due to the relation between daylight resources, artificial lighting and indoor climate (Strømann-Andersen, 2012).

Urban and architectural design often require trans-disciplinary knowledge input through iterative processes. There are several ways to go about creating an integrated design and planning process involving all the relevant professional knowledge and it often evolves and changes as new approaches, methods or tools (AMT's) are introduced. For example, the development of computational support to simulate quantitative data in relation to solar aspects and wind can today assist in the urban design process more than ever (as shown in this chapter) and certification systems on building and urban scales are also pushing this development. The combination of rules of thumb and conventional simulation tools can lead the design from very early crude stages to the more detailed phases. New knowledge can also be developed from simulations into new rules of thumb and create a deeper shared knowledge between the designer world and the engineering world.

This chapter will mainly provide examples of approaches, methods and tools for evaluation of spatial and volumetric design that help to guide the design in early stages with the purpose to enhance energy performance of buildings and neighbourhoods, use of active solar and creating comfortable and healthy outdoor environments through the use of free energies such as daylight and sunlight. Policies and evaluation tools for strategic decisions will be covered in subsequent chapters.

Marja Lundgren & Johan Dahlberg

3.1. EXPERIENCES FROM DENMARK

Olaf Bruun Jørgensen

When developing urban master plans for sustainable cities, it is crucial to push these projects to a more ambitious level than for conventional urban development plans. This includes setting high targets on minimal energy demands and minimal CO_2-emissions and on ensuring the possibilities of utilisation of sustainable energy supply systems. The master plans are developed in a close cooperation between urban planners, architects and consultants with expertise in energy and CO_2 emissions. The key elements in this process are the use of the *Trias Energetica Method* and the *Integrated Design Process*.

The most sustainable way of dealing with energy is not to need energy:

- Hence, the first priority is to reduce the gross energy demand.
- The second priority is to cover the gross energy demand by sustainable energy from renewable energy sources.
- If the entire gross energy demand cannot be covered by renewable energy sources the third priority is to cover the net energy demand by use of fossil fuels in an optimised way.

To ensure good coherence between design, function, architecture and energy demand, the Integrated Energy Design process can be used (IED). The IED process is a working method which integrates the terms ‘environment’ and ‘energy’ in the planning of the city. The characteristics of the buildings (design, location, orientation, shape and function) are adapted to the dynamic characteristics of the surroundings (illustrated in figure 5).

Beyond the logic and coherency of the architecture and technology, the IED process ensures that the investments of future developers are used in a rational way minimising future operational costs.

Minimised energy demands are achieved through ambitious legislation and strict building codes as well as by ensuring good conditions for high utilisation of active solar and daylight.

Urban Planning with Daylight and Solar

The proposed master plans which are described below have been carefully analysed and optimised in order to ensure good daylight access to the individual buildings. This is of key importance for ensuring attractive daylight conditions as it is impossible to adjust for poor daylight access once the buildings have been placed and constructed in an inappropriate way. FredericiaC is a new urban area in the heart of the Danish city Fredericia including apartments, offices, shops, cafés, etc. It has been the intention of the developer to plan a CO_2-neutral urban area through optimisation of solar utilisation, daylight access and solar incidence in urban spaces, while also ensuring a living city. As part of the development of a sustainable new urban area, daylight studies have been carried out in order to ensure attractive daylight conditions in the final master plan for FredericiaC, figure 6.

Daylight analyses were carried out for various proposals for the development plan in order to ensure attractive daylight access in all relevant situations in the new urban plan. The studies were based on a method using the window to wall ratio factor (WWR) to identify whether it will be possible to achieve good daylight conditions for the actual plan. This method, consisting of several steps of both estimated daylight factor levels on a cloudy day and of climate-based simulations of both daylight and sunlight taking into account variation over the year, was developed as part of a industrial PhD at Esbensen Consulting Engineers (Iversen, 2012). The representation, see figure 7, then shows an assessment of the daylight conditions in relation to different glazing levels of the facade. The assessment of very good, good or poor daylight levels indicate the need of design work to be done. The model defines the necessary window to wall percentage of glazed area of the facades needed to obtain good daylight conditions. The key findings from the daylight studies were used to ensure that the daylight conditions for the various building types (apartments, offices, houses, retail, etc.) would all meet the daylight requirements for the respective building types. The results from the studies of the final master plan for FredericiaC are shown in figure 7. For the various building types, the following can be concluded:

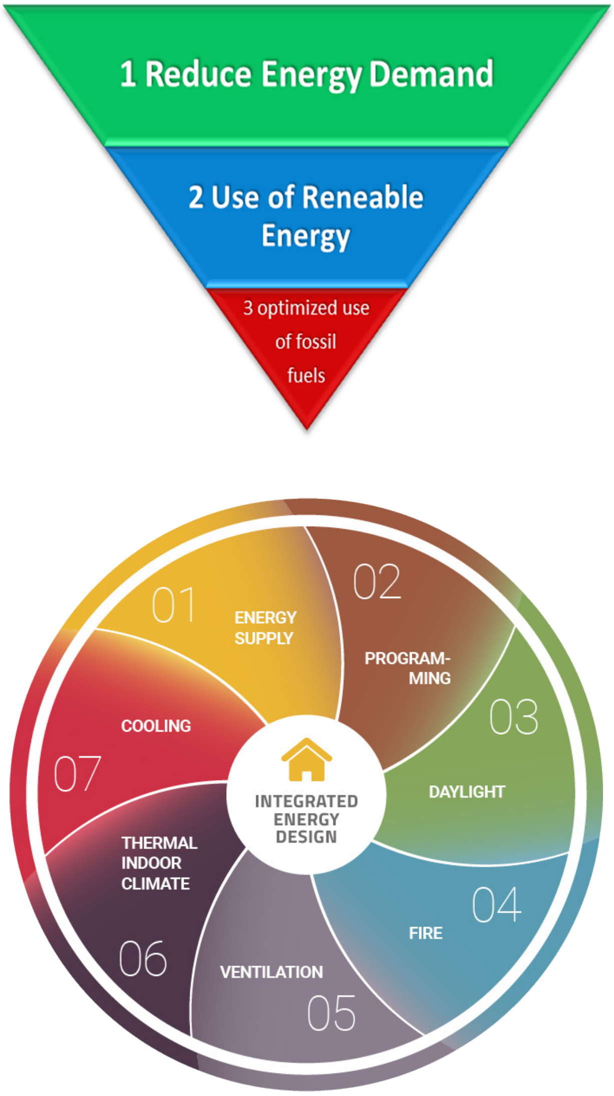


Figure 5: Principle of Trias Energetica Method and the Integrated Design Process

Daylight for residential apartments and offices

The majority of apartments located on the ground floor have good daylight conditions. As access to daylight increases with floor level, it was recommended to design ground floor apartments in two levels in those areas with minor access to daylight (blue and pink areas in figure 7).

It is possible to achieve sufficient daylight access for most of the facades on the ground level and to ensure good daylight conditions for offices at this level.

Figure 6: Final Master Plan for FredericiaC

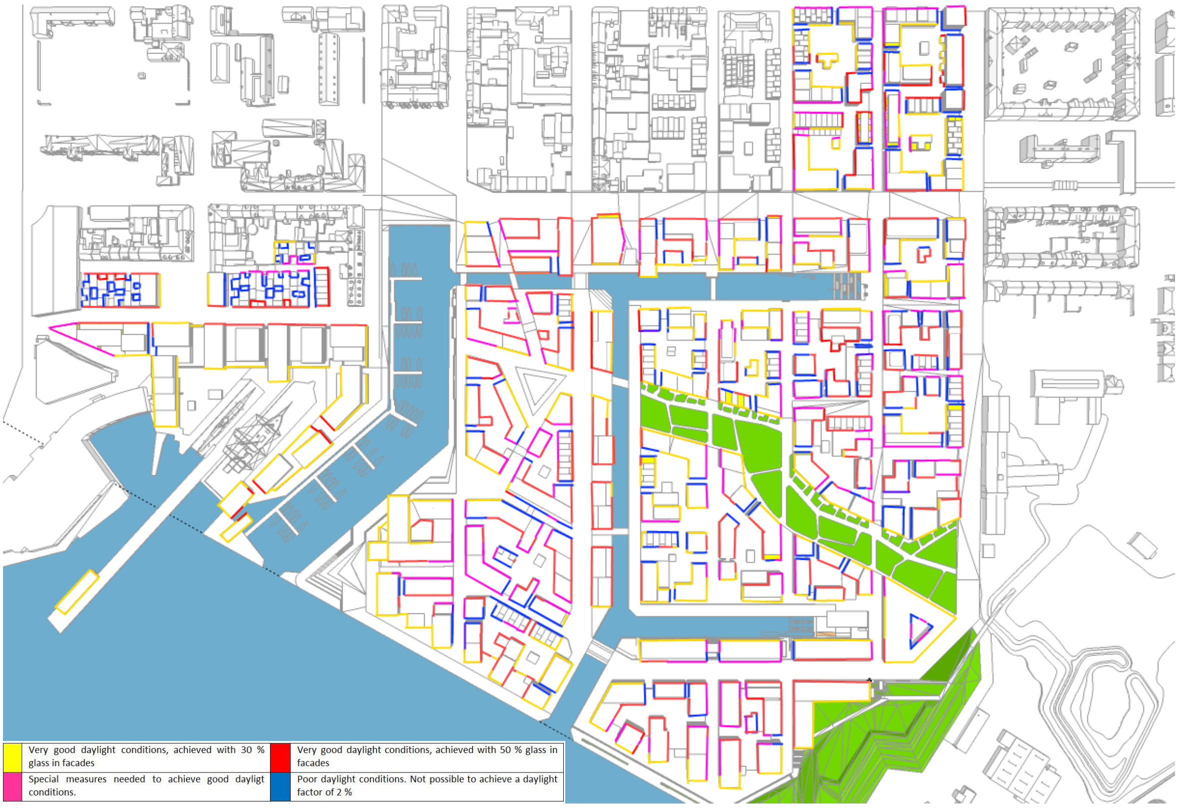


Figure 7: Daylight studies for FredericiaC

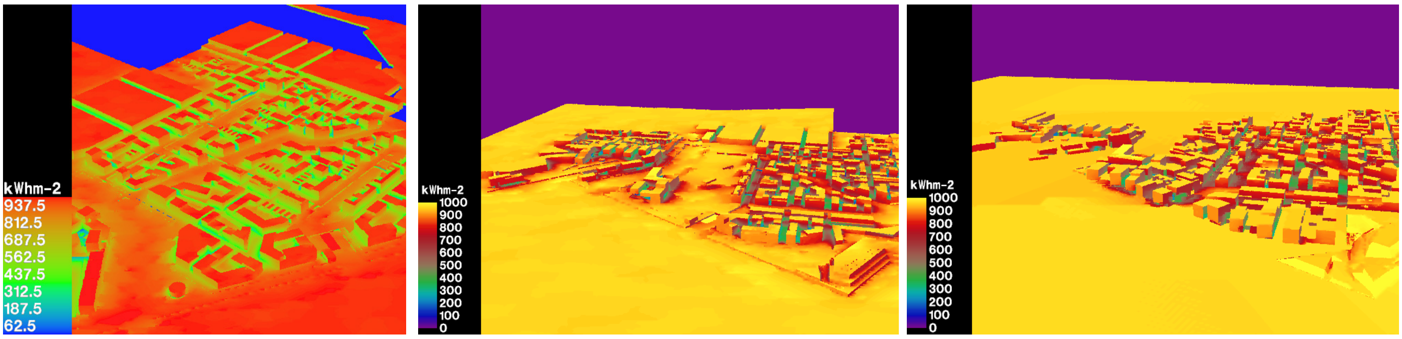


Figure 8 Solar gains on roofs and facades for different master plan proposals for FredericiaC

Daylight for hotels, retail and culture

All these functions have good daylight conditions. Based on the results from the analyses it was possible to set up guidelines for maximum building heights, minimum building distances, recommended facade reflectance and facade window areas in order to ensure good daylight conditions in FredericiaC.

Planning for Active Solar

In parallel to the daylight optimisation, the master plan for FredericiaC and the masterplan for Gehry City Harbour in Sonderborg were analysed with respect to solar access on roofs and facades in order to identify the solar potential and to ensure high levels of insolation for local energy generation from building integrated PV or solar thermal systems. Simulations of solar gains are typically carried out using the Rhino software package. Electricity production from PV-panels are typically calculated using 'PV-SYST'. The solar irradiance on roofs and facades was also analysed at the early planning stage in order to prevent future buildings from causing shading effects on PV-systems implemented in buildings.

Several sets of simulations were conducted for various versions of the development of the master plan for FredericaC. The solar energy potential for three different development plans in FredericaC is shown in figure 8. For all these three plans in general, there are good conditions for implementation of roof integrated PV-panels and only a few roofs are shaded by buildings north of them. For the final layout of the development plan, it was calculated that more than 95 % of the roof area could be used for PV corresponding to an effective area of 65 000 m² of PV-panels. Thus, the total potential electricity production from PV-panels would be approximatley 8 750 MWh/year.

The "Gehry City Harbour in Sonderborg" is a new urban development on the harbour front of the Danish city Sonderborg. The project will include new buildings for housing, hotel, culture, retail, cafés and offices. There were no specific local regulations for implementation of solar. However, through the Project Zero activities, the Municipality of Sonderborg strongly support initiatives focusing on sustainability including various solar measures.

The possibility of a high implementation of PV for electricity production has been ensured by analysing the solar irradiance on roofs and facades for various schemes of the master plan. The simulations were used as a design tool when identifying the optimal orientation and shape of buildings regarding building heights and building distances to ensure high solar gains. As an example, the suitability for implementation of PV was analysed for one initial proposal, see figure 9, and it was concluded that the proposed design did not offer good conditions for a wide implementation of PV. As a consequence, the master plan was changed into a design which offered much better conditions for installing active solar systems.

For the final master plan for Gehry City Harbour, se figure 10, it was calculated that approximately 70 % of the roof area may be used for PV corresponding to 10 400 m² of PV-panels. Thus, the total electricity production from PV-panels would be approximately 1 100 MWh/year corresponding to around 40 % of the total electricity demand in the area.

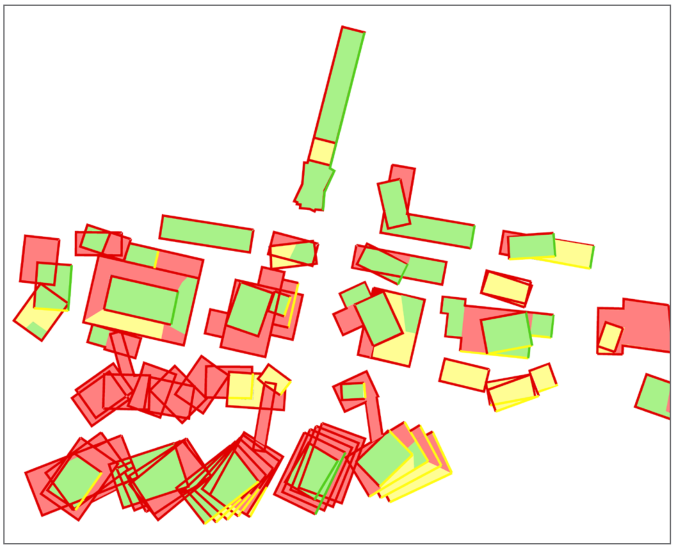
Additional energy supply

Optimisation of daylight and solar is essential when developing sustainable cities and must be considered in the very early stage of developing the master plan.

In addition to solar energy generation, Danish Energy Management & Esbensen A/S also studied the possibilities of providing additional energy supply for space heating and domestic hot water in a cost effective way for the individual users as well as for society.

In Denmark, there is a very well-developed combined heat and power district heating system, which in many cases has very low CO_2-footprints. Typically, such systems are studied and compared to highly efficient heat pump systems. In some cases it turns out that low temperature district heating systems are most attractive, and in other situations, heat pump based systems are preferable. This typically depends on local conditions and individual pricing strategies for electricity and district heating.

Figure 9:Model of proposal for master plan for Gehry City Harbour in Sonderborg



Figur 10: left above: Early proposal for master plan for Gehry City Harbour in Sonderborg.

Left below. Final proposal for master plan for Gehry City Harbour in Sonderborg.

Right above: Results from studies of suitability for implementation of PV in early proposal for master plan in Gehry City Harbour in Sonderborg.

Solar Access in Common Urban Areas

The outdoor micro climate – with respect to solar access – has also been studied at the Gehry City Harbour. In order to ensure a pleasant outdoor climate in the urban spaces of this project, various proposals for the urban plan have been analysed with regard to direct sunlight and shading in central public spaces. Shadowing was analysed for the hours 09:00, 12:00 and 15:00 for the critical time of the year at equinox (March and September 21st). The calculations demonstrate that a dynamic varied insolation is achieved on key urban spaces in the final development plan, see figures 11-13 below. Such studies are very relevant when designing attractive outdoor urban spaces in order to ensure varied and dynamic public space.

Comment

Experiences from the urban development projects described in this chapter has shown that it has been possible to influence the master plans in a way that increases the use of solar and daylight. Other experiences are that it requires comprehensive modelling and documentation to support and enable the acceptance of changes to the proposed master plans; however, it has been demonstrated that such changes are typically very well received by other planners and authorities when developing sustainable master plans.

More detailed information about FredericiaC and Gehry City Harbour in Sonderborg may be found in the report *Task 51/ Report C1 - Illustrative Prospective of Solar Energy in Urban Pllaning: Collection of International Case Studies.*

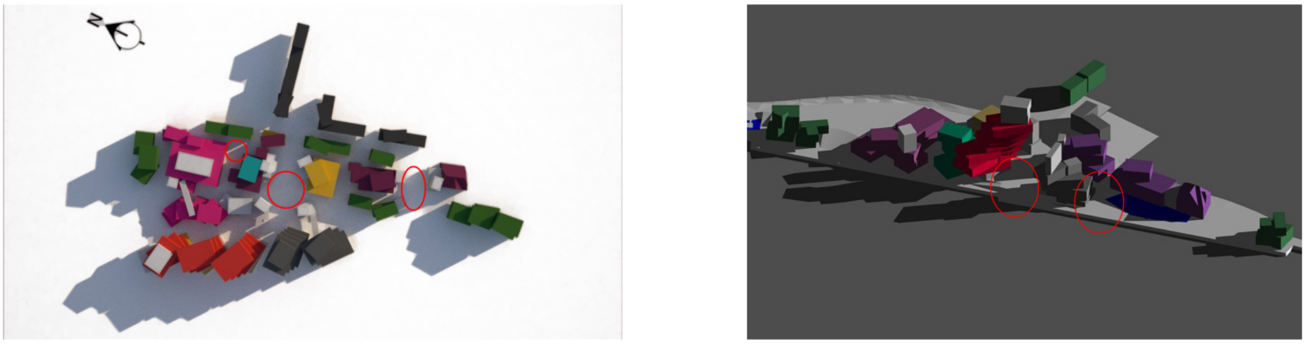


Figure 11: Shadows at 9.00 on the 21st September before (left) and after adjusted master plan

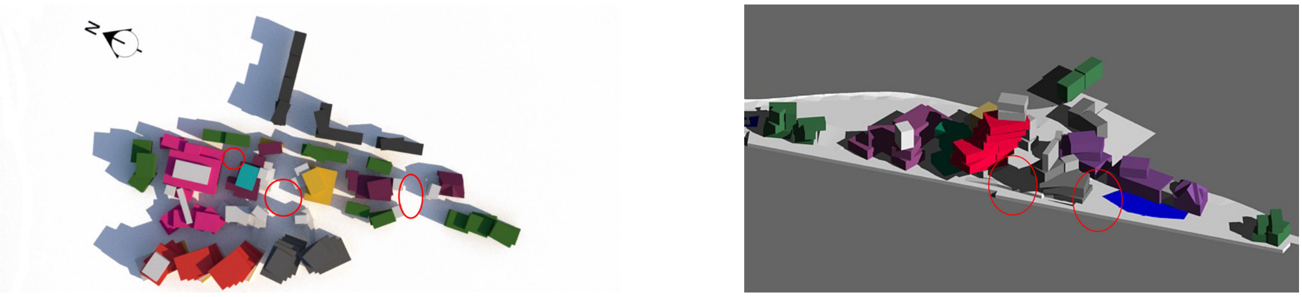


Figure 12: Shadows at 12.00 on the 21st September before (left) and after adjusted master plan

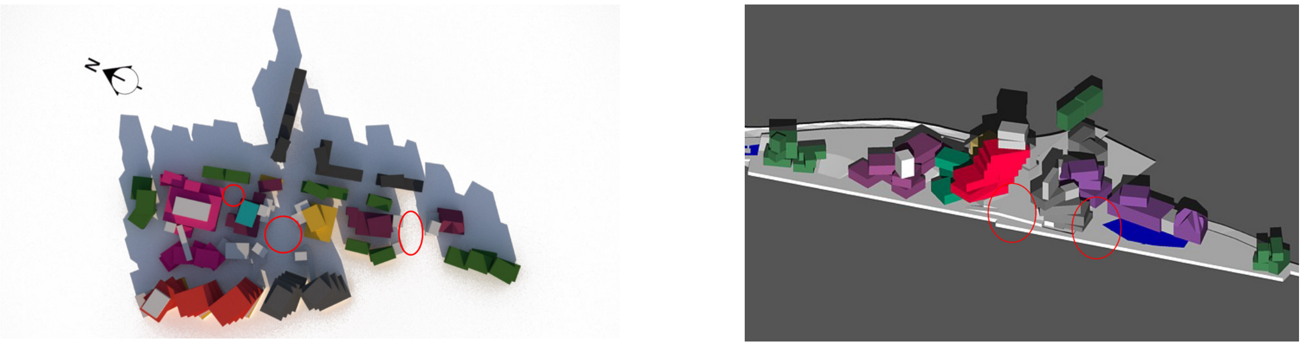


Figure 13: Shadows at 15.00 on the 21st September before (left) and after adjusted master plan

3.2. A DECISION-SUPPORT WORKFLOW FOR EARLY-PHASE NEIGHBOURHOOD DESIGN

Emilie Nault

Performing an assessment of solar-related performance aspects at the early phase of neighbourhood-scale projects is a challenging task, notably due to the low level of design information available and the desire to quickly compare different design alternatives. Many of the existing performance evaluation tools require a detailed model of the building(s) under study, which limits their uptake by non-expert professionals at this early phase and urban scale. Moreover, their application within the design process induces a linear, 'generate-and-test' workflow, where one design variant is evaluated at a time. To obtain a gallery of design alternatives, designers must manually change their inputs to the tool. Considering that the early design phase is characterised by a will to explore the possible design space, the above-described workflow is not the most efficient.

The *Urban SOLar Visual Explorer* (UrbanSOLve) prototype attempts to address these shortcomings through a multi-variant, multi-criteria performance-based workflow, aimed at supporting urban and building design-space exploration from a solar potential perspective. Currently developed as a plug-in for the 3D modelling tool Rhinoceros (Rhino), it enables to quickly estimate the passive (including daylight) and active solar potential of multiple alternatives of an early-stage project, with the goal of providing valuable support to architects and urban designers in their decision-making process.

Overview of the Prototype Tool

Figure 14 illustrates the workflow of UrbanSOLve, from the acquisition of user-inputs to the visualisation of outputs. While a basic level of proficiency with Rhino (or any similar CAD tool) from the user will facilitate his or her experience with UrbanSOLve, no prerequisites are necessary to make use of the prototype.

1. User-inputs

The process starts with modelling, in Rhino, an empty plot (ground layer) on which the new design is to be located, along with the existing surrounding buildings (context), if any. An initial base case design is then defined by positioning buildings on the empty plot. This is done via the UrbanSOLve interfaces, by first selecting (among options) for each building its typology (shape), orientation, function, window-to-wall ratio, as well as its initial dimensions and minimum and maximum values for each of these dimension variables. Each building is subsequently positioned on the plot surface using a corner or centre reference point. Density constraints can be specified in terms of minimum and maximum floor area ratio and site coverage.

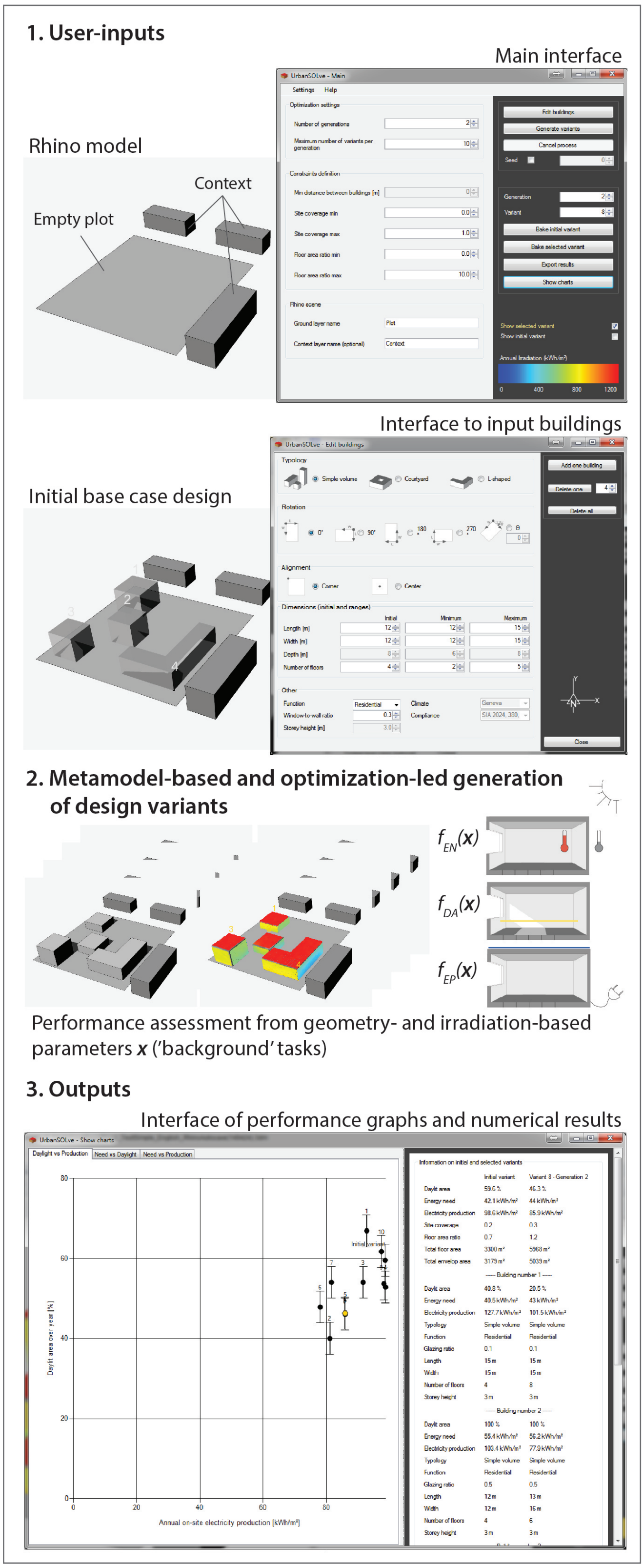


Figure 14: Workflow of the UrbanSOLve prototype in its development status as of 2017

2. Metamodel-based evaluation and optimisation-led generation of design variants

From these user-inputs, UrbanSOLve proceeds to generate and evaluate design alternatives, through a multi-objective (genetic) optimisation algorithm combined with a metamodel-based performance assessment engine. The design alternatives correspond to geometrical variations from the initial design, respecting the dimensions and density intervals defined by the user. The optimisation algorithm ensures that a progressively increasing level of performance is reached during the search for design alternatives (or variants). The metamodel-based performance evaluation consists of mathematical functions taking as inputs a series of geometry- and irradiation-based parameters (e.g. form factor, south-façade average irradiation) and providing as outputs an estimate (or prediction) of the daylit area and energy need for space heating and cooling (passive solar criteria). The third criterion, the active solar potential, is measured by an estimate of the electricity production by PV panels (0.17 efficiency) on roof and facade surfaces that achieve a 500 kWh/m^2 threshold. The Radiance/ Daysim functions are employed to run the irradiation simulation on all exposed building surfaces.

3. Outputs

Results are presented in different formats. An irradiation map of each generated and evaluated variant can be visualised in the Rhino window. A dedicated UrbanSOLve interface displays graphs showing the relative performance of the variants for the three criteria along with a table listing numerical information for the entire design (neighbourhood) as well as for each individual building. All numerical information including user-inputs and results can be exported to text and csv files.

Current Development Status and Outlook

A first version of the prototype was tested among practitioners at the EPFL in October 2015. Encouraging feedback led to a second development phase, where changes were brought particularly to allow more flexibility in the design, facilitate the user experience and interaction with the interfaces, and refine the metamodels' background assumptions. This led to a new version of UrbanSOLve*, which was tested during workshops in May-June 2017 with architects, urban designers/planners, and engineers.

Future work will address some of the limitations related, for example, to the freedom in the design (user-inputs) and validity boundaries of the performance assessment engine. Among the multiple development avenues possible, the adaptation of the plug-in to other CAD tools (e.g. SketchUp) will be considered.

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* UrbanSOLve was developed at the Ecole polytechnique fédérale de Lausanne (EPFL), within the Laboratory of Integrated Performance in Design (LIPID). This work was also supported by the CCEM SECURE project and the EuroTech Universities Alliance. The second development phase was supported by the ENAC InnoSeed programme at the EPFL. Mélanie Huck, architect and computer scientist, contributed significantly to the coding and implementation of the workflow as a digital prototype. Christoph Waibel, PhD student at EMPA, provided the code and support for the optimisation algorithm. Feedback gathered from professionals (architects, urban designers, and engineers) during workshops in 2015 and 2017 was also key in guiding the development of the prototype and assessing its potential as a decision-support tool. More information can be found in the doctoral thesis (Nault, 2016) and recent publications of Emilie Nault.

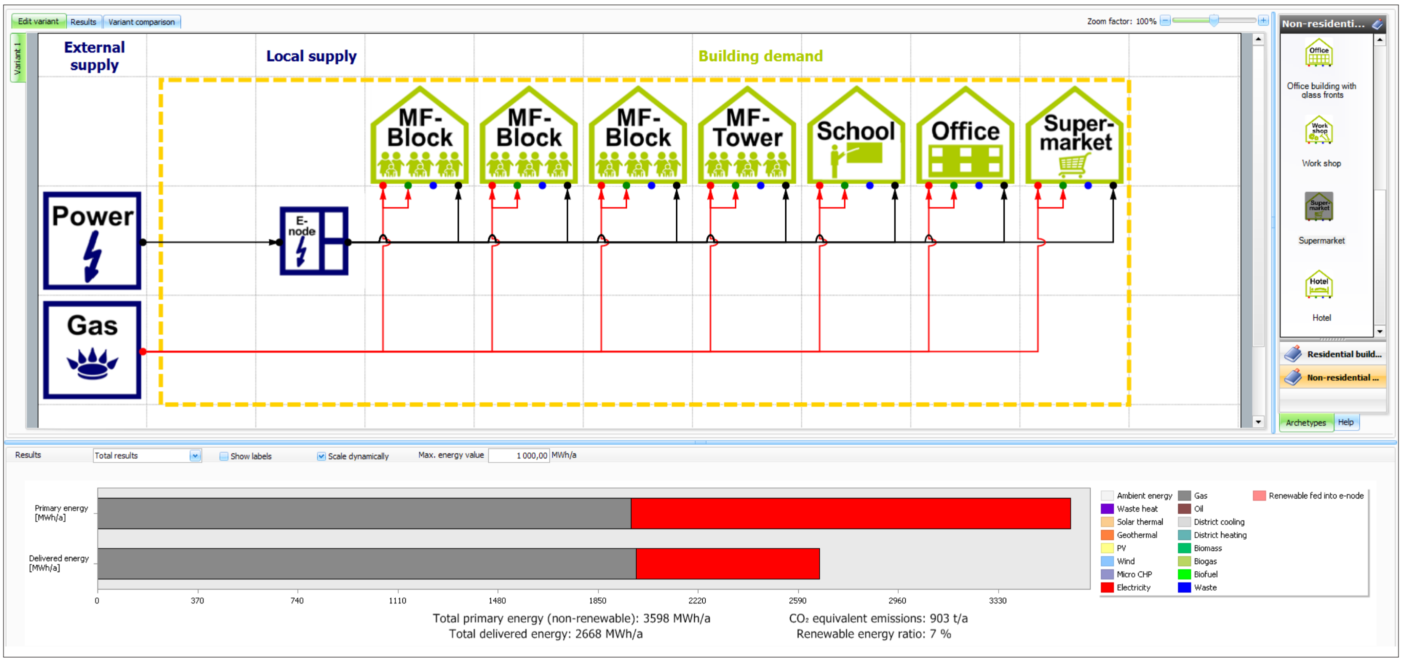
3.3. FROM SOLAR POTENTIAL ANALYSIS TO ENERGY AND EMISSION SAVINGS

Karsten Voss

Assessing the solar potential and its impact on a neighbourhood scale is always linked to the building typology, the buildings energy efficiency level and the energy supply systems. To handle this in the early concept phase the software tool "DECA – District Energy Concept Adviser" was developed within the Annex 51 "Energy Efficient Communities" of the IEA EBC program. The tool comprises a set of individual supporting tools. The very heart is a software for the energy assessment of districts, which uses archetypes and other pre-set configurations to allow for a simple and quick data input mapping all the buildings in the district and their energy relevant properties. Thus, it takes the user just a few steps to identify the energy saving potential of various strategies in the areas of building construction, technical building systems, and centralized supply systems. Solar power systems can be considered on the building scale as well as for the district grid, solar thermal systems on the buildings scale only.

Once the solar areas have been quantified by using e.g. a solar map, see chapter 4.1 on 2D and 3D Solar Maps, or a solar potential calculation the software tool DECA can be applied to estimate the savings with respect to final energy, primary energy or climate gas emissions on the district level. Such combined approach was successfully applied during the 2016 Task 51 summer school in Berlin (Siems & Simon, 2017). Results are immediately visualized in a few seconds and quantified in tables for post processing. Parametric studies can be defined including a graphical result comparison.

The District Energy Concept Adviser can be downloaded and used free of charge after registration: www.district-eca.com It is to be used in MS Windows environment, see example in figure 15 below.



Results: Total results

☐ Show labels

☑ Scale dynamically

Max. energy value: 1 000,00 MWh/a

Total primary energy (non-renewable): 3598 MWh/a
Total delivered energy: 2668 MWh/a

CO₂ equivalent emissions: 903 t/a
Renewable energy ratio: 7 %

Figure 15: Exemplary screen shot of DECA with the configuration field (centre), the building archetype library (on the right) and the results viewer (bottom). Source: Fraunhofer IBP

3.4 . INTEGRATION OF (TROPICAL) MICROCLIMATE INFORMATION IN URBAN DESIGN

Aymeric Delmas & François Garde

Among the places most vulnerable to climate change are areas of high urban growth in the warm, humid tropics. In such places, the global trend of rapid urbanisation and conditions of local warming compound the effects of climate change. In the French tropical Reunion Island, population growth and limited land available make densification of existing urban areas necessary to house the population while limiting the impact of urban sprawl on the natural patrimony of the island. In such a particular context, the scope of solar urban planning should be widened and focus on the integration of the whole range of microclimatic phenomena. Indeed, urban form and design choices (shapes, density, orientations, roof types, materials, urban patterns etc.) influence people's comfort and a building's energy performance through modified thermo-fluid properties (local wind speeds, short and long-wave radiations, air temperature, evapotranspiration etc.) but also the urban heat island level. Thus, achieving sustainable urban areas in the tropics require the integration of microclimatic phenomena in the design process; as such, the following chapter briefly presents new tools and approaches which will convey useful and context-adapted information to support design decisions.

Method

ORCHIDEE is the French acronym for "Outils de Rénovation et de Conception de l'Habitat Intelligent et d'Eco-quartiers à énergie positive En milieu tropical" (Tools for the Renovation and the Design of Smart Habitat and positive energy Eco-neighbourhoods in tropical environments).

The ORCHIDEE project* aims to achieve a balance between comfort, energy efficiency of housing units and the influence of urban and architectural design choices on the quality of urban tropical microclimate, indoor conditions and ultimately integrated energy generation of the buildings. In order to do so, the development of new methods mainly based on simulations which allow the exploration of design solutions combining comfort, energy efficiency and local response to energy needs (integrating active or passive energy systems) is required.

Climate-sensitive design strategies will be defined through the use of neighbourhood-scale 3D modelling tools informed, on the one hand, by geographic information systems and, on the other hand, by local climatic data. These strategies will then be translated parametrically into urban form transformations, conceptual façade or roof modules whose performance will be evaluated thanks to airflow, irradiative and thermal (connected) simulation tools.

A ranking of the explored improvement combinations will be made and a sensitivity analysis will be developed to determine the design variables that are most important for improving comfort and reducing the energy consumption of housing units in hot and humid climates. The originality of the approach is that this sensitivity analysis will be also carried out with regard to the impact on the urban microclimate.

Finally, the tools developed by the ORCHIDEE project will perfectly fit into urban micro-simulation models and urban energy simulation tools. This is a nascent research and development field which, in view of the expectations regarding the evaluation of design and renovation scenarios for more efficient and sustainable neighbourhoods and cities, should become key decision support tools in the future.

Expected Outcomes

The ORCHIDEE project, launched in December 2016, will run for the next 3 years and will focus on developing tools adapted to the design and the renovation of positive energy buildings and neighbourhoods in tropical climate. This project, predominantly funded by the French Environment and Energy Management Agency, aims to address and knock down the following barriers:

- To couple wind flow, solar and thermal simulation models;
- To generate local meteorological files that take into account the geomorphological effects of the urban environment;
- To compare CFD simulation results with wind tunnel measurements;
- To define and validate thermal comfort indices adapted to the tropical urban microclimate constraints. Validation of the defined indices will be performed through field surveys and on-site measurements;
- To explore and assess the performance of renovation and design strategies in terms of comfort improvement at the building and neighbourhood scale;

Finally, the tools and approaches developed within this project will be tested and used on two existing neighbourhoods located on the French tropical island of La Reunion.

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*Partners involved in the project are University of Reunion – PIMENT Physics and Mathematical Engineering for Energy and the Environment) Research Laboratory (coordinator); CNRS Research Federation IRSTV (Institute for Research on Urban Sciences and Techniques); CNRS Research Federation on Solar Energy FEDESOL; SOLENER design office; IMAGEEN design office

3.5 RULES OF THUMB AND SIMULATION TOOLS

Romain Nouvel, Marja Lundgren & Emilie Nault

Methods, consisting of tools and metrics, developed to assess an existing or planned building design are typically conceived for design support at a given moment along the process and for evaluating one or more specific performance aspects at another. The method relates to the match between the amount and type of information a tool or metric requires to conduct the support or assessment act, and the design characteristics known or of interest at the given moment. In practice, a gradual increase in both the level of complexity and accuracy of the methods adopted throughout the design process can be observed. The general trend is to employ heuristics or rules of thumb related to indicators of certain performance aspects, often based on geometrical parameters at the conceptual planning and design stages. Several rules of thumb have been forgotten and less used as digital calculation entered the scene. The need for a renewed interest for heuristic methods would enable the early planning design in order to enhance daylighting measures alongside other solar aspects.

More detailed evaluations of solar- and energy-related issues are often conducted in later design stages, for code-compliance checks or system sizing at the detailed building design phase, through simulation-based tools that require a significant amount of design information (e.g. more detailed design features and building materials). Such evaluations quickly become computationally intensive when applied on larger design scales.

While a large amount of such tools was developed mainly for the building scale (e.g. EnergyPlus frontends DesignBuilder and OpenStudio (SketchUp plug-in), DIVA-for-Rhino based on EnergyPlus and Radiance/Daysim), a much smaller yet growing set of tools are emerging that can better be applied at the urban scale (e.g. ArchiWizard, UMI).

The Integration of Rules of Thumb in Crude Stages of the Planning Process

In very early stages of urban design several aspects are negotiated into the plans, and the work might still be carried out in 2D, due to the frequent changes to the design. In Sweden the concept of general plans, which leaves a lot of freedom to the architectural design, would encompass some work to transform into 3D for the purpose of simulations. Several studies are carried out in this phase such as noise and solar shading studies. For the need of urban densification, new plans often lead to different heights and forms compared to the 19th early 20th century urban design. Daylight studies are then mandatory, to prove that the buildings meet the daylight requirements in the Building Code. At an exhibition at the Swedish Museum for Architecture and Design (ArkDes) in 2016, presented more in detail in the chapter on Awareness and Consultation methods, the relation between urban and building forms and the Swedish building code over different periods, from 1920 to 2010, was investigated (Alenius et al.,2016), see figure 16. It was shown that the geometric obstruction angle, derived from plans and basic sections, can give the planner a lot of knowledge regarding daylight and design challenges. As in the guideline for BRE (Littlefair, 2011) correlations between different indicators of daylight along with illustrations will help binding early stages of planning to the later ones. In short there is a need to create a chronological relationship between heuristic methods (such as rules of thumb), architectural empirical knowledge on how the daylight and urban environment is perceived to the later stages where quantitative measures are assessed through digital validation methods.

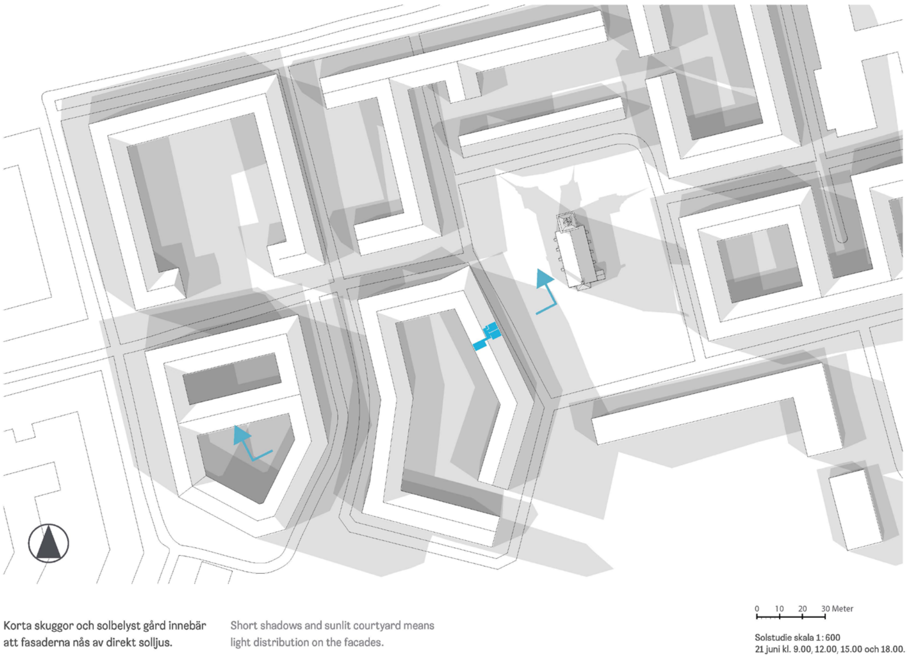
Two Ways to Assess Solar Envelopes

Solar rights in several countries are used in legislation to ensure passive heating of buildings in winter and comfort in public spaces (Capeluto et. al, 2006). The solar envelope is a way to define the boundaries of urban design blocks in relation to such solar rights. The solar envelope is a geometric method continuously developed since the late 70's to support urban planners and architects in integrating new buildings in urban environments, given some solar access criteria. The solar envelope was originally defined as 'the volumetric limits of buildings that will not shadow surroundings' for a minimum number of hours (Knowles, 1981).

In this section, two ways of addressing the solar envelope are presented. The first way is through a simple method of section lines, developed from the solar envelope for a specific climatic region i.e. Israel, making it possible for architects and planners to work with established 2D and 3D design tools. The second way is through a parametric 3D-modelling tool that is becoming more common within the design community.

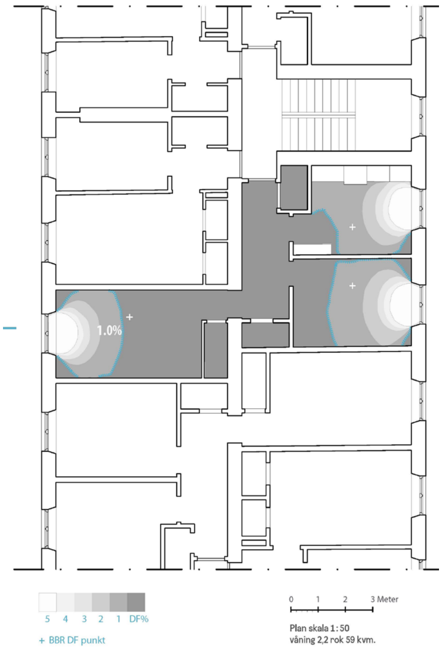
A simple method of section lines

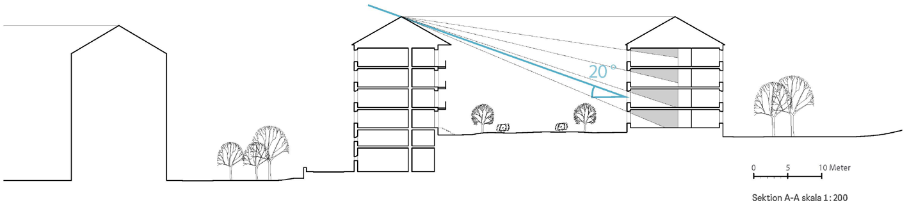
Based on the solar envelope, an Israeli team of researchers has developed a simple section lines method to ensure the fulfilment of a legislation suggested before 2006 where residential buildings should have a certain access to passive solar energy (Capeluto et al., 2006). For the method, they added criteria to ensure that open spaces and sidewalks receive passive solar as well. The section line method was tested in case studies comparing traditional block design with the maximum floor area ratio consistent with ensuring passive solar energy regulation. In the paper where this method is presented, two approaches are tested: one is based on performance regulation where proof needs to be handed in by the architect and the second is the developed section line method that is easy for the architect to implement and authorities to assess (Capeluto et al., 2006). Both meet the regulation and are simple examples of different ways of dealing with geometrical drawing-based methods or 3D-modelling methods.



Korta skuggor och solbelyst gård innebär att fasaderna nås av direkt solljus.

Short shadows and sunlit courtyard means light distribution on the facades.





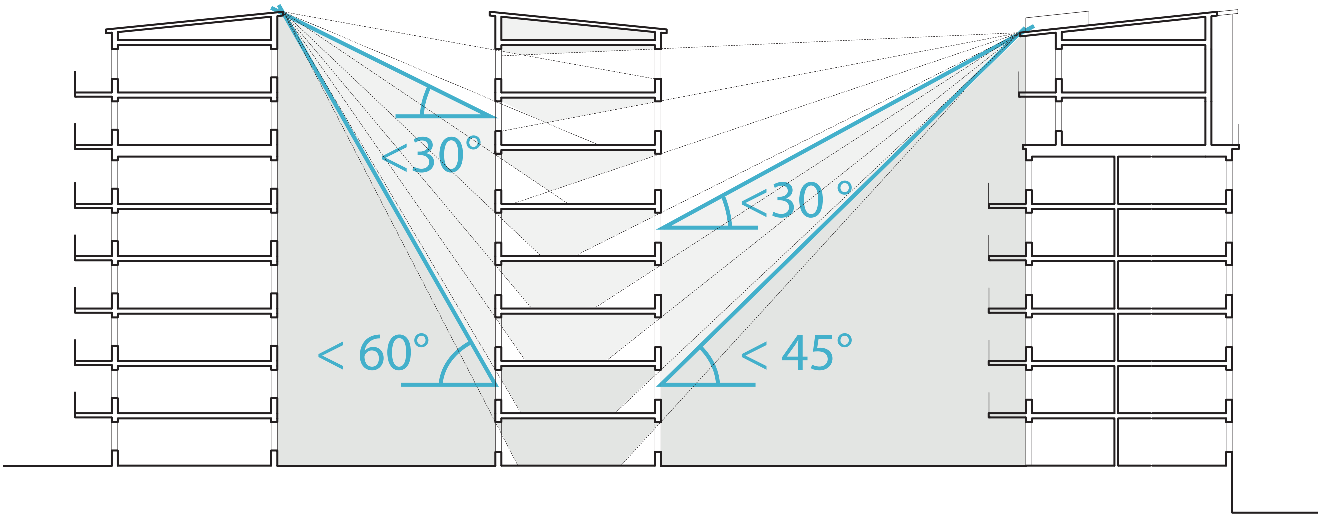


Figure 16: The obstruction angle shows how much of direct skylight that reaches the interior. With obstruction angles below 30 degrees normal window sizes apply. When the obstruction angle reaches 45 degrees there is a need for new strategies to reach the Swedish building code. At the Swedish latitude an average daylight factor of 2 % in a Swedish living room (according to the Swedish standard) this can be a challenge for the new dense areas that are planned. At 45 degrees and beyond the reflected light from facades, the size of balconies and the fenestration sizes as well as the room heights need to be designed in order to reach the minimum 2 % average daylight factor. Illustrations from the ArkDes exhibition (Alenius et al., 2016).

Ladybug-grasshopper used on the Solar Envelope

The solar envelope concept has evolved since the late 70's by distinguishing solar rights envelope, corresponding to the original concept, and solar collection envelope. The latter corresponds to the volumetric limits inside for which new buildings would receive direct sun access during a minimum number of hours (Capeluto & Shaviv, 1997). Both concepts, which can be combined to form a unique 'Solar Volume', refer to hours of sunlight as solar access criteria.

Recently, this method was extended to include solar energy criteria (Morello & Ratti 2009), enabling the design of buildings and building surfaces that are suitable for solar collector integration. This toolset is a plug-in for the graphical algorithm editor Grasshopper (www.grasshopper3d.com), which allows to realize and optimize parametric 3D design, integrated into the 3D editor software Rhinoceros 3D. With the help of the tool, an abundance of building and urban design forms may be assessed and compared in terms of access to the sun, based on few form parameters and urban planning rules.

Although no programming background is required, the simulation environment still requires expertise to use it properly.

Evaluation of Different Solar 3D-design Tools

Beside Ladybug, several solar 3D-design tools have been developed for the urban and building design stages, addressing more or less a public of architects and urban planners.

Four of these tools have been evaluated in terms of usability and model capability by the students of the University of Wuppertal in the framework of this IEA Task 51, see figure 17:

- Archiwizard
- DIVA for Rhino
- OpenStudio
- Autodesk Ecotect

The following aspects were evaluated: the installation process, level of expertise needed, user-friendliness, workflow and iteration possibility, model precision, connectivity to designer tools with regards to import, export and designer changes within the assessment tool, software stability, utility on an urban level and simulation scale.

Results from the evaluation are reported in the report 'State-of-the-art of Education on Solar Energy in Urban Planning'.

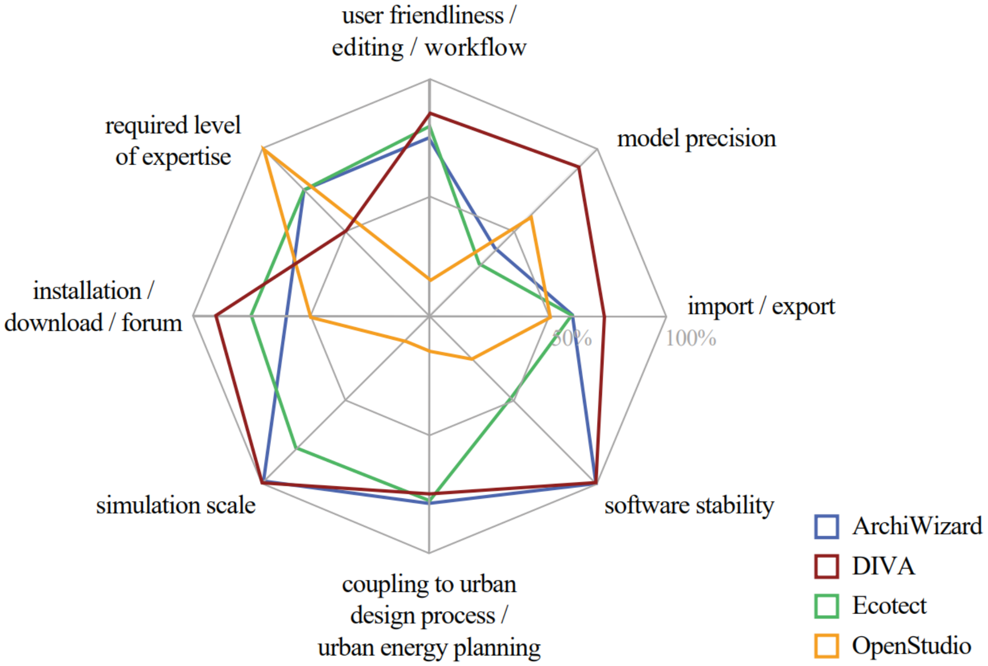


Figure 17: Summary of evaluation of different solar 3D-design tools (Source: BUW, A. Saurbier)

3.6. DAYLIGHT, SOLAR AND COMFORT IN RELATION TO INFILL IN EXISTING URBAN FABRIC

Cristina S. Polo López & Francesco Frontini

In a recent study (Polo & Frontini, 2017) comfort and daylight conditions and corresponding energy needs within a sensitive urban heritage area have been assessed in relation to the obstruction and shading effects from a new infill development. The study shows that comfort related energy and economic impacts of densification may be significant, both in operation and maintenance costs during the life span of the building. This project has highlighted how a methodological approach on solar analysis, considering the urban scale and building scale in parallel, can quantify these effects. The method comprises the use of a series of tools.

The urban pattern, the building volume and facade configuration have impact on the building energy balance and its use of natural and environmental resources. Understanding comfort and energy effects and defining recommendations and theoretical principles can be facilitated by a strategic method for predicting decreases in solar and daylighting availability, especially in the case of an existing urban fabric characterised by infill.

The methodology tested in the VerGe Project combines different tools, including software, to determine the availability of solar energy as well as identifying cases concerning a reduction of sunlight and daylight, and to determine corrective measures where possible. The aim was partly to develop recommendations on a appropriate solar energy exploitation and to begin the process of defining solar rights as well as to have researchers, along with specialised professionals, support public officials and planners who are responsible for updating regulatory plans (Polo López, 2017).

The VerGe Project is within a sensitive heritage area in Lugano Paradiso Municipality, a part of the City of Lugano in Switzerland where monuments are protected by the regulatory plans. A methodology, based on a cluster of tools, was carried out in order to understand and quantify the energy impacts of the future urban development on the existing protected heritage buildings in the area (Polo López & Bonomo, 2016). The aim was to assess specific parameters considering different scenarios in an evolving built environment (current and future urban situations) using a combination of numerical methods and tools. The methodology supported assessments of effects from a new more dense and high-rise urban typology on the existing urban typology. Through computational tools, key aspects relating to the daylight and solar access (such as the reduction of solar irradiation and potential for solar passive strategies and obstructions tested by sky view factor reduction) were analysed as well as consequences for energy demand and human comfort. Furthermore, the study considered the solar potential of renewable energy sources in the area, along with visual effects from active solar integration.

The following indicators were chosen:

A. Shadowing percentage due to obstructions. By comparing the situation before and after in each building studied, it has been possible to calculate the percentage of solar obstruction (sunshine/shading) caused by the other buildings in the area. Results give indications about the possibility of using passive solar strategies (figure 18).
B. Daylight Factor (DF), serves to verify the levels of natural lighting indoors on a cloudy day. This is presented as a percentage through the amount of light indoors and in relation to the light on an unobstructed place outdoors. DF, therefore reflects illuminance levels given by the urban situation and the building and facade configuration that can be directly connected to visual human comfort and energy consumption, e.g. increase of artificial lighting (figure 19).
C. Sky-View Factor (SVF), is a method to analyse the amount of sunlight, free sky view on street level. A small sky view factor will give less light to the street and the rooms in the buildings, affecting visual comfort (figure 20-21).
D. Human comfort, detecting variations in the comfort zone in order to establish the aspects that compromise the fully exploitation of the climate conditions and the possibility of using passive strategies for thermal conditioning (figure 22-24).
E. Building energy performances and active solar/building integrated solar potential, to determine and quantify differences in terms of energy demand caused by the new urban context configuration. Dynamic energy simulations are carried out to assess the real behaviour of the building in terms of energy flows, energy requirements and consumption (figure 25).

In order to assess the effects of the scenarios on these indicators and to calculate the effects of densification in the future urban environment the following tools were used:

- 3D simulations programmes along with Sun-path diagrams through Ecotect software and Daysim RADIANCE software (Indicators A-B)
- Photo processing image methods using ImageJ software and HORIcatcher instrument developed by Meteotest (Indicator C)
- Bioclimatic charts and diagrams (Indicator D)
- Building energy simulation tools (Indicator E)

3D simulation programmes and Sun-path diagrams through Ecotect software were used demonstrate shadowing percentage in the different urban scenarios. Shadowing

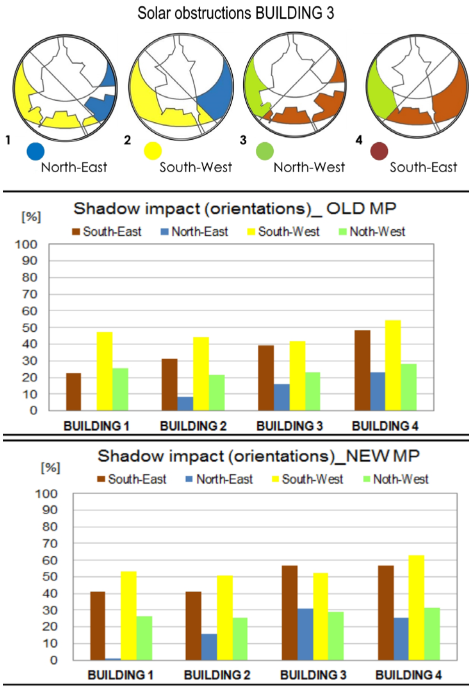


Figure 18: Shadow impacts calculated for each protected building in Paradiso. Diagrams 1 and 3 at the top represent the current situation, Old Master Plan, whereas 2 and 4 the future situation, New Master Plan. Source: ISAAC-SUPSI

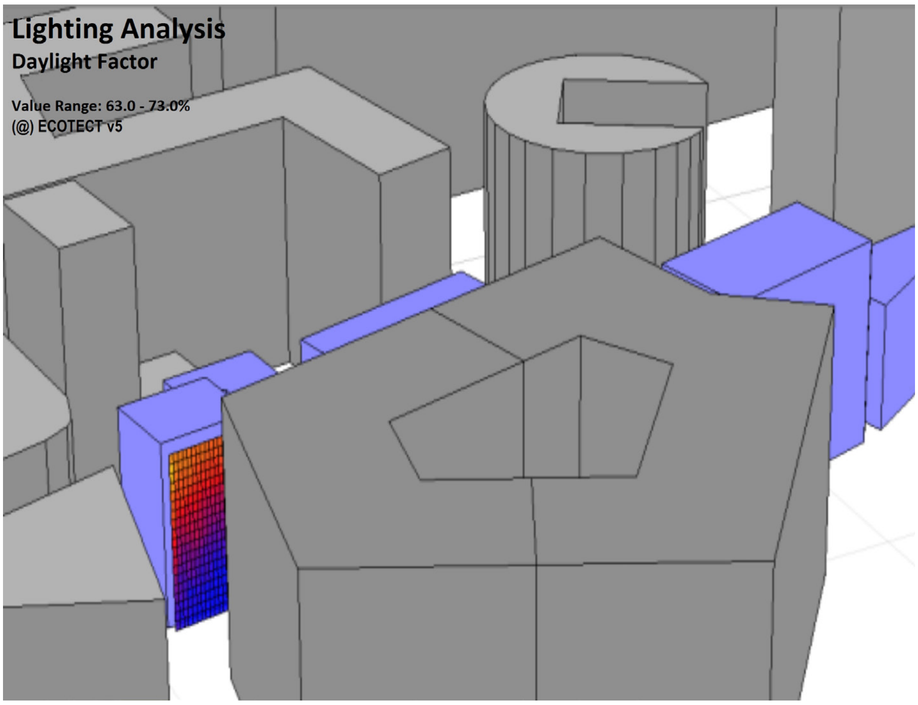


Figure 19: Ecotect daylight factor analysis used to assess the New Master Plan scenario. Source: ISAAC-SUPSI

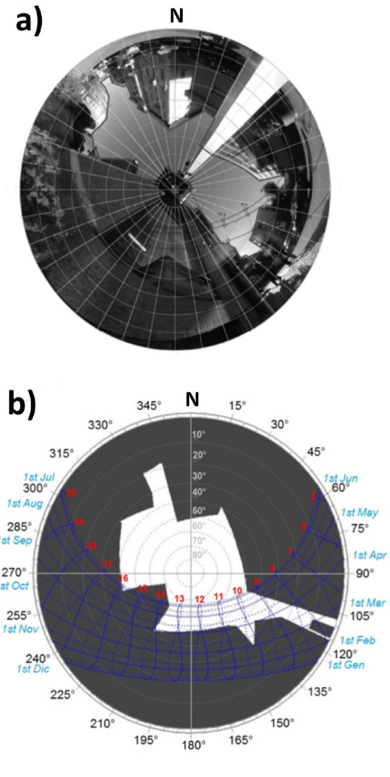


Figure 20 - Sky-View Factor assessment: (a) Image for the current situation, Old MP; (b) software simulation New MP. Source: ISAAC-SUPSI

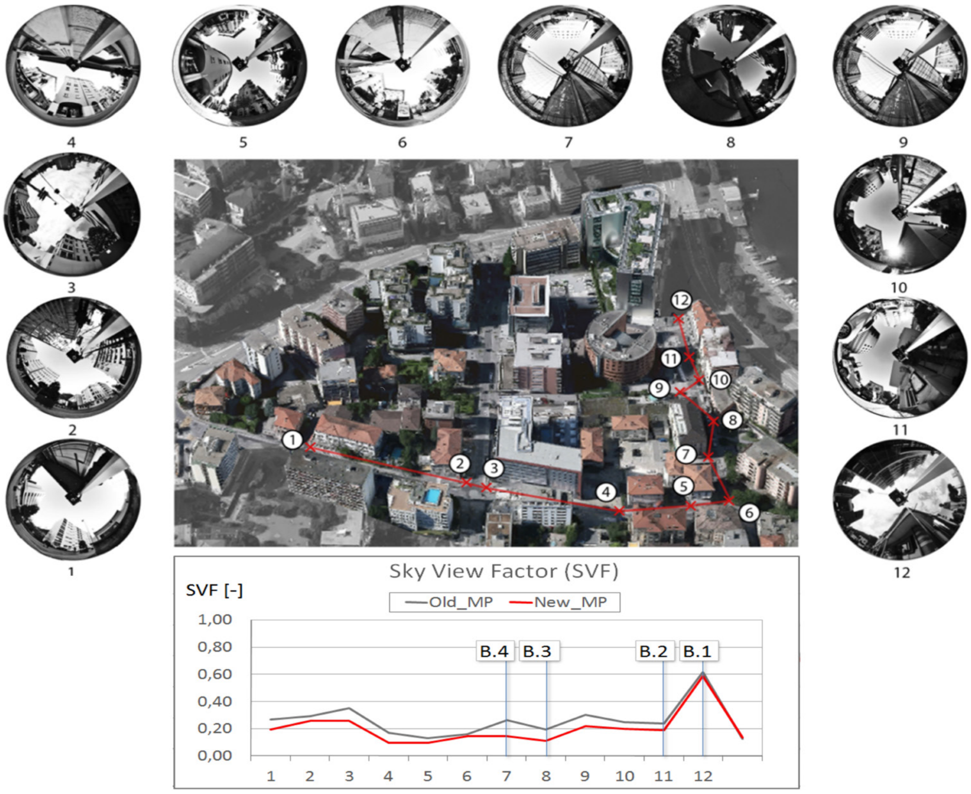
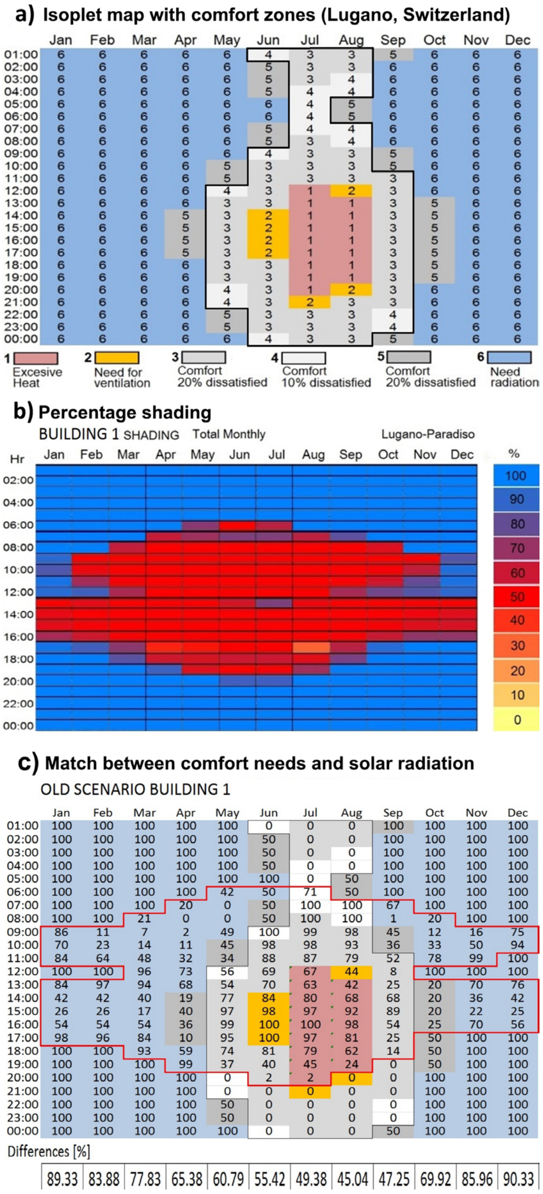


Figure 21 - Sky-view factors have been determined from analysis of hemispherical images collected and taken on site with digital camera and spherical convex mirror. Source: ISAAC-SUPSI



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	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
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18:00	100	100	93	59	74	81	79	62	14	50	100	100
19:00	100	100	100	99	37	40	45	24	0	50	100	100
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00:00	100	100	100	100	100	0	0	0	50	100	100	100

Differences [%]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Differences [%]	89.33	83.88	77.83	65.38	60.79	55.42	49.38	45.04	47.25	69.92	85.96	90.33

Figure 22 - Human comfort assessment: (a) Isopleth map where comfort zones are represented using CBA method, (Polo López, et al., 2016). The black line identified the time period during the year where it is necessary to have shadow to prevent overheating.; (b) Isopleth map showing the average percentage of shading calculated for Building 1 (software simulation by Ecotect); (c) Match between comfort needs and solar obstructions, deviation in percentage (Old MP scenario calculated for Building 1). The same study was performed for the New MP scenario to check differences. Source: ISAAC-SUPSI

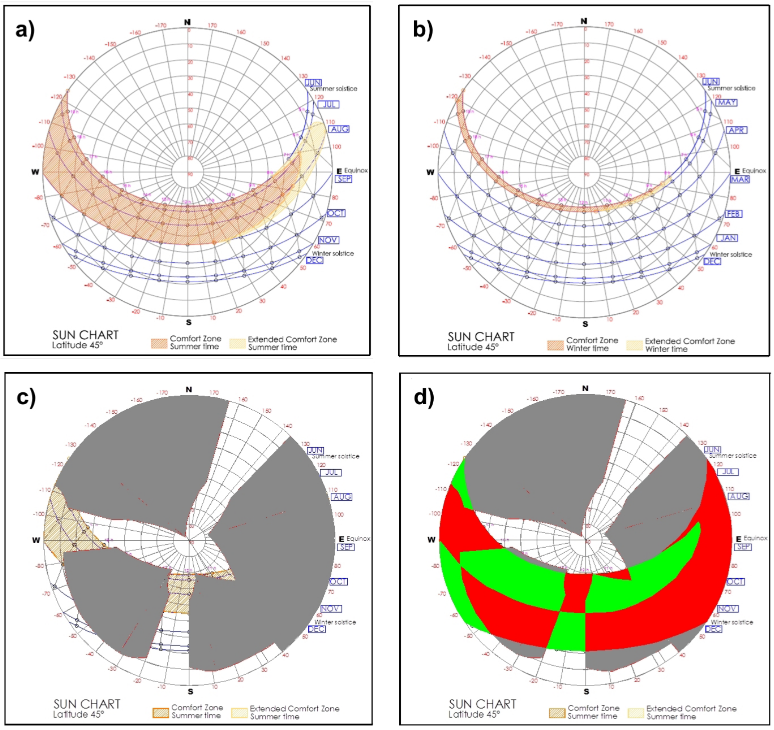

Figure 23 - Comfort zone calculated and represented in the solar polar sun-path diagram (stereographic projection) for Lugano area. Source: Polo López C. S. ISAAC-SUPSI

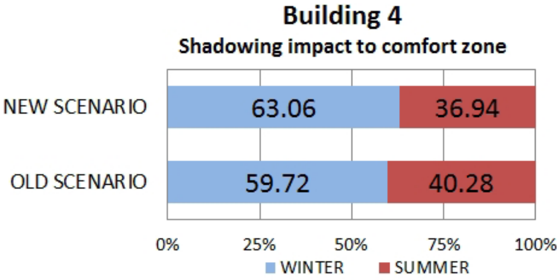

Figure 24 - Shadowing impact (negative impacts in Building 4) to match human comfort requirements, for both scenarios analysed. Source: ISAAC-SUPSI)

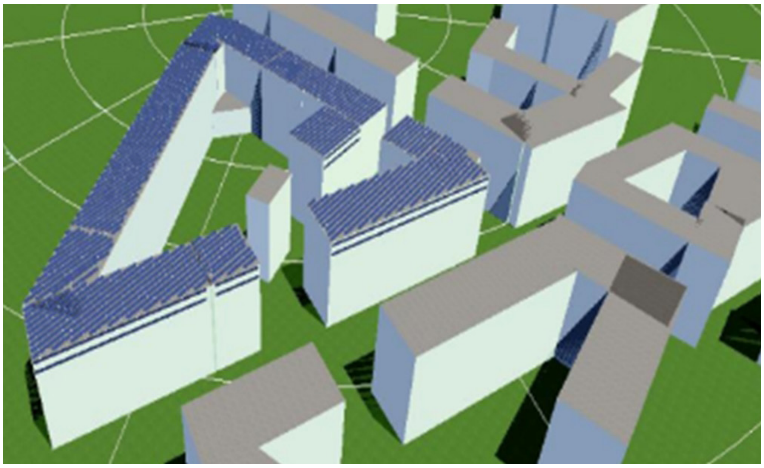

Figure 25 - PV Solar potential analysis conducted with PVSol software. Source: ISAAC-SUPSI

percentage due to new obstructions in relation to the different facades of the heritage buildings was determined. Considering the future dense urban environment, the ground level shows the worst results during wintertime; the shadow increases by up to 17.5 %, levels that result in a direct effect on energy consumption and thermal comfort. To evaluate DF, Ecotect and Daysim RADIANCE software were used to perform annual daylight simulations indoors on each floor of the building. The increased building obstructions from the in-fills change the natural lighting conditions by decreasing the DF indoors. The worst results show up to a 10 % decrease in DF annually. This decrease implies greater dependence on artificial lighting and greater energy demand.

Photo Processing Image Methods

The sky-view factors (SVF) in the dense built environment was verified through photo processing images, where on sight photographs with a digital camera and a spherical convex mirror register the real horizon in the urban area (three-dimensional projections of the surrounding urban space). This was carried out in order to calculate limitations of the amount of direct sunlight and irradiation due to obstacles and to determine SVF modifications (Polo López et al., 2016 a), see figure 20.

Bioclimatic Charts and Diagrams

For the assessing of the fourth indicator, human comfort, bio-climatic charts and diagrams have been used to calculate the ‘ideal comfort zone’ for the specific location with the purpose of establishing the aspects that compromise the fully exploitation of the environmental conditions and the possibility of using passive strategies for thermal conditioning (Polo López et al., 2016 b). The meteorological climate data of Lugano were used to perform this study, using average statistical data from the Federal Office of Meteorology and Climatology – MeteoSchweiz. The ideal comfort zone can also be represented in the solar sun-path diagram (figure 22-23), where 20.a), 21.a) and 21.b) represents the comfort zone during the whole year, in summer time and in winter time respectively for Lugano Paradiso; 20.b) and 21.c) represents the solar obstruction assessment by photographic or analytical methods and 20.c) and 21.d) represents the matching results between solar obstruction and comfort needs. In figure 23.d) positive effects are shown in green and negative effects in red. Visualised in this way, extrapolating conclusions from the diagrams and measuring the impacts become easier for determining when this area will be affected by obstructions from the surrounding environment.

In the VerGe Project study, the shadowing impact was investigated in order to match human comfort requirements. For this specific climate and at annual level, the differences are greater in the morning hours and during the wintertime where this situation may be more critical in the future scenario than now (see figure 24, study performed for Building 4).

Building Energy Simulation Tools

To evaluate the implementation of Paradiso, new urban planning strategies of the cultural protected buildings´ energy behaviour (Sala et al., 2016), energy simulation tools, such as BESTenergy software, were used. The programme uses SketchUp as graphic interface and EnergyPlus for calculations. Detailed analysis was performed for the fifth indicator: building energy performance and solar potential in one of the buildings. The software enables a detailed verification of the real behaviour of the building in terms of energy flows, energy requirements and consumption, considering the total annual amount of primary energy for heating and cooling (kWh/m², yr) in the two different urban simulations scenarios (Old and New MP). Modifications due to artificial lighting as well as domestic hot water (DHW) demand have not been considered. The study shows, as a whole, higher operational energy costs through an increase for thermal demand (approximately 8.5 % of the total annual amount of primary energy for thermal conditioning in comparison the current scenario) even though the summer shading from additional buildings prevents over-heating and reduces internal loads and cooling demand (calculated as up to 66 % if actively cooled). However, this reduction represents only 5 % of the building’s overall energy needs. In summation, this result demonstrates that in some cases new urban designs may result in higher global energy requirements and higher building operational costs at an estimated amount of 7.2 %. In order to evaluate PV solar potential in the new surrounding buildings, PVSol software was used. Active solar was studied as a contributor in the energy balance by renewable energy generation. The PVSol tool was also used for visual assessment of aesthetic impact from the active solar systems, see figure 25, (Polo López et al., 2015).

Conclusions

New infill developments within existing urban areas will result in effects on energy performance in surrounding buildings. These effects can be positive or negative, depending on the urban design and the climatic and environmental site conditions. Energy or economic impacts may be significant, both in operational and maintenance costs, during the full life span of a building. This project has highlighted the need to expand solar analyses with new methodological approaches, considering in parallel both the urban scale and the building scale. Urban planning and building design interrelate with key aspects having a connection to the rational use of natural and environmental resources. Precise quantifications of these effects, through the combined use of different tools and software, can aid in determining the availability of solar energy and in case of negative impacts the design can thus be corrected where possible (Polo López, 2017).

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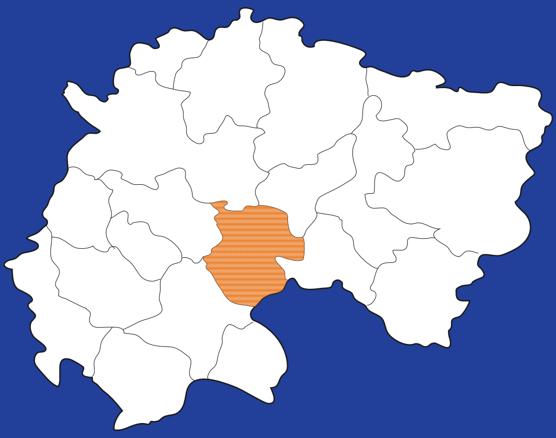
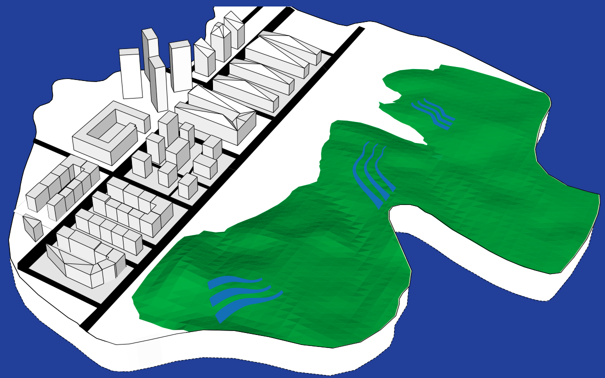
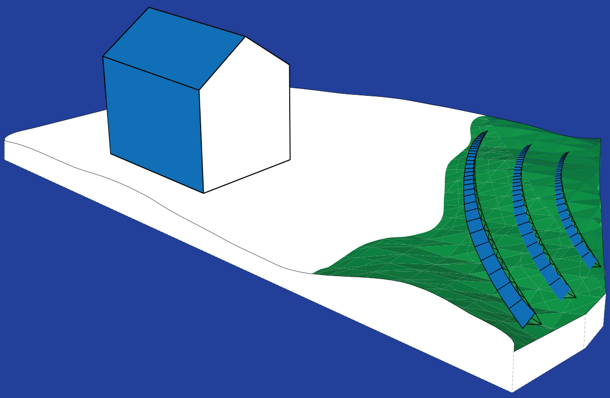
4

ASSESSMENT METHODS AND TOOLS







Urban planning is a complex and political process and many decisions taken often seem arbitrary to the public. The difficulty in balancing different aspects against each other and choosing priorities is not to be underestimated. In this context, solar energy aspects are new and not something that is commonly considered. Therefore approaches, methods and tools have to be easy to use and the results relatively easy to interpret.

The previous chapter presents different examples where tools, often digital simulation tools, are used in a certain order or combination to assess environmental aspects such as energy efficiency, daylight, thermal comfort, and active solar in parallel. The different methods aimed at integrating solar aspects into urban planning through optimization of energy and solar.

The AMT's presented in this chapter are meant to aid urban planners and architects in weighing solar aspects with other criteria in a qualitative way without the need for advanced simulations or external expertise. The methods presented deal mainly with active solar systems and therefore almost always require some kinds of solar potential study. When addressing cultural heritage, the visibility of the urban fabric and its materiality needs to be accounted for. The methods can vary from 2D to 3D urban design scale up to 1:5000 down to architectural design scale of 1:10.

Marja Lundgren & Johan Dahlberg

4.1. 2D AND 3D SOLAR MAPS

Jouri Kanters, Karin Kappel, Emilie Nault, Romain Nouvel, Guiseppe Peronato & Cristina S. Polo López

An increasing number of cities* and even regions are producing online solar maps which can give building owners an indication of the solar energy potential of their roofs, and some cities are additionally including solar potential of facades. These solar maps are both policy and assessment tools.

In order to identify building surfaces suitable for installing solar energy systems, these solar maps quantify the solar potential on building roofs or facades to predict the possible solar energy generation. The majority of solar maps focus on showing the existing urban fabric, but several cities are looking into the possibility of importing planned buildings. The solar maps are produced with new technologies such as photogrammetry technologies and drones**.

Alternatively, the solar potential of every roof and facade may be precisely calculated using a digital model which combines neighbouring buildings and the terrain relief (Digital Surface Models or 3D City Models) with an adapted solar simulation software. Such digital models are available in an increasing number of places. Solar simulation tools integrate radiation models considering urban shading effect and the possibility of reflections.

There is a significant difference in the amount of data that is provided by and shown on solar maps. Some of these maps only provide the irradiation levels on surfaces, others provide the estimated production and maybe even payback times (Kanters et al., 2014). Currently, there is no common methodology on how to categorise the irradiation levels. In a study on 19 solar maps, the categorisation was analysed. The results of this study show that many solar maps classify the incoming radiation into four categories (not suitable, reasonable, good and very good) with a certain range of irradiation. For the 19 solar maps, the average incoming radiation for the category *reasonable* was found to be 65 % of the maximum local irradiation, *good* 77 % and *very good* 90 % (Kanters et. al, 2014).

Several of these new solar maps provide additional aspects beyond solar. More and more tools are over-layering one or more energy related aspects, such as for example energy conservation and potential savings (Nouvel et. al., 2015).

In some cities, the potential for roof application has been studied in detail based on airborne measuring campaigns with radar and/or laser measuring techniques. An example is

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*For example New York, Hamburg, Berlin, Vienna, Stockholm etc.
** More information at for example https://pix4d.com/

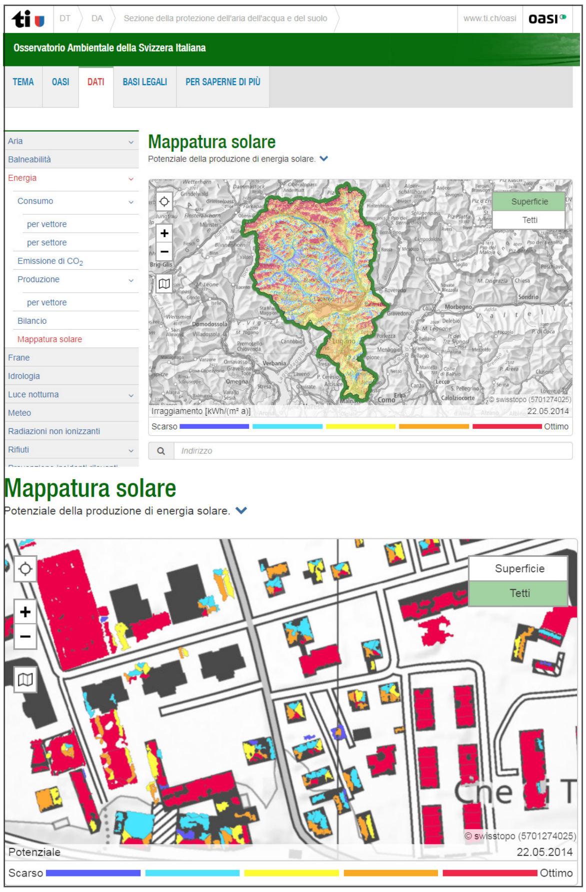


Figure 26: Online Solar potential cadastre of Ticino
Picture of OASI Web page and detail of the solar map.

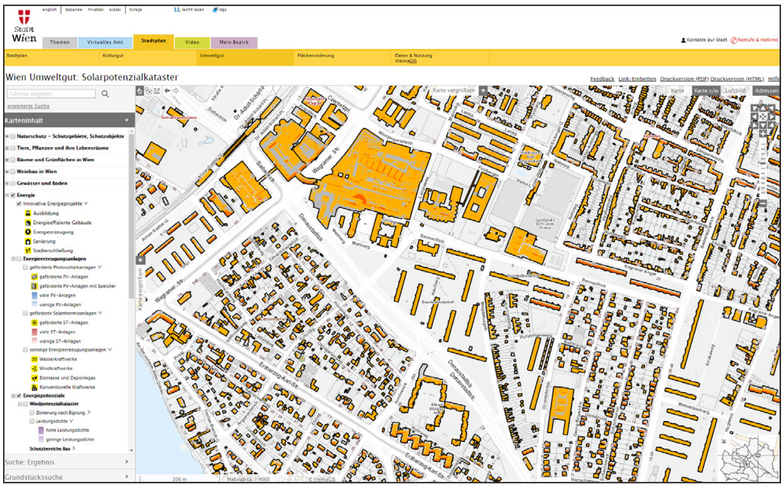


Figure 27: Online solar potential cadastre of the City of Vienna

Figure 28 – swissBUILDINGS3D 2.0 model of buildings use photogrammetric capturing method for a high level of precision and detail. Source: Federal Office of Topography (swisstopo) web page.

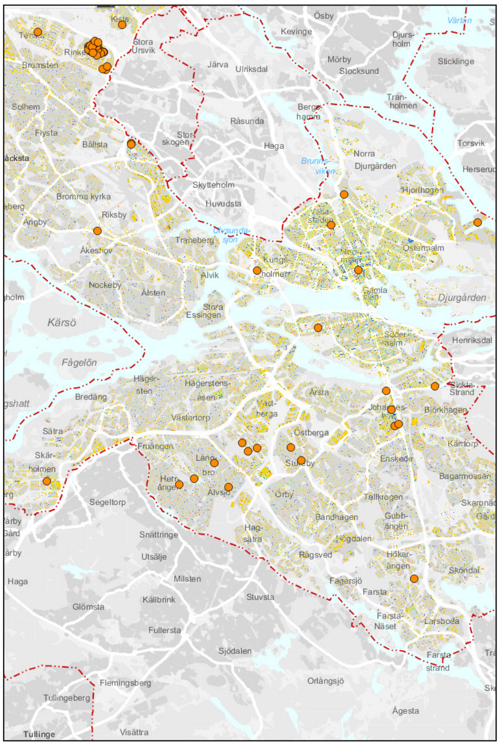
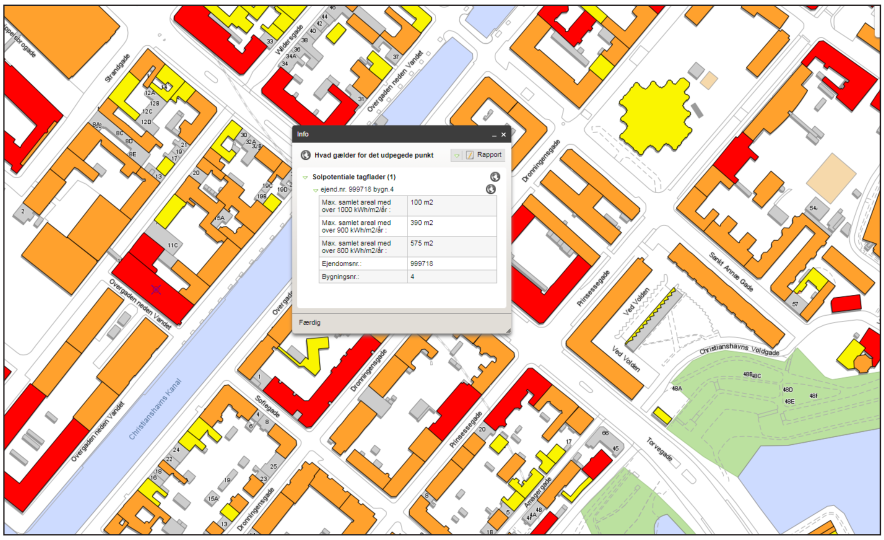


Figure 29: Stockholm Solar Map web page



Hvad gælder for det udpegede punkt

Solpotentiale tagflader (1)

ejend.nr. 999718 bygn.4

Max. samlet areal med over 1000 kWh/m2/år :	100 m2
Max. samlet areal med over 900 kWh/m2/år :	390 m2
Max. samlet areal med over 800 kWh/m2/år :	575 m2
Ejendomsnr.:	999718
Bygningsnr.:	4

Figure 30: Copenhagen Solar Map web page and detail of the solar map

the map of the solar potential in Canton Ticino, Switzerland* which shows the annual solar radiation potential throughout the canton Ticino (figure 26). In this case, it is also possible to ‘zoom in’ to the building scale and the tool explains which parts of the roof that are appropriate – from the point of view of insolation – to install solar systems (solar thermal or photovoltaic). When selecting a single item some essential information appears, in particular for photovoltaic the possible electricity production, investment costs and the annual revenue are indicated. These values are indicative; however, they are a good starting point for real estate owners to quickly get an idea of the solar potential and to decide if further analysis for installing solar systems in their buildings would be interesting. A necessary, subsequent step is to consult with professional expertise to also take into account the general state of the building.

In Austria, the City of Vienna has developed a Solar Map with the intention to give house owners an indication to whether or not a roof is suitable for utilisation of solar, see figure 27. Besides the Solar Map, the tool also gives information about other energy aspects.

In Denmark, the Municipality of Copenhagen has developed a Solar Map**, see figure 30, with the intention to give house owners a clue to whether or not a roof is suitable for utilisation of solar. Besides the Solar Map, the tools also shows a structured data extraction such as a 3D city model with contours and values of solar intensities. The tool can estimate solar potential on a building in terms of solar irradiance, roof size and angle, and additionally gives information about local plans, city planning and listed buildings relevant for the specific building.

Another example is the City of Stockholm which also has a solar map*** available, see figure 29, where you can access information about a specific roof and whether or not it is suitable for solar PV installations.

In Switzerland, the Swiss Federal Office of Energy (SFOE) is currently compiling a national solar map covering roughly one third of the country, in cooperation with the Federal Office of Topography (swisstopo) and the Federal Office of Meteorology and Climatology (MeteoSwiss). This solar map**** uses geodata relating to the buildings from “swissBUILDINGS3D 2.0”, a product of Swisstopo currently under development for the entire country that is a vector based dataset which describes buildings as 3D-models, considering facades, roof overhangs and realistic roof shapes without textures and dormers or annexes. Due to the high level of detail of the buildings´ geometry the new Swiss solar map include solar potential on facades, see figure 28. The map is available for most of the Swiss territory and can calculate the potential heat and electricity production from bulding facade surfaces.

3D city models combining terrain reliefs, buildings and possibly vegetation and city furniture are increasingly used to simulate the incoming solar irradiance on the building surface, and therefore the solar energy generation. For new urban projects built in dense urban areas, it is essential to consider the existing surrounding buildings and the possible external shadings and reflexions. 3D city models are available in an increasing number of cities (especially the open standard CityGML).

Based on this 3D city model of new urban developments and existing environments, solar simulation tools for 3D modelling can assist in the selection of the best building forms optimising the solar utilisation, equally for all buildings.

In the earlier chapter on *Integrated urban design and planning suppor*t examples are given on how simulation tools enable the comparison of master planning variants in order to select the one with the highest solar energy generation potential, able to reach nearly zero energy standards for given boundary conditions (e.g. fixed floor area, building lines, maximum building height).

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* Available on the portal of environmental data Environmental Observatory in Switzerland OASI (http://www.oasi.ti.ch/web/)
**Available on https://www.kk.dk/solceller
*** Available on http://solkartan.miljo.stockholm.se/stockholms-solkarta/

**** Available on (http://www.bfe-gis.admin.ch/sonnendach/

4.2. SUNSCAPE INDEX: A METHOD FOR SOLAR LOAD-MATCH IN NEW URBAN ENVIRONMENTS

Marja Lundgren

Solar energy can be utilised in buildings to a much higher degree than is the case today, but the first obstacle is at the urban level. Local authorities currently lack the approaches, methods and tools to assess the potential for active solar energy.

As a response, Sunscape index, a systematic method of evaluation of solar energy for the development of new areas was developed in 2011; methodology was developed by White arkitekter AB with some parts formulated in collaboration with SpaceScape. Formative steps were carried out by Marja Lundgren, who led the development of Suncape Index and was previously an expert in Task 41; a national study completed with the support of The Swedish Energy Agency and ARQ foundation.

The method is designed as an index linking issues related to architecture, economy and environment to what we call 'potential' and is aimed at visualising, analysing and evaluating the conditions for active solar energy.

In order to work with Sunscape index, additional solar potential studies needed to be performed, and thus, additional MS Excel tools – not yet released publicly – have been developed to handle load match. Subsequent work has been carried out on load match comparisons and collection of real data for energy use for the Swedish conditions.

Utilisation of a method having the ability to illustrate the potential for active solar energy has several purposes which include the following:

- *Increase awareness* of the amount of renewable energy that can be produced within a current district. This can inform environmental policies in areas or cities on the environmental potential.
- *Create opportunities* for municipalities to actively work with the integration of solar energy in architecture, the architecture potential. The method is developed for the urban planning stages from urban design to architectural design, i.e. upon receiving a building permit.
- *Allow for an early assessment* of the economic potential of solar energy, the market potential. The market potential evaluates the basic conditions for a solar energy investment, and can also inform of the synergies between several property owners in so-called clusters.

In a test case, White simulated in 3D in IES Virtual Environment, but any validated programmes work to serve this purpose. The market potential estimates also obtained validated solar radiation data from an interactive website that was developed by the Joint Research Centre, which is under the European Commission. Values are from a GIS database.

Today, Sunscape index handles no legal or political issues (such as purchases and sales of real estate, or commons, etc.). These are questions that we hope can be raised in other forums, as our ambition is for the tool to help highlight the need for investigations relating to standards, law and politics.

The Method Sunscape Index

The index is divided into three potentials – environmental, architectural and economical (figure 31). Each of these potentials address four categories, listed below in descending order:

Area

Each potential has three key aspects to be evaluated in relation to solar energy:

1. Main aspect

Each potential includes a number of key aspects that are crucial for the design of solutions for each potential.

2. Supportive aspect

For each key aspect, a number of important elements exists that can improve or impair the conditions for solar energy exploitation.

3. Unit

A unit is selected to evaluate the solar energy utilisation in different ways for each potential. It provides information that can influence the ambitions of a comprehensive policy for a district.

Within architectural potential, we focus on aspects and elements that will affect the solar energy potential, i.e. the solar irradiation.

In a very early stage, one can evaluate the architectural design or use this approach as a support, a provision of guidelines in order to reach a certain amount of solar energy generation. We have listed three areas relevant in urban design and detailed planning scales.

A. *Urban design involving volumes, orientation, street structure and street design and topography.*
B. *Building design involving roof scapes and facade scapes.*
C. City furniture

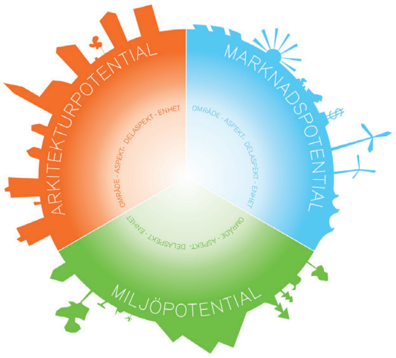


Figure 31 – Architectural potential in Sunscape Index The architectural potential – energy coverage

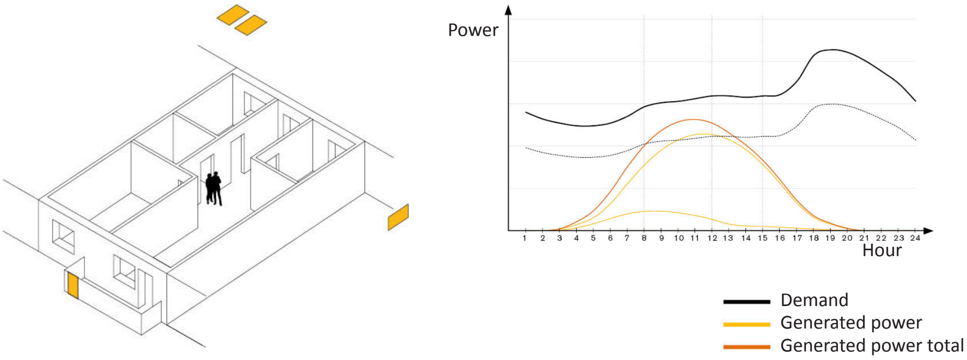
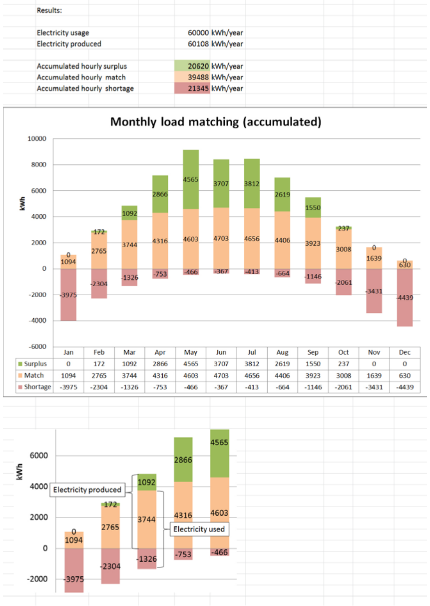


Figure 32 – Illustrative concept of dimensioning PV system based on load match

Figure 33 – Energy coverage map of 'Årstafältet'. Dark green means high energy coverage ratio



Results:

Electricity usage	60000	kWh/year
Electricity produced	60108	kWh/year
Accumulated hourly surplus	20620	kWh/year
Accumulated hourly match	39488	kWh/year
Accumulated hourly shortage	21345	kWh/year

Monthly load matching (accumulated)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
🟩 Surplus	0	172	1092	2866	4565	3707	3812	2619	1550	237	0	0
🟧 Match	1094	2765	3744	4316	4603	4703	4656	4406	3923	3008	1639	630
🟥 Shortage	-3975	-2304	-1326	-753	-466	-367	-413	-664	-1146	-2061	-3431	-4439

Figure 34 – Example from the Sunscape Index MS Excel tool

For each of these (A-C), there are elements to work with and consider; such as reflexions from water or building materials, how to work with the green structure as complementing and not in conflict, how to work with risks as shadowing, how to work with double functions and pedagogical elements.

To achieve active solar energy generation, the architectural design is evaluated with the index energy generation, divided into two units: energy coverage = energy generation/energy use and panel efficiency = energy generation/panel in sqm. The energy coverage can be set to yearly, monthly, daily or hourly. Panel efficiency has a direct relation to the costs.

The Market Potential

Within the economical/market potential, we assess the surface available in relation to these factors:

A. The energy need related to the energy performance of the quarter through energy profiling and goals as well as sqm.
B. Assess the life cycle costs (LCC) or other economical methods in relation to energy costs.
C. Assess complementary techniques to solar in order to get a holistic overview of the relation between district and local production of energy.

In this section we study load match on an hourly basis and have developed an MS Excel tool for this (figure 32-34).

4.3. QSV: A METHOD FOR RECONCILING SOLAR ENERGY AND HERITAGE PRESERVATION

Maria Cristina Munari Probst & Christian Roecker with contributions from Pietro Florio, Laurent Deschamps, Sébastien Hausammann

New energy regulations, together with mandatory solar fractions for electricity and domestic hot water are introducing new materialities and geometries in buildings, resulting in new forms of architectural expression which are slowly modifying our city landscapes.

The increased use of active solar collectors in buildings is clearly necessary and welcome, but brings major challenges in already existing environments. The large size of solar systems at the building scale requires a thoughtful planning, as these systems may end up compromising the architectural quality of the building, threatening the identity of entire urban contexts.

Sacrificing architectural quality to promote solar energy can be counterproductive, leading straight to the opposite effect in the long term. There are already ongoing heated discussions between different involved parties in most cities. On one side ‘solar pros’, concerned by the urgency of maximising renewable energy use, are asking for a total installation freedom; on the other side are architects and building heritage institutions expressing their concerns about the impacts of such systems and asking to restrict their use to certain urban contexts only. De facto, both concerns – maximising solar energy and protecting the architectural quality of the built environment – are justified and both should, when possible, be simultaneously addressed. Furthermore, even in the most critical situations, good architectural integration is possible, but this clearly requires appropriate design and often comes with higher investment costs (figure 35).

LESO-QSV Method Objectives

The question is no longer to be *in favour* or *against* the use of solar systems in cities, but rather to define minimal local levels of integration quality and identify the factors needed to set smart solar energy policies that are able to preserve the quality of pre-existing urban contexts while allowing solar energy use. The LESO-QSV approach gives clear and objective answers in this debate (Munari Probst & Roecker, 2011 and 2015).

A. *First it sets the innovative notion of architectural ‘Criticity’ of city surfaces in relation to their need for integration quality.*
B. *Then, it clarifies the notion of ‘Architectural integration quality’ and proposes a simple evaluation method.*
C. *Based on a) and b) it helps authorities set and implement precise local acceptability requirements (LESO-QSV acceptability).*
D. *Finally, it proposes a way to tailor solar energy policies to specific local urban contexts by mapping the architectural ‘criticity’ of city surfaces, and by crossing this map with the city solar irradiation map (LESO-QSV cross mapping).*

Architectural ‘Criticity’ of City Surfaces

Integration quality is always desirable, but not always that crucial. With concern to spreading the use of solar energy, expectations about integration quality may be reduced, as in the instance of industrial or commercial areas and/or city surfaces like flat roofs that are not visible.

The level of visibility of the surface from the public domain and the level of sensitivity of the urban context determine de facto the architectural criticity of a city surface and the related need for integration quality. To structure the issue, a criticity grid is established by crossing the three identified levels of visibility (low-medium-high, figure 36) with the three identified levels of sensitivity (low-medium-high, figure 37), defining nine criticity situations for which quality expectations have to be set.

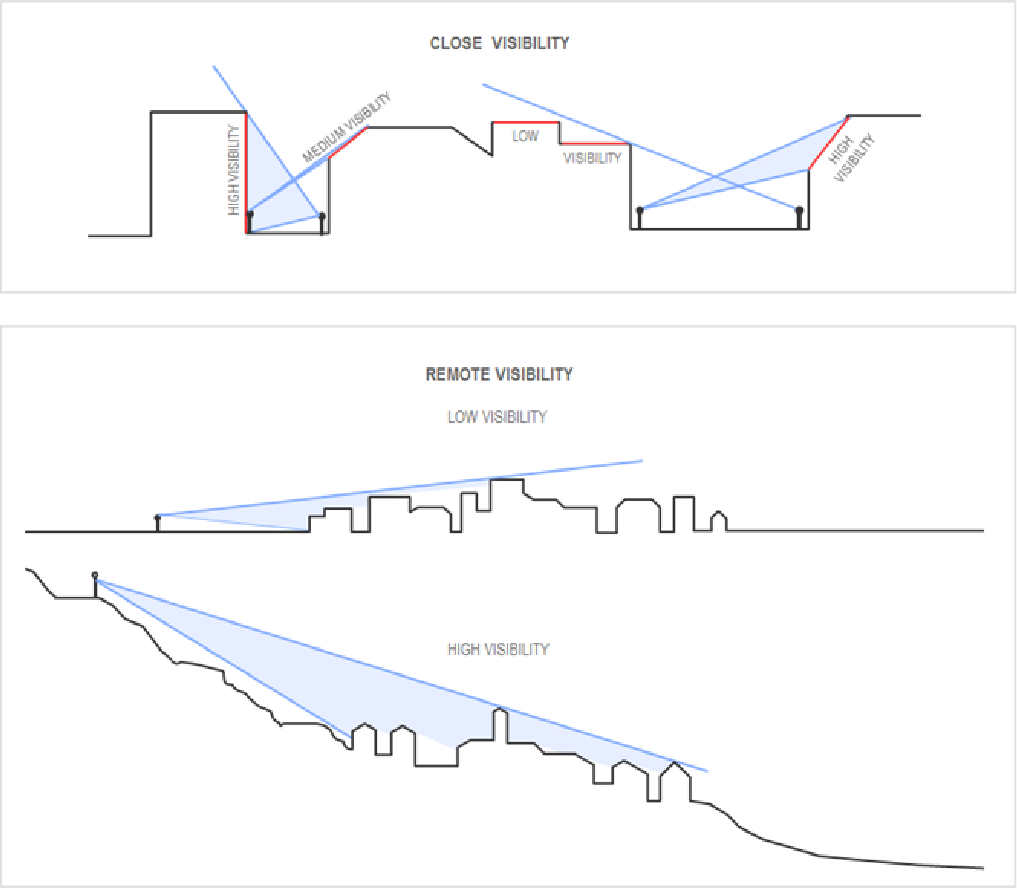
Assessing Architectural Integration Quality

Requiring a certain level of integration quality implies being able to assess that quality. Often this is considered a matter of personal taste, but recent studies have confirmed the existence of implicit criteria shared by the architecture community and leading de facto to the architectural integration quality perception (Krippner & Herzog, 2000; Munari Probst, 2008; Munari Probst & Roecker ed., 2012)

To be perceived as integrated, the system has to be designed as an integral part of the building architecture, i.e. all the formal characteristics of the solar system (field size/position; visible materials; surface textures; colours; module shape/size; joints) have to be coherent with the global building design logic.

Based on these findings, the LESO-QSV approach proposes a qualitative assessment method articulated into 3 simple steps, grouping the integration criteria to keep the procedure light and making the evaluation as objective as possible. The coherency of system geometry, system materiality, and system details are evaluated using a three level scale (fully - partly - not coherent). Since this is a qualitative evaluation, the partial results cannot be expressed by numbers and cannot be synthesised in a single mean value. Hence, the choice is made to represent each partial evaluation as a coloured arc of a circle (green, yellow or red according to the level of coherency) which is combined with others forming a complete circle made of 3 sectors. The overall system quality is given by the number of sectors of each colour (figure 38).

Figure 35: Top: New Solar Buildings (left: 3M office building, Milan, M.Cucinella; right: Endesa Pavilion, IAAC, Barcelona) Middle: Solar renovations (left: Franciscan Monastery,Graz, Austria; right: SchlossWalbeck-Castel, Germany). Bottom: Photovoltaic system integrated on the roof of Aula Pierluigi Nervi, Vatican



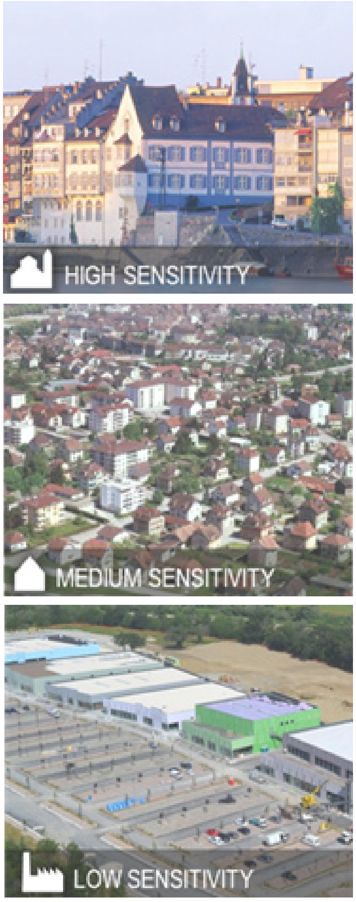


Figure 36: Left: different levels of visibility of city surfaces from the public domain
Figure 37: Right: different degrees of sensitivity of existing urban contexts

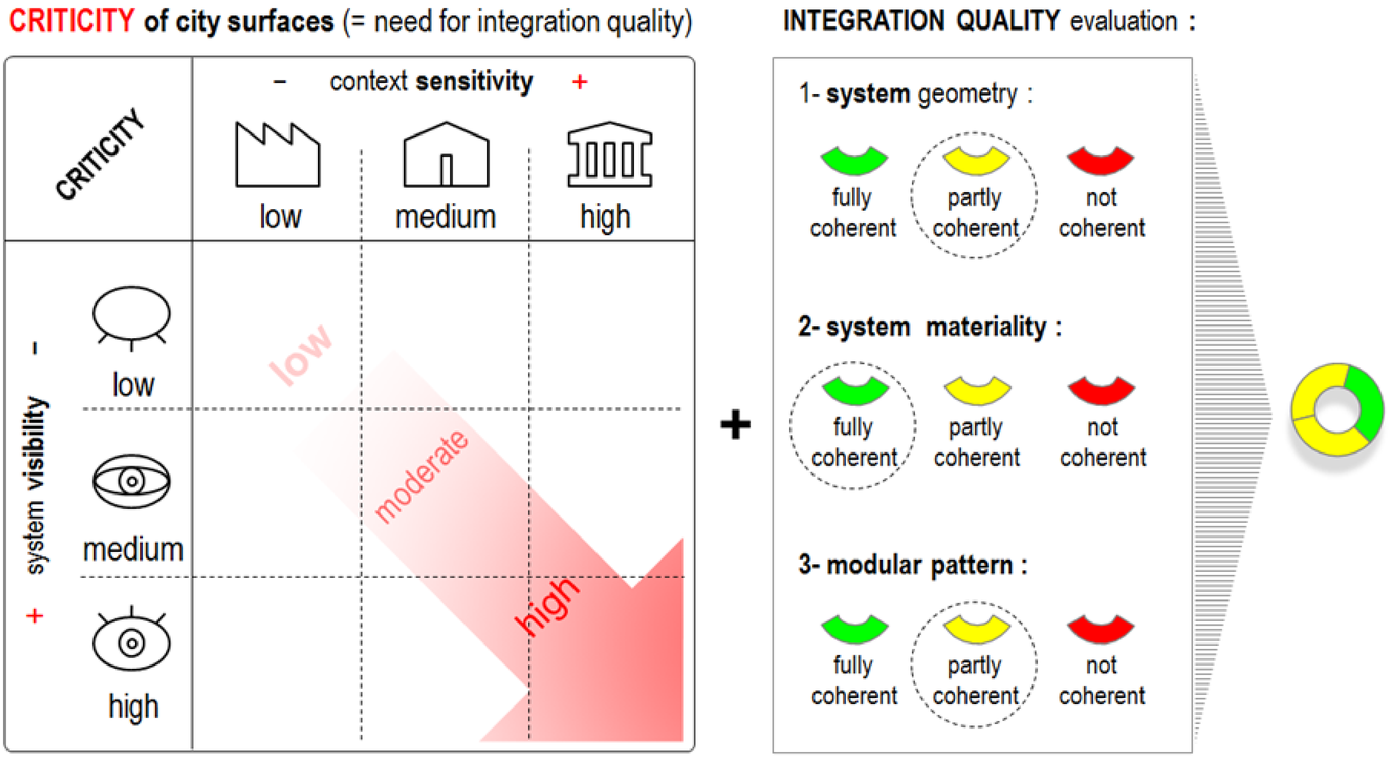


Figure 38: left: architectural criticity; right: 3 steps integration quality evaluation method

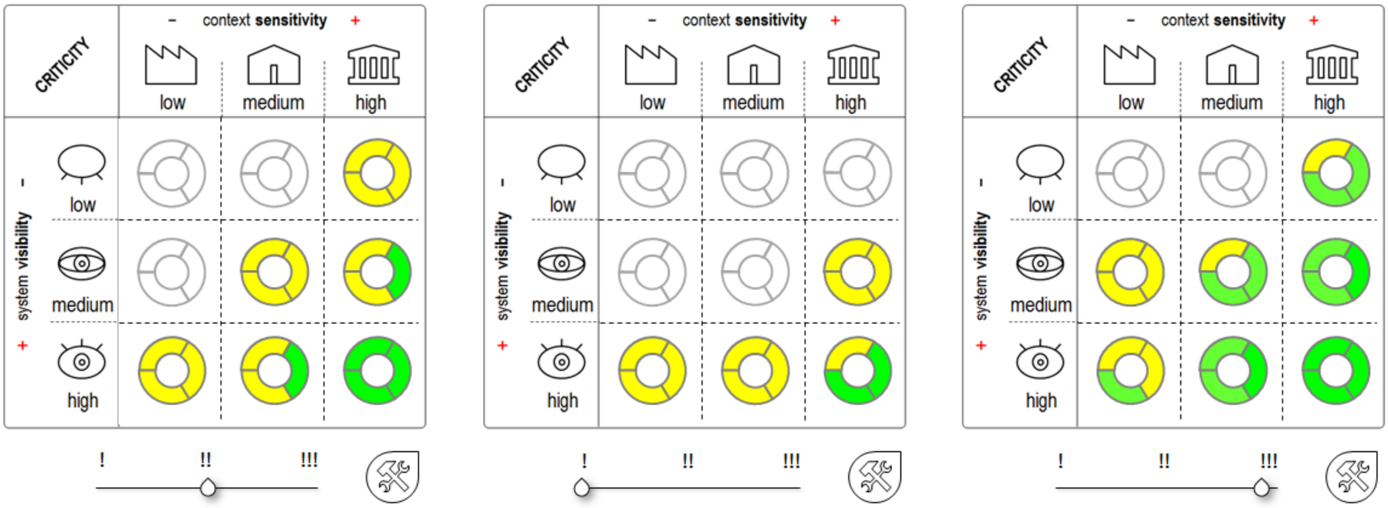


Figure 39: local quality expectation grids, more or less severe depending on the local reality.

‘LESO-QSV Acceptability’ tool

The level of quality required for each criticity situation is not absolute and constant, but depends on many temporal and local factors, such as the energy context, the availability of other renewable energy sources, the general integrability of market products and the consequent difficulty in designing good integration solutions, the city identity and image, its political orientation and economic structure, etc. Therefore, the method does not provide an absolute grid of quality requirements, and is rather conceived to support authorities in establishing local quality expectation grids, more or less severe depending on the local context (figure 38).

LESO-QSV GRID software

To help authorities apply this method, a multi-purpose software tool has been developed, called LESO-QSV GRID (figure 39). Quality expectations are represented by the same three sector circles used for the acceptability grid setting. Evaluation of the integration quality is described in the earlier section *Assessing Architectural Integration Quality*. Three “standard” sets of quality requirements of gradual severity (demanding - standard - permissive) are made available to authorities (“choix de grille”), together with the additional option of setting a fully customised grid.

To help authorities choose the most appropriate ‘acceptability grid’, a large palette of integration cases is displayed that shows, in real time, which integrations would be acceptable and which ones would have to be rejected with the selected settings. This example database can be scrolled through, showing the effect of the grid over a very extensive set of integration approaches and criticity situations.

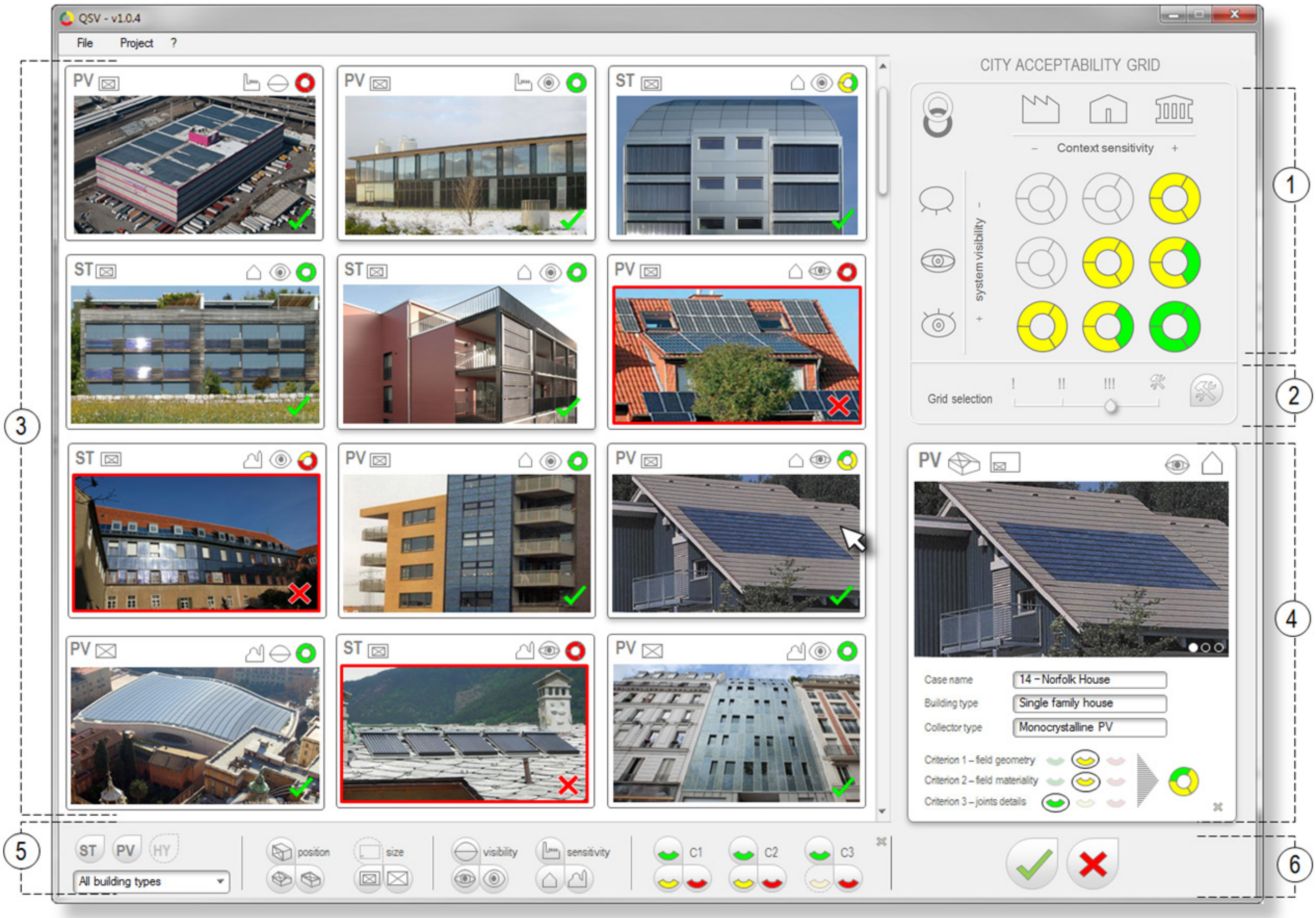
The same software is as well intended to be used with minor adaptations as an educational tool for architects, installers and building owners. The wide palette of examples can provide inspiration from good examples, show errors to be avoided or give ideas on how to improve the quality of a project which would be rejected in its present state. It can also help municipalities explain in an interactive and visually convincing way how the method works and justify to users potential project rejections.

Selection buttons are available in the bottom part of the screen to display a chosen subset of integration examples within selected situations (visibility / context sensibility / type and size of solar systems (figure 40).

LESO-QSV Cross Mapping tool

If the previously described acceptability tool is reactive and meant mainly for protection, the second tool derived from the criticity concept, called ‘LESO-QSV Cross mapping’, is proactive and meant for energy policy planning.

Presently, the only information available to planners and authorities to make decisions on solar promotion, regulations or financial incentives is the amount of solar energy received by the various city surfaces, displayed on solar maps. These maps vary in accuracy and detail levels (rough surfaces only, roofs tilt or not, facades etc., but their only goal is always to assess the solar potential of city surfaces, with no concern for their specific urban context. As already explained, the urban context has a major impact on solar application strategies and should therefore also be made available to planners. To answer this need the ‘LESO QSV-Cross mapping’ tool proposes to map the architectural criticity of city surfaces and to superimpose this information over the solar map. This allows for weighing solar potential of each surface against the expected architectural integration effort.



Case name: 14 – Norfolk House
Building type: Single family house
Collector type: Monocrystalline PV

Figure 40: Main screen of the LESO-QSV GRID programme: 1 - Acceptability grid of the specific city: i.e. required integration quality for each criticity level (system visibility; context sensitivity). These are the criteria to be met for the installation to be accepted; 2 - Acceptability grid setting bar (for municipality use only): integration requirements can be selected by using pre-established grids (more or less severe) or built to measure; 3 - Integration examples showcase: a database of more than 100 cases is shown according to the selected filters setting (5). This showcase is meant to: help municipalities to set a convenient acceptability grid by showing the impact in acceptancy of pre-defined sets of quality requirements; work as a model for authorities for how to objectively evaluate integration quality; inspire architects, installers, building owners etc. ; 4 - Case details window: The window appears while clicking on a specific case. The detailed evaluation of quality become visible, together with other more precise information and additional pictures of the case; 5 - Filter bar: The case studies can be filtered according to solar system type, position, dimension, context sensitivity, system visibility, integration quality; 6 - Accepted / not accepted cases button filter.

Differentiated policies and educated decisions can then be based on this, more comprehensive, information, keeping in mind that solar integrations are possible also in delicate situations (figure 36). Although, in these cases, design efforts and cost investments will probably be higher. If these extra efforts are not affordable, it might be preferable to postpone the operation; poor integrations usually end up just discouraging new users. By contrast, if well designed, such examples can be among the strongest driving forces for the solar change through the reimbursement of their extra cost.

Next Steps

The criticity map mentioned above indicates for each city surface its visibility from the public domain and its sensitivity in relation to the urban context. As part of a PhD thesis work, a process to automatically establish the visibility of the surfaces in 3D models of cities is currently being developed at the LESO laboratory. The information related to surface visibility will not only consider the purely physical visibility from the public domain but will develop a hierarchy to the various vantage points (as e.g. the view from a major city square is usually more crucial than one from a secondary parking lot).

Conclusion

As more and more pressure is building up to increase the use of solar as a replacement for fossil energies, there is an urgent need for new responsible ways to implement the solar collecting elements in the urban contexts.

The concept of 'architectural criticity' at the basis of the LESO-QSV method offers valuable possibilities to implement such responsible policies. The two inferred tools can contribute to finding valuable solutions to the problematic balance between solar energy promotion *and* urban context protection.

The method has also been used to assess the quality and acceptability of the different solar integration approaches proposed by the set of case studies collected documented in the report *Task 51/Report C1 - Illustrative Prospective of Solar Energy in Urban Pllaning: Collection of International Case Studies.* and is a core resource in three courses currently taught at EPFL (Ecole Polytechnique Fédérale de Lausanne, Switzerland) and Università IUAV in Venice (Italy).

In November 2016, the method was awarded the *Innovator of the Year Prize* in Sweden.

4.4. BUILDING SURFACES VISIBILITY ASSESSMENT: AN OPPORTUNITY TO ENABLE ACTIVE SOLAR POLICIES

Pietro Florio & Maria Cristina Munari Probst with contributions from: Christian Roecker, Andreas Schüler & Paul Becquelin

Strategic Planning Scale

On the strategic planning level (about 1:100 000 – 1:30 000), buildings and neighbourhoods can be recognised in districts. Regarding sensitivity, particularly sensitive (or non-sensitive) districts can be identified in an area that otherwise is assessed as a uniform medium-sensitive territory. In GIS zones with different heritage categories in accordance with the method of context sensitivity presented in the previous chapter can be marked in maps. As such protected zones in land use plans can be marked as highly sensitive areas, commercial and industrial zones as low sensitive areas. These considerations needs to be coupled with a deep understanding of the local specificity and a constructive discussion with the local site protection authorities. In several countries heritage professionals are responsible for these assessments.

Visibility instead, can vary a lot from building to building and even from façade to façade, making it meaningless to estimate a “district average” visibility index. At this stage of the planning process, this variable is less related to geometrical or physical phenomena, but rather to the mass perception of a place as its global visual interest within the “public”. Such a “collective interest” can be estimated by mapping the squares, the road axes, the sightseeing points that are (or have been) more significant in the cultural representation of the city. Another possibility is to compute the density of photos taken in a given territory, with a higher density meaning a higher interest. An example of this computation for the metropolitan area of Geneva is shown in figure 41, with a partial overlap of the most photographed zones and the most sensitive zones e.g. city centre (Florio et al., 2017).

Urban Design Scale

At the scale of urban design (about 1:10 000 – 1:2500), urban fabric becomes visible and division between public, semi-private and private space becomes evident. A first estimation of solar energy potential can be made with regards to building form and orientation within the urban pattern. In this case too, sensitivity level may inferred from land use zones, by taking into account special clusters of buildings, such as particular squares or well-known settlements, ideally in agreement with the local authority for cultural heritage protection. Visibility depends mainly on geometric factors and reciprocal obstructions and is evaluated per building roof. It means that, at this stage, it is more important to know whether a surface on the roof can be visible or not, and from how many unobstructed locations, rather than trying to quantify the degree of physical perception from each view point. This would require more detailed form definition and a complete material mapping of the different surfaces, which is appropriate to the following stages in the planning process.

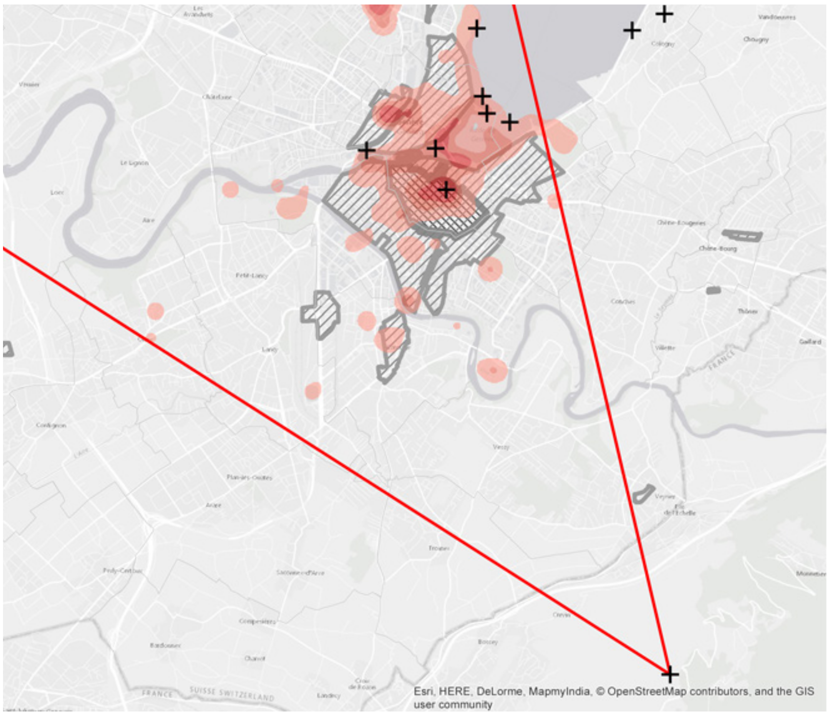
Concerning urban design level, one possible geometric indicator for GIS applications is the “cumulative viewshed” (also known as “times seen”), which counts the number of times each building surface is intercepted by a visibility ray coming from several points sampled on the public space. *Figure 42* shows an example of possible application of this method to the roof areas of the city of Carouge (Geneva metropolitan area), where ratios representing the visible portion and the most radiated surface of roofs are compared. Best radiation is achieved in industrial areas where streets are wider and buildings not very tall with flat roofs making them less visible. Buildings characterized by both low visibility and high solar radiation, which might be prioritized for solar refurbishment, are around 10-15 % of the total (corresponding to 15-20 % of the total roof surface).

Detailed Planning Scale

Detailed planning level (about 1 : 2000 – 1 : 500) entails the definition of building components. Differences between façades become relevant at this stage as well as urban furniture (lamps, benches, advertisements, car parking) and vegetation occlusion: envelope surfaces represent the granularity of the map. Usually maps at this scale focus on one district with a constant level of sensitivity or across a couple of different sensitivity zones.

Visibility is now dependent on physical factors such as visual acuity and contrast and has to be quantified for each envelope surface beyond the simple distinction of “visible”/ “invisible” features made in the previous section. To do so, visibility rays are cast from a grid of possible vantage points on the public space to mesh subdivisions of building surfaces, representing possible solar installation spots: visual stimulus is quantified as the solid angle produced by a target feature (mesh face) on the spherical visual field of each observer (vantage point) and related to the smallest perceived stimulus (threshold). This ratio can be converted to a metric everyone is familiar with, the logMAR visual acuity measure: it is issued from the typical test of “reading the characters” performed by an optician.

Figure 43 shows this index, here mentioned as “visual amplitude” (A/V), calculated on a 1.50 m resolution mesh on building surfaces of the “Hollande” district in Geneva, Switzerland. Contributions from a set of viewpoints are



Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Figure 41: Collective interest as a visibility index at the strategic planning scale. Density of web-shared photos in the metropolitan area of Geneva, overlapped on the highly sensitive zones issued from the land use plan. Significant viewpointst located in squares, lake walks and hills are highlighted.

Figure 42: Roof suitability analysis in Geneva, extraction of Carouge district. Roof surfaces are classified by a combination of insolation and visibility thresholds (CHECKMATRIX). Highly sensitive areas are surrounded by thick dashed lines and listed buildings by a contour and a shadow effect.

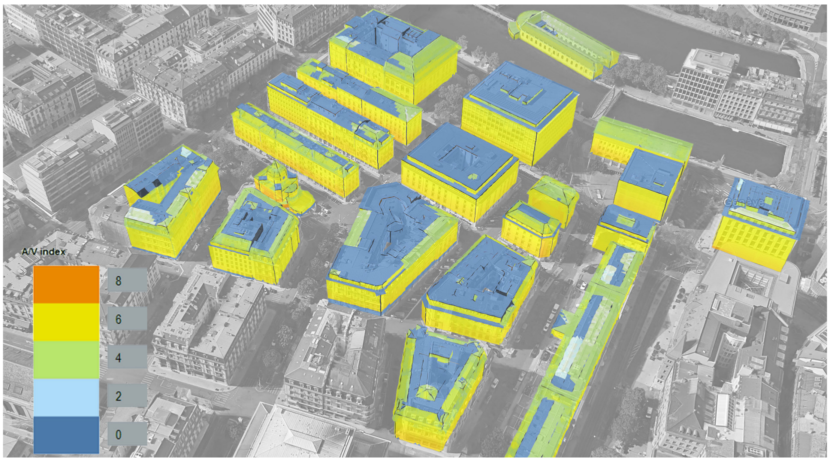
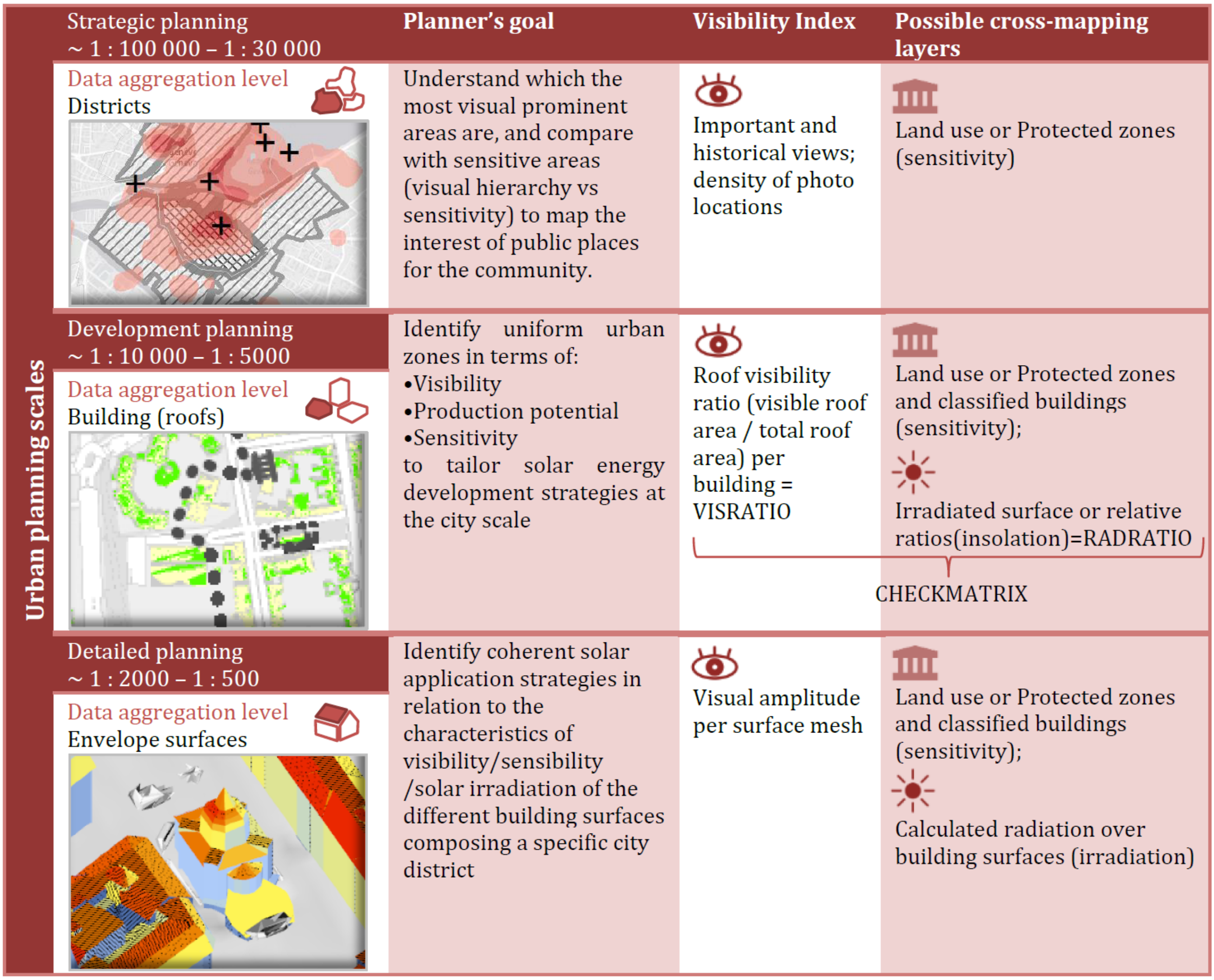


Figure 43: Visual amplitude index of the envelope surfaces in the Hollande district, Geneva.



Urban planning scales	Planner's goal	Visibility Index	Possible cross-mapping layers
Strategic planning ~ 1 : 100 000 – 1 : 30 000 Data aggregation level Districts	Understand which the most visual prominent areas are, and compare with sensitive areas (visual hierarchy vs sensitivity) to map the interest of public places for the community.	Important and historical views; density of photo locations	Land use or Protected zones (sensitivity)
Development planning ~ 1 : 10 000 – 1 : 5000 Data aggregation level Building (roofs)	Identify uniform urban zones in terms of: •Visibility •Production potential •Sensitivity to tailor solar energy development strategies at the city scale	Roof visibility ratio (visible roof area / total roof area) per building = VISRATIO	Land use or Protected zones and classified buildings (sensitivity); Irradiated surface or relative ratios(insolation)=RADRATIO
		CHECKMATRIX	
Detailed planning ~ 1 : 2000 – 1 : 500 Data aggregation level Envelope surfaces	Identify coherent solar application strategies in relation to the characteristics of visibility/sensibility /solar irradiation of the different building surfaces composing a specific city district	Visual amplitude per surface mesh	Land use or Protected zones and classified buildings (sensitivity); Calculated radiation over building surfaces (irradiation)

Figure 44: Summary of the proposed scale-dependent methodology

averaged to get a mean visual amplitude index per mesh face. It can be noticed how flat roofs are not visible (A/V index = 0), especially from narrow streets, and façades are on average 50 % more perceptible than tilted roof pitches (Florio et al., 2016). As for the other stages in the planning process, these results can be overlapped on a 3D solar radiation map to compare the variables (see examples of 3D solar radiation maps in the previous section).

This GIS approach to visibility, see figure 44, supports the implementation of the QSV Cross mapping tool described in the previous chapter and gives opportunity to define smart solar promotion policies (Munari Probst & Roecker, 2015).

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5

AWARENESS AND CONSULTATION METHODS IN URBAN PLANNING

In this chapter different planning, awareness and consultation methods for public, professionals and decision-makers (design support, knowledge, guidelines) involved in urban planning are presented. In the earlier Task 41 *Solar energy and Architecture* several relevant guiding documents and websites were developed for the architectural design stage. Here we present these together with local spin-offs into guidelines that can inspire other countries, regions and municipalities to develop guidelines for the balance between solar energy and architecture not least for the building permit process. Another way to support development of BIPV for challenges in existing urban areas can be through competition as one of the examples show. A challenge for the dense city is designing for daylight, addressed through an exhibition in Sweden and presented here as inspiration for the architectural repertoire.

Marja Lundgren & Johan Dahlberg

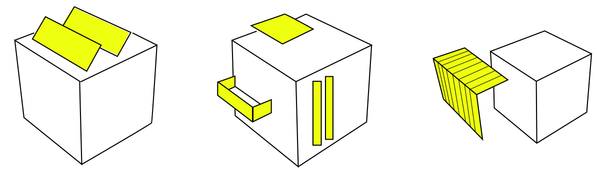
5.1. GUIDELINES FROM MUNICIPALITIES ON ACTIVE SOLAR

Marja Lundgren

More and more cities around the world publish solar maps over their city with the goal of accelerating solar energy implementation (Kanters et al, 2014). Upon realisation of the potential of solar roofs, the general public also started requesting advice as a result of this new awareness. The Task 41 deliverables have been useful in communicating with city planning offices, as well as functioning as guidelines and support for the city planning offices when dealing directly with the public. Presently, the Task 41 illustrations (figure 45) and description of architectural approaches are published in several Swedish guidelines for the public in regard to the building permit process (figure 46 and 48).

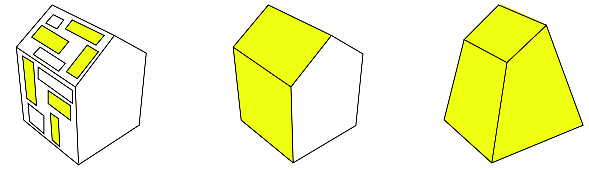
Important formal aesthetical aspects in the architectural design stage are the coherence between the building design and the positioning and dimension of the solar panels, how the materials, surface texture and colours are compatible with and relating to the other surfaces of the building, how the module sizing and shape are compatible with the building composition grids and various dimensions of other building skin materials and that the jointing types are carefully considered when choosing product and mounting method (Munari Probst & Roecker ed., 2012).

As an important support to the evaluation of or guidance of stakeholders in regard to the different types of integration illustrated in figure 45 as well as the mentioned formal aesthetical aspects are the website: case study collection (http://task41casestudies.iea-shc.org/), see figure 47 for screenshot from website.


added technical element

added technical element with double function

free-standing structure


part of surface composition

complete facade / roof surface

form optimised for solar energy

Figure 45: Illustration from IEA Task 41 Solar Energy and Architecture, http://task41.iea-shc.org

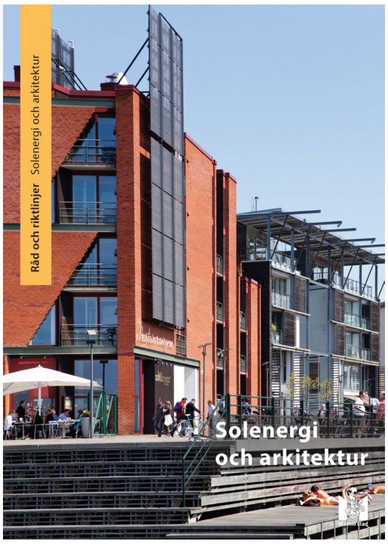
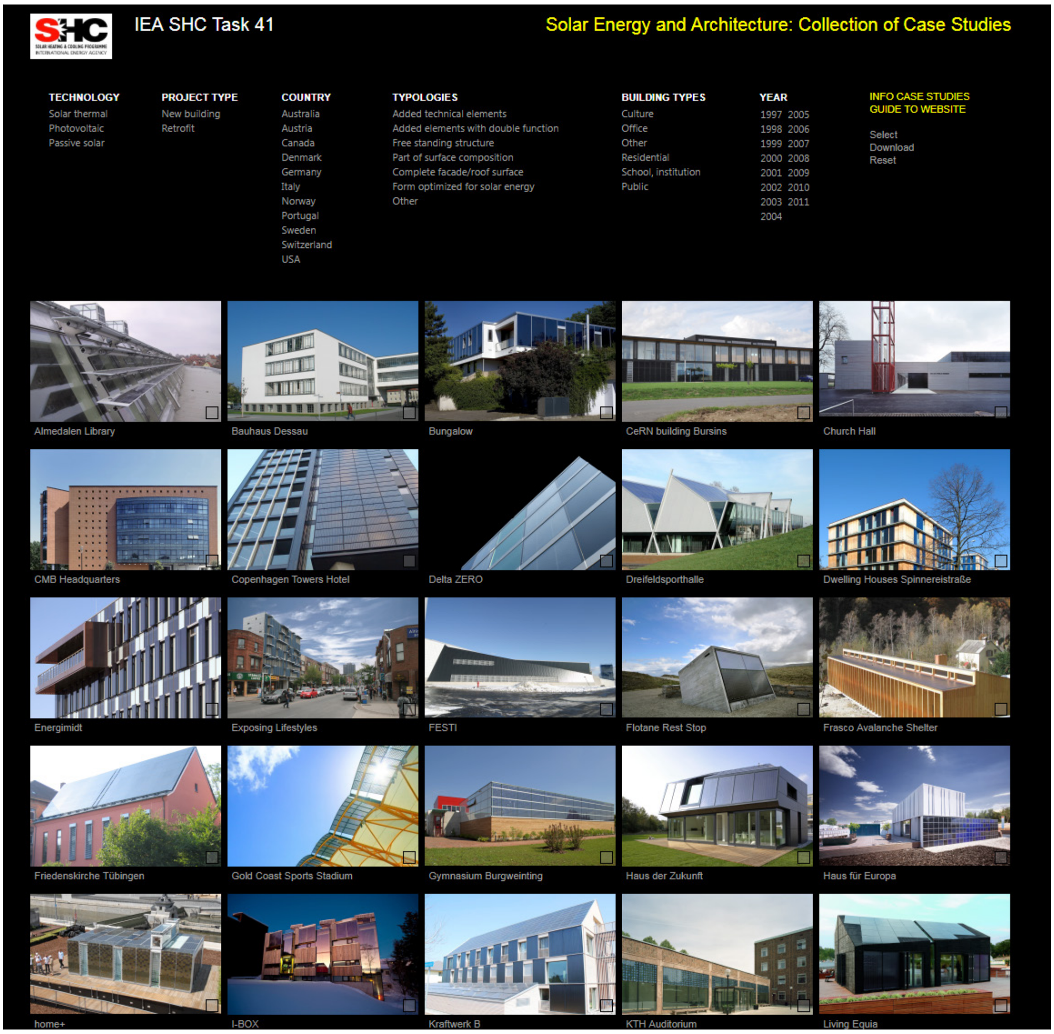


Figure 46: Examples from the Malmö City guidelines for Solar energy and Architecture and Linköping City guidelines



IEA SHC Task 41

Solar Energy and Architecture: Collection of Case Studies

TECHNOLOGY
Solar thermal
Photovoltaic
Passive solar

PROJECT TYPE
New building
Retrofit

COUNTRY
Australia
Austria
Canada
Denmark
Germany
Italy
Norway
Portugal
Sweden
Switzerland
USA

TYPOLOGIES
Added technical elements
Added elements with double function
Free standing structure
Part of surface composition
Complete facade/roof surface
Form optimized for solar energy
Other

BUILDING TYPES
Culture
Office
Other
Residential
School, institution
Public

YEAR
1997 2005
1998 2006
1999 2007
2000 2008
2001 2009
2002 2010
2003 2011
2004

INFO CASE STUDIES
GUIDE TO WEBSITE

Select
Download
Reset

Figure 47: Screenshot of the IEA Task 41 Solar Energy and Architecture case study collection website http://task41casestudies.iea-shc.org/

Solenergi i stadsmiljö
– en vägledning

Linköpings kommun
linkoping.se

2. Solenergi och byggnader

Anläggningar med solpaneler placeras vanligen på en byggnads tak eller fasader. Vid nybyggnad kan panelerna integreras som en del av byggnaden. När det gäller befintlig bebyggelse kan panelerna placeras ovanpå det befintliga tak- eller fasadmaterialet eller integreras i byggnaden och ersätta ett befintligt ytskikt. Beroende på platsen och byggnaden och det uttryck man vill åstadkomma kan olika förhållningssätt väljas. Nedan följer exempel på olika sätt att arbeta med solenergianläggningar i förhållande till byggnaden.

Solpaneler på tak eller fasad

Det är vanligt att solpaneler placeras på tak och fasad. Detta kan förekomma både på ny byggnad och befintlig byggnad. När paneler sätts på befintlig byggnad blir det ett tillskott som ska anpassas och samspela med byggnaden. Vid nybyggnad kan solpanelerna tas med som ett utformningselement från början. Paneler som placeras synligt på tak och fasad bör samspela med byggnadens komposition av fönster, dörrar och andra fasadelement. Samspelet handlar bland annat om mönsterverkan som kan ses på långt håll t ex då mörka solpaneler placeras på tak eller fasad med annan kulör.

Solpaneler som hel fasad eller tak

Att ersätta en hel fasad eller ett helt tak med solpaneler passar bäst vid nybyggnad eller omfattande renoveringar. I ny bebyggelse är det ofta ett bra arkitektoniskt grepp. I befintlig bebyggelse kan det vara mer tveksamt då det kan finnas kulturhistoriska värden att värna och kan upplevs som ett alltför avvikande uttryck. Då en hel vägg ersätts med solpaneler bör man beakta att växter i närheten av fasaden kan skugga och ge sämre effekt av anläggningen. Det finns dock möjlighet att genom tekniska lösningar minimera störningar från skugga.

Solpaneler på platta tak

Solpaneler kan ställas på befintliga platta tak i uppställda rader på stativ. Detta kan passa bra då takytorna är stora och där taken inte är så exponerade t ex i industri- och verksamhetsområden. I mer exponerade lägen bör panelerna placeras indragna från takfoten för att vara mindre synliga från gatan. När taken är synliga från högre byggnader bör uppställningen av paneler anpassas till takformen, till exempel genom att placeras symmetriskt och med lika avstånd till takfoten.

5

Solpaneler med dubbelfunktion

Solpaneler kan användas istället för andra material så som balkongfronter eller solavskärmning och får då dubbla funktioner. Både nya och befintliga byggnader med stora glasytor kan behöva skärma av solen och solavskärmningen kan då få en dubbel funktion genom att solpaneler placeras som solavskärmning. Balkonger är ofta orienterade mot solen och har därför från början ett bra läge för solpaneler. Detta passar bra att använda sig av främst i ny bebyggelse. I befintlig bebyggelse kan det upplevas som ett alltför avvikande uttryck.

Solpaneler som fristående struktur

En fristående byggnadsdel i anslutning till byggnaden kan framhävas genom solpaneler. Det kan t ex vara ett skärmtak, en entré eller ett trapphus. Den fristående strukturen kan ha en storlek och ett uttryck som följer huvudbyggnaden eller förhålla sig friare till denna. Ett friare förhållningssätt kan tillföra något nytt och bidra till ett nytt uttryck. Den här placeringen kan passa i ny bebyggelse, men kan också fungera i befintlig bebyggelse där det finns en byggnadsdel som avviker från byggnadens uttryck.

Byggnad optimerad för sol

Vid nybyggnad kan man redan i planeringen arbeta för att bidra till energieffektiva lösningar. Genom en genomtänkt placering och utformning av byggnaderna eller byggnaden kan solens instrålning tas till vara på bästa sätt. Stora ytor med solpaneler mot öster, söder och väster i fördelaktiga vinklar och utan skuggning bidrar till att energiproduktionen ökar. Att vinkla upp väggar mycket mot solen kan dock innebära att de utsätts för mer påfrestningar från klimatet än en vertikal vägg.

Illustrationer: IEA TASK 41 Solar Energy & Architecture.

Bra att veta!

Vad ger bäst effekt?
Det som avgör hur stor effekt man kan få av en solenergianläggningar är husets orientering, taklutning och eventuella skuggningar. Söderläge är optimalt men även väst och öst fungerar bra. Solpanelerna ger bäst effekt när de placeras i lutning mellan 15-60 grader. Skuggning ska alltid försöka undvikas. Solcellspaneler producerar bäst i soligt och kyligt klimat då effekten blir bättre i kallare klimat. Det svenska klimatet är därför väl lämpat för solenergianläggningar.

6

Figure 48: Examples from the Malmö City guidelines for Solar energy and Architecture, in Linköping Municipality in Sweden guidelines

5.2. A WEBSITE FOR INNOVATIVE SOLAR PRODUCTS FOR ARCHITECTURAL INTEGRATION

Maria Cristina Munari Probst, Laurent Deschamps, Christian Roecker
with contributions from Sébastian Hausmann, & Pietro Florio.

Despite all the available solar technologies, solar energy systems are still not used enough in buildings today. One of the main reasons lies in a general architects' reluctance to integrate such systems in their projects. This reluctance comes from several factors: lack of architects' knowledge in the field, lack of simple dimensioning tools for the early design phase, administrative hurdles and, last but not least, lack of adequate offer in market products designed for building integration, especially for solar thermal (Farkas & Horvat, 2012).

A website has been set up in order to address these issues by presenting on one hand the innovative solar products available on the market today and, on the other hand, the information needed to optimally integrate them in the architecture of a building. The project of establishing and maintaining a public website was started within Task 41 (http://task41.iea-shc.org/publications), and is presently taken over by Task 51 (http://task51.iea-shc.org/publications), see figure 49.

Website Purpose

The website was developed with the intent to address the lack of architects' knowledge on active solar technologies (technical specificities, integration issues, architectural possibilities etc.) (Munari Probst & Roecker, 2012 and 2013) and the difficulty to find building-oriented products, still very rare in the market today (Munari Probst & Roecker eds., 2014; Farkas et al, 2013).

To tackle the lack of technical knowledge, the website provides simplified information on the use of solar energy in buildings, on the specificities of available active technologies (photovoltaics, solar thermal, hybrid), and a set of architectural integration guidelines (excerpts from Task 41 deliverable DA2: Solar energy systems in architecture: integration criteria and guidelines) (Munari Probst & Roecker ed., 2013). To help deal with the difficulty to find market products conceived for building integration, the website provides a comprehensive collection of innovative products with an enhanced level of building "integrability".

For a website which goal is to offer easy information access to users with limited knowledge in the field, ergonomics is fundamental. Simple information on the specific uses of active solar technologies in buildings is available for download in the general "home" section (figure 49); external Internet links are presented to complete the information. From the homepage, users can access three technology specific sections to find suitable products and/or specific information.

The technology sections (Photovoltaics / Solar Thermal / Hybrid) are organised to comply with the needs of both the new user who discovers the solar technologies and the regular user who wants simple and easy access to specific information. Therefore, the concept of the website was based on straightforward access to relevant products.

The pages are designed to present either the whole set of sheets on one technology or only the product sheets that might be suited for his building application. Therefore, the page offers two sets of selection criteria (figure 51):

- Sub-technology choice-(s)
- Building area(s) available for the system

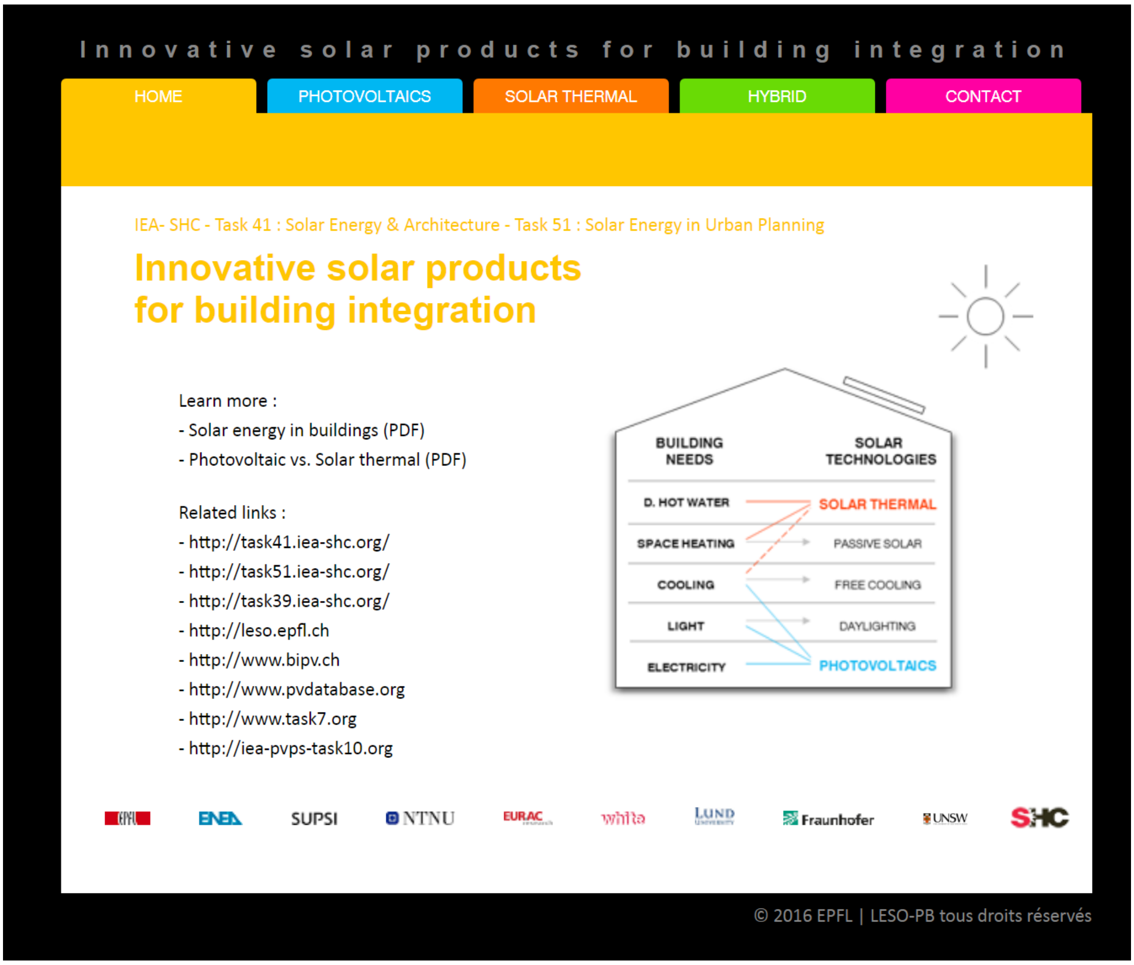
Available sub-technologies are selected via tick-boxes, while possible implementation zones on a building are visualized using icons. The user unaware of the technologies' characteristics can select them all or refer to detailed information using the "LEARN MORE" button. Once the pre-selection is completed, the "GO" button launches the sorting process.

Collection of market products

The collection of existing products suitable or specifically targeted to architectural integration was first organised with the contribution of Task 41 experts and is presently updated with the help of Task 51 experts. Photovoltaics and solar thermal specialists scrutinize their respective national markets to come up with a collection of products adapted to integration.

Specific to this task is the need to obtain the maximum information not only on the technical characteristics of the products, but also on their "integrability" characteristics: material and finishing, colour and texture choice, dimension flexibility, jointing, etc.

There have been quick up and downs in the market of solar products, but the choice have been to keep innovative products even if they are presently out of production or the commercial brand is out of market, since the properties of the innovative products can be relevant information in order to develop new or other commercial solar products or customise products without starting from scratch. Products no longer commercially available are presented in a dedicated section, right after commercial ones.



IEA- SHC - Task 41 : Solar Energy & Architecture - Task 51 : Solar Energy in Urban Planning

Innovative solar products for building integration

Learn more :
- Solar energy in buildings (PDF)
- Photovoltaic vs. Solar thermal (PDF)

Related links :
- http://task41.iea-shc.org/
- http://task51.iea-shc.org/
- http://task39.iea-shc.org/
- http://leso.epfl.ch
- http://www.bipv.ch
- http://www.pvdatabase.org
- http://www.task7.org
- http://iea-pvps-task10.org

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Figure 49: Screenshot of the main page. Source: http:// solarintegrationsolutions.org/

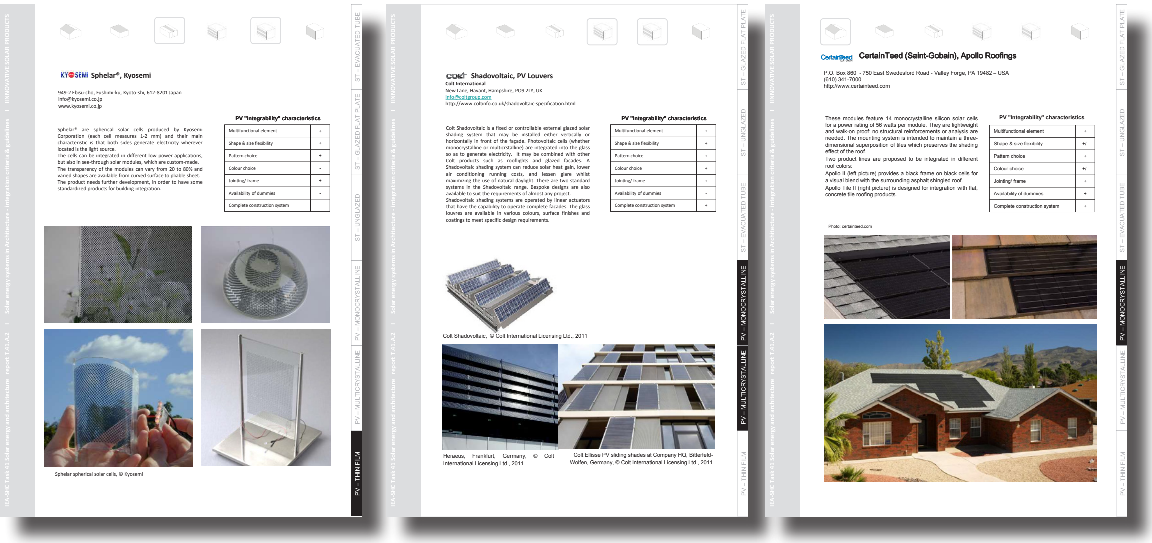


Figure 50: Typical innovative product sheets

Presentation of Available Products

To be able to present the needed information in an attractive and uniform way, a general template was developed, to be used in publications and for the website. One sheet per product facilitates maintenance of the website when adding new products or removing products no longer in commerce. The template comprises 6 zones (Figure 50):

A. Product brand and description
B. Evaluation table of integrability characteristics
C. Technical drawing(s)
D. Picture(s) of implementation example(s)
E. Product technology group
F. Possible use on building part(s)

The first zone (a) gives a short description of the product highlighting its key characteristics and specificities, like adaptability to a whole system, colour and/or dimension availability, used materials, etc. Manufacturer references give access to more detailed information.

The second zone (b) consists of a table evaluating the product integrability potential using the criteria established within the Task 41:

- Multifunctionality
- Shape and size flexibility
- Glazing texture choice
- Absorber texture choice/ Absorber texture adequacy
- Absorber colour choice/ Absorber colour adequacy
- Jointing options/ jointing adequacy
- Availability of dummies, meaning non-active identical parts
- Part of a complete construction system

The third zone (c) is dedicated to technical information, showing close view(s) or drawing(s) of the product, while the last specific zone (d) is dedicated to pictures of the product integrated in buildings. The two remaining zones are common to all sheets. Zone "e" highlights the technical family of the product (photovoltaic thin film, unglazed flat plate collectors etc.) while the zone (f) indicates the area(s) of the building where the product can be installed.

Product Selection and Download

The choice of sub-technology type and position on building (figure 51) brings the user the whole set of sheets corresponding to the criteria/wishes/research (figure 50). Some products disappear from the market, because their manufacturers have gone bankrupt or they have been replaced: these products are still available in the selection to inspire future developments, under a clear sign mentioning "out of commerce".

In the selection example, figure 51, all monocrystalline and multi-crystalline products adapted for pitched or flat roofs are presented. The option is open to download all sheets ("ALL") or just a subset by clicking the relevant ones. The pdf format of the sheets make them readable on all media, including tablets like iPad for instance, while keeping the file size limited (under 400 Kb).

Conclusion

The presented website, developed within Task 41 and further operated within Task 51, represents a significant result of IEA SHC common work. By addressing major barriers to the use of active solar technologies, this site should improve architects' knowledge and increase their willingness to use solar. Complemented by the Task 41 and Task 51 other publications and references (Farkas et al., 2010, Munari Probst & Roecker, 2007 and Munari Probst et al., 2013/2016) this represents a complete and up-to-date source of information for the successful integration of solar energy in buildings and cities.

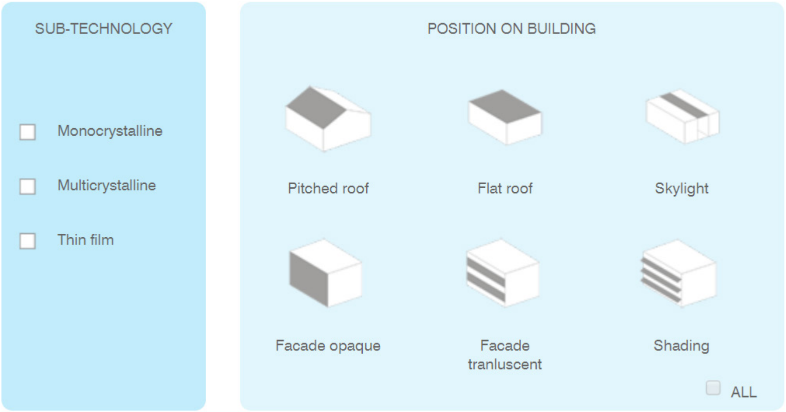


Figure 51: PV selection page

5.3. PRODUCT DEVELOPMENT ADDING ON TO GUIDELINES FOR DESIGN PROFESSIONALS ON BIST

Marja Lundgren

In Task 41 Solar Energy and Architecture it was noted in surveys and among the experts that product developments on building integrated solar thermal (BIST) were necessary (Farkas & Horvat, 2012). The product range for building integration was much larger in photovoltaics than solar thermal (Farkas & Horvat, 2012). New products and knowledge on how to develop new products is therefore desired.

In 2010 a new product line for BIST was developed as a collaboration between an architectural firm and a solar thermal company. The first product is an extremely thin, flat solar-thermal product, tested in collaboration with a building facade company, SAPA. The goal was to create a product line for integration in conventional facades. This product was also presented within the IEA Task 41 website collection of innovative products (Munari Probst et. al, 2013 and 2016). During the process it became obvious that there is a need to present the product as any other material with the same range of opportunities for facade design. Therefore, a guideline was produced for architects, builders and urban planners to be referenced during the architectural design phase. This guideline is of general interest for those who want to know more about solar thermal integration.

Guideline, design and testing were executed by White and S-Solar. Earlier research by EPFL demonstrates that etching the inner side of the outer glass (Munari Probst & Roecker, 2011), as a design option does not adversely compromise the efficiency of the solar thermal but creates a visual matte surface. In addition to holding the role of product designer, White and S-Solar decided to further support design work by developing architect guidelines for the products; the guidelines create a basis for product variation in alignment with architect and clients ambitions. Very important for this work was the thesis by Munari Probst (2008) and the formal aesthetic criteria presented in Task 41 (Munari Probst & Roecker, 2012). The guideline as it is, now goes beyond a certain brand, and shows the potential with BIST and the variation possible in placing, patterns, jointing and mounting.

DESIGNVÄGLEDNING

PRISMA – GRÖN ENERGI. ESTETIK. EKONOMI.

S•SOLAR

2

PRISMA.MER ÄN BARA FASAD.

gigenererande material betalar av sig, det finns det andra byggmaterial som gör. Vi måste ställa om till ett hälle baserat på förnybar energi av resurshänsyn och imatpåverkan. Solfångare genererar värme eller kyla ges helt nya uttryck for att bli en naturlig ersättare takmaterial. 99

RTNER & ENVIRONMENTAL SPECIALIST, WHITE ARKITEKTER

I fasad, tak och balkong

r solfångarmoduler avsedda för byggnadsintegrering i fasadytor och bjälklagsavtäckningar, räcken och tak. Egentligen är variationsmöjligheten oändlig, det är du som bestämmer gen. I bilden intill visas exempel på placeringar i fasad.
är utvecklad för att projektanpassas. I varje projekt kan Prisma med enkla medel anpassas kapa unika byggnader med olika mönster, infästning, glasstruktur och placering. Olika ryck som alla ger energi.
designvägledning informerar om möjligheterna med Prisma. Den är riktad till dig som kt, byggherre eller arbetar vid stadsbyggnadskontor.

4

PRISMA. MER ÄN BARA FASAD.

FASADYTAN

Prismas uttryck kan varieras i glasuttryck, infästning och placering. I denna vägledning presen-eras hur grundmodulen kan anpassas till önskat fasaduttryck med olika glasbehandling, olika glastexsturer, infästningslösningar och hur modulerna kan placeras i fasader.

risma är avsett för byggnadsintegrering i fasad och tak, i bröst-ingar, täckning av bjälklag i glasade fasader, balkongräcken ch tak.
Prisma är ett klimatskal som ger ett effektivt skydd mot värme, yla och fukt. Genom att även ta tillvara solens energi minskar yggnadens energi- och effektbehov samtidigt som Prisma levererar förnybar värme eller kyla.
Prisma är ett moduluppbyggt arkitektoniskt byggelement om kan levereras i olika storlekar, ytbehandlingar, infästnings-lösningar och har mycket lång livslängd med ett minimalt un-erhållsbehov.

Utvecklad för nordiskt klimat. Prisma har utvecklats för att möta kraven från byggindustrin och drift i ett tufft nordiskt klimat. Kraven på design, hög effektivitet och kvalitet ligger i fokus. Det här innebär ännu bättre prestanda vid användning på sydligare breddgrader.

Med två olika typer av glasbehandlingar kan mönsterverkan skapas. Glasbehandlingar med ***etsning*** påverkar inte verkningsgraden nämnvärt, medan ***screentrycksbehandling*** täcker glasytan varför procentandelen screen påverkar verkningsgraden i motsvarande proportion. Här följer vägledning för skräddarsydda lösningar med högt utnyte av förnybar energi och ett varierat uttryck.

Figure 52: Pages from design guidelines for BIST

5.4. ARCHITECTURAL COMPETITION AS DRIVER OF SOLAR SOLUTIONS IN EXISTING URBANITY

Karin Kappel

In 2015 a competition was held in Copenhagen: the aim was to find a solution which could be a demonstration project as the municipality has many properties that face energy renovation in the coming years. Red tile roofs combined with solar panels is an architectural challenge when it comes to energy renovation.

With the competition, the intention was to create architecturally good scalable solutions for building integration of solar panels, when replacing the whole roof. The teams invited were each consisting of an architectural firm and a solar supplier. Two of the proposals are presented with images: The entry by HL Architects and Gaia Solar focuses on the ease of integration and the other entry by Svendborg Architects and Solar Elements on context as a main principle.

The entry with focus on the ease of integration presents a panel made up of three layers: an orange back sheet, the solar cells, and a terracotta-coloured glass plate with satin matte surface. The panels are mounted so that the vertical structure of the tile is also found in the panels. Alu-profiles and details are coloured in the shade of the tile.

The other entry with focus on context integration creates a new type of solar panels that contain a diversity of red tones related to tile, which aims at the material and colour diversity we know from this type of roof. This proposal outlines an extensive typology of solar panels that can fit in different contexts. Each solar panel can accommodate up to five different colours, customized the existing roof colour and patination. Tiles normally last for 80 years, which is longer than the life time of solar cells, and the intention is to make a new colour scan of the patinated roof when the solar panels are to be replaced, to find an appropriate new colour combination of the solar cells.

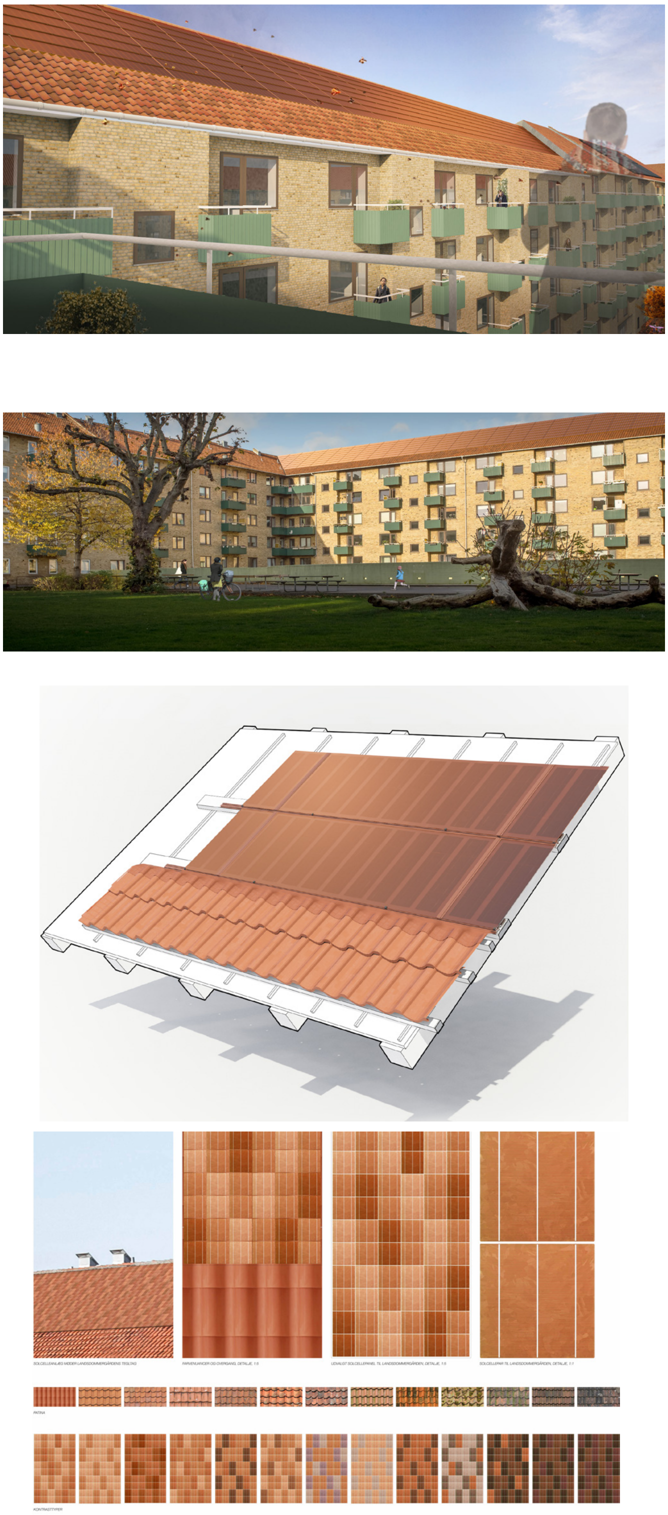


Figure 53: The winning project by HL Architects and Gaia Solar. Project by Svendborg Architects and Solar Elements is focusing on old tile roofs with a great variety of colours

5.5. A WEBSITE PLATFORM ON BIPV FOR PROFESSIONALS, PUBLIC AND DESICION-MAKERS

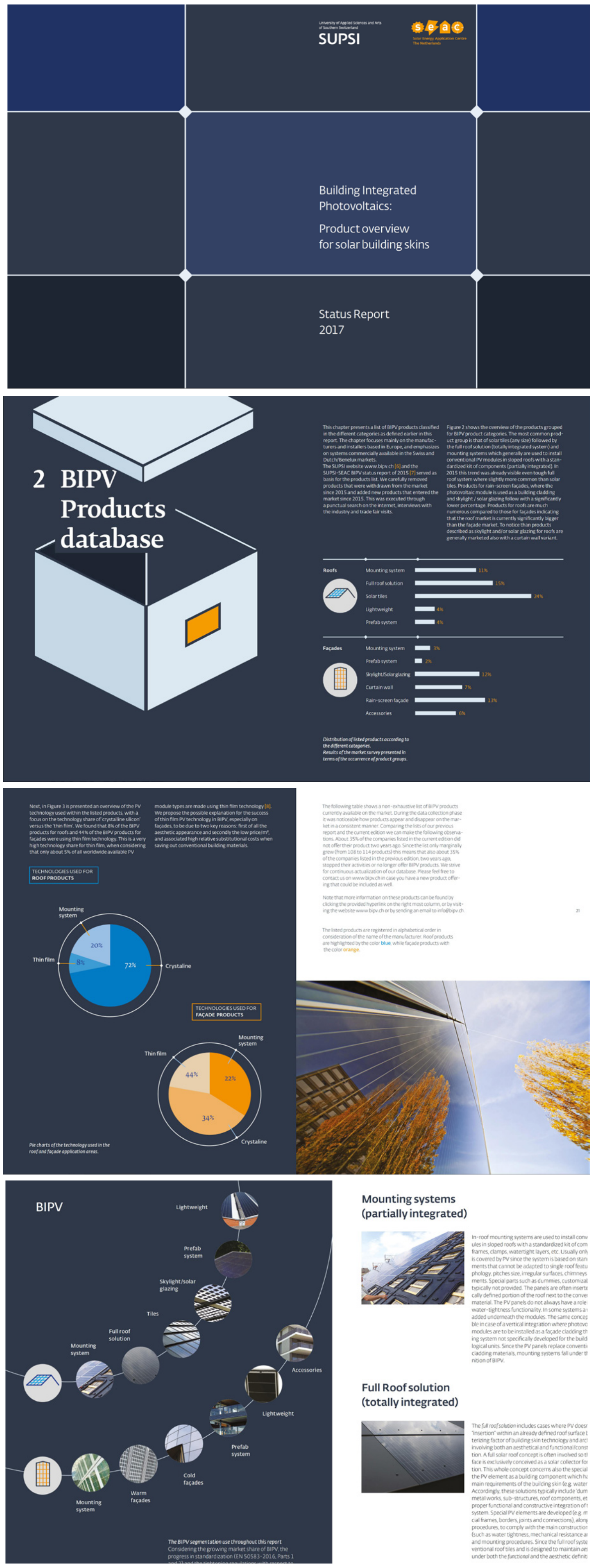
Cristina S. Polo López & Francesco Frontini

The Swiss BiPV Competence Centre, within the Institute for applied sustainability to the built environment (ISAAC) of the University of applied sciences and arts of southern Switzerland, offere a new and appropriate building integrated (BIPV) approach to photovoltaics for professionals, public and other decision-makers since 2005. Applied research, training and professional advice are the pillars on which its activities are founded.

The website platform http://www.bipv.ch/ is one of the means of communication for the Swiss BiPV Competence Centre where it is possible to find essential information concerning PV technology integration in buildings.

Explained in detail are the different aspect related to technologies, energy production, aesthetics, general requirements, cost and incentive feed-in-tariff system, quality and environmental considerations. Different reference projects for BIPV in Switzerland and abroad (best cases) and an actualized database of products and systems are included for consultancy. Different building integrated PV modules (BIPV modules), mounting systems and other innovative products for building integration are collected, divided in different subcategories according to their function as building element (es. solar tiles, glasses for roof, façade elements, metal panels, flexible modules, shading devices, etc.). The database of BIPV products and projects shows specific details in descriptive technical sheets. Guidelines and other useful information for architects and designers are available as a software collection and graphic tools (3D parametric ArchiCAD objects) developed by ISAAC with the financial support of Swiss Federal Office of Energy SFOE, with the aim to simplify the elaboration and presentation of photovoltaic material in architectural renderings.

It is also possible to upload the Status Report on BIPV, a joint publication of Solar Energy Application Centre (SEAC) with the Swiss BIPV Competence Centre of SUPSI (Zanetti et al., 2017; Frontini et al., 2015). The report addresses the status of the BIPV product portfolio in Europe and is updated every other year. The central section is a database of commercially available BIPV products targeting architects and other stakeholders in the BIPV market. The report contains a classification of BIPV products, information on BIPV pricing and a number of BIPV project highlights in Europe (Bonomo et al., 2017; Bonomo et al., 2015).


SUPSI

Building Integrated
Photovoltaics:
Product overview
for solar building skins

Status Report
2017

2 BIPV
Products
database

BIPV

Mounting systems
(partially integrated)

Full Roof solution
(totally integrated)

Figure 54: Report from www.bipv.ch website
Source: ISAAC_SUPSI.

5.6. BUILDING-INTEGRATED SOLAR THERMAL SYSTEMS IN THE ARCHITECTURAL DESIGN STAGE

Christoph Maurer & Tilmann Kuhn

Building-integrated solar thermal collectors (BIST) can be aesthetic and ecological and at the same time offering considerable economic savings compared to conventional, building-added (BAST) solar thermal collectors (Munari Probst & Roecker, 2011, Maurer et al., 2017). Urban planning can allow for the selection of the most suitable areas on the building envelopes of a district (see chapter 4: Assessment Methods and Tools). Methods have been developed to handle BIST systems from early district planning phases up to the detailed planning of the services of a building.

Solar building envelopes are more complex than conventional building envelopes and therefore there is need for guidance. Figure 55 presents a schematic drawing of a conventional building envelope with a building added solar thermal (BAST) collector and a building-added solar thermal (BIST) collector. BAST collectors are surrounded by ambient air and can be calculated by existing standards (ISO 9806, 2013). BIST collectors are influenced by the temperature of the building interior which exceeds the equations of this standard.

Conventional building envelopes can be characterised by constant U and g values (also known as solar heat gain coefficient or solar factor). In BIST systems, the temperature of the fluid influences the energy flux through the building envelope which leads to variable U and g values (Maurer & Kuhn, 2012). Typically, BIST elements add insulation to the building envelope, while BAST systems have the absorber disconnected from the building envelope by the air in between the facade or roof and the back of the collector. Therefore, BAST have usually more back losses than BIST which means that the solar thermal performance of BIST is typically higher than the solar thermal performance of BAST. The heat losses through the gap between the BAST collector and the building envelope typically lead to smaller cooling loads and higher heating loads of the building.

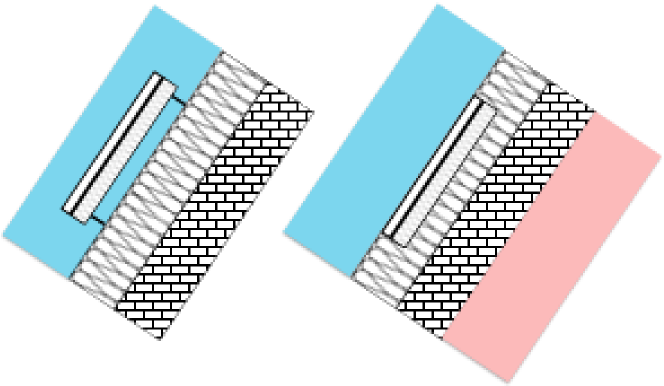


Figure 55: Schematic drawing of a building-added solar thermal collector (BAST, left) and a building-integrated solar thermal collector (BIST, right).

For the early urban planning phases, we recommend to neglect the effect of the building integration of the solar thermal collectors and to calculate the solar thermal performance according to the ISO standard and heating and cooling demand with constant U and g values and to keep in mind that the solar thermal performance of BIST will be a bit higher than this first approximation and that BIST will shift a bit of the heating load to a cooling load.

In later phases of the urban planning when the heating and cooling demands should be known more accurately, the simple models for BIST (Maurer et. al, 2015) are recommended. For collectors which are characterised as BAST collectors according to the ISO standard, the recommended simple BIST calculation model offers equations to calculate parameters for the BIST case based on the parameters which are provided for the BAST case according to the ISO standard. With improved parameters, the calculation of the solar thermal performance of the early urban planning case can be easily updated for this second approximation. The simple BIST calculation models (Maurer et al., 2015) also offer equations for how the variable U-value can be calculated for a second approximation of the heating and cooling demand. Even for custom-made BIST collectors, a simple node model is presented in the simple BIST calculation model (Maurer et. al, 2015) through the use of a second equation, so that no programming is necessary.

At the final phase in urban planning, the architectural design phase, when the building services of the buildings need to be designed, detailed physical models of the BIST building envelopes can be provided from a manufacturer (Maurer et al., 2013). BIST may be more complex than conventional building envelopes, but this complexity can be kept within a simulation model which can be handled as easily as other simulation models in simulation environments.

This section has presented three methods for how to deal with BIST in different phases of urban planning. In the beginning, a quick estimate neglects the building integration. To improve the accuracy, simple BIST models are recommended. For the detailed planning of building services, detailed BIST models can be provided. In this way, urban planning can use the aesthetic, ecological and economic advantages of solar thermal building envelopes for districts with very little carbon emissions.

5.7. EXHIBITION ON DAYLIGHTING FOR URBAN PLANNERS

Marja Lundgren with contributions from Malin Alenius

During the time frame of work on Task 51, it has become more and more apparent that municipalities, architects and builders in Sweden lack knowledge on daylighting. The legislation has in between 1994 and 2013 only set demands on a building design level; urban planning aspects have not, however, been regulated in a direct manner (Bournas et.al, 2017). At the same time, the need for housing has increased in the cities, such as Stockholm, Gothenburg and Malmö. Density has increased in cities since 2000 and is now on levels unprecedented historically (Alenius & Lundgren, 2016). On a national level the National Board of Housing, Building and Planning estimates the need for 700 000 new dwellings by 2025, and the majority to be built before 2020, at a needed rate of 88 000 dwelling units per year (2016). The Swedish action research within Task 51 Subtask B has therefore focused on the Case Study partners' expressed needs for guidelines on daylight.

Work was carried out on daylight in conjunction with the Swedish Museum for Architecture and Design (ArkDes) which resulted in an exhibition demonstrating the connection of 100 years of knowledge, city planning and design to the laws, to the needs of today. Five residential areas along with their surrounding blocks were presented with shadow studies* in scale 1:600 and sections in 1:200 with heuristic rules of thumb that are incorporated in standards that guide the law (Alenius et al., 2016). The major components of these rules of thumb are the obstruction angle and its relation to daylight levels. Additionally, plans in 1:50 with static daylight simulations from the respective architectural eras were presented together demonstrating the relation to legislative demands (Alenius et al., 2016). Architectural design know-how relates in one part to a repertoire of intrinsic case studies and its architectural solutions of problems (Lundeqvist, 1999). This exhibition room contributes to the architectural repertoire by presenting the relation between specific and carefully chosen case studies relating to planning and legislation, exemplifying when the urban level and the building design level respectively enhances or diminishes the possibilities for minimum levels of daylight.

Since 2014, the legislative demands on the daylight factor have been expressed quantitatively. Daylight factor takes into account diffuse and reflected daylight but not sunlight. In the exhibition, a film was also shown from each living room where both skylight and sunlight are present. In accordance with Swedish legislation, at least one room in a dwelling unit shall have direct sunlight at some point during the year. This is a very vague demand at present, creating a lot of uncertainty.

This work has proven to be very pedagogical as it visualises daylight historically through to current times by demonstrating not only the relation of buildings and block types to large scale city planning, but also details, such as balcony and façade design. Quantitative and qualitative aspects, the latter meaning what people actually experience, are successfully brought together through drawings, text and film.

The collective material from the exhibition in conjunction with relevant knowledge and approaches, methods and tools from ongoing and published research is set to be published into a guidebook in Swedish for urban planners and urban designers before the end of Task 51.

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* shadow studies are also called solar studies, and are not quantitative as irradiance studies.

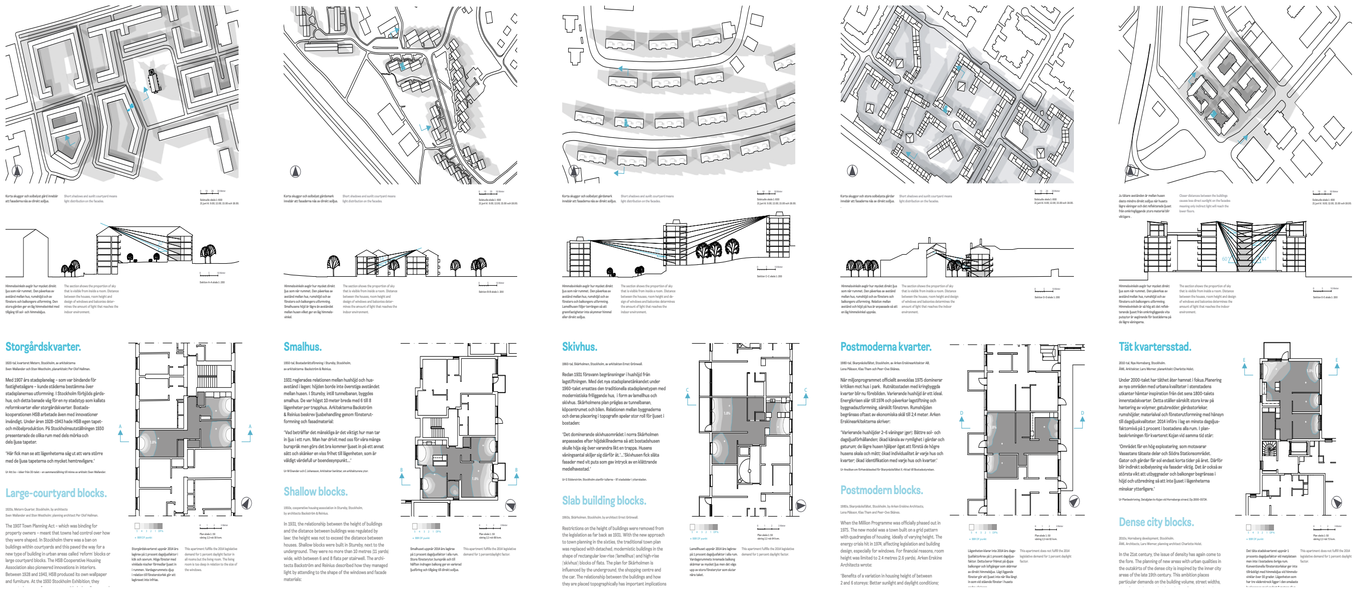

Figure 56: Material shown at ArkDes exhibition

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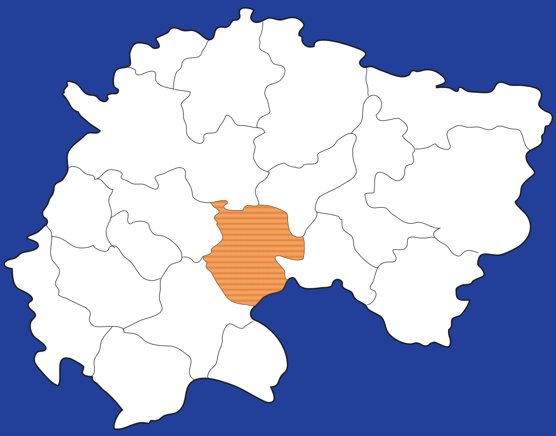
6

SOLAR ENERGY IN LANDSCAPE PLANNING



European Union member states are committed to installing a total of 84 000 MW worth of photovoltaic systems by 2020 – with a major portion of the new capacity installed as very large, open-field power plants – in order to help meet the target of 20 % energy share from renewable sources. As governments devote ever-larger amounts of subsidies to help the industry achieving grid parity, today a growing public opposition to photovoltaic installations is the most significant obstacle to fulfilling the new energy policies of Europe (Mérida-Rodríguez *et. al.,* 2015). Energy infrastructures are still primarily perceived as eyesores intruding in what is commonly considered as uncontaminated natural landscape, adding to a general anxiety over the environmental crisis engulfing the planet.

While the natural environment is the result of human activities, often created over millennia, our actions during the last 50 years have altered ecosystems to an extent and a degree unprecedented in human history (Millennium Ecosystem Assessment, 2005). One of the most tangible consequences of our collective alienation from the logics and the cycles of nature is our increasing vulnerability to catastrophic events (Guha-Sapir et al., 2011). Today, however, human presence in critically unstable areas of Europe is not only unavoidable, in view of a fast-expanding population and the resulting scarcity of available land (EC, 2014), but it might be indispensable to the conservation and sustainable use of its ecosystems.

As a result, increasingly larger budgets are being devoted to the protection of vulnerable communities and the preservation of valuable natural resources in critical areas, such as coastal cities, earthquake-prone regions and zones exposed to landslides (Humanitarian Aid, 2017).

Simone Giostra

6.1. WHAT IF? REMEDIATING VULNERABLE LANDSCAPES WITH LAND INTEGRATED PHOTOVOLTAICS

Simone Giostra

The LIPV* project tries to reconcile these two powerful and seemingly conflicting forces: a large-scale implementation of clean energy infrastructures and the preservation of our natural environment. Recognising the impending energy revolution as the driver for transforming current planning practices, the project proposes a synergetic integration of productive activities, energy infrastructures, natural resources and urban fabric in a radical new model of land development.

The research takes on environmental emergencies where business-as-usual solutions do not work – like protecting coastal cities such as Hamburg from rising sea level, or like in Almeria where the land is severely compromised and the largest congregation of greenhouses worldwide have caused a major crisis, from heavy pollution to intolerable levels of salinity in the ground to social segregation.

What if the vast amount of financial resources devoted to environmental protection projects and emergency rescue efforts (plus the large subsidies for renewable energy) were redirected toward the installation of large-scale photovoltaic energy infrastructures?

Invisible Forces

In one of his seminal writings, Buckminster Fuller declares:

> *"[...] Forms are inherently visible and no longer can 'form follow functions', because the significant functions are invisible."*

Accordingly, the present research recognises the emergence of these "invisible forces" in shaping our environment: sunlight, wind pressure, thermal storage potential, water drainage, slope orientation, and other natural features intrinsic to the land shall guide the planning of a new energy infrastructure.

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*The research project 'Land Integrated Photovoltaics – The New Energy Landscape of Europe' was generously funded by the Institute of Energy and Transport of the JRC (Joint Research Centre) European Commission

Figure 57: Vulnerable landscape: the largest congregation of greenhouses worldwide (Almeria, Spain)

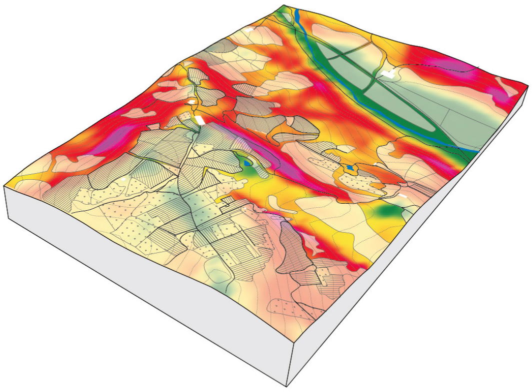

Figure 58: 'Invisible forces': analysis of solar potential and other relevant land features (Montalcino, Italy)

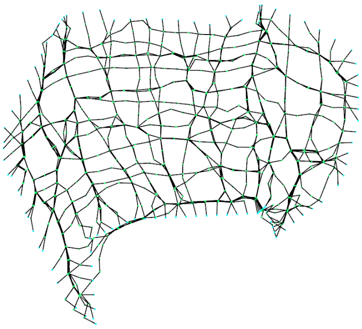

Figure 59: Tessellation: Rule-based manipulation of water flow lines as base for land subdivision (Almeria, Spain)

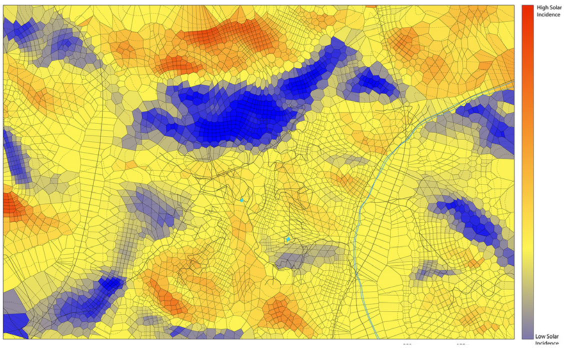

Figure 60: Energy analysis: evaluation of relevant energy forces associated to parcels (Montalcino, Italy)

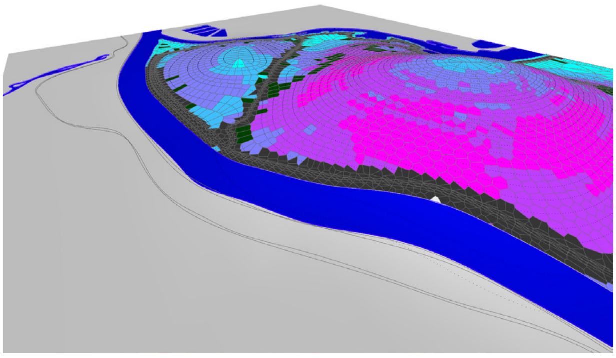

Figure 61: Land use allocation using parametric software (Hamburg, Germany)

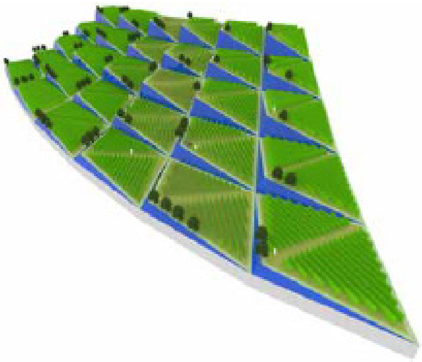

Figure 62: Modular Infrastructure: system components are associated to each cluster (Montalcino, Italy)

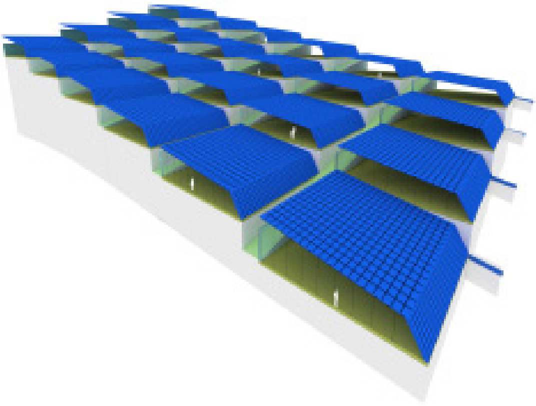

Figure 63:Performance evaluation (Almeria, Spain)

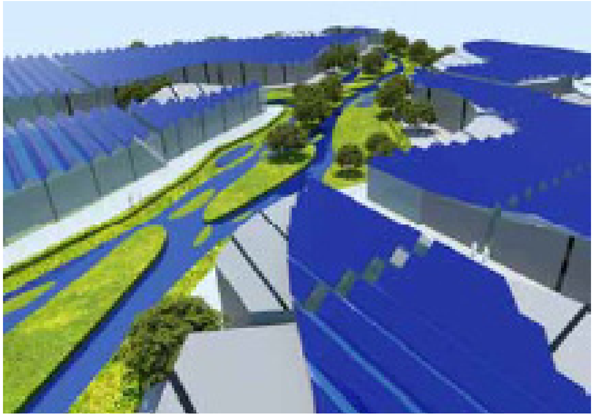

Figure 64: Design integration: the new infrastructure adapts to specific site conditions (Almeria, Spain)

Areas of interest were selected based on sun exposure and other relevant factors, using satellite imagery, GIS and historic data publicly available. Within the selected areas, existing infrastructures and other physical systems were surveyed, in order to identify opportunities of integration. Issues of visibility, economy of scale, synergy with additional systems and services, accessibility and maintenance, productivity and efficiency were evaluated before selecting one or more areas for development.

Tessellation

Generally, traditional land subdivision is the result of accumulated processes of state appropriation, inheritance, or exploitation and extraction of surpluses by the industry. In all cases, it is never a logical or efficient use of natural resources and preservation of the environment. In fact, it is the fragmentary and irrational land division that often leads to the inefficient use of resources, as well as to expensive public infrastructure work and prohibitive emergency response efforts (Boone & Modarres, 2009).

We argue that in areas undergoing critical transformations or afflicted by a chronic state of emergency, a radical reconfiguration of land parcels is the necessary step in implementing remediation efforts and toward re-establishing a sustainable balance of the ecosystem. The first act of all three demonstration projects is to develop a new logic of tessellation that is appropriate to the particular forces acting on each specific ecosystem. It should be noted that in many cases the environmental emergency results from political and economic forces and from the failure of the government to act in defence of the environment (Pearson, 2010). In the present study, the parametric design process that produces the new land parcels responds exclusively to natural forces and land features.

Energy Analysis and Mapping

The resulting tessellation of the land allows for an effective and detailed evaluation of the relevant energy forces associated to each tassel. Using environmental analysis software, we produced a series of different maps for quantitative analyses of relevant parameters; as a result, each new land parcel was defined by values of solar radiation, slope angle, surface water drainage, soil content, and other indicators of environmental performance. Colour-coded maps resulting from the analyses offer a explicit, intuitive reading of large portions of land, while retaining a level of precision in the underlying data-sets associated to the maps. The particular digital format in which they are written makes them ideal as bases for further manipulations and association to geometric properties via parametric design software.

Land Use Allocation

A particular combination of parameters may indicate the ability of a given parcel to perform a specific task, that is, it reveals the 'vocation' of a lot for certain land uses, including – but not limited to – its potential for energy generation. Slope or gradient might be an indicator of vulnerability to land erosion, or additional costs associated to earth retention. Similarly, the ability of the parcel to drain groundwater might be connected to salinity levels, or other factors that might affect its intended use. Pre-existing land uses are obviously a crucial factor in determining the new roles and they were maintained whenever possible, in an effort to minimise unnecessary conflicts with established property rights.

Modular Infrastructure

A limited number of typologies of intervention was associated to each family of parcels: design strategies were then translated into physical infrastructures, using modular system components with the ability to adjust to local conditions and to respond 'point-by-point' to the originating data set. In all cases, the particular design response was triggered by the associated environmental maps. The resulting modular system whether dwellings, energy infrastructure, or productive units was engineered to integrate with existing networks and with additional systems components that might be appropriate to the site.

Performance Evaluation

Preliminary design solutions were tested repeatedly through an iterative process and a progressive optimization of the energy performance of the given solution (figure 63). A comprehensive evaluation of energy performance and other benefits resulting from the system integration are also part of the present study. Quantitative energy analyses are complemented by graphical material for evaluation of visual impact and integration to the landscape.

Design Integration

The integration of the different typology units into the landscape shows the variety of design solutions and the ability of the new infrastructure to adapt to specific site conditions (figure 64). Suggestions on the technical implementation of the proposed architecture conclude the research, together with a series of rudimentary renderings intended to give a first, unapologetic view of a radically new energy landscape.

6.2. MULTI-CRITERIA ANALYSIS METHODS ON ENERGY DECISIONS (CHOOSING BETWEEN SOLAR AND OTHER RES)

Daniele Vettorati

The sustainable energy planning includes a variety of objectives, as the decision-making is directly related to the processes of analysis and management of different types of information (technological, environmental, economic and social).

Very often, the traditional evaluation methods, such as the cost- benefit analysis and macro-economic indicators, are not sufficient to integrate all the elements included in an environmentally thorough energy plan. On the contrary the multiple criteria analysis (MCA) provides a tool, which is more appropriate to assemble and to handle a wide range of variables that are evaluated in different ways and thus offer valid decision support.

The MCA can provide:

- Energy planning alternatives through the parallel evaluation of multiple criteria for energy planning
- Qualitative and quantitative evaluation criteria

In the MCA method, the criteria are usually identified by the actors involved in the energy planning process and can be quantitative or qualitative. MCA qualitative methods are used when some or all data are not available in quantitative terms, and qualitative criteria and measurements must be applied. Different MCA techniques exists. The Analytical Hierarchy Process is the most popular technique followed by outranking techniques PROMETHEE and ELECTRE.

REGIME is instead a growing MCA qualitative method used in energy planning. It is based on the possibility of partial compensation among the different criteria which affects the evaluation of the various policy alternatives.

A common set of considered criteria for energy planning is according to figure 65.

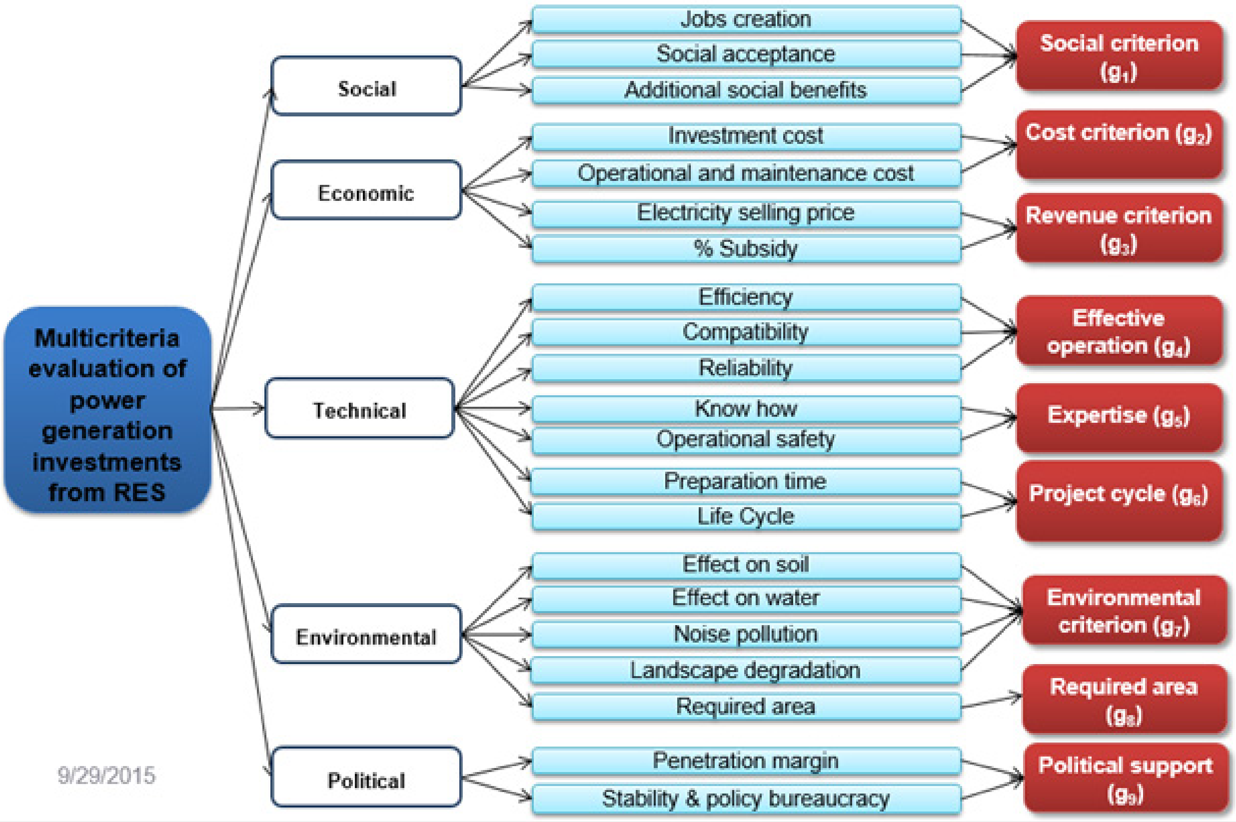

Figure 65: Conceptual model of EIA methodology

6.3. NEGOTIATION BETWEEN SOLAR AND OTHER ASPECTS OF SUSTAINABILITY

Marja Lundgren

The multiple criteria analysis (MCA) presented in the last section (6.2) is a method that helps planning to negotiation between different vital aspects of a landscape area. In several of the case studies on landscapes, aspects such as multi-use of land is addressed. Land is attractive and important from a sustainable point of view. Multi-criteria analysis to be used as decision tools therefore needs to address this. According to Grêt-Regamey & Hayek (2013) there is a need for approaches that allow for spatially explicit identification of suitable areas for these new elements of renewable energies (RES) in the landscape in relation to ecosystem services and biodiversity, defined through TEEB 2010. They list the following as important when analysing spatial potentials for RES; "(1) consider the spatial potential for a mix of the different RES (at a choice in early stages between different RES), (2) show different possible alternatives of exploiting the maximum capacity with an explicit formulation of the trade-offs between the systems´ technical-economic requirements and the value of ecosystem services (ES), (3) integrate the relevant stake-holder knowledge and values into the evaluation, and (4) provide methods for utilizing the broad range of spatial indicators on different spatial scales in participatory spatial planning processes...". They also refer to Stremke when underlining that a sustainable energy landscape with implemented RES needs to account for and secure other required ecosystem services.

In their study they start with the macro scale of strategical planning with mapping of the general potentials of different renewable energy technologies (RET) as solar thermal, photo-voltaics systems, hydropower, wood and moist biomass and wind turbines are compared to general potentials of ecosystem services (ES). Ecosystem services can be timber, food, erosion prevention, habitat, enjoyment of scenery, non-recreational appreciation of landscape features, travel to natural ecosystems for ecotourism, heritage value etc (Grêt-Regamey & Hayek, 2013). Then this is input in a multicriteria decision analysis. This second step connects the multicriteria analysis tool to a scale equivalent to the scale used in this report - urban and landscape design level - where spatially explicit maps of land-use change combinations that differ regarding RET and amount of energy output are compared with ES. As Grêt-Regamey & Hayek pinpoints the "weighing" of criteria can often be arbitrary why they suggest stakeholder feedback to be implemented. In order to communicate with stakeholders, they use Geographic Information System-based (GIS-based) three-dimensional (3D) visualisations of the possible energy landscapes (Grêt-Regamey & Hayek, 2013). The case study of Grêt-Regamey & Hayek is within a sensitive area in Switzerland where the landscape aesthetics and animal habitat, agriculture and recreational tourism were at stake when implementing RET. They therefore presented a parallel to the MDA on RET, quantified in power output criteria, with criteria formulated as the yield of agriculture, the quality of the habitat and the sensitivity of the view. The last aspect relating to sensitivity of view was tested through comparison of RET-solutions in a participatory workshop setting where 3D-visualizations were used (Grêt-Regamey & Hayek, 2013).

In this task, we have found case studies of solar energy, where the choice between RET often was made already, but were the negotiation between solar energy, ecosystem services and biodiversity, visual landscape qualities and heritage issues were carried out. They could be carried out according to a regulated Environmental Impact Assessments (EIA) or by using a more traditional design project process where several different professions were collaborating. In Denmark the regulated planning process demands that the local authority perform a screening for whether or not an EIA is to be carried out. The planning process is regulated by public hearing periods where the new plan is presented. In the Danish landscape case study example Solar District Heating Brædstrup the agricultural land and project goals for solar plant sites were to address the challenge of maintaining accessibility and attractiveness for the public and green corridors for animals (Lobaccaro et al., 2017) Political goals to transform the energy sector towards using renewables in combination with state funding made the Solar District Heating Brædstrup, Denmark. Parts of the area were reserved for leisure and recreation with visual aspects assessed through project visualisations of the plant in relation to the surrounding landscape. A smaller portion of the land contains a sensitive natural area protected by the Danish Planning Act from a heritage point of view. The active use of EIA created a way for the balancing act.

As presented in the earlier section on Landscape Environments (1.3) Scognamiglio introduces the concept of landscape ecology, that integrates a focus on (a) spatial pattern, (b) the area viewed in an aerial photograph or from a high point of the land, and (c) unity provided by repeated pattern. In the report on landscape case studies of Task 51 a set of *formal functional features* has been used as analysing tools through terms developed in the work by ENEA (Scognamiglio, 2016). The terms used for *formal functional features* were patterns, differentiated into mosaic patterns such as patch, corridors and matrix models, and edges based on landscape ecology approaches and methods (Lobaccaro et al.,2017). In relation to the large-scale patterns of the landscape, and the secondary scale of the solar system (PV or ST) the connectivity in between is analysed. In the left section of the template of the case study

SOLAR LANDSCAPE

Figure 5 - The spatial system as a whole (Pattern) (Source: [2])

Figure 6 - The photovoltaic space (Source: [2])

Figure 7 - The "pore" space (Source: [2])

FORMAL FUNCIONAL FEATURES
PATCH - PATTERN - EDGES/BORDERS

Patch type				
Small		○	Large	●
Straight borders		●	Convoluted borders	○
Grain type				
Small patches		○	Large patch	●
Pattern				
Porous		○	Dense	●
Pattern type				
Stripes	Parallel	●	Not parallel	○
Island	Uniform patches	○	Varied patches	○
Random		○		
Edge/Borders				
Continuous		○	Discontinuous	●

SOLAR SYSTEM
TECHNOLOGY AND PRODUCTION OF TOTAL AREA OF MODULES

1. Energy features

Nominal power: 1.4 MWp
Number of modules: 7 500 m^2
Technology: PV panels Sunpower SP320 Wc
Density of power: 1 MWp/ha
Land use intensity: -
Normalized yearly energy generation: 2 000 MWh/MWp/a

2. Engineering features

Orientation, inclination and patterns is defined as regular, linear and parallel associated. Cover: grazing for greenhouse function.

3. Spatial features

Modules: Height: 0.9 m; Width: 1.2 m; Area: 7 500 m^2; Color: Blue; Azimuth angle: varies; Tilt angle: varies; Height from the ground: 3.5 m
Borders: Thickness: 0 m; Height : 0 m;

SOLAR SYSTEM SPACE
PATCH AREA

Connectivity
Looking from the top view there is a kind of discontinuity between the ground where the solar field is placed and the surrounding landscape.

Functions
The solar field performs other added function such as organic agriculture under greenhouses and recuperation of water.
The ground underneath of the modules is agricultural and natural, while the feature of the supporting systems was studied for having a greenhouse function.

Other features
The occupation ratio (%) of the system results equal to 40%, while the height from the ground has been set as follows: minimum height equal to 3.5 m and maximum height is 4.1 m.

References: [2] Scognamiglio, A. (2016). 'Photovoltaic landscapes': Design and assessment. A critical review for a new transdisciplinary design vision, Renewable and Sustainable Energy Reviews, pp 629-661

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Figure 66: Landscape case study. Page from Task 51/Report C1 - Illustrative Prospective of Solar Energy in Urban Planning Collection of International Case Studies

there are five distinctions, the patch type, the grain type, the pattern, the pattern type and the edges/borders. All of these concern to the visual aspects of solar systems in sensitive landscapes. This is a step towards another visual assessment based on criteria, which in parallel with those presented on solar and architecture, in Task 41, may assist in processes already in early stages. On the top of this page are some of the nine assessment categories, were *formal functional features* is one.

The projects enclosed in the case study report (Lobaccaro et al., 2017) are the Canadian Case study Sarnia *Photovoltaic Power Plant*, the Danish *Solar District Heating Braedstrup*, the French *Agrinergi 5* and *Les Cedres* and the Italian *Agrovoltaico*. These case studies show different solutions and different weighing of parameters, where at one end we find the Canadian case is more of a traditional economic-technological optimized site with no double functions corresponding to a low landscape sensitivity and at the outer other end we find the Agrinergi 5 at La Reunion, the French island, where the landform is highly sensitive from not at least a visual perspective and the multifunctional aspects have been used extensively. In all French projects at Reunion Island, agriculture and farming in some way, including animal farming have been applied. In order to study the aspects of *formal functional features, solar systems, solar system space, landscape factor, landscape preservation, multi-functionality, impact category, impact or burden and the description of alleviation, mitigation strategies* and *design approaches.* These categories can also be used as a design guiding tool for an interdisciplinary design project process.

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IEA SOLAR HEATING AND COOLING PROGRAMME (IEA SHC)

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 62 projects have been initiated, 53 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, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61)
- 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

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