Planning for solar access in Sweden: routines, metrics, and tools

Jouri Kanters, Niko Gentile and Ricardo Bernardo

Energy & Building Design, Lund University, Lund, Sweden

ABSTRACT
Sweden has set ambitious goals concerning future sustainable cities. Solar energy plays a vital role in this transformation, since it directly relates to our health and well-being, on-site renewable energy production, economic activity, and social interaction. Therefore, prioritizing solar access already in the urban design phase is important to create equal possibilities for everyone living and working in cities and communities. There is little known about how solar access is prioritized and assessed in the current urban planning process in Sweden. Therefore, two workshops were conducted with urban planners working at Swedish municipalities to establish a baseline, gaps and needs. The results identified three themes: (1) the role of solar access in the urban planning process, (2) suitable solar access metrics and threshold values, and (3) tools. A proper definition of solar access is missing, and only daylight indoors is regulated in the later stage. Therefore, the urban planners rank solar access as following: (1) daylight indoors, (2) day- and sunlight outdoors, and (3) active solar energy production. The participating municipalities had different routines concerning daylight but there were no established routines for solar access for outdoor spaces or active solar energy production. There was a need for better access to tools that can (1) provide quick feedback to iterate several design alternatives, (2) flag for ‘critical points’ in the zoning plan for solar access, (3) take other parameters into account, e.g. microclimate, and (4) visualize the performance of neighbourhoods for solar energy to other actors.
1. Introduction

Sweden has set ambitious goals concerning sustainable cities and communities, and they are mainly based on the Agenda 2030 goals of the United Nations (United FORMAS, 2018; Nations, 2015). Solar energy plays a vital role in this transformation to sustainable cities and communities, since it directly relates to our health and well-being (#3 Good Health & Well-being), the possibility to generate renewable energy on site (#7 Affordable Clean Energy), the deployment of economic activities and social interaction, and our productivity. Therefore, prioritizing solar access already in the urban design phase is important to create equal possibilities for everyone living and working in cities and communities.

There is a clear tendency of Swedish cities getting denser, resulting in a lack of adequate daylight access in buildings and outdoor environments (Bournas & Dubois, 2019). This does not only affect our health but it could also result in a higher energy use (Strømann-Andersen & Sattrup, 2011). Recently, people in strict lockdown during the corona-pandemic have experienced limited access to sun- and daylight. Such a lockdown has not only led to an increase of depressions (Iob et al., 2020), but it also affected the real estate market. Buyers tended to purchase and to move into homes that have access to a balcony or a garden, and which are suited to use as home office (Hemnet, 2020; Nordlander, 2020). Although this could be a temporary development, research showed that 25% of the people that have worked more at home during the pandemic is also planning to do so in the future (Hamersma et al., 2020), leading to a shift towards the future home that will serve more than a residential function resulting in an increasing need for adequate solar access into homes.

Urban planners play a crucial role in the planning process of these sustainable and liveable cities (Kanters & Wall, 2016, 2018). Swedish municipalities and cities have a planning monopoly meaning that they decide how the land is used within the city boundaries. The planning process consists of several stages, but the key planning phase in Sweden is the detailed development plan (DDP). This is comparable to the formal planning phase as defined in (Urban learning, 2017). The DDP is a document that states how a neighborhood (roughly ~5–10 buildings) within a municipality is to be built and how land and water area is to be used. The DDP is a 2D map with the footprints of buildings, their functions and other plan regulations, e.g. building heights and roof inclination. After the DDP phase, the buildings will be developed by real estate developers. The Swedish building regulations (BBR) regulate for instance, daylight access in buildings (Swedish National Board of Housing; Building and Planning, 2020) and it is up to the real estate developer (and their architects and engineers) to comply with those rules. However, urban planners should ensure – already in the DDP phase – that requirements stated in the BBR can be met, but there are however no specific requirements or guidelines how urban planners should ensure this (Swedish National Board of Housing; Building and Planning, 2016). In general, there is little known about how solar access is prioritized and assessed in the current urban planning process in Sweden. Therefore, this study aims at:

- establishing a baseline, intended as planners’ motivations to plan for solar neighbourhoods, planners’ definitions of solar access and current planners’ routines for such planning,
• defining gaps, intended as divergences or inconsistencies between what is known from research on solar neighbourhoods and what is done during the actual planning process, and
• defining needs; based on the baseline and defined gaps.

For this purpose, two digital workshops were conducted with urban planners of Swedish municipalities.

1.1. Daylight requirements indoors

The Swedish Building Regulations require daylight access to rooms where people stay more than temporarily. This daylight access is formalized by the requirement of a point Daylight Factor above 1% measured at 0.8 metres height, at half the room depth, and 1 metre away from the darkest lateral wall (Swedish National Board of Housing; Building and Planning, 2020). The Daylight Factor calculates the ratio between the illuminance of a particular point in the interior to that of the unobstructed exterior under the CIE overcast sky (with a fixed Ground Ambient light level of 11,921 Lux) and is still widely used in Europe for its ease, despite criticism for its inability to consider variable sky conditions, changes in climate, position of the sun, building orientation and location (Dogan & Park, 2018). The recent European Standard for Daylight in Buildings (CEN, 2018) proposes a more climate-based approach to Daylight Factor, where target Daylight Factors differ for different geographical location (CEN, 2018). More advanced daylight metrics, in particular climate-based metrics like the Daylight Autonomy (DA), the Continuous Daylight Autonomy (cDA) and Spatial Daylight Autonomy, provide a more detailed assessment of the daylight performance (Dogan & Park, 2018; Reinhart & Wienold, 2011).

1.2. Sunlight access on building envelope and outdoor environments

Sun- and daylight access on the building envelope is less regulated and only a handful of metrics are used worldwide. The most common one is the Direct Solar Access Hours (DSAH); a quantification of hours that direct solar rays hit a surface, normally specified for a certain period of time. Table 1 shows an overview of metrics used for solar access in different countries, based on literature (Li et al., 2019; De Luca & Dogan, 2019) and input from experts of the International Energy Agency Solar Heating Cooling programme Task 63 Solar Neighbourhood Planning (IEA SHC, 2020). The mentioned metrics can be considered as an expression of solar rights, which are rights that can determine ‘whether and how an individual can take advantage of the sun’s light, warmth, or energy, and they can have significant economic consequences’ (Bronin, 2009).

In outdoor environments, there is even less legislation on solar access, even though this is considered as a crucial part of sustainable cities and communities. In Sweden, there is only a recommendation of access to at least five hours of direct sunlight between 09:00 and 17:00 on the 21st of March/September in ‘residential buildings and on playgrounds and places to sit’ (Swedish National Board of Housing; Building and Planning, 1991). It remains however unknown if this recommendation is often used within Sweden during the urban planning process, as well as the rationale behind this metric. The use of of sunlight in outdoor areas can have direct financial consequences because a property
Table 1. Overview of metrics used to evaluate solar access on building envelope.

| Metric                          | Threshold                     | Date       | Time         | Place                                      | Type of building                                      |
|--------------------------------|-------------------------------|------------|--------------|--------------------------------------------|--------------------------------------------------------|
| China Direct solar access hours | ≥ 2, 3 hours                  | 20-Jan     |              |                                            | Residential                                            |
| China Direct solar access hours | ≥ 1 hour                      | 21-Dec     |              |                                            | Residential                                            |
| Czech republic Direct solar access hours | > 1.5%                     | 01-Mar     |              |                                            | Residential                                            |
| Denmark Window to Floor Ratio | > 10%                         |            |              |                                            | Residential                                            |
| Estonia Direct solar access hours | ≥ 50% probable sun hours   | 22-Apr to 22-Aug |              |                                            | Façade of every living space                          |
| France Direct solar access hours | ≥ 2 hours                    | 21-Dec     |              |                                            | Residential                                            |
| France Window to Floor Ratio | >1/6                          |            |              |                                            | Residential                                            |
| France Window to Wall Ratio | at least one room with >30% glazed surface |            |              |                                            | Residential                                            |
| Germany Direct solar access hours | ≥ 1 hour                    | 17-Jan     |              |                                            | Residential                                            |
| Germany Direct solar access hours | ≥ 4 hours                    | 21-Mar, 21-Sep |              |                                            | Residential                                            |
| Italy Window to Floor Ratio | ≥ 1/8                        |            |              |                                            | Residential                                            |
| Netherlands Window to Floor Ratio | ≥ 1/10                      |            |              |                                            | Residential                                            |
| Norway View outside |                                      |            |              |                                            | Every room for continuous occupancy must have at least 1 window with sufficient view to the outside |
| Norway Obstruction angle | ≤ 45°                        |            |              |                                            | Blockage of the view to the outside                     |
| Poland Direct solar access hours | ≥ 3 hours                    | 21-Mar, 21-Sep | 7:00–17:00 |                                            | Permanently occupied rooms                             |
| Poland Direct solar access hours | ≥ 1.5 hours                  | 21-Mar, 21-Sep | 7:00–17:00 |                                            | At least one room in apartment buildings               |
| Metric                        | Threshold                                      | Date      | Time               | Place                                                                 | Type of building |
|-------------------------------|------------------------------------------------|-----------|--------------------|-----------------------------------------------------------------------|------------------|
| Slovenia                      | Direct solar access hours ≥ 2 hours            | 21-Dec    |                    | Direct solar access hours ≥ 2 hours                                   | Residential      |
| Slovenia                      | Direct solar access hours ≥ 4 hours            | 21-Mar, 21-Sep |                    | Direct solar access hours ≥ 4 hours                                   | Residential      |
| Slovenia                      | Direct solar access hours ≥ 6 hours            | 21-Jun    |                    | Direct solar access hours ≥ 6 hours                                   | Residential      |
| Slovakia                      | Direct solar access hours ≥ 1.5 hours          | 1-Mar to 13 Oct |                    | Windows of 1/3 of apartment living area, calculated on point centered on the glazing | Residential      |
| UK                            | Direct solar access hours 25% Annual Probable Sunlight Hours | Whole year |                    | Room window.                                                          | Residential      |
| European Union                | Direct solar access hours ≥ 1.5 hours (good), ≥ 3 hours (very good), ≥ 4 hours (optimal) | Between 1-Feb and 21-Mar |                    | At least one habitable room in the dwelling should have exposure to sunlight | Residential      |
owner can grow garden vegetables (Kim et al., 2018), produce commercial crops for resale, or use sunlight instead of electricity to dry laundry – all of which save or generate income (Bronin, 2009) or running a café with outdoor seating.

1.3. Solar access for active production

With the increasing amount of active solar energy production within cities, it has become more common to protect the production of heat and electricity of existing solar energy systems, as well as to guarantee a good future energy production of planned solar energy systems. Solar rights for active solar energy systems are specified in different ways in different countries, considering it for instance, as a property right, like in many US states (Bronin, 2009), or a right to a guaranteed sunlight duration (Li et al., 2019). In many US states, solar easements are in place.

2. Material and methods

In this chapter, the material and methods are presented.

2.1. Study design

This study can be seen as a first step into an interactive research project. Interactive research is a development of action research where researchers and practitioners engage in dialogue from the beginning of the research project (Coghlan & Brydon-Miller, 2014; Svensson et al., 2007). Interactive research is meant to foster innovation (Lundvall, 2016), and it bears potential to advance in policy making, especially at regional level (Pålshaugen, 2014). In this project, the interactive research process was limited to the mapping of motivations, definitions, and routines about planning for solar access for both the researchers and the urban planners (Figure 1).

2.2. Data collection

The study was implemented by conducting two (digital) workshops with urban planners from the municipality of Lund (South Sweden, ~120,000 inhabitants) and the city of Malmö (South Sweden, ~350,000 inhabitants). The first workshop was organized separately with each city, and it lasted for 45 minutes; the second workshop was performed with both cities together and lasted for about two hours. Both workshops were held in Swedish (Table 2).

Beside the urban planners, the three authors attended each of the workshops. One acted as facilitator, while the others had a passive role during the workshops. Their duties were to make sure that enough information was collected to cover the workshop goals and to moderate the discussion when it moved off-topic or was running overtime.

2.2.1. Workshops 1 – Exploring local motivations, definition, and routines

The overarching goal of Workshop 1 was to understand the role of solar access in the larger scope of the local detailed planning process. The discussion focused on four key themes and was conducted as a focus group workshop. The focus group followed a semi-structured protocol consisting of four open-ended questions (Table 3). The specific goals
Figure 1. Workflow for the current research project, based on (Ellström, 2007).

Table 2. Overview of the workshops.

| Workshop 1 – Malmö | Workshop 1 – Lund | Workshop 2 – both Lund and Malmö |
|--------------------|-------------------|----------------------------------|
| Four participants (three female, one male) | Three participants (one female, two male) | Four participants (three female, one male) | Two participants (one female, one male) |

Table 3. Themes and questions for the Workshop 1.

| Aim                        | Main question                                           | Follow-up questions                                                                 |
|----------------------------|--------------------------------------------------------|--------------------------------------------------------------------------------------|
| Establishing background    | Can you briefly describe your experience as city planner? | - How many years have you worked as city planner?                                   |
|                            |                                                        | - Did you fill other roles in this municipality?                                     |
|                            |                                                        | - Did you ever cover political roles?                                                |
|                            |                                                        | - Have you worked in other municipalities?                                           |
| Establishing baseline      | How important do you think solar access is in the current detailed planning process? | - How do you define solar access?                                                    |
|                            |                                                        | - Which aspects of solar energy are most important to you?                           |
|                            |                                                        | - Do you think that the availability of solar energy is sufficiently taken into account in the detailed planning process?|
|                            |                                                        | - Do you think that today’s BBR requirements or recommendations are sufficient to ensure good access to daylight?|
| Establishing needs         | How do you today take solar access into account in the detailed planning process? | - Who is responsible for planning for solar access?                                   |
|                            |                                                        | - Which are normally the constraints?                                                |
|                            |                                                        | - Do you experience conflicts or tensions between conflicting demands? If yes, how are they solved?|
of Workshop 1 were: (1) to identify the background of participating urban planners, (2) to define the relevance and goals of solar access in the local detailed planning, (3) to describe the local routines used to account for solar access, and (4) to pinpoint the current urban planners needs to ensure good solar access.

The moderator welcomed the urban planners, presented the long-term goals of the workshops, informed the participants about ethical aspects like the management of personal data, and briefly explained the guidelines for the workshop. During the whole workshop, the moderator shared a presentation with the main questions on screen. The urban planners held the conversation, while the moderator intervened only when urban planners were bewildered. The moderator prompted the urban planners with a follow-up questions (Table 3) in case the conversation was stuck or if not enough information was collected for the main question. Once the first main question was answered exhaustively, the facilitator moved to the second question and so forth. Follow-up or more detailed questions were planned and used only when the question did not self-sustain, or if some topics were not sufficiently covered (Table 3).

The results from Workshop 1 were later used as base for discussion in Workshop 2.

2.2.2. Workshop 2 – Solar analyses as discussion foundation

Workshop 2 was conducted roughly three months after Workshop 1 and it aimed to obtain a better overview on urban planners’ understanding of solar access and their future needs.

The workshop was introduced with a short qualitative summary of the two Workshops. This way, the urban planners from the two municipalities could get acquainted with each other routines when planning for solar access and it also served as a check if the main things were captured by the authors.

In addition, to serve as a basis for discussion in Workshop 2, different solar access analyses were performed before the workshop, using the software Rhino and Grasshopper, Ladybug, Honeybee and DIVA4RHINO. The analyses were conducted for two actual development areas, one in Lund and one in Malmö, on which the interviewed urban planners are currently working. The urban planners provided the 3D models of the areas. The results were presented to the urban planners before the workshop by email and during the workshop. The analyses were accompanied with a short text explaining how they were simulated, and which assumptions were made. The following analyses were performed:

(1) Daylight factor (DF) with varying WWR. Indicating how much floor area received DF > 1%
(2) Vertical Sky Component on facades
(3) Fraction of solar access on courtyards, 21 March 2012 noon
(4) Direct solar access on courtyards, 21st March
(5) Annual direct solar access on courtyards
(6) Annual solar potential/solar fraction
(7) Spatial Daylight Autonomy in buildings

An example of analyses 3, 4, and 5 is shown in Figure 2.
The analyses included (A) the daylight requirements as stated in the Swedish building regulations (point 1 in the bullet list), (B) those normally performed by urban planners in their own cities as understood in Workshop 1 (points 2–3), and (C) extra analyses deemed important by the researchers (points 4–7). The analyses aimed at contrasting concepts and theories of the researchers and the urban planners, in coherence with the study design (Figure 1).

The discussion were based around two aims, see Table 4. The procedure for asking questions and collecting answers was identical to that of Workshops 1.

2.3. Data analysis

The audio records of the workshops were transcribed by a professional transcription service. The verbatim, in Swedish, were analysed conducting a deductive content
Table 4. Themes and questions for the Workshop 2.

| Aim                  | Questions                                                                 |
|----------------------|---------------------------------------------------------------------------|
| Establishing gaps    | Do the analyses bring insight about ‘solar neighbourhoods’ to the urban planners? |
|                      | Which metrics are hard to understand?                                     |
|                      | Which metrics are missing?                                                |
| Establishing needs   | Is the way the analyses are visualized meaningful for the urban planners and/or could they serve as a basis for communication with, e.g. politicians? |
|                      | In which format are the analysis better to be visualized? E.g. ‘static’ (PDF/print) versus ‘interactive’ |

analysis (Elo & Kyngäs, 2008; Kyngäs et al., 2020). The deductive approach was preferred as (A) previous knowledge formed a good basis to build the semi-structured protocol of the workshops and (B) it was deemed more appropriate for the small sample of subjects. The goal-framing theory (Lindenberg & Steg, 2013) was used as analysis matrix to map motivational drivers to plan for solar access. The goal-framing theory argues that individual environmental behaviours are driven by three possible goals: (1) a normative goal, i.e. to act the way is expected or required, (2) a gain goal, i.e. to act the way one will benefit, and (3) a hedonic goal, i.e. to act the way will make the individual feeling better. The theory argues that there might be one focal goal at a time, but more goals can be activated simultaneously. Although the goal-framing theory addresses individuals, it still offers a convenient way to map motivational drivers of individuals working in an organization. In this specific case, the goal-framing theory was used only as analysis matrix for the deductive content analysis of motivations. The analysis matrix and example of statements used to map motivations are provided in Table 5.

Previous knowledge on tools, routines, and methods used by architects and urban planners for solar urban planning was used as analysis matrix to map definitions, routines, gaps and needs of urban planners in relation to urban solar access (Kanters & Horvat, 2012; Kanters & Wall, 2014, 2016, 2018).

One of the researchers conducted the deductive content analysis. The other two researchers went independently through the verbatim and the analysis performed by the first researcher. Later they discussed different interpretations of the results over several meetings.

Table 5. Analysis matrix used for the deductive content analysis about motivations to plan for solar access.

| Have the following statements, or similar ones, been mentioned or reflected during the workshops? | How? |
|-----------------------------------------------------------------------------------------------|------|
| Normative goals                                                                                 |      |
| ● There are legal requirements that I should guarantee                                         |      |
| ● The department at the municipality have been always working this way                          |      |
| ● Planning for solar access is part of the sustainability goals of the municipality            |      |
| Gain goals                                                                                    |      |
| ● These analyses are not conducted in other municipalities and we can show we are a step ahead |      |
| ● It is a way to increase the value of my work                                                 |      |
| Hedonic goals                                                                                 |      |
| ● I feel good when my decisions can help building better solar neighbourhoods                  |      |
| ● I would be happy to live in such neighbourhood                                             |      |
3. Results

In this chapter, the results of the workshops are presented.

The participating urban planners all had a rather long experience as a (municipal) urban planner (10–25 years). Many of the urban planners had worked at other municipalities or at private companies.

Three main themes were identified from the workshops:

1. Solar access in the urban planning process
2. Suitable solar access metrics and threshold values
3. The role of tools

The three themes are discussed here as subchapters. For all the three identified themes, a baseline, gaps and needs could be established.

3.1. Solar access in the urban planning process

The main theme solar access in the urban planning process is here subdivided in the subthemes ‘legislation and limits of the detailed development plan’, ‘priority in the urban planning process’ and ‘routines’.

As a general finding, urban planners recognized that a definition of solar access is yet missing. In lack of a definition, they tend to identify three different ambitions for the urban planning process of neighbourhoods in terms of solar access: (1) guarantee daylight indoors, (2) provide day- and sunlight outdoors, and (3) provide good conditions for solar energy production (Table 6). These ambitions come with different priorities, and the following ranking was found:

‘Access to the sun. to create good solar conditions in places and on yards is a central part of considerations about how to work with a neighborhood development. But ensuring good conditions for solar cells ... I would definitely not say that this is something that is considered particularly in a detailed planning process, but it is probably more that ... it can be concluded that some places can be good for solar cells or solar panels [...] more in retrospect’ (urban planner #1)

3.1.1. Legislation and limits of the detailed development plan

Urban planners confirmed that the only legislative requirements on solar access are the indoor daylight requirements stated in the BBR (indoors, point DF > 1% at 0.8 height at 1 metre from the darkest wall) which must officially be met by the real estate developer in a later stage, not in the urban planning process. However, the urban planners indicated

| Priority level solar | Aspect                      |
|----------------------|----------------------------|
| 1                    | Daylight indoors           |
| 2                    | Day- and sunlight outdoors|
| 3                    | Active solar energy        |
that the DDP should be designed in such a way that the real estate developers, in a later stage, can fully exploit their right to build the number of apartments or dwellings that was set in the DDP, having sufficient daylight access. If urban planners fail in that, the municipality might have legal consequences which might result in financial compensation for the real estate owners. The urban planners referred to several legal cases where this had happened.

'Some parts of BBR’s expressions are not even . . . they do not even know how to interpret them. And judging from this [legal, nda] case, I perceived it that even the reviewing bodies [(judges)] also have difficulty interpreting the BBR. Having access to direct solar radiation [as stated in the BBR] . . . it seems that there are different interpretations about how hard this should be interpreted. The Supreme Land and Environmental Court judged that [...] if you are in the middle of the city center and you have access to all the qualities that are present there, you can waive the BBR requirements [of direct sunlight, nda] more than you can do if you build a completely new neighbourhood’ (urban planner #2)

Several urban planners also discussed the threshold value of the current daylight requirements itself, exemplifying the fact that many buildings that have been constructed a long time ago are considered to have good daylight and solar access, but would not meet today’s requirements.

A standard detailed development plan can set, besides the footprint of the buildings and its functions, also other terms that could influence the framework for solar and daylight access in buildings and public spaces. The urban planners discussed that it is possible to regulate for instance, the reflectance of materials that must be used on the exterior walls, but that the DDP is not very suitable regulating the installation of active solar energy systems. For that, separate contracts with real estate developers were considered to be a better option.

Existing guidelines and recommendations for (mainly outdoor) solar access were not followed and since they are recommendations, not legislation, outdoor solar access does not have the same priority as daylight indoor. In particular, the urban planners discussed the recommendations of ‘Solklart’: at least 5 hours of direct sunlight between 9 AM and 5 PM on the 21st of March/September in ‘residential buildings and on playgrounds and places to sit’ (Swedish National Board of Housing; Building and Planning, 1991).

3.1.2. Priority in the urban planning process
Prioritising solar access (both sun- and daylight) depends partly on the individual urban planner. The urban planners expressed that the assignment of the urban planner is, amongst others, to ensure good solar access to public spaces, streets and courtyards. They did not necessarily consider ensuring solar access for active solar energy production as their task, resulting in a very low priority in the urban planning process.

“My assessment is that we, as urban planners, are very focused on the public spaces. So, streets, squares and then the open spaces. To create a good life. […] it’s about the outdoor environment, public environment and a good living environment. Where do you want to be somewhere, where do you want to sit, where do you want to play, where do you want to be in a restaurant, outdoor seating?” (urban planner #3)

‘You work in some kind of borderland between the optimal solar condition, which is not a building at all, and the worst solar condition, which is completely built, and then you
work with . . . the optimal exploitation, so to speak. But finding exactly this balance between high-quality courtyards, urban canyons, and opportunities to build well for daylight in the building as well . . . to solve everything in the plan right from the start, is a challenge in some way’. (urban planner #2)

Other aspects in the urban planning process, which directly affects solar access, are often higher prioritized in the urban planning process: high density (expressed by politicians), large building depth and a maximum exploitation of the plot (expressed by real estate developers). Urban planners face these conflicting demands and have to make choice satisfying both the normative goals, set by norms and political direction, and the own professional and societal goals to design better, more liveable and sustainable neighbourhoods.

The urban planners of Malmö described to have become more pro-active on the aspect of reaching adequate daylight levels because real estate developers could not fully exploit their right to build. It should be kept in mind that Malmö is a larger city than Lund, therefore aiming for a higher density, which results more likely in conflicts regarding daylight access.

The urban planners from both Malmö and Lund discussed that experts at the local Building Permission Office, those who assess application for building permits, do not always have competence, time, and resources to check if daylight requirements are entirely fulfilled.

Finally, urban planners recognized the monetary value of adequate access, exemplifying it with, e.g. the fact that solar access (in (semi-)public spaces) is important for the exploitation of restaurants, placement of balconies, solar energy production, etc.

3.1.3. Routines

The two municipalities had different routines concerning daylight indoors, which is the only normative requirement that urban planners should make possible to fulfil. There were no established routines for outdoor solar access or the active solar energy production.

The established routine in Malmö was:

- Step 1: determine the obstruction angles in the neighbourhood. If those obstruction angles were lower than 30°, the situation should not lead to problems for daylight access. If the obstruction angles were above 45° there was a need for an in-depth analysis (however this 45° is questioned by the urban planners).
- Step 2: if obstruction angle > 45 deg, then a Vertical Sky Component (VSC) analysis is performed by external consultant through a tender.
- Step 3, if the VSC analysis also indicated a critical situation, an in-depth analysis on the building level needs to be performed.

In Lund, there was no specific established routine, but often, shading studies were performed to assess the sun- and daylight access in the detailed development plan. This different routine might be linked to the lower pressure for densification in Lund.
3.2. Suitable solar access metrics and threshold values
The urban planners discussed which threshold values and ranges of metrics would be suitable when assessing solar access. There are presented here in the different subchapters.

3.2.1. Quantification of solar access
The participating urban planners express that there is a lack of a more general definition of solar access in Sweden. A definition on solar access in legislation which is applicable in all municipalities is something that the urban planners would like to see. Besides a definition, the urban planners expressed the wish to also define a metric and a threshold value for that metric. As an example, the daylight factor was mentioned, which all the participating urban planners agreed was clear and straightforward. The urban planners expected however doubted that qualitative aspects of solar access – e.g. how much sun is needed on an inner courtyard for people to start ‘using’ it – is harder to quantify then if a neighbourhood can be self-supportive with locally produced solar energy.

Since a clear definition, metric and threshold lacks today, it makes it very hard for urban planners to argument for good solar access in their daily work.

3.2.2. Indoor daylight access
The urban planners were presented different analyses for indoor daylight access (analyses 1, 2, and 7). For the Daylight Factor analysis, several options with different Window to Wall Ratios were presented, mainly for them to understand the architectural consequences for achieving an adequate daylight access. This way of visualization was appreciated by the urban planners. They were also curious to learn that after a certain point, increasing the WWR does not necessarily play a significant role anymore.

Urban planners expressed that they would like to see the relation between Vertical Sky Component and the Daylight Factor. This relationship has for instance, been studied by Olina and Ne. (2018), which stated that a VSC of 29% is preferred to reach a DF of 1, but at least 15%. The urban planners experienced that the threshold used in the VSC analyses were ‘worst-case scenarios’ and that advanced simulations in a later stage always have shown that daylight access seems to be better than expected.

3.2.3. Outdoor sunlight access
Urban planners were presented different analyses (3–5). Analysis III was presented in two ways: as an absolute number based on the climatic file and as a relative number (compared to possible direct solar hours under clear sky).

The participating urban planners experienced analysis 5 (Annual direct solar access on courtyards) as a metric with the highest level of detail. They stated that it was hard to interpret the total amount of solar hours per year as a number, and that it is better to have it as a percentage of an unobstructed surface. The annual direct solar hours was also considered as an indicator how a residential yards can be used, for instance, where to place green and grey areas.

Analysis 3 (Direct solar access on courtyards, 21 March 2012 o’clock) was deemed easy to understand (also closest to ‘classic shading study’) and it was discussed that this
performance indicator could lead to a certain type of shape of neighbourhood that performs best for 12 o’clock South sun.

Urban planners reacted that none of the presented analyses shows the solar access in the morning, afternoon and evening. A Performance Indicator that could take temporal differences into account might be an interesting add-on to the range of metrics. Simple shading studies showing solar conditions in the morning, afternoon, and evening were considered to work well, are easy to understand and have a high communicative value. The advanced analyses shown here can be a complement, not a replacement of the shading studies.

It was discussed that a performance indicator for a good outdoor environment (well-lit) would include the fact that a certain part of that environment should have good solar access during time of the year that people want to be outside in Sweden. The exact threshold value really depends on the end-user and ranges from the needs of children to elderly.

Urban planners discussed if performance indicators should have ‘sharp’ thresholds, but they preferred rather an indication how the detailed development plan performs for certain indicators on a scale (a range).

3.2.4. Active solar energy

Urban planners were presented with analysis 6 (categorized solar potential for solar energy and possible theoretical coverage of energy by means of active solar energy systems). The potential for active solar energy was considered to be mainly interesting for real estate developers since they have to do the actual investment and as a counter argument for densification since densification can shade existing solar energy systems and thus reduce the output of those systems. Even though urban planners can set a range for the roof inclination and other regulations, real estate developers and their architects still set the final roof inclination and shape which impact the final performance of photovoltaic and/or solar thermal systems.

In addition to the shown analysis, the urban planners would like to see the potential of the roof and façade separately, since façades are not often considered as potential places to install solar energy systems. It was also considered to be interesting if the analysis would show those surfaces that are financially feasible to install active solar energy systems and showing financial performance indicators such as payback time.

3.3. Role of analyses/tools

Urban planners agreed that they do not have access to advanced tools, or do not have the right skills to use them. Advanced simulations are often done later in the building design phase by the real estate developer and their architects and/or engineers.

The participating urban planners concluded that they need better access tools that can:

(I) provide quick feedback to the urban planners to iterate several design alternatives during all stages in the urban planning process,

(II) indicate ‘critical points’ in DDP for daylight and solar access within a predetermined range,

(III) take other parameters into account, such as density, wind and other microclimate parameters,
(IV) visualize the performance of neighbourhoods for solar energy (passive + active) to other actors, like politicians, real estate developers, and inhabitants of the municipality/city.

Most urban planners are using Trimble SketchUp and prefer to have a connection from that program that would provide them access to the tools that have the abilities as mentioned above. They were however also open for other solutions. External programs and solutions that exist today are offering complex and fast evaluations for urban planners, but they introduce an additional new tool for the urban planners and a dependency on that specific solution.

3.3.1. Informing the urban planner
The participating urban planners were very engaged in the issue of ensuring good sun- and daylight in their zoning plans. Therefore, they would like to be able to perform analyses early in the process (sketch phase). Those quick feedback loops could enable urban planners to have an iterative process where they can optimize and assess different alternatives for solar access. Only two urban planners indicated that early support in sketch phase is interesting, but that for the majority of cases, advanced analyses (like a DF analysis done in a later phase) is sufficient. If the analyses (for solar access) are slow, they will not be done before a later phase (when windows are specified, etc).

‘Depending on how simple these analyzes are to perform, you can use them earlier in the process. Is it possible to use them to evaluate a sketch so that you can make a sketch cycle in half a day or something and adjust the block shape or something else and test if it gets better, then it can change the process. If they are heavier and harder, then they will not be done until later and then maybe you will start discussing building depth or windows ... that is, how large a window area is needed, or maybe you adjust the floor plan in case it makes a difference. But it is very important how fast cycles’ (urban planner #4)

Real-time analyses were obviously preferred, but in general it was considered the faster the better. If analyses can be conducted within minutes, it would still be able to fulfil its purpose of being a simple and quick way to run daylight/solar access analyses.

3.3.2. Communication
Urban planners were presented with the analyses (1–7) both in a ‘static format’ (PDF format to print or to view on their screen) but also as a ‘dynamic’ format: a 3D model with analyses accessible from a website. Urban planners were positive about the additional options in the dynamic format; e.g. easy to get right point of view, easy to access making it of high communicative value. They expressed a wish for an animation showing the position of the sun and shading patterns over year.

Colours play a very important role in communication. The urban planners expressed that the colours should be carefully selected: the brightest colour on those place in the inner courtyard which is brightest (blueish colours for shading and yellow/red for places with high solar access).
4. Discussion and conclusions

The research aim of this project was to gain more knowledge on how solar access is prioritized in the current urban planning process in Sweden. Results from workshops with local urban planners were categorized in three themes: (1) the urban planning process, (2) threshold values and suitable metrics, and (3) tools. For the three identified themes, a baseline, gaps and needs could be established. Baseline refers to the current state-of-the-art concerning current priorities, routines, and adequate tools. Gaps refers to the difference between a desired level of planning for sunlit neighbourhoods and the current situation. Needs relates to the required means to achieve the desired level of planning. One of the limitations of this study is that only a limited number of municipalities and urban planners where present in this study.

Baseline

Although urban planners mention that one of their main assignments is to design good neighbourhoods, including ensuring good solar access to public spaces, streets, courtyards and buildings, solar access is not prioritized. This result is in accordance to previous findings (Kanters et al., 2013; Kanters & Wall, 2018; De Luca & Dogan, 2019). Ranking the three different aspects of solar access (daylight indoor, sun- and daylight outdoors, and active solar energy), resulted in the highest priority given to daylight indoors, followed by sun- and daylight outdoors, and lastly active solar energy. The highest ranking for daylight indoors is directly related to legislative requirements. Since there is a lack of a definition, suitable metrics, threshold and most of all legislation, municipalities do not focus on solar access in outdoor spaces and on active solar energy. The tools that are currently used focus on assessing if the legal requirements for indoor daylight are met. It seems that urban planners develop additional routines when the requirement for indoor daylight seems difficult to achieve. They define local theories based on existing metrics, preferring easy rules-of-thumb and using locally developed routines to determine what it is ok and what it is not. Tools for assessment of solar access outdoors are very basic and assessments for active solar energy production are normally not performed.

These findings show how normative goals are heavily dominant in the urban planning process where legal requirements for daylight indoors are assessed while solar access outdoors is not.

Gaps

Urban planners point out that in the current planning process, it is possible to design detailed development plans that makes it almost impossible to comply with the daylight requirements stated in the building code. This could potentially lead to legal consequences and financial compensations which points out to the need for improvement of the metric and/or the urban planning procedure. Furthermore, urban planners clearly state that ensuring adequate solar access outdoors should be given higher priority in the urban planning process as it is part of one of their main assignments and due to its added values. However, they recognize the high complexity of the topic which could partially explain that there is currently no clear definition of what ‘adequate solar access’ means.
and how it can be evaluated. Such finding is in accordance with literature, where there is substantial research on daylight metrics related to indoor environments, but little research is carried out on solar access in outdoor environments.

This shows once more the motivation being predominant normative where urban planners point out that there is no definition they can use. A gain and hedonic goals seem to co-exist since they recognize that adequate solar access outdoors has important value for the liveability and sustainability of neighbourhoods.

**Needs**

Urban planners identified several needs to overcome the previously described gaps which can potentially be the basis for future research work. To evaluate solar access in the urban planning process it is important to first establish meaningful key performance indicators, i.e. most relevant metrics to evaluate solar access outdoors. Thereafter, it is necessary to determine suitable threshold values for these indicators. An appropriate approach seems to investigate a range of threshold values since it is important for urban planners to be able to design several alternatives. Together, the indicators and thresholds should define what ‘adequate solar access’ is. Furthermore, urban planners identify the need of a digital tool(s) that incorporates the indicators and thresholds into a holistic analysis instrument that fits into current routines and knowledge. Such tool(s) should be able to, not only provide quick feedback regarding solar access for several design alternatives, but also adequate visualization of the analysis to non-technical stakeholders such as politicians, real estate developers, and inhabitants.

Generally, although the importance of planning for sunlit neighbourhoods is highly recognized by urban planners (hedonic goal), the current urban planning procedure strongly follows normative goals based on legislation. Therefore, if planning for sunlit neighbourhoods is to be implemented, results from this study show a strong dependence on existing legislation being adapted. A new legal framework for solar access seems essential, which has to be embedded in Sweden’s Planning and Building Act which guides the daily work of the urban planners, rather than being part of the Building Regulations.

In such context there is a needed of research on new metrics and thresholds. Furthermore, this would pose an opportunity to revise the existing method for analysing levels of indoor daylight which is described in scientific literature as being too simplistic. The urban planners’ wishes for metrics that take different time slots into account can for instance, be found in LEED option 2 (indoor daylight): 300–3000 lux, 9 AM and 3 PM > 75% space at equinox)). Concerning outdoor solar access, potential new metrics need to be developed with the daily praxis of the urban planners in mind, and could for instance, focus on being ‘relative’ metrics rather than ‘absolute metrics’, like the Annual Probably Sunlight Hours as legislated in the United Kingdom, which relates the solar access of a zoning plan to an unobstructed plane. If a development of new metrics would take place, urban planners could play a larger role in the development of sun- and daylit cities and neighbourhoods. The needs for further research are significant and the available literature is scarce which points to a knowledge gap.
Highlights

- There is no definition for solar access in the Swedish urban planning process

Solar access is prioritized in the following ranking in the urban planning process: (1) providing daylight access for indoor use, (2) solar access outdoors, and (3) solar access for active systems

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ORCID

Jouri Kanters [http://orcid.org/0000-0002-4731-7203
Niko Gentile [http://orcid.org/0000-0001-5721-6644
Ricardo Bernardo [http://orcid.org/0000-0002-8156-5323

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