SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Technology Position Paper

Solar Neighborhood Planning

May 2024

Technology Collaboration Programme by iea

Contents

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DOI: 10.18777/ieashc-task63-2024-0005

This position paper provides an overview of solar strategies for neighborhood planning, outlining their importance, potential, and development. It addresses issues for policy and decision makers, other stakeholders, and influencers and presents high-level information as a basis for the uptake and further development of this application. It concludes by highlighting existing challenges and the actions needed to best utilize solar radiation in urban environments.

1 Introduction and Relevance

Planning solar neighborhoods takes into account the onsite generation of renewable energy to enable photovoltaics (PV) and solar thermal technologies to be implemented or prepared for, as well as creating access to daylight and sunlight to achieve healthier urban environments. Solar neighborhoods also create environments that increase energy self-sufficiency and resiliency to energy price fluctuations, reducing the dependence on energy imports and thus helping future-proof towns and cities. Solar neighborhoods contribute to advancing the United Nations' Sustainable Development Goals (UN SDG)[1].

A neighborhood is a spatially defined, specific area, often including different types of buildings and functions, open spaces, and infrastructure. A neighborhood can be part of a larger city or a smaller village. It can be part of an urban area or a rural development or represent an isolated community. It can also be connected to a district heating/cooling network or outside of it, resulting in very different boundary conditions and challenges related to the energy system. Solar planning of neighborhoods is pertinent when new areas are being developed, and existing neighborhoods need renovation and development.

Utilizing solar gains for various applications in the built environment is not a new practice. For instance, the ancient Romans captured and amplified sunlight for heating homes and baths in a basic form of passive solar heating. However, a large portion of the potential for improving energy efficiency and utilizing solar energy in existing buildings has yet to be fully explored. A combination of making buildings more energy efficient – through refurbishment interventions and new developments – and increasing the implementation of renewable energy sources (RES) is, therefore, a key issue to reduce fossil energy use and greenhouse gas emissions towards a low carbon energy transition. Globally, goals and specific targets are set to reduce our environmental impact on the climate and secure future energy supply[2].

Increased use of solar energy is one of the leading development paths, where the urban fabric needs to utilize passive solar gains and daylight to reduce energy consumption in buildings and improve indoor and outdoor comfort for inhabitants. In addition, active solar energy systems integrated in the urban context contribute to the production of renewable energy in the form of heat and electricity. All these solar strategies support cities and citizens in achieving sustainable and healthy developments. Since the built environment has a long lifetime, we must also ensure long-term solar access for buildings and outdoor environments when developing neighborhoods and cities.

[1] https://sdgs.un.org/goals

[2] For example, EU initiatives aim to make Europe the first climate-neutral continent by 2050, all while ensuring future energy security and affordability.

2 Current Status

The ongoing climate and energy crisis is pushing cities to develop strategies for achieving zero/plus-energy or carbon-neutral neighborhoods. Some cities are front-runners, establishing exemplary showcases of sustainable urban areas by deploying passive and active solar strategies and integrating solar systems[3]. Experiences can be used to learn from and inspire each other. Many public and private initiatives exist. The global Covenant of Mayors emphasizes the importance of climate change mitigation and adaptation and increased access to clean and affordable energy[4]. The Covenant of Mayors in Europe has a vision that by 2050, everyone will live in decarbonized and resilient cities with access to affordable, secure, and sustainable energy[5].

In the pursuit of sustainable urban development, integrating solar energy emerges as a pivotal solution, offering both challenges and opportunities for cities. Therefore, the importance of solar access, solar strategies, and the role of digital tools in solar planning of urban environments must be clearly understood.

2.1 Solar access

Although the extensive use of passive and active solar strategies can pave the way for more sustainable urban environments, pressures from population growth and the lack of adequate legislative frameworks to facilitate energy transition in cities are major challenges.

In ancient English law, the "right-to-light" regulates the right to a reasonable proportion of the natural unobstructed flow of direct solar radiation onto one's property. This "right-to-light" relates to windows and indoor daylighting and is also known as "ancient lights"[6]. Today, we need a "right-to-light" for indoor daylighting, a healthy outdoor environment, and to ensure solar access for active solar panels on buildings and outdoor areas. In some countries, solar easements are in place to protect the installed capacity of solar energy systems. Climate change and increasing heat waves also highlight the need for "right-to-shade," especially in urban areas experiencing urban heat island (UHI) effects. However, there is a lack of specific standards regulating these aspects at a neighborhood level.

2.2 Solar strategies

Passive solar strategies utilize sunlight to improve thermal and visual comfort indoors and outdoors while reducing energy consumption for heating, cooling, and lighting[7]. In addition to solar gains through windows, passive strategies include materials and devices that interact with solar radiation to control surface temperatures and their impact on the outdoor and indoor environment. Further, urban greening is a passive strategy that contributes to energy saving, surface and air temperature cooling, and can provide food, as in the case of urban agriculture.

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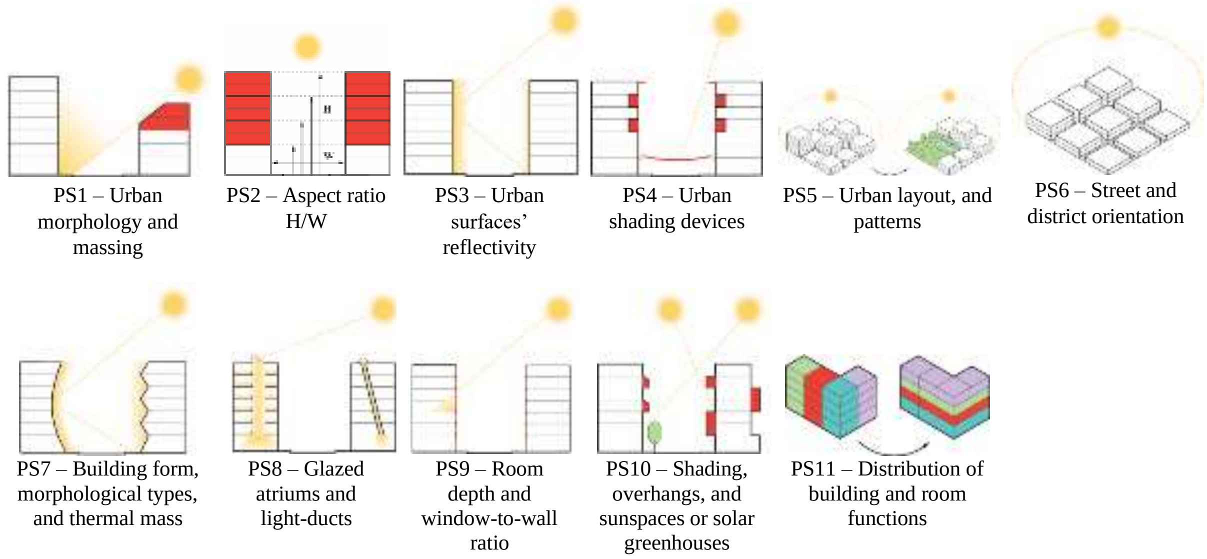
[3] https://task63.iea-shc.org/case-studies; https://task51.iea-shc.org/case-studies

[4] https://www.globalcovenantofmayors.org/

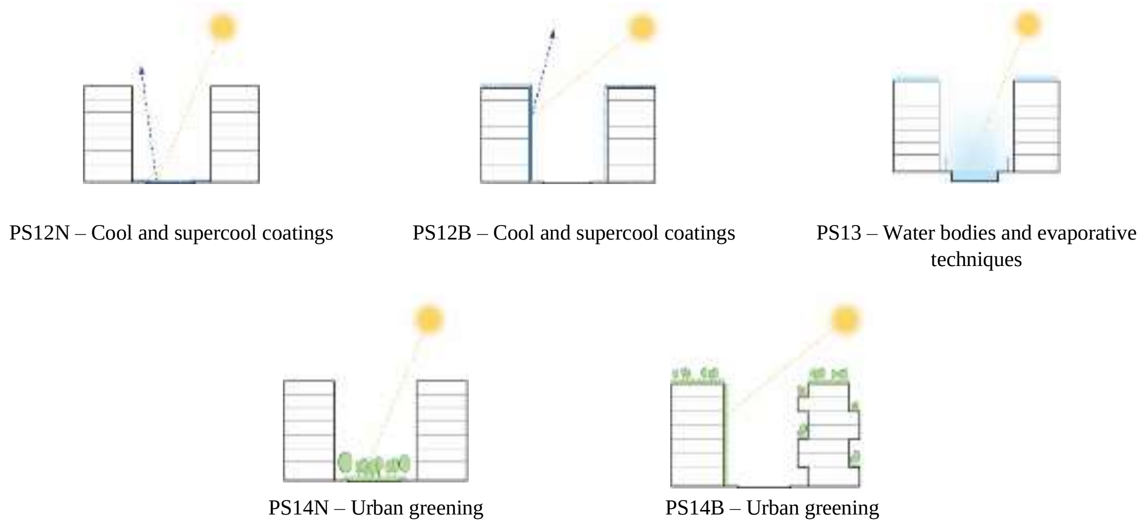
[5] https://eu-mayors.ec.europa.eu/en/about/objectives-and-key-pillars

[6] On ancient lights, the evidence of surveyors thereon. By architect Robert Kerr (1865). London: John Murray, Albemarle Street.

[7] C. Hachem-Vermette, K. S. Grewal & M. Wall (eds.), Strategies for the Design of New and Existing High Energy Performance Solar Neighborhoods, Report A1, IEA SHC Task 63, 2024, https://doi.org/10.18777/ieashc-task63-2024-0003



Passive solar strategies applied to the planning and design at the neighborhood and building scale, from M. Manni et al. (2023)[8]

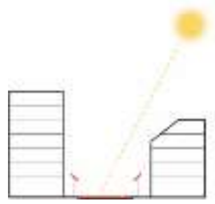


Other passive solar strategies applied to the planning and design at the neighborhood and building scale, from M. Manni et al. (2023)

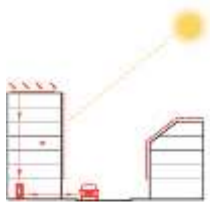
Active solar energy systems can be efficiently implemented in urban environments. Solar thermal and, in particular, photovoltaic (PV) panels producing electricity are increasingly being used, especially when integrated into or added to building envelopes. Inter-building areas, pavements, roads, and urban furniture are also suitable surfaces for integrating solar systems and energy generation[9]. Sun-tracking reflector systems for active daylighting control, concentrating and redirecting sunlight onto otherwise dark areas, are also labeled as active solar strategies.

[8] M. Manni, M. Formolli, A. Boccalatte, S. Croce, G. Desthieux, C. Hachem-Vermette, J. Kanters, C. Ménézo, M. Snow, M. Thebault, M. Wall, G. Lobaccaro, Ten questions concerning planning and design strategies for solar neighborhoods, Building and Environment, Volume 246, 2023, 110946, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2023.110946

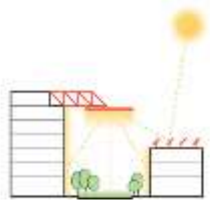
[9] S. Croce, C. Hachem-Vermette, M. Formolli, D. Vettorato, M. Snow, Surface Uses in Solar Neighborhoods, Report B1, 2022, https://doi.org/10.18777/ieashc-task63-2022-0002



AS1N – Energy generation from solar systems at neighborhood scale.



AS1B – Energy generation from solar systems at building scale.



AS2 – Heliostat and sun-tracking reflector systems.

Active solar strategies applied to the planning and design at the neighborhood and building scale, from M. Manni et al. (2023)

Challenges arise from the competing uses of urban surfaces and around the implementation of active and passive solar strategies in urban planning. The same surface can have multiple potential usages (e.g., green facade and roof, building integrated solar panels), and the same strategy can impact different parameters. For example, solutions to enhance access to daylight may also increase solar thermal stress, worsening the users' thermal comfort on hot days if the solar radiation is uncontrolled.

2.3 Digital tools and data to support solar planning

Many cities have developed solar cadasters for building roofs to inform stakeholders of areas with solar potential through various key performance indicators (KPIs). Such KPIs can, e.g., relate to energy, environmental or economic performances. However, estimating the solar potential of whole neighborhoods is much more complex, in particular, the solar potential for facades due to inter-building reflections and shading phenomena taking place at the neighborhood scale. Solar cadasters can be a valuable and useful source of information as urban and energy planning supporting tools, but still, developments are needed to identify and use common KPIs, standardized outputs, and visualizations to communicate technical information in a more user-friendly way[10].

The digitalization of the built environment allows us to carry out performance predictions, analyze and compare different urban planning and design strategies in the early urban design phases[11], and assess, for example, the impact of climate change on the urban environment. Digitalization is also a key aspect for visualizing relevant solar data that, together with intelligible KPIs and a user-friendly interface, can (i) facilitate stakeholder involvement and citizen participation in the design process, (ii) promote the social acceptance of solar applications, and (iii) support municipalities in the development of roadmaps for solar energy implementation[12].

The design of solar neighborhoods requires a multi-criteria approach that takes into account many factors. Advanced computer tools and linking several digital platforms to perform complex analyses are needed. However, despite the large number of tools available today, many of them still lack interoperability. Solar design workflows mostly consist of a model chain (i.e., a chain of different tools), and few provide the sufficient level of integration required by building and urban design practitioners. Moreover, municipalities rarely have the time and infrastructure resources needed for data acquisition, elaboration, and digitalization tasks. As a

[10] J. Kanters & M. Thebault (eds.), Opportunities for Improved Workflows and Development Needs of Solar Planning Tools, Report C2, IEA SHC Task 63, to be published in 2024, see: https://task63.iea-shc.org/publications

[11] Grewal, K. & Hachem-Vermette, C., Decision-Making Tool for Solar Neighborhood Planning: User Manual, Report A2, IEA SHC Task 63, 2024, https://doi.org/10.18777/ieashc-task63-2024-0004 including the tool: https://task63.iea-shc.org/decision-making-tool

[12] J. Kanters & M. Thebault (eds.), Identification of existing tools and workflows for solar neighborhood planning, Report C1, IEA SHC Task 63, 2022, https://doi.org/10.18777/ieashc-task63-2022-0001

result, these tasks are usually performed by private parties, who provide limited access to the data. At the same time, the field of advanced simulation is evolving rapidly and will be influenced by Artificial Intelligence and Machine Learning, allowing for faster and more advanced analyses for larger neighborhoods and for different time horizons (i.e., short, medium, and long-term), which may create new opportunities.

3 Potential

Exploring the solar potential in neighborhoods offers significant opportunities and includes both qualitative and quantitative aspects. Solar neighborhoods have the potential to create environments that are:

- energy (resource) self-sufficient
- using a high share of RES
- resilient to energy price fluctuations or dependence on energy imports
- achieving and guaranteeing high levels of thermal and visual comfort, both indoors and outdoors, and improving air quality - resulting in a healthy and livable environment for citizens
- supporting the creation of climate-proof cities.

Further, solar neighborhoods contribute to achieving UN Sustainable Development Goals[13]. Solar planning for neighborhoods and cities considers and enables a) local renewable (solar) energy production, b) passive solar gains for space heating and increased thermal comfort indoors and outdoors, c) daylighting of buildings and outdoor areas and reducing the need for electric lighting, d) good solar access for green spaces (building roofs/facades and other outdoor areas) that reduce stormwater, support biodiversity and improve air quality, and e) good solar access achieving high quality growing conditions for local food production.

Solar neighborhoods will therefore contribute, in particular, to the following UN goals:

	SDG1 - No Poverty Solar radiation is reaching the whole world, more or less intensely, and is varying throughout the day and year. It is a free energy source for all, and technologies exist to harvest solar energy as heat and electricity. Such active solar strategies for energy production contribute to reduce energy poverty and inequality and limit the influence of energy price fluctuations. Poverty is also about social exclusion. With good solar access, urban agriculture can expand. Urban agriculture can have social functions, citizens gathering with common goals to grow local food. Local food production can also have a positive impact on reducing food prices, which are increasing in many countries, and thus reducing poverty. Urban agriculture is also linked to SDG2.
	SDG2 - Zero Hunger Urban farming and local food production within solar neighborhoods can improve the access to food resources for everyone. For example, greenhouses or open-air gardens can be installed on rooftops to grow vegetables and other crops, depending on climatic conditions. Community gardens and allotments can also be used. Vertical farming may be appropriate in dense cities with limited land area.

[13] Take Action for the Sustainable Development Goals - United Nations Sustainable Development

SDG3 - Good Health and Wellbeing Solar strategies, especially passive solar, will enhance human indoor and outdoor comfort conditions within the solar neighborhood environment, thereby improving human health and wellbeing. Access to daylight is important for human health, and strategies for good daylight conditions indoors and outdoors are fundamental in solar neighborhoods. Solar gains also provide passive heating. The combination of using passive solar gains and shading strategies is a key to achieving high levels of thermal comfort, indoors and outdoors.
SDG7 - Affordable and Clean Energy Clean energy production and energy self-sufficiency are two important aspects in the design of solar neighborhoods. Our daily life depends on reliable and affordable energy. A spatial proximity between energy production and energy consumption is a supporting concept, and can also support the proximity between urban residential areas and urban services. Local renewable energy production and urban agriculture can also reduce food transport and thus all together contribute to achieve SDG7.
SDG9 - Industry Innovation and Infrastructure Solar neighborhoods can have an impact on industry, innovation, and infrastructure, particularly in relation to active and passive solar solutions. Introducing and promoting solar technologies, urban agriculture, and supporting new local industries and companies in cities and neighborhoods, can help to establish innovative solutions and products. Such support can help competitive activities/companies to generate employment and income.
SDG10 - Reduced Inequalities A wide range of solutions can be implemented in solar neighborhoods in the context of climate. Therefore, any country can apply solar neighborhood design principles to achieve carbon-neutrality and energy self-sufficiency, regardless of the economic context, thus reducing inequalities.
SDG11 - Sustainable Cities and Communities With 70% of people expected to live in cities by 2050, this goal is about making cities and human settlements inclusive, safe, resilient and sustainable. Solar neighborhood design and development considers economic, environmental, energy, and social aspects through multi-criteria analyses using specific performance indicators. This approach to neighborhood planning enables more sustainable cities and communities.
SDG13 - Climate Action Design and technology solutions for solar neighborhoods can contribute to (i) mitigate urban overheating through innovative cool materials and secure the “right-to-shade”; (ii) decrease the amount of carbon emissions in the atmosphere; (iii) compensate the carbon footprint of the neighborhood by generating clean energy from RES; and (iv) mitigate more frequent and extreme weather situations, e.g. by reducing storm water (green roofs, facades and outdoor areas).
SDG15 - Life on Land The design principles that characterize solar neighborhoods have a positive impact on biodiversity, reintroducing animal species in areas they used to inhabit before human-induced transformations. Green roofs, facades and outdoor areas, and urban agriculture, are examples that can support this biodiversity.

4 Actions Needed

Despite ongoing developments of solar strategies, technologies, digital tools, data handling, etc., significant challenges and barriers remain[14]. These are related to the lack of regulations

[14] M. Manni, M. Formolli, A. Boccalatte, S. Croce, G. Desthieux, C. Hachem-Vermette, J. Kanters, C. Ménézo, M. Snow, M. Thebault, M. Wall, G. Lobaccaro, Ten questions concerning planning and design strategies for solar neighborhoods, Building and Environment, Volume 246, 2023, 110946, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2023.110946

on the exploitation of sunlight and access to light, sun and shade, social acceptability and/or lack of knowledge about solar strategies, competing uses of urban surfaces, drawbacks of some technologies, complex modeling of urban areas, and low profitability or failure to consider added values of solar strategies.

To face such challenges, some actions are identified below:

Challenge	Action needed	Action by whom
Lack of legal rights to long-term solar access in indoor and outdoor urban environments, for daylight, thermal comfort, solar energy production, etc.	**Legal reforms** as to solar access protection to secure investments in renewable energy and sustainable developments. **Improve planning approval processes** where informed decisions can be made.	Policy makers, legal entities (integrate KPIs and targets in legislation), municipalities Municipalities
Lack of Right to Shade, to improve thermal comfort in hot urban areas	**Develop shading strategies and KPIs**, and include them into **planning regulations and guidelines** for urban design	R&D community, urban planning departments, urban planners & architects, legal entities
Impacts of climate change on urban environments	**Integrate permeable surfaces** into the built environment to increase resilience to climate change effects and to enable urban farming. **Use of cool materials** and **vegetation** to control surface temperatures and mitigate urban heat island (UHI) effects.	Urban planners, architects, consultants R&D community, urban planners, architects
Citizen and city acceptance of implementing passive and active solar strategies	**Develop materials and components** to architecturally integrate solar panels and passive strategies into the built environment. More colors, hues, patterns, sizes, to increase flexibility in design and use of sustainable materials. **Adapt urban regulations** to enable the integration of solar strategies in protected heritage areas. **Increase awareness** among decision makers on the available strategies and their potential. **Increase stakeholder engagement** in urban planning and design[15].	R&D community, product/material developers Municipalities, legal entities R&D community, architects, consultants Municipalities, developers, citizens

[15] N. Caballero, J. Balest, G. Giacovelli (eds.), An Integrated Framework for Stakeholder and Citizen Engagement in Solar Neighborhoods - ENGAGED framework for stakeholder engagement and behavioral design, Report B3, IEA SHC Task 63, 2024, https://doi.org/10.18777/ieashc-task63-2024-0001

Challenge	Action needed	Action by whom
Low profitability, or lack of considering added values of solar strategies	**Define business models** for solar neighborhoods to ensure long-term viability, scalability, and financial sustainability of solar initiatives[16].	R&D community, consultants
	Include and **elucidate added values** (human health and well-being, resilience, energy security, biodiversity etc.) in business models.	R&D community, consultants, investors, economists
Competing uses of urban surfaces	Identify potential synergies and conflicts, address multi-disciplinary challenges, and **evaluate the contribution of surface uses** to climate resilience and sustainability.	Urban designers, architects, consultants
	Include the definition of urban surface uses as part of the **design process** of solar neighborhoods	Educators, urban designers, architects, consultants
Lack of knowledge and competence to manage solar strategies in urban design	Further **develop solar cadasters**, standardize types of outputs, visualizations, facilitate links to digital tools for analyzes.	Tool developers
	Develop tools handling the neighborhood scale, integrating 3D models, dynamic behavior and emerging surface treatments.	Tool developers, R&D community
	Improve tool interoperability, **develop KPIs and target values** for solar related indicators.	Tool developers, R&D community
	Develop advanced computer techniques (e.g., machine/deep learning, AI), and organize data to realize more reliable and detailed **digital twins** of buildings and cities.	Tool developers, R&D community
	Develop guidelines to support urban design.	R&D community, architects, urban planners, educators
	Strengthen teaching and dissemination for knowledge transfer, both at universities and for professionals.	Educators

[16] E. Wilczynski, Solar Neighborhood Financing Mechanisms and Business Models, Report B2, IEA SHC Task 63, 2024, https://doi.org/10.18777/ieashc-task63-2024-0002