SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

DESIGN GUIDELINES FOR URBAN SURFACE USES IN SOLAR NEIGHBORHOODS

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IEA SHC Task 63 “Solar Neighborhood Planning”

Design Guidelines

Urban surfaces (i.e. all surfaces that characterize physically and morphologically the built environment from a radiative, thermal, and hydrological perspective) and the different ways in which they can be designed and exploited have been extensively discussed in the IEA SHC Task 63 report "Surface uses in solar neighborhoods".

The aim of this document is to provide a **synthetic guide to assist urban planners, designers and practitioners in defining urban surface uses**, by integrating the exploitation of solar energy (through active and passive solar strategies) with the enhancement of climate resilience and sustainability within the planning and design process of solar neighborhoods.

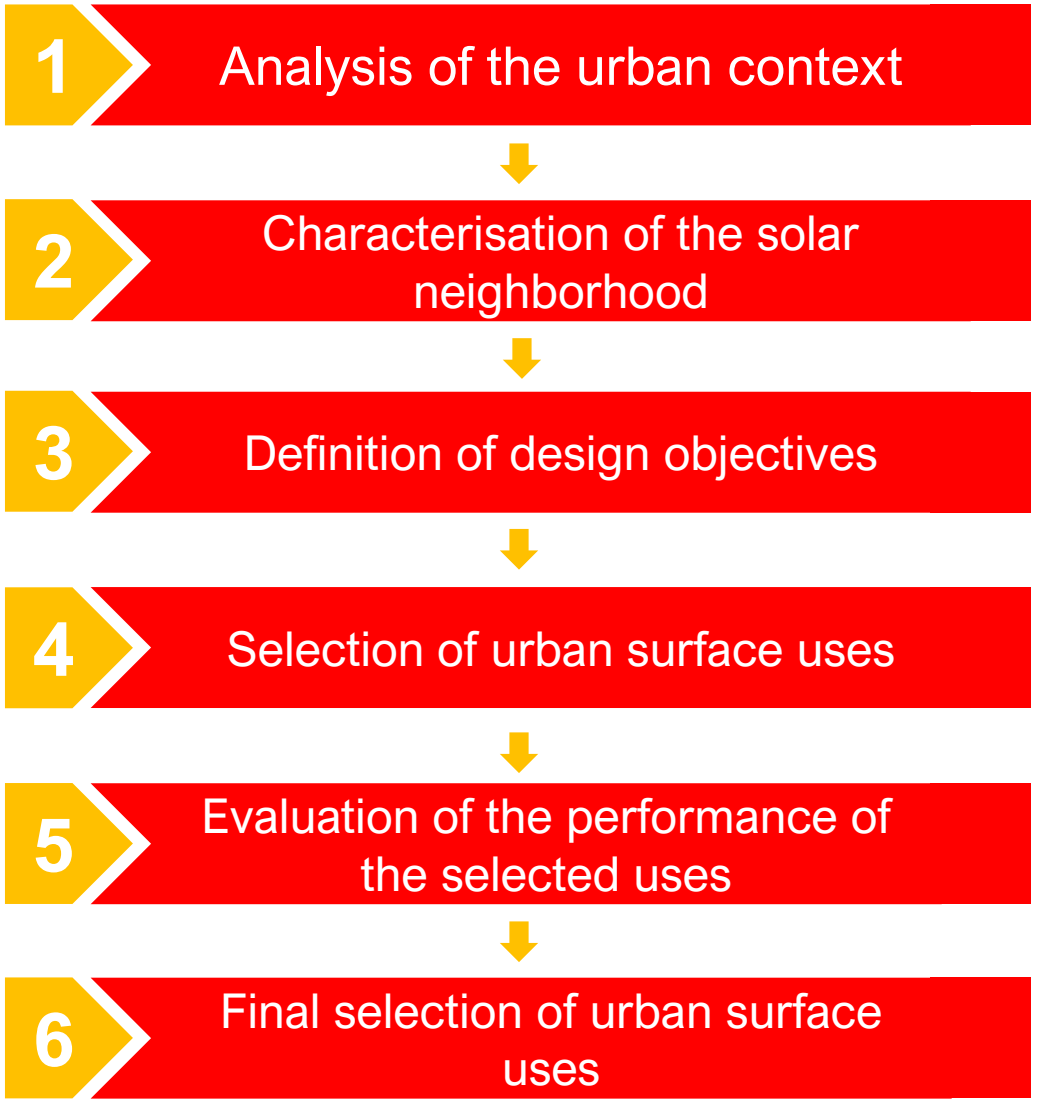
Design Guidelines

Due to the variety of solutions and design strategies, defining urban surface uses is a **multi-disciplinary and complex process** that requires both **quantitative and qualitative data** to make informed decisions.

The proposed design workflow provides guidance on the main steps to be taken to consider surface uses during the design process and suggests **methods and tools suitable** for the process.

The workflow consists of six steps; for each step, this guideline provides some key questions to be answered during the design process and explains the actions to be taken to answer them and the objective of doing so.

To support the user, the guidelines contain links to all relevant Task 63 outputs and hyperlinks to help navigate the content.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1 Analysis of the urban context

What are the project boundary conditions at the city level?

AIM	Understand the **boundary conditions of the project** and the **priorities** that have been set at **the municipal level** and that may influence the choice of surface uses in the neighbourhood.

ACTIONS

⇒ Analyse the geographical, hydrogeological and climatic conditions of the city to better understand its environmental conditions and vulnerability to natural hazards.

⇒ Analyse urban planning and governance policies, municipal plans and regulations to:

→ Identify municipal requirements and/or incentives that may influence the design of surface uses (e.g.: minimum percentages of permeable or vegetated surfaces, energy efficiency requirements, design regulations, etc.).

→ Identify the climate resilience and sustainability objectives at the municipal level (e.g., in the European context, consider the provisions of the Sustainable Energy and Climate Action Plan).

METHODS AND TOOLS	Contents of municipal plans and legislation (*more on the relevance of legislative framework for the development of solar neighborhoods*), Local climate analysis based on the elaboration of historical data series, Use of climate tools (e.g. Climate Consultant, Ladybug tools for Grashopper, etc.) and analysis of typical meteorological year weather files (e.g. epw data).

2 Characterization of the solar neighborhood

What are the relevant morphological characteristics of the neighborhood?

AIM	Identify the **areas that could be modified or accommodate new uses** (existing neighborhoods), or the **areas suitable for integrating different solutions** (new neighborhoods) and collect **relevant input data** for both the creation of 3D models and the selection of solutions.
ACTIONS	⇒ Characterize the solar neighborhood in terms of → urban morphology → existing/already designed urban surface uses, materials and characteristics, including the proportion of permeable and impermeable surfaces, the presence of existing solutions (e.g. PV panels, green roofs, etc.), and vegetation
METHODS AND TOOLS	Use of 3D models, Urban plans, GIS data, Aerial images, Photos, On-site visits

2 Characterization of the solar neighborhood

What are the environmental conditions and stressors in the neighborhood?

AIM	Clearly understand the **site-specific environmental conditions, hazards and risks**, and set the baseline for defining and analysing surface use design strategies that enhance the **climate resilience and sustainability** of the project.

ACTIONS

⇒ Analyse local environmental conditions (i.e. topography, hydrology, climate, vegetation, soils) to identify, among others:

→ relevant vulnerabilities (e.g. presence of UHI, location of hot spots or flood prone areas, slope stability risks, etc.)

→ positive features to be preserved (e.g. vegetated areas providing cooling)

The climate assessment should include, as a minimum, analysis of: average monthly rainfall and temperature ranges, solar radiation, prevailing winds, seasonal solar angles.Thoroughly consider the current and projected impacts of climate change on the solar neighborhood and its functioning.

- Identify observed, predicted and future natural hazards that may have a relevant impact on the solar neighborhood and its operation (e.g. earthquakes, landslides, etc.)

METHODS AND TOOLS	Use of municipal environmental data, measurements collected during field monitoring campaigns, results of environmental tools. *The report "Identification of existing tools and workflows for solar neighborhood planning" provides more information and references on tools.*

2 Characterization of the solar neighborhood

What do stakeholders think about the design and the needs of the neighborhood?

AIM

Involve all relevant stakeholders in the design process from the earliest stages.

Local stakeholders can play a key role in contributing to an informed decision-making process and can provide different types of knowledge, complementary to those of scientists and urban decision-makers, that are important for defining context-specific solutions.

ACTIONS

⇒ Identify all the relevant stakeholders for the project, including local community members and vulnerable and marginalized groups

⇒ Involve the stakeholders in setting site-specific objectives by seeking relevant information about local conditions, issues, and expectations of the project

⇒ Consider and discuss with stakeholders the potential equity and justice impacts of the project (e.g. risk of gentrification, equal access to green spaces, accessibility, impact on energy poverty, etc.)

METHODS AND TOOLS

Stakeholder mapping, Community engagement activities, Focus groups, Co-design activities, Living Labs, Workshops, Focus Groups, etc.

The report "An Integrated Framework for Stakeholder and Citizen Engagement in Solar Neighborhoods" provides useful information and proposes a multi-stage framework for participatory urban planning that integrates insights from behavioral design into a stakeholder engagement process.

3 Definition of design objectives

What are the objectives of the surface use design?

AIM	Define the **key objectives to be considered in the selection of surface uses**, with particular emphasis on **climate resilience** (i.e. the ability of the neighborhood to protect its inhabitants and infrastructure from the effects of climate change and extreme weather events) and **sustainability** (i.e. efficient use of resources).
ACTIONS	⇒ Define the site-specific climate resilience and sustainability objectives based on information gathered in Steps 1 and 2 ⇒ Group the defined objectives into primary and secondary according to their relevance. Primary objectives refer mainly to targets specifically set as a result of the neighborhood level analysis. Secondary objectives complement the primary ones and include more general targets set at the city level. ⇒ In addition to climate resilience and sustainability objectives, which are paramount in the definition of urban surface uses, all the requirements of the local regulatory framework and building codes (e.g. minimum levels of daylight, minimum percentage of energy consumption to be covered by renewable energy sources, etc.) need to be taken into account. ⇒ Discuss the objectives definition with the stakeholders.
METHODS AND TOOLS	Traditional practices of urban planning and architecture, Multi-criteria approaches, Workshops

4 Selection of urban surface uses

What surfaces are available in the neighborhood and where are they located?

AIM	**Identify the surfaces**, both on the building envelope and on the ground, that can **accommodate or integrate** each new use.

ACTIONS

⇒ Identify the available surfaces

⇒ Characterize the identified surfaces in terms of

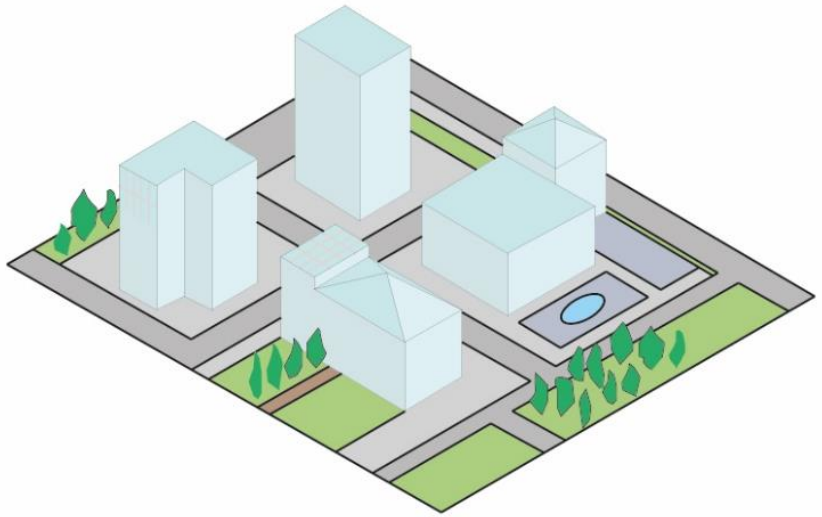
- → Location (i.e. building surfaces: façade, roof, intermediary space; ground surfaces: road network, open spaces, topography)
- → Area (m^2)
- → Possible restrictions on the use of the surface (e.g. the presence of air-conditioning systems in the case of roofs or façades, or the need to support the weight of vehicle traffic in the case of ground surfaces, etc.).
- → Orientation and exposure (e.g. consider whether the surface is fully or partially shaded during the day)

⇒ Ownership (particularly relevant for existing neighborhoods)

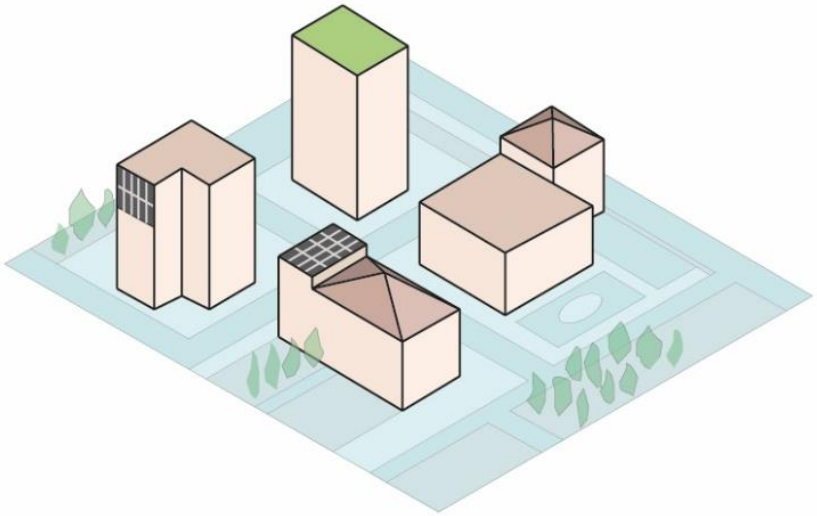
METHODS AND TOOLS	2D and 3D models of the neighborhood, GIS data, Aerial images, Design activities and workshops

4 Selection of urban surface uses

What surfaces are available in the neighborhood and where are they located?



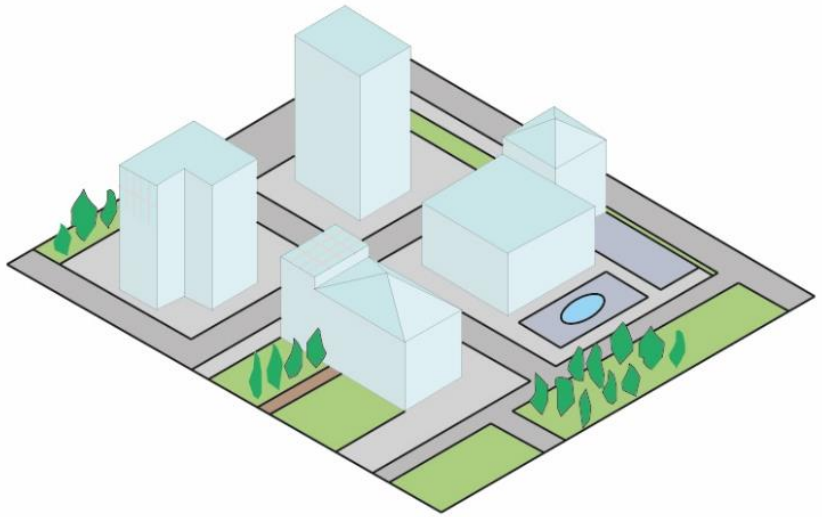
GROUND SURFACES



BUILDING SURFACES

4 Selection of urban surface uses

What surfaces are available in the neighborhood and where are they located?



GROUND SURFACES

Road Network

Roads
Sidewalks
Cycle paths

Open Spaces

Public areas
Urban parks
Spaces in between buildings
Parking areas
Brownfields

Open Spaces

Rivers
Lakes
Hills
Mountains
Urban furniture

4 Selection of urban surface uses

What surfaces are available in the neighborhood and where are they located?

Façades

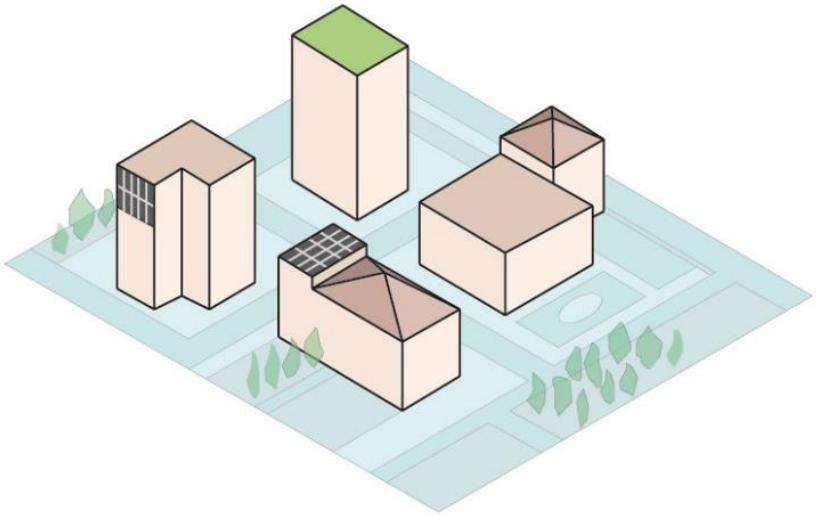
Opaque surfaces
Transparent surfaces
Balconies
Louvres

Roofs

Flat
Tilted
Curved
Other forms

Intermediary Spaces

Open atria
Courtyards



BUILDING SURFACES

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?

AIM	Select the **most appropriate surface uses** for the solar neighborhood.

ACTIONS

⇒ Based on the type of surface, identify the suitable uses for each available surface previously selected.

At this point, it is highly relevant to consider all the urban surface uses that might be implemented in the neighborhood, avoiding focusing only on pre-selected ones (e.g. photovoltaics for renewable energy generation), in order to maximize the potential benefits obtainable.

⇒ Among the identified solutions, select those that may be more beneficial to the objectives set for the project.

⇒ Clearly select the location for each solution.

⇒ Consider all the potential synergies among surface uses (e.g. in the case of solar green roofs, the presence of vegetation might increase the efficiency of photovoltaic systems).

⇒ Particularly in the case of existing neighbourhoods or neighbourhoods to be developed in consolidated urban areas, consideration should be given to compliance with heritage regulations, aesthetic requirements and materials to be used.

⇒ Involve the stakeholders in the selection process.

METHODS AND TOOLS

The Surface Use Sheets available in report B1 provide useful information on each solution, while the report "Strategies for the Design of New and Existing High Energy Performance Solar Neighborhoods" provides more detail on solar strategies.

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?

ACTIVE SOLAR ENERGY SYSTEMS

PASSIVE SOLAR ENERGY SYSTEMS

GREEN SOLUTIONS

WATER SOLUTIONS

URBAN AGRICULTURE

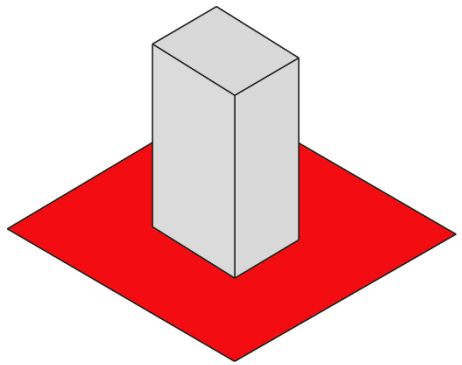
COOL MATERIALS & INNOVATIVE SOLUTIONS

SMART SOLUTIONS

TRADITIONAL USES/MATERIALS

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?



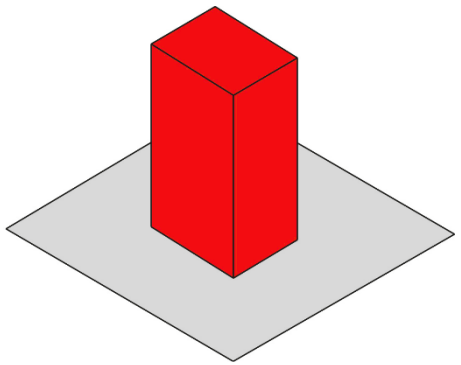
GROUND SURFACES

Road network	Roads	✓	-	✓	✓	-	✓	-	✓
	Cycle paths	✓	-	✓	✓	-	✓	-	✓
	Sidewalks	✓	-	✓	✓	-	✓	-	✓
Open spaces	Public areas	✓	-	✓	✓	-	✓	-	✓
	Urban parks	✓	-	✓	✓	✓	-	-	✓
	Spaces in between buildings	✓	-	✓	✓	✓	✓	-	✓
	Parking areas	✓	-	✓	✓	-	✓	-	✓
	Brownfields	-	-	✓	✓	✓	-	-	✓
Topography	Rivers	-	-	✓	✓	-	-	-	✓
	Lakes	✓	-	✓	✓	✓	-	-	✓
	Hills	-	-	✓	-	-	-	-	✓
	Mountains	-	-	✓	-	-	-	-	✓
	Urban furniture	✓	-	✓	-	-	-	-	✓

Suitable surface uses: ✓

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?



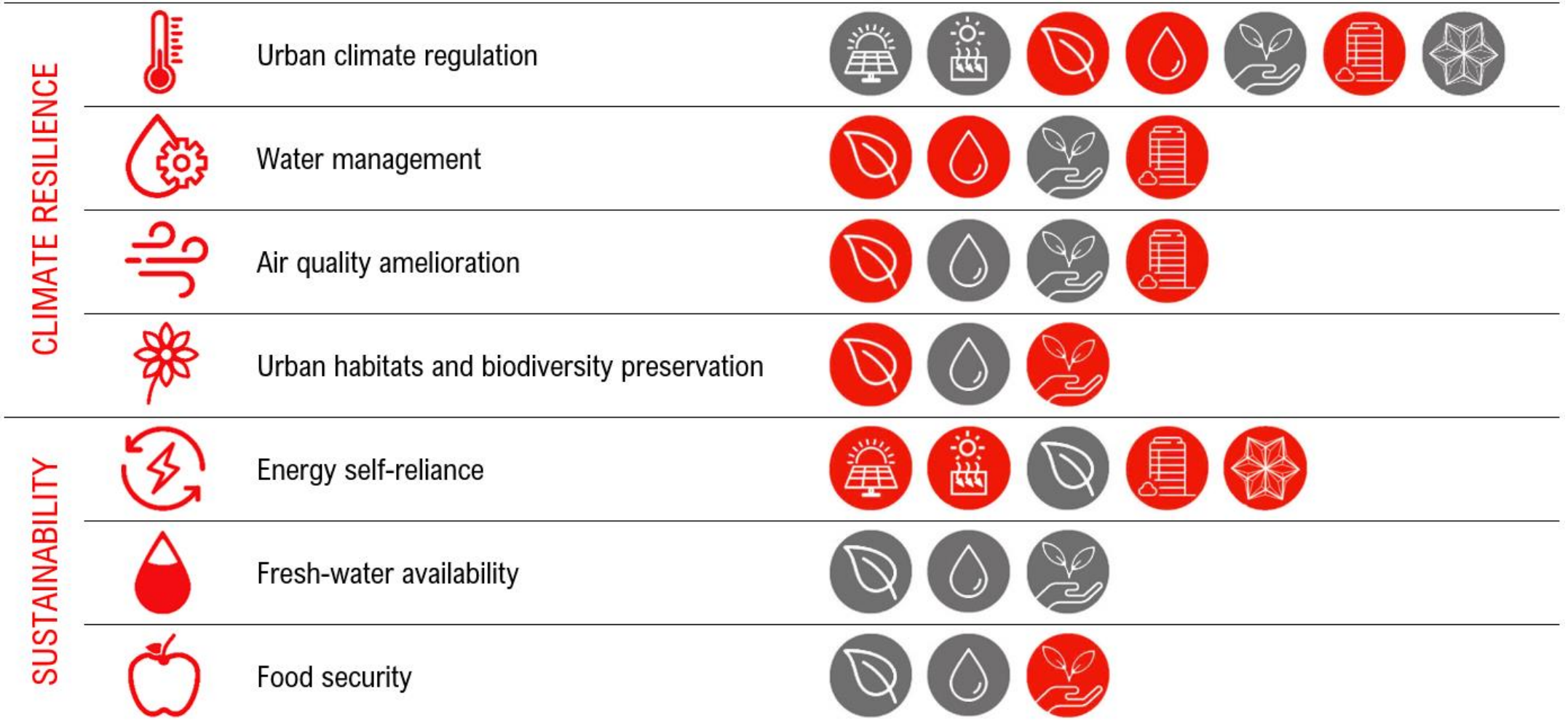
BUILDING SURFACES

Façades	Opaque surfaces	✓	✓	✓	✓	✓	✓	✓	✓
	Transparent surfaces	✓	✓	✓	✓	✓	-	✓	✓
	Balconies	✓	-	✓	-	✓	-	-	✓
	Louvres	✓	-	-	-	-	-	✓	✓
Roofs	Flat	✓	✓	✓	✓	✓	✓	-	✓
	Tilted	✓	-	✓	-	-	✓	-	✓
	Curved	✓	-	✓	-	-	✓	-	✓
	Other forms	✓	-	✓	-	-	✓	-	✓
Intermediary spaces	Open atria	-	✓	✓	✓	✓	✓	-	✓
	Courtyards	-	✓	✓	✓	✓	✓	-	✓

Suitable surface uses: ✓

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?



Contribution to objectives: primary (red icons), secondary (grey icons)

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?

ACTIVE SOLAR ENERGY SYSTEMS

PV/BIPV	S	-	S	-	P	-	-	-	✓	✓
ST/BIST	S	-	S	-	P	-	-	-	✓	✓
Hybrid PV/ST systems	S	-	-	-	P	-	-	-	✓	✓
Solar pavements/roads	S	-	-	-	P	-	-	✓	-	-
Asphalt solar thermal collectors	S	-	-	-	P	-	-	✓	-	-
Acoustic PV road barriers	-	-	-	-	P	-	-	✓	-	-
Photovoltaic carports	-	-	-	-	P	-	-	✓	-	-
PV-integrated urban furniture	-	-	-	-	P	-	-	✓	-	-
Solar powered urban artworks	-	-	-	-	P	-	-	✓	-	-

Contribution to objectives: P: primary contribution - S: secondary contribution

Suitable surfaces: ✓

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?

PASSIVE SOLAR ENERGY SYSTEMS

Windows/Glazed walls & roofs	S	-	-	-	P	-	-	-	✓	-
Trombe walls	S	-	-	-	P	-	-	-	✓	-
Sunspaces/Solar greenhouses	S	-	-	-	P	-	-	-	✓	-
Shading devices	S	-	-	-	P	-	-	-	✓	-
Natural ventilation	S	-	-	-	P	-	-	-	✓	-
Heliostat & Reflector systems	S	-	-	-	P	-	-	-	-	✓

Contribution to objectives: P: primary contribution - S: secondary contribution

Suitable surfaces: ✓

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?

GREEN SOLUTIONS

Amenity green spaces (Parks, Botanical gardens, ...)	P	S	P	P	-	-	-	✓	-	-
Linear green spaces (Roadside planting, Riverbank green, ...)	P	P	P	P	-	-	-	✓	-	-
Functional green spaces (Raingardens/Bioswales)	P	P	P	P	-	-	-	✓	-	-
Temporary green spaces	S	S	S	-	-	-	-	✓	-	-
Vertical planting systems	P	-	P	-	-	-	-	✓	-	-
Vegetated pergolas/bus stops	P	S	S	P	-	-	-	✓	-	-
Horizontal greening systems	P	P	P	P	S	-	-	-	-	✓
Vertical greening systems	P	S	P	P	S	-	-	-	✓	-

Contribution to objectives: P: primary contribution - S: secondary contribution

Suitable surfaces: ✓

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?

WATER SOLUTIONS

Water surfaces (Lakes, Rivers, Canals ...)	P	P	S	P	-	-	-	✓	-	-
Mist spraying & Water curtains	P	-	S	-	-	-	-	✓	✓	-
Watering techniques	P	-	S	-	-	-	-	✓	-	✓
Water squares	-	P	-	-	-	S	-	✓	-	-
Water harvesting facades	S	P	-	-	-	S	-	-	✓	-
Water walls for thermal mass	S	-	-	-	S	-	-	-	✓	-
Roof ponds	S	-	S	-	-	-	-	-	-	✓

Contribution to objectives: P: primary contribution - S: secondary contribution

Suitable surfaces: ✓

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?

URBAN AGRICULTURE

Ground-based farming	S	S	S	P	-	-	P	✓	-	-
Edible green walls	S	S	S	S	-	-	P	-	✓	-
Rooftop farming	S	S	S	S	-	-	P	-	-	✓
Hydroponics	S	-	-	-	-	-	P	-	✓	✓
Aquaculture & Aquaponics	S	S	S	-	-	S	P	✓	-	✓
Apiculture	-	-	-	P	-	-	P	-	-	✓
Microalgae-based biomimicry	-	-	P	S	S	-	P	✓	✓	✓

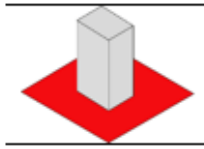
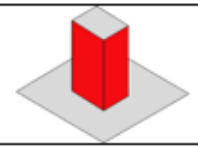
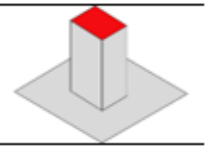
Contribution to objectives: P: primary contribution - S: secondary contribution

Suitable surfaces: ✓

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?

COOL MATERIALS AND INNOVATIVE SOLUTIONS

										
Highly reflective & emissive materials	P	-	-	-	S	-	-	✓	✓	✓
Thermochromic materials	P	-	-	-	S	-	-	✓	✓	✓
Retroreflective materials	P	-	-	-	S	-	-	-	✓	✓
Cool materials with photocatalytic properties	P	-	P	-	S	-	-	✓	-	✓
Cool membranes with PCM	P	-	-	-	S	-	-	✓	✓	-
Cool photoluminescent paints	P	-	-	-	S	-	-	✓	✓	✓
Evaporative pavements	P	P	-	-	S	-	-	✓	-	-

Contribution to objectives: P: primary contribution - S: secondary contribution

Suitable surfaces: ✓

4 Selection of urban surface uses

What uses are suitable for the surfaces identified?

SMART SOLUTIONS

Electrochromic/Photochromic glass	S	-	-	-	S	-	-	-	✓	-
Solar responsive facades	S	-	-	-	P	-	-	-	✓	-
Wind driven responsive facades	S	-	-	-	P	-	-	-	✓	-
Animation & lighting tech.	-	-	-	-	-	-	-	-	✓	-

Contribution to objectives: P: primary contribution - S: secondary contribution

Suitable surfaces: ✓

5 Evaluation of the performance of the selected uses

Do the surface uses selected for the solar neighborhood contribute to the design objectives and provide the expected benefits/impacts?

AIM	Evaluate the **environmental performance** of the selected solutions to verify their **contribution to the design objectives** and to **maximize the multiple-benefits** that the selection of multiple surface uses can provide at the neighborhood level.
ACTIONS	⇒ Carry out environmental analyses depending on the design objectives of the project (e.g. solar potential analyses for active solar systems, daylight analyses for passive strategies, microclimate analyses for heat reduction strategies such as green solutions, etc.). ⇒ Always consider all the potential impacts of the chosen surface uses (e.g. using cool materials may reduce building surface temperatures but have a negative impact on outdoor human thermal comfort; or creating an urban forest may be beneficial for outdoor microclimate conditions but reduce ventilation and consequently increase pollutant concentrations).
METHODS AND TOOLS	Use of numerical models and environmental analysis tools, depending on the parameters to be analysed (e.g. ENVI-met, Ladybug tools for Grasshopper, Diva for Rhino, etc.). *Report C1 and Report C2 provide more information and references on tools, while the Solar Neighborhood Decision-Making Tool can facilitate the selection of active and passive solar strategies.* *In the case of existing neighborhoods, the results of the environmental analyses or monitoring data collected in Step 2 can be used as a baseline for comparison. Otherwise, in the case of new neighborhoods, different solutions could be analysed and compared.*

5 Evaluation of the performance of the selected uses

Are there potential conflicts or synergies between the selected surface uses?

AIM	Understand the **main conflicts** and the **potential synergies** among solar active and passive strategies and other solutions in solar neighborhoods to **avoid inefficiencies and competition** in the use of urban surfaces and contribute to the **provision of several benefits.**

ACTIONS

⇒ Adopt a comprehensive approach to the urban surface use design

→ Avoid conflicts by differentiating the use of surfaces

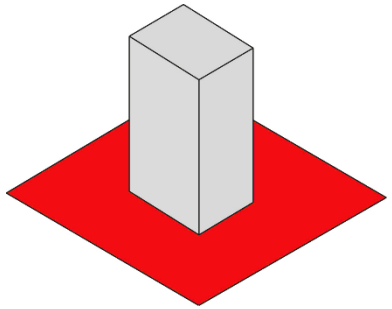
Integrating several surface uses in an urban area helps on one side to avoid major conflicts, and on the other side to boost the potentialities of each solutions and reduce its drawback.

→ If economically and technically feasible, adopt solutions that integrate more than one surface uses (e.g. solar green roofs or multifunctional façades)

METHODS AND TOOLS	Analysis of solutions able to integrate more surface uses, Design process, Technical information from the producers of the materials/solutions to be used. *Report B1 provides useful information in Chapter 5 on conflicts and synergies between active and passive solar strategies and other surface uses for both ground and building surfaces surfaces.*

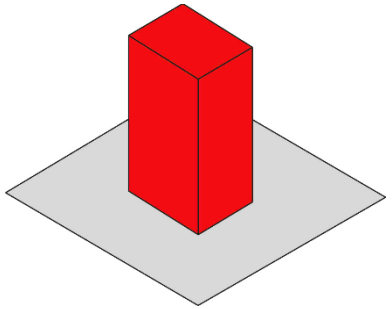
5 Evaluation of the performance of the selected uses

Are there potential conflicts or synergies between the selected surface uses?



GROUND SURFACES

	✓	✓	✓	?
	Landscape photovoltaics	Floating photovoltaics Solar ponds	PV greenhouses Aquavoltaics	Increase of solar potential by reflected radiation



BUILDING SURFACES

	✓	✗	✓	?
	Solar green roof Biosolar roof Multifunctional façade systems		Productive façades Solar greenhouses	Increase of solar potential by reflected radiation

6 Final selection of urban surface uses

Are the selected surface uses suitable for the project?

AIM — Check that the solutions chosen are **consistent with the overall objectives and design features** of the project.

ACTIONS

⇒ Consider all the requirements relevant to the project. For example (but not limited to):

- → National and local building and energy codes
- → Energy performance (focus on net zero energy buildings)
- → Building structural stability
- → Fire safety
- → Maintenance requirements of each chosen solutions (e.g. watering, mowing, fertilizing, etc. for green roofs, regular cleaning to maintain reflectivity for cool roofs, etc.)
- → Conformity of the design with the requirements of green building rating systems (e.g. LEED, BREEM, etc.) if the project is going through the certification process

⇒ In the case of projects located in Europe, compliance with the do-not-significant-harm (DNSH) principles of the EU taxonomy should be relevant; in the case of projects located outside Europe, compliance with local environmental sustainability requirements

6 Final selection of urban surface uses

Are the selected surface uses suitable for the project?

ACTIONS ⇒ Also consider the various impacts that construction activities can have, such as

- → Life cycle and embodied carbon impacts, at the neighborhood and building level, but also at the level of individual surface uses. Where possible, priority should be given to the use of building materials and systems (e.g. PV panels) with an environmental certification (e.g. EPD - Environmental Product Declaration).
- → Impacts of the project on principles of justice and equity at neighbourhood and city level (also based on stakeholder views)
- → Contribution of relevant solutions – i.e. green and water solutions, urban agriculture - to urban ecology and biodiversity (e.g. check that native species adapted to the site-specific conditions have been selected)

METHODS AND TOOLS

LCC/LCA analyses, Energy performance analyses and energy certifications, Databases of certified products and materials (e.g. EPD library), National and local building and energy codes

The case studies webpage provides examples of solar neighborhoods analysed from different perspectives, including, among others, lessons learned and recommendations, and environmental, social and other impacts.

6 Final selection of urban surface uses

Are the selected surface uses suitable for the project?

EXEMPLARY CASE STUDIES

One Central Park, Sydney (Australia)

White Gum Valley, Perth (Australia)

EVE Park, London (Canada)

HSCE Building, Xi'An (China)

6 Final selection of urban surface uses

Are the selected surface uses suitable for the project?

EXEMPLARY CASE STUDIES

Li'Ao Community, Ningbo (China)

Sønderhaven, Brædstrup (Denmark)

ZAC Ferney-Geneve (France)

Area Zip Nord, Padua (Italy)

6 Final selection of urban surface uses

Are the selected surface uses suitable for the project?

EXEMPLARY CASE STUDIES

Sinfonia, Bolzano (Italy)

Žilina (Slovakia)

Veddesta, Stockholm (Sweden)

6 Final selection of urban surface uses

Are there funding mechanisms and/or incentives in place to support the implementation of the selected surface uses?

AIM — **Financially support the implementation** of the selected solutions during both project development and operation.

ACTIONS

⇒ Identify and apply for incentives and/or financing mechanisms that could support the project already at the design phase. Financing will need to be in place by the start of construction to cover core overheads or capital expenditure.

- → Consider the range of benefits at the consumer, local and developer levels
- → Identify the real market potential of the project and the suitable business models
- → Analyse investment risks
- → Engage the community to encourage and accelerate investment

Consider that a variety of surface uses, and the use of multiple technologies can make solar neighborhoods more flexible than traditional developments and less sensitive to the cost of a single technology.

METHODS AND TOOLS

Traditional financing mechanisms, Innovative financing mechanisms, Crowdfunding mechanisms

The report "Solar Neighborhood Financing Mechanisms and Business Models" provides insights into financing mechanisms and business models to promote solar neighborhood development.

For more information on the IEA SHC Task 63 work, including many free publications, please visit www.task63.iea-shc.org, and read the Technology Position Paper.

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