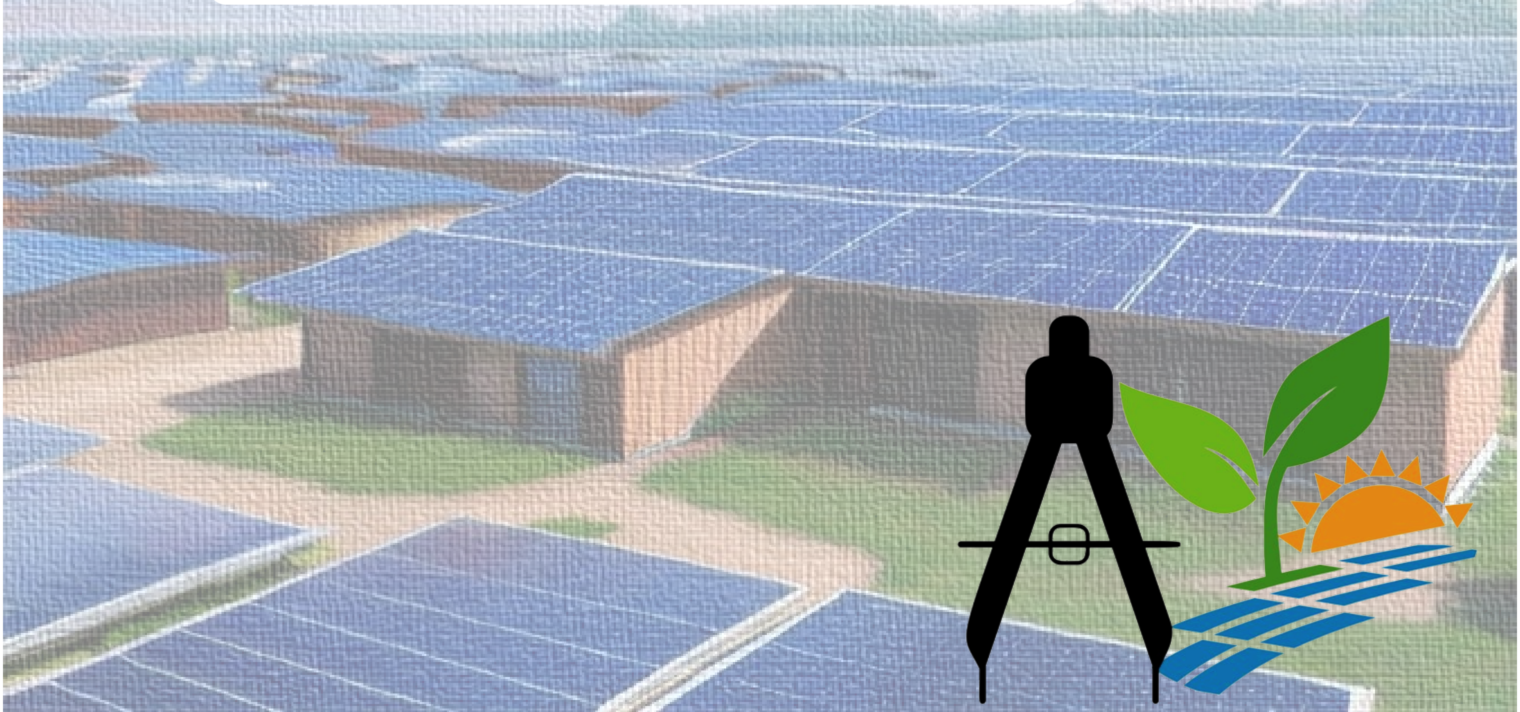
SHC
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Decision-Making Tool for Solar Neighborhood Planning

User Manual



IEA SHC TASK 63 | SOLAR NEIGHBORHOOD PLANNING

Technology Collaboration Programme
by iea

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Decision-Making Tool for Solar Neighborhood Planning

This is a report from SHC Task 63: Solar Neighborhood Planning and work performed in Subtask A: Solar Planning Strategies and Concepts

Authors: Kuljeet Singh Grewal and Caroline Hachem-Vermette

Date: May 2024
Report A2, DOI: 10.18777/ieashc-task63-2024-0004

Technology Collaboration Programme
by iea

Authors

Kuljeet Singh Grewal
Future Urban and Energy Lab for Sustainability (FUEL-S)
Faculty of Sustainable Design Engineering (FSDE)
University of Prince Edward Island, Charlottetown, PE, Canada

Caroline Hachem-Vermette
Department of Building, Civil and Environmental Engineering
Gina Cody School of Engineering and Computer Science
Concordia University, Montreal, QC, Canada

Reviewer

Maria Wall
Division of Energy and Building Design
Department of Building and Environmental Technology
Lund University, Lund, Sweden

Solar Heating and Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency.

Our mission is *To bring the latest solar heating and cooling research and information to the forefront of the global energy transition.*

IEA SHC members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling.

Our focus areas, with the associated Tasks in parenthesis, include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54, 69)
- Solar Cooling (Tasks 25, 38, 48, 53, 65)
- Solar Heat for Industrial and Agricultural Processes (Tasks 29, 33, 49, 62, 64)
- Solar District Heating (Tasks 7, 45, 55, 68)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61, 70)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, Test Methods and LCA/LCoH (Tasks 14, 24, 34, 43, 57, 71)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58, 67)

In addition to our Task work, other activities of the IEA SHC include our:

- SHC Solar Academy
- *Solar Heat Worldwide*, annual statistics report
- SHC International Conference

Our members

Australia	France	Slovakia
Austria	Germany	South Africa
Belgium	International Solar Energy Society	Spain
Canada	Italy	Sweden
CCREEE	Netherlands	Switzerland
China	Norway	Türkiye
Denmark	Portugal	United Kingdom
EACREEE	RCREEE	
ECREEE	SACREEE	
European Commission	SICREEE	

For more information on the IEA SHC work, including many free publications, please visit www.iea-shc.org

Contents

Contents i
List of Figures .....
List of Tables .....
1 Executive Summary **1**
2 Introduction **2**
2.1 Definition of solar strategies 2
2.2 Definition of single objectives 4
2.3 Definition of composite objectives 5
2.4 Getting started 5
3 User Guide **6**
3.1 Input selection 6
3.1.1 Decision criteria and associate weights 8
3.2 Output from the user interface 9
3.2.1 Adoption score 9
3.2.2 Objective selection-based output 10
3.3 Example application cases 11
3.3.1 Single objectives case 11
3.3.2 Composite objectives case 12
4 Conclusion **14**
4.1 Future scope 14
Acknowledgements **15**
References **16**

List of Figures

Figure 1: Overall layout of the decision-making tool 2
Figure 2: Fields for the selection of neighborhood type, location climate types, objective types, and objectives ... 6
Figure 3: Decision-making tool interface field to define weights for various criteria (a) no error scenario when sum of weights equal to 1, and (b) error scenario when the total is not equal to 1 9
Figure 4: Output of the decision-making tool when a single objective is selected 10
Figure 5: Output of the decision-making tool when a composite objective of low/net-zero carbon neighborhood is selected 11
Figure 6: Solar strategies selection for various single objectives for very cold/cold climates (taken from (Hachem-Vermette et al., 2024)) 12
Figure 7: Application of the tool for very cold/cold climate to meet composite objectives of (a) low/net zero and (b) reduced total energy consumption for new and existing neighborhoods 13

List of Tables

Table 1: Description of solar strategies considered in the decision-making tool 2
Table 2: Definition of single objectives considered in the development of the decision-making tool 4
Table 3: Definition of composite objectives within the development of the decision-making tool 5
Table 4: Relationship between various single objectives and solar strategies 7
Table 5: Relationship of composite objective with various single objectives 7
Table 6: Importance of weightage to each criterion for existing and new neighborhoods 8

1 Executive Summary

The solar neighborhood decision-making tool offers a structured approach to selecting sustainable solar strategies for neighborhood development, catering to professionals such as architects, urban planners, energy planners, and policymakers. The tool considers various passive and active solar strategies, including window placement, solar chimneys, photovoltaic (PV) systems, and solar thermal collectors, to enhance building performance and reduce energy consumption. Users can customize their selections based on specific criteria such as neighborhood type, climate conditions, and objectives, and assign weights to decision criteria like ease of implementation, cost, accessibility, environmental impact, and acceptance. The tool calculates an adoption score for each strategy, summarizing its overall impact and relevance, and offers both single and composite objectives to cater to different user needs. The output of the tool provides recommendations for suitable solar strategies based on user inputs, helping users make informed decisions towards achieving their sustainability goals. Examples demonstrate how the tool can be used to select solar strategies for specific objectives in different climate types, providing valuable insights for sustainable neighborhood development.

2 Introduction

The decision-making tool for solar neighborhood planning discussed in this document offers a structured approach to choosing solar strategies for sustainable neighborhood development. Users can customize their selections based on specific criteria such as neighborhood type, climate conditions, and objectives. The tool provides recommendations for passive and active solar strategies, considering factors like ease of implementation, cost, accessibility, environmental impact, and acceptance. By assigning weights to decision criteria, users can prioritize their goals and make informed decisions. The tool calculates an adoption score for each strategy, summarizing its overall impact and relevance. Additionally, it offers both single and composite objectives to cater to different user needs, ensuring a comprehensive approach to solar strategy selection. Users may refer to (Hachem-Vermette et al., 2024) for further detailing of tool development as this document is more focused on guiding the tool's application. The tool is intended to be used by professionals such as architects, urban planners, energy planners, educators, and policymakers. Figure 1 presents the representation of the overall user interface for the developed decision making tool.

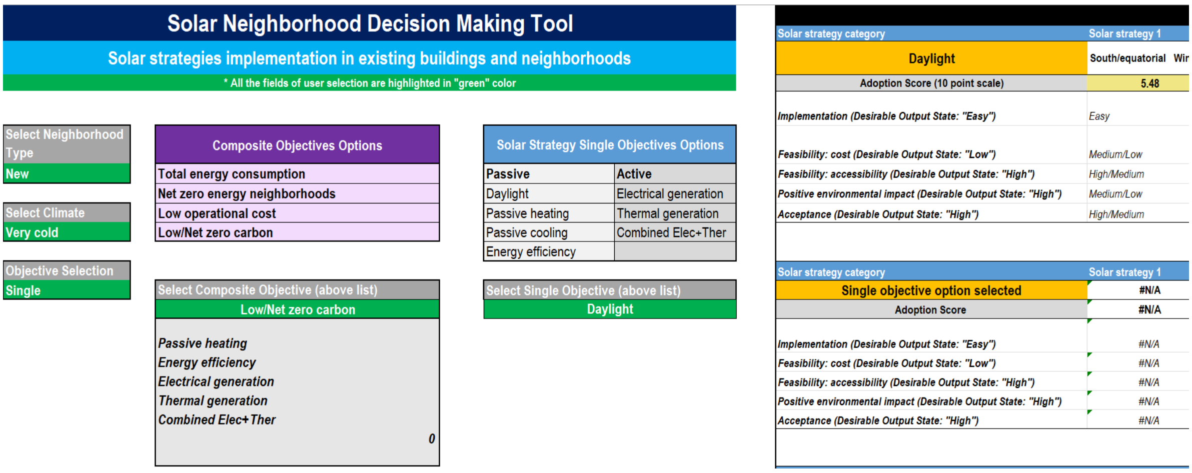


Figure 1: Overall layout of the decision-making tool

2.1 Definition of solar strategies

This decision-making tool considers various passive and active solar strategies. Passive and active solar strategies play a crucial role in sustainable building design by harnessing the sun's energy to reduce energy consumption and promote environmental stewardship. Passive strategies, such as strategic window placement and thermal mass integration, optimize natural light and heat gain. Active strategies, such as photovoltaic (PV) systems and solar thermal collectors, generate renewable energy and support heating and cooling needs. Integrating these strategies can enhance building performance, reduce utility costs, and contribute to a greener future. Table 1 presents a detailed description of all considered solar strategies in the development of this decision-making tool. However, in the current version of the tool, this list is not extensive as it does not consider other solar strategies such as shading devices, thermal mass, etc. The extensive detailing of various solar strategies can be found in report by (Hachem-Vermette et al., 2024).

Table 1: Description of solar strategies considered in the decision-making tool

Solar strategy	Description
	Passive Solar Strategies
South/equatorial window	It utilizes the concept of direct solar gain to minimize thermal energy use of the building. This strategy involves strategically placing windows and glazing, particularly on the southern or equatorial side of a building (depending upon the location such as south for Earth's upper hemisphere locations), to allow sunlight to enter the interior space. When sunlight enters space heating is enhanced by the

	greenhouse effect resulting in desirable indoor temperature during winter. Further, it also enhances the daylighting in the building. This solar strategy can be further integrated with thermal mass to store heat for evening usage.
North /non equatorial window	This strategy is useful in gaining less direct sunlight which helps in lighting as well as some passive solar heating. It enables daylighting into the building without direct glare as well as limited heat gain. Such a strategy helps avoid overheating of buildings in summer. It may be also utilized for natural ventilation. Overall, it can be a valuable solar strategy, especially for hot climates.
East/west window	East-facing windows as a solar strategy help in getting sunlight during morning hours, hence useful to gain indoor heat and daylight during winter, especially for cold climates. However, it may result in unwanted heat gain in hotter climates thus overhangs, awnings or blinds can be used still benefitting daylighting. Similarly, west-facing windows enable heat gain during the afternoon hour that can be utilized for thermal gain and daylighting in cold climates. Further, such a strategy can be sized as a desired application and can be strategically integrated with thermal masses.
Light tube	This solar strategy is sometimes also referred to as solar tube, sun tunnel, or tubular skylight. It has a dome that captures the sunlight, which is then transported indoors with the aid of a reflective tube and diffuser to enhance daylighting into the building. Such a strategy is highly beneficial to maximize daylighting and energy efficiency when the installation of windows or skylights is not possible.
Skylight	It is installed on the ceiling or roof of the building to gain natural light into the building. The skylights can be fixed and ventilated (can be opened for ventilation). This solar strategy helps improve daylighting and energy efficiency as well as promotes ventilation in case a ventilating skylight is used.
Operable windows	This solar strategy provides more controlled natural ventilation because of the ability to open and close to regulate the air flow resulting in control over indoor temperature and humidity. Additionally, it promotes energy efficiency, health, and wellbeing improving human comfort as well as can be used as emergency escapes. It includes various window types such as casement, awning, hopper, sliding, and single/double hung.
Solar chimneys	It is also known as a thermal chimney and solar updraft tower. This strategy utilizes passive solar energy to enhance natural ventilation in the building creating a solar ventilation system. A vertical shaft captures sunlight and creates a temperature difference between the air within the chimney and the surroundings. This temperature difference facilitates the air flow through the chimney resulting in natural ventilation. Essentially it has three components; a dark color collector, a shaft, and a ventilation opening. It promotes energy efficiency, indoor air quality, and natural ventilation yielding less operational cost.
Solar access	It is defined as the availability of direct sunlight in a specific location during the day and time of year. Such a strategy can be an important consideration for urban planning and architectural design as well as govern renewable energy design, daylighting, and passive solar gains. It can be accessed by solar path diagrams and solar access software.
	Active Solar Strategies
PV on roofs	Installing (photovoltaic (PV) panels on the roof is an attractive option to integrate renewable energy generation in buildings to offset electricity costs. It can be installed on a variety of roof types such as flat roofs, pitched roofs, and even irregular roofs (i.e., curved). Components include PV panels, mounting systems, inverters, and wiring. This solar strategy can be grid-tied or stand-alone (it applies to all PV strategies presented in this work). Structural integrity of the roof as well as relevant local building codes must be considered before installation of PV panels on roofs.
PV on facades	PV technology can be also integrated into building facades to generate electricity as well as serve as an architectural element. Such a strategy can be integrated into equatorial façades that receive the maximum amount of sunlight during the day. Orientation of the building, angle of the façade, shading, and structural integrity as well as local building codes must be considered before adopting PV on building facades.
PV in neighborhood surfaces	PV systems can be also integrated into various neighborhood surfaces such as streets, sidewalks, parking lots, open spaces, and unused spaces. This promotes space utilization, and energy generation, reduces the heat island effect as well, and may improve aesthetics depending upon design.
Semi-transparent PV	Such technology serves two purposes generating electricity and allowing sunlight to the indoor space. Sometimes it is also referred to as solar glass or glazing. This is commonly used as building-integrated photovoltaics (BIPV) and can be used with skylights, facades, and windows. It improves energy efficiency, aesthetics, and space utilization. However, the efficiency of such a system is lower than opaque PV panels. Careful design considerations should be considered to minimize glare and heat gain.

PV/thermal technologies	This solar strategy combines PV, and solar thermal collectors thus generating both electricity and thermal energy. Typically, thermal collectors are situated behind the PV surfaces that can capture heat for hot water, space heating, and other thermal usages in the building. Components include PV modules, thermal collectors, heat exchangers, pumps, and control systems. Due to the capture of thermal energy overall efficiency of the system can be improved. Additionally, heat energy capture regulates the temperature of PV modules thereby increasing the electrical output.
PV + heat pump	This strategy considers a PV installation integrated with a heat pump for space heating and cooling applications, where the heat pump utilizes solar-based electricity. Heat pumps may be air, water, or geothermal sourced, however, air-source heat pumps are common and easily accessible. While designing such an integrated system several factors such as the size and orientation of PV panels as well as the efficiency of the heat pump and building heating/cooling needs should be carefully considered.
STC on roofs	Solar thermal collectors (STC) can be installed on the roof to capture sunlight, heating water and air for building-related applications like water and space heating. Typically, flat plate (with dark flat plate absorber, glazing, and insulation) and evacuated tube (use glass tubes having absorber tubes with heat transfer fluid or water) STC are used for such applications. Roof orientation, structural integrity, and local building codes must be considered for such solar strategies.
STC on facades	Similar types of STC such as flat plate and evacuated tube can be used on the exterior walls of the building and be used for hot water as well as space heating applications. Façade orientation, structural integrity, and local building codes are relevant to be considered.
STC in neighborhood surfaces	Similar to PV on neighborhood surfaces, STC-based solar strategy can be also integrated into neighborhood surfaces such as streets, sidewalks, and parking lots. However, the transfer of thermal energy to a building may be challenging and costly as it may require relevant transport systems and well-insulated piping infrastructure. Orientation and shading of STC should be also considered while deploying STC on neighborhood surfaces.

2.2 Definition of single objectives

In designing solar neighborhoods, a range of objectives related to daylight, passive heating, passive cooling, energy efficiency, and solar energy generation plays a crucial role in creating sustainable, comfortable, and energy-efficient communities. In this decision-making tool, several single objectives are available for user selection as presented in Table 2. The tool is generalized to accommodate and expand the single objectives list as desired in the future.

Table 2: Definition of single objectives considered in the development of the decision-making tool

Single objective	Description
Daylight	This objective focuses on maximizing daylight access in buildings to reduce the need for artificial lighting, thus saving energy and improving occupant well-being and productivity. In solar neighborhoods, efficient daylighting design can enhance indoor comfort, improve energy efficiency, and reduce reliance on external power sources.
Passive Heating	The objective of passive heating is to utilize the sun's energy to warm indoor spaces, reducing the need for mechanical heating systems. Particularly, such an objective while designing solar neighborhoods is valuable in colder climates, where solar heat gain can help maintain comfortable indoor temperatures and lower heating costs.
Passive Cooling	The passive cooling objective aims to reduce the need for air conditioning by utilizing natural ventilation to keep buildings cool. Additionally, shading and thermal mass can be also utilized to promote passive cooling, however, so far in this work ventilation is considered to fulfill the passive cooling objective. In solar neighborhoods in hotter climates or during summer, passive cooling can help maintain comfortable indoor temperatures and reduce the overall energy consumption for cooling.
Energy Efficiency	To achieve energy efficiency as an objective for solar neighborhoods various solar strategies resulting in reduced energy demand are considered. Further, combining energy-efficient features with solar energy active systems can significantly reduce the community's carbon footprint and energy costs (such an approach is addressed in composite objectives).
Electrical Generation	This objective is related to active solar strategies that include photovoltaic (PV) systems to generate electricity to power neighborhoods. In solar neighborhoods, the adoption of PV systems can help generate clean electricity and increase energy resilience.

Thermal Generation	Thermal generation as an objective in solar neighborhood design focuses on harvesting solar energy to heat water or air for space heating, or other thermal applications. In solar neighborhoods, integrating solar thermal systems can decrease the demand for conventional heating fuels and lower greenhouse gas (GHG) emissions.
Combined Electrical + Thermal	This objective intends to combine PV and solar thermal systems for the simultaneous generation of electricity and thermal energy. This integrated approach maximizes the use of solar resources and enhances the overall energy efficiency of buildings.

2.3 Definition of composite objectives

In the context of designing solar neighborhoods, composite objectives play a crucial role in shaping the overall energy performance and environmental impact of built environments. These objectives combine various single objectives to achieve overarching targets related to energy consumption, operational cost, and carbon neutrality. In this section, four key composite objectives are discussed such as total energy consumption or low operational cost, low/net zero carbon, and net zero energy neighborhoods. Detailed description of composite objectives is presented in Table 3.

Table 3: Definition of composite objectives within the development of the decision-making tool

Composite objective	Description
Total energy consumption or Low operational cost	This objective focuses on minimizing the overall energy consumption of buildings in different climate types. It includes maximizing daylight access to reduce the need for artificial lighting, utilizing passive heating to minimize the need for mechanical heating systems, and implementing energy-efficient features to reduce overall energy demand and operational costs.
Low/Net zero carbon	This objective aims to minimize or eliminate carbon emissions associated with building operations. Strategies include passive solar strategies to reduce the need for fossil fuel-based heating, and energy-efficient features to reduce overall energy demand and carbon emissions. Further, the objective incorporates electrical and thermal generation systems to reduce reliance on carbon-intensive energy sources.
Net zero energy neighborhoods	This objective aims to design neighborhoods where the total energy consumed by all buildings is equal to the renewable energy generated within the neighborhood. Strategies include maximizing daylight, utilizing passive heating, and cooling techniques, integrating energy-efficient features, and implementing electrical and thermal generation systems to achieve net-zero energy status.

2.4 Getting started

To access the solar strategies decision-making tool from the IEA website, follow these steps:

1. Visit the IEA Task 63 website (International Energy Agency) at https://task63.iea-shc.org/.
2. Navigate to the “Software” section in the "Resources" section of the Task 63 website, or go directly to the information about the tool and the download here: https://task63.iea-shc.org/decision-making-tool
3. Click on the download link or access point to initiate the download or launch the tool online.

Once you have downloaded the tool, you will need to open it using Microsoft Excel, as it is an MS Excel-based tool. Make sure you have MS Office installed on your computer to open and use the tool effectively. If you encounter any issues during the download or access process, you may refer to the IEA website's support or help section for further assistance.

3 User Guide

This chapter explains the step-by-step approach to using the solar neighborhood decision-making tool. First, various inputs required for the tool are discussed. Thereafter, the adoption score and output from the tool are presented which aids the user in interpreting the results obtained from the tool.

3.1 Input selection

In the tool's input selection fields (Figure 2), users are presented with a range of input selection parameters to tailor their choices based on specific criteria. These parameters include the selection of neighborhood type, and distinguishing between new and existing neighborhoods, which can significantly impact the feasibility and effectiveness of solar strategies. Climate type selection is also crucial, with options ranging from very cold to very hot climates, ensuring that the chosen solar strategies are suitable for the local climate conditions. The tool is designed to accommodate single or multiple objectives, allowing users to prioritize their goals, whether it is maximizing energy efficiency, reducing carbon footprint, or optimizing cost-effectiveness.

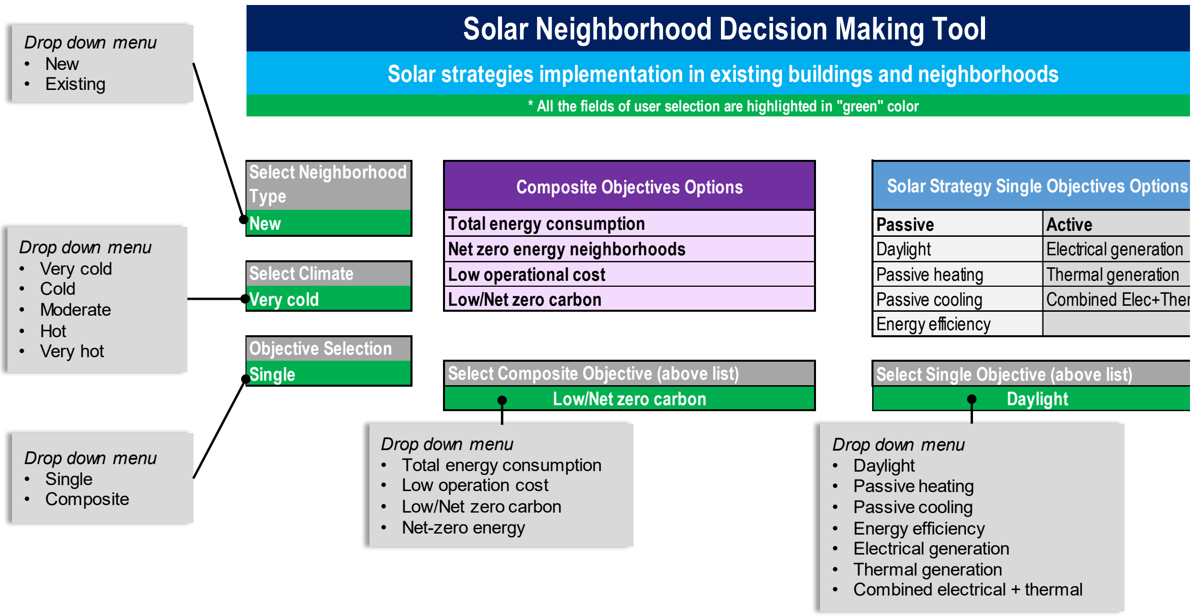


Figure 2: Fields for the selection of neighborhood type, location climate types, objective types, and objectives

In the solar strategies selection tool, users can choose between single objectives and composite objectives to tailor their selection criteria. Single objectives focus on specific aspects of solar strategies, such as daylighting, passive heating, passive cooling, energy efficiency, electricity generation, thermal generation, and combined electricity and thermal generations. These objectives allow users to target specific goals based on individual strategies. Single objectives and their respective solar strategies are presented in Table 4.

Alternatively, composite objectives offer a broader scope, encompassing multiple aspects of solar strategies and their impacts. Examples of composite objectives include total energy consumption, net-zero energy, low operational cost, and low/net-zero carbon neighborhoods. These objectives provide a more holistic view of the impact of solar strategies, considering the overall energy performance and sustainability of the neighborhood. Users can select either single objectives or composite objectives based on their specific goals and priorities. The relationship between composite and single objectives for various climate types is indicated in Table 5. The tool allows for flexibility in objective selection, ensuring that users can customize their approach to solar strategy selection based on their unique requirements and objectives. User selections within the tool will be highlighted in green, providing visual feedback and aiding in decision-making.

Table 4: Relationship between various single objectives and solar strategies

	Single objective type	Passive				Active		
	Single objective	**Daylight**	**Passive heating**	**Passive cooling**	**Energy efficiency**	**Electrical generation**	**Thermal generation**	**Combined electrical + thermal**
Solar strategy	1	South/equatorial Window	South/equatorial Window	Operable windows	South/equatorial Window	PV on roofs	STC on Facades	PV/thermal technologies
	2	North /non equatorial window	East/west window	Solar chimneys	North /non equatorial window	PV on facades	STC on roofs	PV + heat pump
	3	East/west window	Solar access		East/west window	PV in neighborhood surfaces	STC in neighborhoods	
	4	Skylight			Light tube	Semi-transparent PV		
	5	Solar access			Skylight			
	6				Operable windows			
	7				Solar chimneys			
	8				Solar access			

Table 5: Relationship of composite objective with various single objectives

Composite objective	Climate type			
	Very cold/Cold	**Moderate**	**Hot**	**Very hot**
Total energy consumption	• Daylight • Passive heating • Energy efficiency	• Daylight • Passive heating • Passive cooling • Energy efficiency	• Daylight • Passive cooling • Energy efficiency	• Daylight • Passive cooling • Energy efficiency
Low operational cost	• Daylight • Passive heating • Energy efficiency	• Daylight • Passive heating • Passive cooling • Energy efficiency	• Daylight • Passive cooling • Energy efficiency	• Daylight • Passive cooling • Energy efficiency
Low/Net zero carbon	• Passive heating • Energy efficiency • Electrical generation • Thermal generation • Combined electrical + thermal	• Passive heating • Passive cooling • Energy efficiency • Electrical generation • Thermal generation • Combined electrical + thermal	• Passive cooling • Energy efficiency • Electrical generation • Thermal generation • Combined electrical + thermal	• Passive cooling • Energy efficiency • Electrical generation
Net zero energy	• Daylight • Passive heating • Energy efficiency • Electrical generation • Thermal generation • Combined electrical + thermal	• Daylight • Passive heating • Passive cooling • Energy efficiency • Electrical generation • Thermal generation • Combined electrical + thermal	• Daylight • Passive cooling • Energy efficiency • Electrical generation • Thermal generation • Combined electrical + thermal	• Daylight • Passive cooling • Energy efficiency • Electrical generation

3.1.1 Decision criteria and associate weights

To assess various solar strategies depending upon single or composite objectives, a decision-making criterion based on adoption scores has been created. This criterion quantifies factors such as ease of implementation, feasibility (including cost and accessibility), acceptance, and environmental impact. Within the framework of the proposed decision-making tool, users have the option to assign weights to decision criteria or constraints. These weights, ranging from 0 to 1, influence the overall adoption score. Thus, Table 6 explains the importance of weightage to each criterion for both existing and new neighborhoods. To set weights to criteria for evaluating different solar strategies, the user needs to consider the importance of each criterion in achieving overall objectives. By setting weights to these criteria based on their importance to specific goals and priorities, users can effectively evaluate and compare different solar strategies to make informed decisions. A detailed sensitivity analysis can be found in (Hachem-Vermette et al., 2024) to understand the effect of varying weights corresponding to each criterion. Furthermore, Table 6 indicates the desirable output state and its interpretation that the user can use while interpreting the results from the tool under each criterion.

Table 6: Importance of weightage to each criterion for existing and new neighborhoods

Criteria	Description	Desirable Output State	Interpretation of Desirable Output State
Ease of implementation	Assign a higher weight to this criterion if the ease and simplicity of implementing a solar strategy are crucial. For example, if users prioritize strategies that can be easily integrated into existing structures without significant modifications, assign a higher weight to this criterion.	Easy	The desirable output state is "Easy," the implementation of solar strategies that are simple and can be easily integrated into new/existing structures without significant modifications.
Cost	If cost-effectiveness is a key factor, assign a higher weight to the cost criterion. This will prioritize solar strategies that offer the best value for money in terms of initial investment and long-term savings.	Low	The desirable output state is "Low," indicating the cost-effectiveness of solar strategies that offer the best value for money in terms of initial investment.
Accessibility	Consider assigning a higher weight to accessibility if the availability and ease of access to the required technology and resources are critical. This criterion can help users prioritize strategies that are readily available in the market.	High	The desirable output state is "High," indicating the availability and ease of access to the required technology and resources is easy.
Positive Environmental impact	If reducing environmental impact is a top priority, assign a higher weight to this criterion. This will prioritize solar strategies that have a lower carbon footprint and contribute positively to environmental sustainability.	High	The desirable output state is "High," indicating strategies with a lower carbon footprint and positive contribution to environmental sustainability.
Acceptance	Assign a higher weight to acceptance if public perception and acceptance of the solar strategies are important. This criterion can help users prioritize strategies that are more likely to be embraced by the community or stakeholders.	High	The desirable output state is "High," indicating strategies that are more likely to be embraced by the community or stakeholders.

Furthermore, Figure 3 illustrates the decision-making tool interface, showcasing the field where users can define weights for various criteria. In the first scenario (Figure 3a), the user has correctly assigned weights, resulting in a sum equal to 1. This indicates a valid and properly balanced set of weights for the criteria, ensuring the tool functions accurately. However, in the second scenario (Figure 3b), the user has made an error by assigning weights that do not add up to 1. This situation requires the user to adjust the weights to ensure they total 1, as an incorrect sum can lead to skewed results and inaccuracies in the decision-making process.

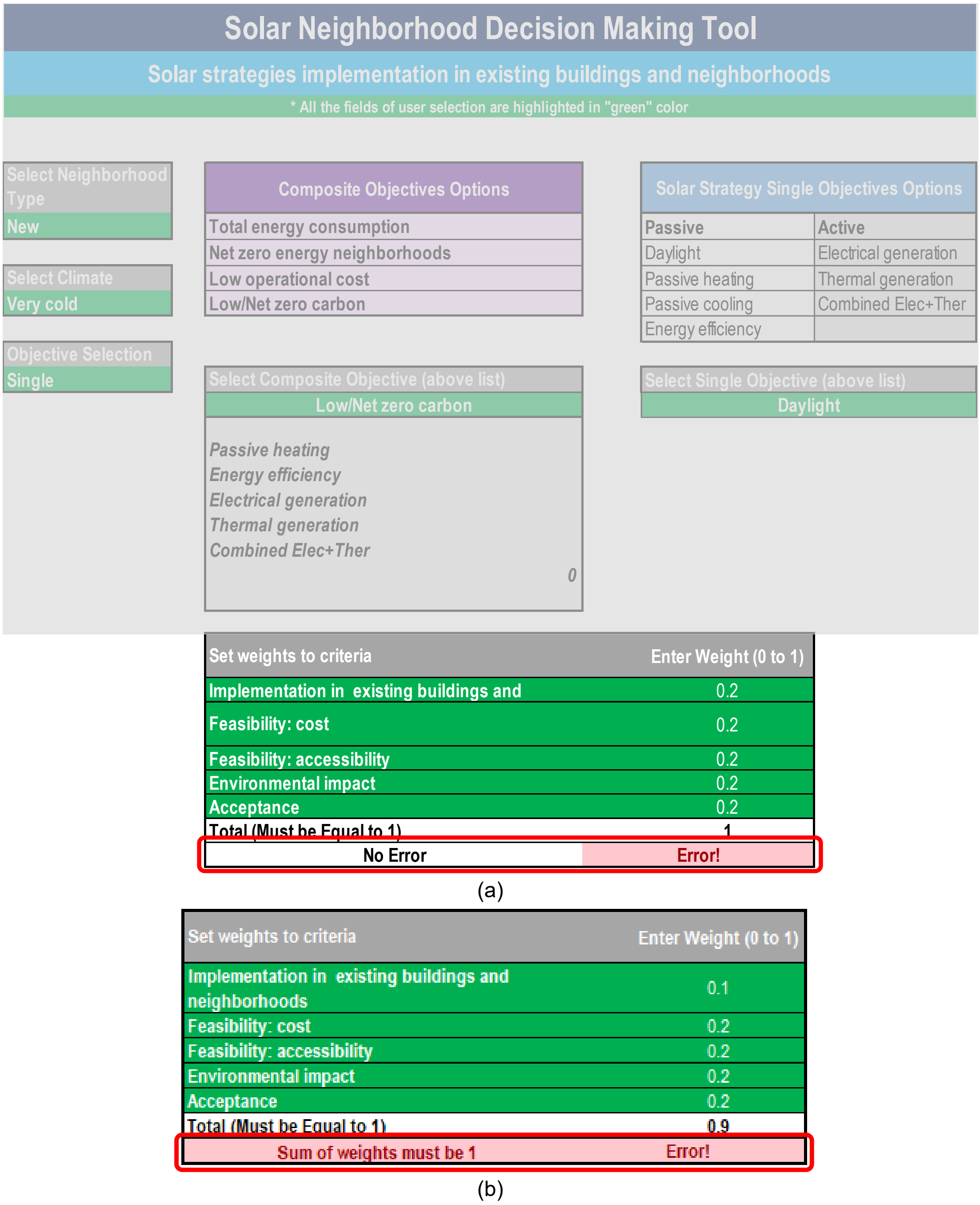


Figure 3: Decision-making tool interface field to define weights for various criteria (a) no error scenario when sum of weights equal to 1, and (b) error scenario when the total is not equal to 1

3.2 Output from the user interface

Users can customize the tool by selecting their objectives, weather conditions, and neighborhood types, as well as assigning weights to decision criteria. Based on the selection, the user can visualize the adoption score for each strategy depending on the selected inputs. This section first explains the details of the adoption score and then discusses the output from to decision-making tool in the events of selecting single and composite objectives.

3.2.1 Adoption score

The total adoption score for each solar strategy is calculated to summarize the combined impact of all evaluation scores across various categories, including implementation, cost, accessibility, environmental impact, and acceptance. Equation 1 is introduced in this study to compute this score.

$$S_{ad,overall} = [W_i S_i - W_c S_c + W_a S_a + W_{ei} S_{ei} + W_{ac} S_{ac}] \quad (1)$$

The overall adoption score ($S_{ad,overall}$), is a comprehensive metric influenced by several factors. For example, S_i represents the implementation score, which is evaluated separately for new and existing neighborhoods. Additionally, scores for cost (S_c), accessibility (S_a), environmental impact (S_{ei}), and acceptance (S_{ac}) contribute to the overall adoption score. The weights assigned to these factors (represented as W_i, W_c, W_a, W_{ei} and W_{ac}) can be customized based on the user's priorities in the decision-making process. To facilitate interpretation, the overall adoption score is converted into a 10-point scale for easier understanding. For more details, see (Hachem-Vermette et al., 2024).

3.2.2 Objective selection-based output

Figure 5 illustrates the output of the decision-making tool interface, based on the selection of objectives (single or composite), weather type (very cold, cold, moderate, hot, or very hot), and neighborhood type (new or existing) as well as weights to decision criteria (as explained in section 3.1.1.). In the case of composite objective, the selection tool then suggests a set of relevant single objectives based on these selections. Subsequently, the decision-making process considers the adoption of solar strategies and implements criteria/constraints to suggest suitable solar strategies for the neighborhood. Figure 4 shows the output of the decision-making tool when the user selects a single objective such as increasing daylighting for a new neighborhood in a very cold climate, defining equal weights to each criterion or constraint. Figure 5 illustrates the output of the decision-making tool when a composite objective of achieving a low or net-zero carbon neighborhood is selected. In this scenario, the tool provides a comprehensive set of single objectives to achieve selected composite objectives under given input conditions (i.e., a new neighborhood in a very cold climate defining equal weights to each criterion in this case). These recommendations may include a mix of passive and active solar strategies, as well as other sustainable practices, aimed at reducing carbon emissions and promoting environmental sustainability within the neighborhood. The tool may also provide insights into the feasibility, cost-effectiveness, and environmental impact of each recommended strategy, helping users make informed decisions toward achieving their low or net-zero-carbon goals. Further, based on the adoption score, users can prioritize the relevant solar strategies and make decisions for implementation.

OUTPUT								
Solar strategy category	Solar strategy 1	Solar strategy 2	Solar strategy 3	Solar strategy 4	Solar strategy 5	Solar strategy 6	Solar strategy 7	Solar strategy 8
Daylight	South/equatorial Window	North /non equatorial window	East/west window	Skylight	Solar access	Light tube	0	0
Adoption Score (10 point scale)	5.48	5.36	5.32	4.62	5.20	3.78	#N/A	#N/A
Implementation (Desirable Output State: "Easy")	*Easy*	*Easy*	*Easy*	*Easy/Easy, depending on other constraints (e.g. cost)*	*Easy/Easy, depending on other constraints (e.g. cost)*	*Easy, depending on other constraints (e.g. cost)*	#N/A	#N/A
Feasibility: cost (Desirable Output State: "Low")	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	#N/A	#N/A
Feasibility: accessibility (Desirable Output State: "High")	*High/Medium*	*High/Medium*	*High/Medium*	*High/Medium*	*High/Medium*	*Medium*	#N/A	#N/A
Positive environmental impact (Desirable Output State: "High")	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	#N/A	#N/A
Acceptance (Desirable Output State: "High")	*High/Medium*	*High/Medium*	*High/Medium*	*High/Medium*	*High/Medium*	*Medium*	#N/A	#N/A

Solar strategy category	Solar strategy 1	Solar strategy 2	Solar strategy 3	Solar strategy 4	Solar strategy 5	Solar strategy 6	Solar strategy 7	Solar strategy 8
Single objective option selected	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Adoption Score	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Implementation (Desirable Output State: "Easy")	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Feasibility: cost (Desirable Output State: "Low")	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Feasibility: accessibility (Desirable Output State: "High")	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Positive environmental impact (Desirable Output State: "High")	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Acceptance (Desirable Output State: "High")	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Figure 4: Output of the decision-making tool when a single objective is selected

OUTPUT								
Solar strategy category	Solar strategy 1	Solar strategy 2	Solar strategy 3	Solar strategy 4	Solar strategy 5	Solar strategy 6	Solar strategy 7	Solar strategy 8
Passive heating	South/equatorial Window	East/west window	Solar access	0	0	0	0	0
Adoption Score (10 point scale)	5.48	5.32	5.20	#N/A	#N/A	#N/A	#N/A	#N/A
Implementation (Desirable Output State: "Easy")	*Easy*	*Easy*	*Easy/Easy, depending on other constraints (e.g. cost)*	#N/A	#N/A	#N/A	#N/A	#N/A
Feasibility: cost (Desirable Output State: "Low")	*Medium/Low*	*Medium/Low*	*Medium/Low*	#N/A	#N/A	#N/A	#N/A	#N/A
Feasibility: accessibility (Desirable Output State: "High")	*High/Medium*	*High/Medium*	*High/Medium*	#N/A	#N/A	#N/A	#N/A	#N/A
Positive environmental impact (Desirable Output State: "High")	*Medium/Low*	*Medium/Low*	*Medium/Low*	#N/A	#N/A	#N/A	#N/A	#N/A
Acceptance (Desirable Output State: "High")	*High/Medium*	*High/Medium*	*High/Medium*	#N/A	#N/A	#N/A	#N/A	#N/A
Solar strategy category	Solar strategy 1	Solar strategy 2	Solar strategy 3	Solar strategy 4	Solar strategy 5	Solar strategy 6	Solar strategy 7	Solar strategy 8
Energy efficiency	South/equatorial Window	lorth /non equatorial windo	East/west window	Light tube	Skylight	Operable windows	Solar chimneys	Solar access
Adoption Score	5.48	5.36	5.32	3.78	4.62	5.10	3.21	5.20
Implementation (Desirable Output State: "Easy")	*Easy*	*Easy*	*Easy*	*Easy, depending on other constraints (e.g. cost)*	*Easy/Easy, depending on other constraints (e.g. cost)*	*Easy/Easy, depending on other constraints (e.g. cost)*	*Easy, depending on other constraints (e.g. cost)*	*Easy/Easy, depending on other constraints (e.g. cost)*
Feasibility: cost (Desirable Output State: "Low")	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*High/Medium*	*Medium/Low*
Feasibility: accessibility (Desirable Output State: "High")	*High/Medium*	*High/Medium*	*High/Medium*	*Medium*	*High/Medium*	*High/Medium*	*Medium/Low*	*High/Medium*
Positive environmental impact (Desirable Output State: "High")	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*	*Medium/Low*
Acceptance (Desirable Output State: "High")	*High/Medium*	*High/Medium*	*High/Medium*	*Medium*	*High/Medium*	*High/Medium*	*Medium/Low*	*High/Medium*
Solar strategy category	Solar strategy 1	Solar strategy 2	Solar strategy 3	Solar strategy 4	Solar strategy 5	Solar strategy 6	Solar strategy 7	Solar strategy 8
Electrical generation	PV on roofs	PV on facades	PV in neighborhood surfaces	Semi-transparent PV	0	0	0	0
Adoption Score	5.08	4.19	3.90	3.87	#N/A	#N/A	#N/A	#N/A
Implementation (Desirable Output State: "Easy")	*Easy/Easy, depending on other constraints (e.g. cost)*	*Easy/Easy, depending on other constraints (e.g. cost)*	*Easy, depending on other constraints (e.g. cost)*	*Easy, depending on other constraints (e.g. cost)*	#N/A	#N/A	#N/A	#N/A
Feasibility: cost (Desirable Output State: "Low")	*Medium*	*High/Medium*	*Medium*	*High/Medium*	#N/A	#N/A	#N/A	#N/A
Feasibility: accessibility (Desirable Output State: "High")	*High/Medium*	*Medium*	*Medium/Low*	*Medium*	#N/A	#N/A	#N/A	#N/A
Positive environmental impact (Desirable Output State: "High")	*Medium*	*High/Medium*	*Medium*	*High/Medium*	#N/A	#N/A	#N/A	#N/A
Acceptance (Desirable Output State: "High")	*High/Medium*	*Medium*	*Medium*	*Medium*	#N/A	#N/A	#N/A	#N/A
Solar strategy category	Solar strategy 1	Solar strategy 2	Solar strategy 3	Solar strategy 4	Solar strategy 5	Solar strategy 6	Solar strategy 7	Solar strategy 8
Thermal generation	STC on facades	STC on roofs	STC in neighborhoods	0	0	0	0	0
Adoption Score	3.56	4.41	3.57	#N/A	#N/A	#N/A	#N/A	#N/A
Implementation (Desirable Output State: "Easy")	*Easy, depending on other constraints (e.g. cost)*	*Easy/Easy, depending on other constraints (e.g. cost)*	*Moderate/Easy, depending on other constraints (e.g. cost)*	#N/A	#N/A	#N/A	#N/A	#N/A
Feasibility: cost (Desirable Output State: "Low")	*High/Medium*	*High/Medium*	*High/Medium*	#N/A	#N/A	#N/A	#N/A	#N/A
Feasibility: accessibility (Desirable Output State: "High")	*Medium/Low*	*High/Medium*	*Medium/Low*	#N/A	#N/A	#N/A	#N/A	#N/A
Positive environmental impact (Desirable Output State: "High")	*High/Medium*	*Medium*	*High/Medium*	#N/A	#N/A	#N/A	#N/A	#N/A
Acceptance (Desirable Output State: "High")	*Medium/Low*	*High/Medium*	*Medium*	#N/A	#N/A	#N/A	#N/A	#N/A
Solar strategy category	Solar strategy 1	Solar strategy 2	Solar strategy 3	Solar strategy 4	Solar strategy 5	Solar strategy 6	Solar strategy 7	Solar strategy 8
Combined Elec+Ther	PV/thermal technologies	PV+heat pump	0	0	0	0	0	0
Adoption Score	4.36	4.65	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Implementation (Desirable Output State: "Easy")	*Easy/Easy, depending on other constraints (e.g. cost)*	*Easy/Easy, depending on other constraints (e.g. cost)*	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Feasibility: cost (Desirable Output State: "Low")	*High/Medium*	*High/Medium*	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Feasibility: accessibility (Desirable Output State: "High")	*High/Medium*	*High/Medium*	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Positive environmental impact (Desirable Output State: "High")	*High/Medium*	*High/Medium*	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Acceptance (Desirable Output State: "High")	*High/Medium*	*High/Medium*	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

(b)

Figure 5: Output of the decision-making tool when a composite objective of low/net-zero carbon neighborhood is selected

3.3 Example application cases

In the examples, the selection of solar strategies is tailored to meet specific objectives, whether single or composite considering very cold/cold climates demonstrating sample results obtained from the tool.

3.3.1 Single objectives case

Figure 6 presents a collection of solar strategies tailored to meet specific goals in very cold/cold climates, with each criterion given equal weight. For instance, various window types, such as south or equatorial windows, north or non-equatorial windows, and east-west windows, along with solar access, are all considered equally important for enhancing daylighting compared to alternatives like skylights and light tubes. However, the overall adoption score remains moderate due to the uniform weighting of criteria like ease of implementation, cost, accessibility, environmental impact, and acceptance. For passive heating, strategies involving south, or equatorial windows and solar access are favored, while for passive cooling, operable windows receive a moderate score. On the other hand, the solar chimney has a low overall adoption score, primarily due to its high cost and lower acceptance, especially in cold climates. When assessing energy efficiency across all eight solar strategies considered, most strategies, except for skylights, light tubes, and solar chimneys, show similar overall adoption scores. In terms of meeting the specific objectives of electrical and thermal generation, active strategies are preferred, with rooftop systems being more popular than façade and neighborhood surface installations. Additionally, hybrid electric and thermal strategies receive lower adoption scores when considering cost.

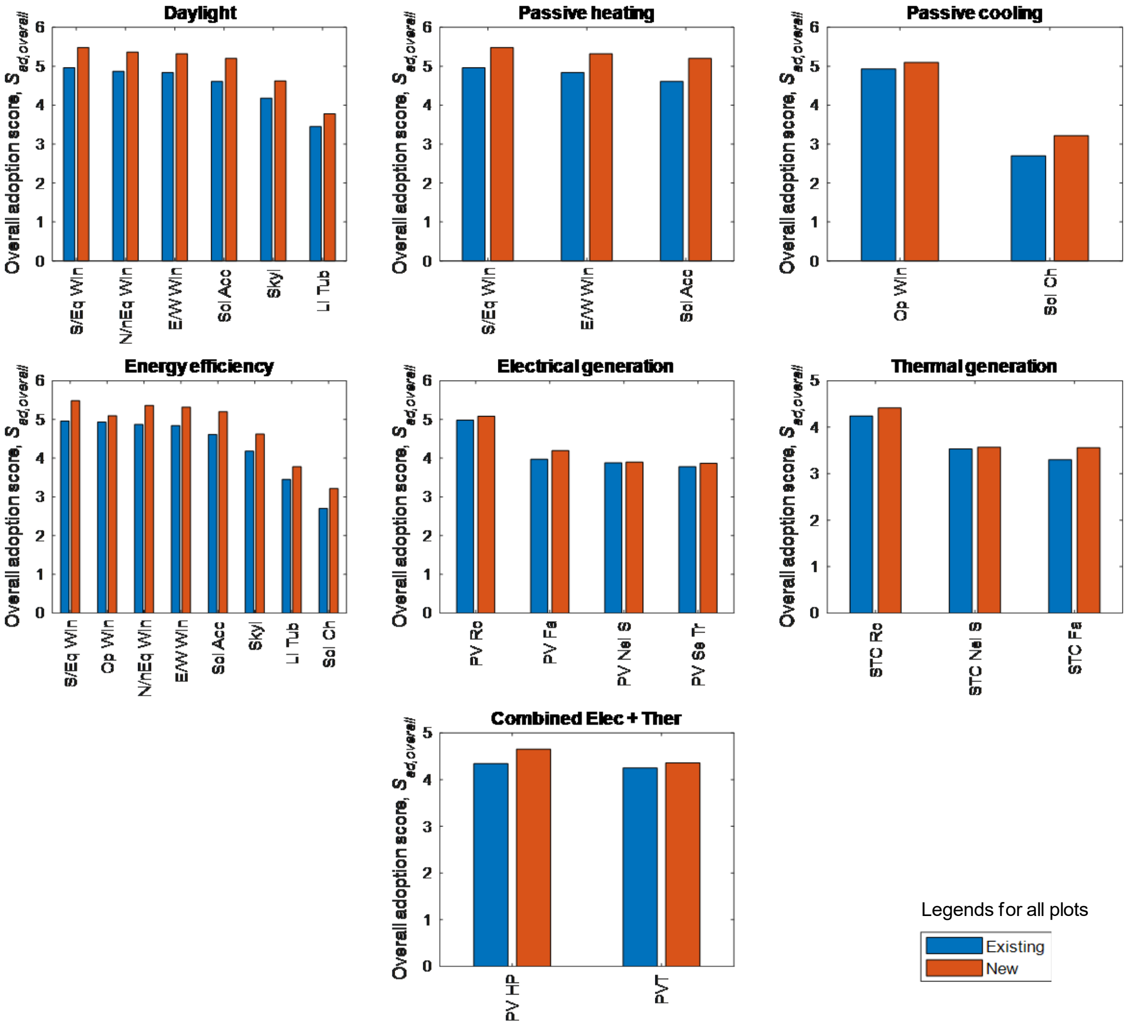


Figure 6: Solar strategies selection for various single objectives for very cold/cold climates (taken from (Hachem-Vermette et al., 2024)**)**

3.3.2 Composite objectives case

Figure 7 depicts the assessment of solar strategies for achieving two composite objectives: low/net zero neighborhoods and reduced total energy consumption in new and existing neighborhoods assigning equal weight to each criterion. In Figure 7a, PV on roofs is identified as the most desirable strategy, with passive strategies like incorporating various types of windows following closely behind. Conversely, for the objective of reduced total energy consumption (Figure 7b), passive strategies are favored, with windows being the top choice, followed by solar access, skylights, and light tubes. Solar chimneys are rated as the least preferred strategy for reducing total energy consumption.

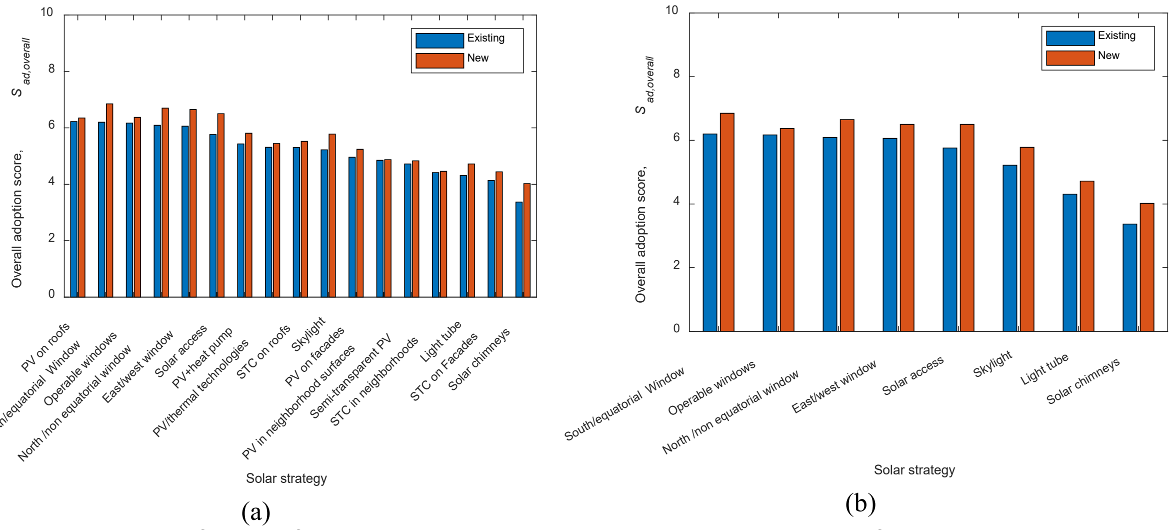


Figure 7: Application of the tool for very cold/cold climate to meet composite objectives of (a) low/net zero and (b) reduced total energy consumption for new and existing neighborhoods

4 Conclusion

The solar neighborhood decision-making tool offers a structured approach to selecting solar strategies for sustainable neighborhood development. By considering various passive and active solar strategies, users can customize their selections based on specific criteria such as neighborhood type, climate conditions, and objectives. The tool provides recommendations for both single and composite objectives, allowing users to prioritize their goals and make informed decisions. The tool calculates an adoption score for each strategy, summarizing its overall impact and relevance based on factors such as ease of implementation, cost, accessibility, environmental impact, and acceptance. By assigning weights to decision criteria, users can tailor the tool to their unique requirements and objectives. The tool's output provides users with a clear understanding of the most suitable solar strategies for their neighborhood, helping them create sustainable, energy-efficient communities. Overall, the solar neighborhood decision-making tool offers a comprehensive approach to selecting solar strategies, facilitating the design of environmentally friendly and energy-efficient neighborhoods. Its user-friendly interface and customizable features make it a valuable resource for urban planners, architects, and developers seeking to integrate solar energy into their projects.

4.1 Future scope

The tool is in its early stages, and several limitations need addressing in future work. The pilot testing focused on sending surveys to a limited population, comprising IEA SHC Task 63 experts, to assess survey effectiveness, and response variability, and to build the tool's basic structure. To facilitate user visualization, an automatic graph generation feature indicating results will be added to the tool. Future efforts will refine the survey design, determine a more accurate sample size, and include diverse professionals (e.g., architects, engineers, planners, and developers) to improve the tool's effectiveness. Sensitivity analyses will estimate the impact of sample size on results. Considering the dynamic nature of solar energy, energy efficiency technologies, regulations, and economic conditions, regular updates to the tool are necessary to prevent data and prioritization from becoming outdated. Future research aims to enhance assessment accuracy, conduct scenario analyses to evaluate uncertainties and response variations and incorporate variables that quantitative data may miss.

Acknowledgements

Participants of Task 63 are duly acknowledged for their participation and feedback for this research work activities.

References

C. Hachem-Vermette, K.S. Grewal, G. Desthieux, J. Hasan, and S. Yadav (2024), *Strategies for the Design of New and Existing High Energy Performance Solar Neighborhoods,* Report A1, IEA SHC Task 63, 2024, DOI: https://doi.org/10.18777/ieashc-task63-2024-0003