

Solar Architecture in Energy Engineering

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Solar Architecture represents the confluence of the two disciplines of energy engineering and architecture. The concept of Solar Architecture defines a decision-making process to select, design, deploy, and operate solar energy-enabled solutions for environments where solar energy resources are part of the energy mix. The principles of Solar Architecture include maximizing solar energy harvesting from solution's surfaces with a positive balance of energy, carbon, and cost provided by the solution. Solar Architecture application selection is built on two major cornerstones, features and groups, defining the best options in energy engineering of a solar solution. Solar surfaces are key to solar architecture. They are the "heart", and balance-of-system components are the "muscles" of solar solutions. Addressing energy losses in photovoltaic, solar to thermal, and solar to chemical energy conversion allows for increasing energy harvesting yield. Life Cycle Assessment and solar energy harvesting methodologies based on solar surface characteristics define Solar Architecture Balance. This balance allows for defining energy, carbon, and cost return on investment for solar solutions and selecting the best solution for related assets/environment.

Keywords: solar architecture ; energy engineering ; solar solution ; application category ; application group ; solar surface ; energy conversion ; energy harvesting ; energy losses ; solar irradiation ; life cycle assessment ; balance ; carbon ; cost ; return on investment

This Solar Architecture guide describes the practice of efficiently and productively harnessing the main source of external energy supplying our planet, solar energy. Solar energy is vital to life on Earth, accessible to everybody, and transformable to other key sources of energy such as electrical, thermal or chemical.

To harvest solar energy, sunlight must strike a surface. We are surrounded by these surfaces in the built and natural environment.

Optimized "solar surfaces" are always well organized. In the natural world, photosynthetic plants are the most sophisticated practitioners of solar architecture. In the built environment, there are more challenges in achieving both practical and beautiful solutions. As Vitruvius famously said, one must strive to achieve "firmness, commodity, and delight".

Energy engineers know that "solar surfaces" are essential to energy harvesting but not the only part of it. Solar energy harvesting is provided by a "system" in which solar surfaces are the core. Depending on the nature of an engineering solution, the balance-of-system components may differ from each other and vary from application to application.

This guide describes how Solar Architecture in Energy Engineering enables solar energy harvesting.

History

Energy engineering is one of the emerging engineering disciplines, based on energy sustainability and involving energy efficiency and clean energy concepts for and approaches to any environment.

We believe that energy engineers were among the first to recognize the value and importance of energy in our environments, and our ability to use and leverage energy in our lives. They led the engineering community in its understanding of the importance of solar energy, and of the tools for solar energy conversion into electricity and thermal energy with its further use in thermochemical and thermodynamic applications.

The history of moving solar energy into the mainstream of engineering practices is well known.

Solar energy has been recognized and used through many centuries of human history. In early settlements around the world, the Sun has typically been a key factor in the design and construction of indigenous buildings.

However, the first large-scale energy engineering attempt was successfully achieved in space in the 1960s and 1970s by spacecraft [1][2].

The leadership of energy engineers has had a practical result: practices “in space” through designing, building, and launching spacecraft led to practices “on Earth”, and advancements in materials and costs allowed for mainstreaming solar solutions.

Solar energy harvesting achievements through thinking and sharing were merged with leadership, knowledge, and skill in architecture, the art and technique of designing and building [3]. In the energy crisis of 1970s, architects took the “relay race baton” in Solar Architecture passed to them by the minds of engineers. An example in Canada is The Ark, a 1970s experiment in sustainable living in Prince Edward Island, PEI [4].

Sustainable architecture thinking continued to grow. The visions, concepts, and strategies of Solar Architecture demonstrating an approach to “change the face of architecture” [5] and expressing “in built form ... a new direction in the development of mankind” [6] started being publicly discussed by building architects and engineers in the very early 21st century.

Establishing the Solar Architecture approach as “the basis for all buildings” was seen as an immediate transition in practices that would allow clean energy planning, development, and operations to be integrated in new and existing buildings.

As solar energy use in buildings became better understood by its users, solar engineers helped utilities to catch up in the 2000s and 2010s. This brought to action utility-scale solar power plants and defined opportunities for commercial and residential rooftop solar power generation solutions. Energy engineers also worked with urban planners to promote and create urban photovoltaic [7] and rural agrivoltaic [8] landscapes.

These achievements in the 2010s and 2020s have been extended to much broader areas: advanced exterior and interior building envelopes, residential microgrids and grid-interactive efficient buildings, electric mobility and its charging infrastructure—all enabled with solar energy resources and energy-engineered. These practices also contributed to new solar energy standards for open outdoor spaces and landscapes.

Today, we apply our energy engineering knowledge and skills to every existing aspect of solar energy in our daily lives.

Solar Architecture Principles

The Solar Architecture approach and vision is built on a key junction of two fields of activity: energy engineering and architecture.

Energy Engineering, based on principles of sustainability, is an increasingly critical discipline as humanity grapples with the transition from fossil fuels to renewables. Solar energy engineering is becoming one of the key engineering endeavors to negotiate that transition.

Architecture is the process and the product of planning, designing, constructing, and operating solutions [9]. Initially involving buildings, landscapes, urban design, and naval and seismic applications, architecture evolved in many modern techniques or fields for structuring abstractions in system engineering [10].

The “Solar Architecture” vision addresses solutions with embedded solar energy harvesting built on “solar surfaces” and bringing solar energy resources.

The guiding Solar Architecture Principles supporting this vision are defined as follows:

- > Maximize solar energy harvesting on solution’s surfaces.
- > Maximize positive energy, carbon, and cost balance in solution’s life cycle.

Definitions

The following definitions are used in this guide.

Energy Resources:

Energy resources are resources for the continuous provision of energy through energy generation, transmission, distribution, storage, and consumption chain.

Solar energy resources are resources available for continuous provision of solar energy through chemical, thermal, or photovoltaic energy transformation.

Energy Harvesting:

Energy harvesting is the process by which energy is extracted in an environment from sources such as solar energy, wind energy, tidal energy, etc.

Solar energy harvesting is the process of extraction of energy by solar energy resources such as photovoltaic, concentrated solar, or thermal solar resources.

Solution:

Energy-enabled solution is a solution for providing energy resource mix for built, industrial, and entertainment environments.

Solar energy-enabled solution (solar solution) is a solution for providing energy resources for environments where solar energy resources are part of the energy mix.

Energy Engineering Practice:

Energy engineering practice includes:

- Selecting and comparing solution options for energy resources;
- Choosing the best option in terms of energy resources, their use, cost, and carbon footprint; and
- Deploying and maintaining the use of the chosen energy resource mix.

Sustainable energy engineering practice:

- Selects and compares solution options for energy resources where renewable energy is a growing and preferably—a dominating resource in the energy mix; and
- Minimizes the use, cost, and carbon footprint of the energy mix.

Solar energy engineering practice is focused on:

- Selecting and comparing solution options for solar energy resources; and
- Deploying and maintaining the use of solar energy resources.

Sustainable Architecture:

Sustainable architecture minimizes harmful impacts to communities and the ecosystem at large through “improved efficiency and moderation in the use of materials and energy” ^[11].

Solar Architecture is a sustainable system architecture addressing solar energy harvesting capability embedded in solar solutions.

Solar Architecture Balance:

Solar architecture balance is a set of Solar Architecture metrics. It includes:

- Energy balance—the difference between solar energy harvested by the solution (the energy absorbed by the solution’s solar harvesting surfaces over its life cycle) and energy embedded in a solution;
- Carbon balance—the difference between carbon saved (the carbon dioxide not emitted by a solution or an environment the solution is a part of due to the solution’s operations during its life cycle) and carbon embedded in the solution; and

- Cost balance—the difference between the saved cost of energy (the cost that would be paid to a utility/energy service provider should the solution not use solar energy harvested by the solution in its operations over the life cycle) and the cost of the solution components and operations.

Life Cycle Assessment:

Life Cycle Assessment (LCA) is an analysis technique to assess environmental impacts of a product over the entire period of its life.

Period of Use:

The period of use is defined by the solution's durability (the ability to last over time, resisting wear, breakage, deterioration, etc.) during its life cycle.

Decision-making:

Decision making is a process ensuring the best solar solution selection.

Using the above definitions, this guide describes Solar Architecture in Energy Engineering as a decision-making process to select, design, deploy, and operate solar energy-enabled solutions. It starts with choosing solar solutions applicable to a set of assets in a target environment; defines solar surfaces and related energy harvesting technologies; assesses energy, carbon, and cost balance over the life cycle of these solutions; and completes with final decisions on the best solution option selected.

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