# SOLAR APPLICATION and INTEGRATION

Active and passive solar systems and equipment - those elements which capture the sun's energy for heating bath and wash water; heating swimming pools for extended season use; generating electricity to power devices; cooking food; warming and cooling buildings, etc.

Solar equipment use is growing in Arizona neighborhoods, cities and towns. Buildings are incorporating solar as part of the basic equipment package. People want to use solar equipment because it is cost effective, resource saving, simple to use and understand, and there is a logical, direct and unencumbered energy resource in the sun as it moves across the sky

Solar applications and technology which provide for a building's performance and resident needs, is no longer some "future" thing. Today, solar elements and equipment are a growing part of the mainstream palette of a building, along with electric service and meters, piping, water heaters, fire sprinkler systems; air conditioners and coolers, etc.

All of these are integral elements to a buildings' operation in meeting needs as well as comforts. To this list, and in many cases, replacing some items on the list, Arizonans are incorporating solar devices, equipment, and design elements.

Reasons for this incorporation may vary - from saving money to saving the environment, and the applications range from use of solar hot water heaters to photovoltaic panels to cool towers. Whatever the reason, the resultant application of solar strategies and equipment have a physical and visual impact on the built environment.

Just as in the use of any other type of equipment, the use of solar equipment can have a direct impact upon a building - its' performance, its' look, functional layout, and even its' form and shape. At the same time, the building also has an impact upon the optimal use of solar strategies and equipment, affecting both placement and performance. .

# ISSUE

## Codes, Covenants, and Restrictions

As Arizona's population and economy grow, there is also growth in the building market. Increasing numbers of people need more buildings, and meeting the need for more buildings results in developments and subdivisions. These developments reflect the public desire and demand for value. neighborhood identity and integrity, and to this end, developments often have defined conditions of building and site appropriateness, identified as Covenants, Conditions and Restrictions (CC&R).

Historically, CC&Rs were drafted to mitigate, among other things, unsightly installations of roof mounted equipment - television aerials, evaporative coolers and heating/air conditioning equipment

Definitive CC&R's established an aesthetic standard in order to maintain visual integrity, which was believed to be a primary element in maintaining property value. Today, subdivision requirements have a common restriction - no equipment visible on a building, most notably on the roof.

Unfortunately, this "no equipment on the roof" restriction comes into conflict with optimal conditions of solar equipment placement, effective solar equipment utilization, good solar design, and sometimes even in direct conflict with Arizona law. Ideally, the installation of solar equipment should achieve optimum performance for the owner, but restrictive CC&Rs have negatively impacted performance by forcing placement of equipment in situations of limited exposure to the sun; locations that require longer runs (of piping, wiring, etc.) than necessary; locations which require restrictive, and sometimes costly, screens; and/or placement of equipment in less than optimum exposure angle to the sun - each and all of which provide less than optimal results for the owner.

Recently, in litigation involving a Home Owner Association's (HOA) attempt to restrict resident use of solar equipment on building rooftops (the only, and most effective, place it could be used), Arizona courts ruled against the restriction, and reinforced the solar rights of Arizona citizens.

The Arizona Solar Energy Industries Association (ARISEIA) has initiated workshops and activities with HOAs throughout Arizona to provide appropriate standards of solar equipment incorporation, and solar installation guidelines, in order to mitigate future conflicts between homeowners and HOAs, and to meet State legislative intent. To this end, the Arizona. Department of Commerce Energy Office has supported this endeavor, and continues to be a resource for Arizona citizens.

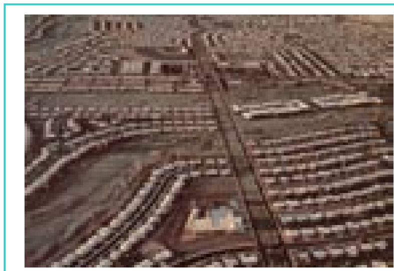
# ISSUE

## Design and Aesthetics

The desire for optimum equipment performance is sometimes in conflict with site and building conditions, especially with existing buildings.. Poorly oriented or sloped roof conditions require use of mounting structures to achieve optimum and correct relationship between equipment and the solar resource.

While effective in establishing proper orientation and attitude of solar panels, these installations project a discontinuity with the building form and design, and are perceived by many as unsightly appendages to otherwise attractive buildings.

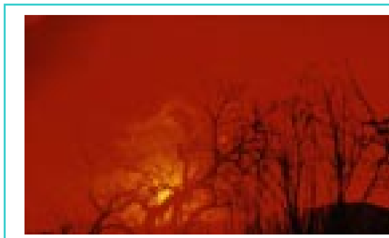
Today's Arizona subdivisions have fallen away from response to local conditions into copying stylistic characterizations (California Style, Santa Fe style, etc.), instead of evolving an appropriate environmental response which would result in a truly Arizona style.  Subdivisions are laid out with numerous considerations - density, views, circulation, etc. but with little or no consideration for basic tenets of good energy, solar and environmental design.



Energy issues are dealt with by adding insulation and efficient mechanical systems without consideration of using the positive aspects, or mitigating the negative impacts, of the site and the climate to reduce both the amount of equipment used, and amount of energy required to run it.

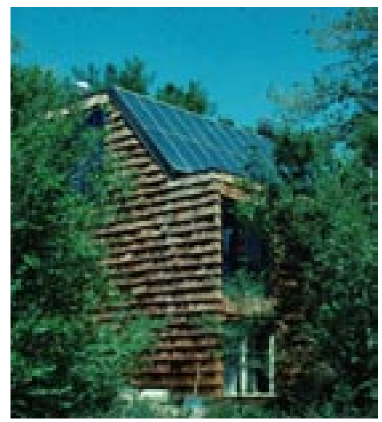
Effective energy actions involving orientation, building shape, space planning, glazing, and/or incorporation of active and passive solar and energy efficient equipment as part of the building are overlooked. Desert houses face west into the intense sun; roofs are flat in snow country; inordinate areas of glass wrap buildings, and building forms and structure do not readily allow for integration of solar equipment as part of the building fabric.

While the idea and the ideal of maintaining a neighborhood character and quality is desirable, current design and construction practices make integration of solar strategies and equipment problematic, and when coupled with restrictive CC&Rs, provide conditions for conflict, litigation and unhappiness - all which are counter to the heart of a neighborhood environment and value (one of belonging and being a part of shared community), and being able to use Arizona's most prevalent resource - the sun.



# Integration

Solar integration is easily implemented in the design and construction of a new building  - equipment and solar element incorporation can be executed to make the project a seamless and integrated "whole". Proper building orientation and siting can be established.  Appropriate building form can simplify the incorporation of equipment into the structure. Proper space planning can optimize the distribution systems related to solar equipment use (piping, wiring, etc



Problematic is the integration of solar devices and elements into the existing Arizona building stock.

Existing buildings come in an array of orientations, forms, roof shapes, construction and materials - some are very compatible with use of solar strategies and integration of equipment, and others are not, posing negative conditions for the owner wishing to use solar.

Even award winning Arizona architecture suffers from poor energy considerations, with glass walled boxes in the dessert. Poorly planned existing building sites may not have any appropriate location for a solar installation. Building roofs may not have appropriate angle or orientation to the sun. Restrictive CC&Rs may prohibit the placement of equipment on a effective south facing roof, or require screening that may effectively reduce equipment performance, or force placement of equipment in locations, which effect performance.

Whether it be new or old buildings, Arizonans respond positively to the idea of an integrated "whole". New construction and additions can provide a solar continuity that is more acceptable than and those that look stuck on and have an incompatibility of material or form.  What is needed is a result, which meets both the functional requirements of the equipment and aesthetic sensibilities of the people, providing the best for Arizonans and Arizona architecture.

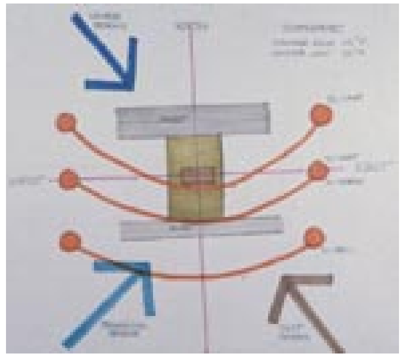
## SOLAR EQUIPMENT INTEGRATION & AN APPROPRIATE ARCHITECTURE

The sun's movement is in a predictable pattern. As the earth makes its annual elliptical trip around the sun, its axial tilt provides for the seasonal changes in the northern hemisphere. The summer sun is high overhead and its appearance and impact are longer in duration and more intense during summers, whereas the sun's appearance is shorter in duration and lower in the horizon as it traverses the winter sky. Like all applications that use the sun's energy, exposure is a primary and critical element. While simple direct exposure will get results, ideal positioning provides the optimum performance of any piece of solar equipment or strategy, whether it is a solar water heater, a photovoltaic panel, a solar cooker or even a passive solar heated building.

The 3 primary aspects of optimizing performance of solar equipment are uninterrupted exposure to the sun through orientation; appropriate angle to the sun (tilt angle); and effective placement.

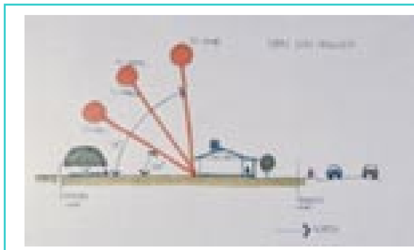
### Orientation

Maximum performance of solar equipment and passive heating strategies is based on continued exposure to the sun. Outputs are optimized when there is clear connection to the sun for the entirety of daylight hours - the more exposure to the sun, the more water can be heated, the more electricity generated, and the more heat can be collected for comfort. Collector locations must be face the sun's path as it traverses the south sky, free of shade, for the entirety of daylight hours



### Tilt Angle

Solar water heating is most effective when it can provide hot water under coldest conditions - i.e. winter. The winter sun is lower on the horizon so the ideal angle of a collector should more vertical (to 45 degrees). Solar pool heating is more in demand in the colder parts of the year so this angle of exposure can be equally important. PV modules tilted at an angle equal to the local latitude give the maximum yearly output for a fixed tilt mounting. This tilt angle is a very necessary condition for optimizing solar equipment use.



**Positioning** and orientation have significant impact upon the performance of any system. Location of equipment is a critical consideration. Placement optimizes conditions by having short runs of delivery - water heated by a solar collector should have as short a run to the storage and/or use as possible to minimize transfer heat losses. Electrical installations benefit from short connections to control systems. Reduced runs mean less material, less labor and materials for installation, less maintenance in the future, and less overall cost.

### Toward Energy Architecture

An additional benefit of solar equipment placement is one that directly impacts the shape and form of a building, adding visual interest as a byproduct of the solar functionality. Passive solar buildings take their form and shape from the direct relationship in using natures resources. - Elongation along the East/West axis provides more southern exposure and minimizes unwanted east and west exposures to intense summer sun; roof forms and/or elements which incorporate solar equipment and strategies; vertical forms of cooling tower projections; recessed windows and doorways for thermal tempering; and colors and textures which take advantage or mitigate conditions.

## APPLICATIONS AND EXAMPLES

Implementation of solar equipment and solar strategies have a range of options, from integration on site to integration as part of a building.

Currently, there are 2 major pieces of solar equipment - solar water heater systems (panels, piping, storage) and photovoltaic systems (modules, wiring, electrical equipment, electrical "storage" for off grid installation). There are also a number of other pieces of solar applications like cookers, roof ponds, thermal chimneys, cool towers, etc.

Arizonans have been resourceful, creative and ingenious in the incorporation of solar equipment and strategies. Rural Arizona with less governmental restriction, more sense of rootedness, and more commitment to using solar and renewables have been in the forefront of solar integration and use. The variations of solar integration range across the State from urban areas to rural sites, and they all are responses to conditions, type of equipment and application, and needs of their Owners.

### Equipment Placement Adjacent the Building

*** Ground Mounting -**

If there is appropriate access to the sun, ground mounting has been used successfully for fixed photovoltaic arrays as well as individual modules on trackers, which follow the course of the sun to optimize operation. Panels mounted in open areas on a site allow for freedom of operation and movement necessary for a tracking system, and/or for ease of installation, access for maintenance and adjustment for both tracking and fixed systems.

Rural Arizona application of this strategy has been applied to passive water heating (thermosiphon), or for radiant floors. Since hot water rises, and cold water settles, the thermosiphon system has the collector lower than the tank or application. This convective loop runs continuously as the sun shines

Some applications with south sloping sites, place collector panels lower than the floor level of the house (and storage tank) to capitalize on the thermosiphon effect of this passive approach.

In these ground-mounting applications, solar equipment is located in response to the ease of location; ease of access, and direct and easy maintenance, or in response to the terrain, equipment type, and end use. Some installations have integrated equipment as part of a building element such as a porch.

In all cases, proper orientation as well as proper tilt angles can be easily achieved, thereby having equipment operate at its optimum in providing electricity and/or hot water.

### *Separate Building Mount -

Sometimes, equipment is mounted on an adjacent structure. Photovoltaic systems that are completely off-grid and provide all of electrical service and power needs, require an extensive amount of batteries in order to store enough electricity for nighttime and overcast day usage.

Batteries require a well-ventilated area. Some applications provide a dedicated structure for this purpose, and incorporate the photovoltaic panels onto the roof, and equipment such as inverters and controls are placed within the structure, thereby minimizing runs between panels, inverters, and storage

Solar water heating systems used for heating pool water in order to extend the swimming season can be incorporated into trellis and shading structures that are part of a patio and pool area. Since there is no necessity for storage (the pool water is heated directly) this provides a direct connection with short runs and minimal line loss inefficiencies.

## Equipment Placement on the Building

Equipment can be mounted directly on buildings as separate attachments. While solar equipment can be attached to any part of a building that has good southern exposure, the most advantageous location may be at the roof. Roofs generally provide a condition of unencumbered and unshaded access to the sun's path, and the location puts equipment out of the way. Additionally, a roof appli-cation may allow for placement of equipment directly above other elements of a system (hot water tank area or mechanical room for photovoltaic equipment, etc.) thereby reducing runs which then reduce installation and materials costs.

Ideal exposure of photovoltaic and solar water heating panels is at an angle that maximizes the performance of the equipment. Since the winter sun is available for a shorter time than in the summer, and is lower to the horizon, water heating equipment performance is optimized when tilted perpendicular to the sun's rays. Photovoltaic placement is more variable and dependent on time of year usage.

Unfortunately, most buildings are not designed for inclusion of these optimal exposures and angles and Arizonans have had to apply creativity to attaining performance from the solar systems they are using.

### * Rack installations

Equipment can be placed on building mounted racks which place panels at the correct orientation and angle to the sun, mitigating. conditions of poorly oriented and sloped roofs. While effective in providing proper conditions for equipment performance, these installations are perceived as unsightly and incompatable with the building design.

To address the issue of visual discontinuity some installations have incorporated screens, which prevent viewing the equipment and racks. While screening can be executed in a manner to blend with the building architecture in flat roof situations, it is much more problematic in pitched roof and poor orientation conditions. Screening and other such visual barriers must be large enough and spaced from the equipment sufficiently enough in order to minimize shading which negatively impacts performance.

## Flush Mounting

Equipment is placed flush to existing roof slopes in order to provide a visually compatible installation with the architecture. of the building Arizona owners and contractors have successfully installed solar equipment that is accommodating to existing roof slope configurations. While effectively addressing the aesthetic issue, such placements result in less than optimal performance of equipment due to less than ideal orientations.

## INTEGRATION NOW

Solar Integration - Combining building structure and form; optimal functional requirements of solar strategies; and solar equipment into the fabric of a building as a single, unified expression. Integration combines solar equipment and strategies as a part of the building fabric and architectural expression and design, sometimes coupling multiple energy and resource efficiency strategies. The building planning, design and construction provide appropriate conditions for energy efficient operations and integration of active and passive solar equipment.

## Solar Integrated Buildings

A solar integrated building incorporates ideal conditions for both passive and active solar applications, from space heating and cooling to power generation to incorporation of solar hot water systems. Integrated energy buildings, and building elements, are correctly located in terms of orientation, and exposure to the sun and correctly structured to provide appropriately angled roofs and elements for optimal solar equipment performance. Additionally, an integrated solar energy building is one that evolves its design and expression - its character and style - from the attributes of its solar (active and passive) and energy.

Integrated systems solar buildings vary in execution and expression, even while maintaining common attributes and premises related to environmental conditions and resources in both passive and active solar applications

## Integrated Photovoltaic Systems

New developments in photovoltaic systems are bringing panels that both generate electricity and are part of the building system. This dual function application easily incorporates to solar building design and construction that provides appropriate roof pitches for optimum solar exposure.

The photovoltaic system, a solid state semiconductor technology converting the sun's energy directly to electricity, without moving parts, or making noise, is developed as a Building Integrated PV system which integrates photovoltaic technology into the building construction, sometimes replacing or integrating with existing building materials that form the structure's exterior "skin" - i.e. the roof or wall system. The PV system then becomes a dual-purpose element, not only generating electricity for the inhabitants but also acting as the roof and/or wall of segment of the building.

Appropriately oriented and pitched roofs are also compatible for inclusion of solar hot water panels that benefit from ideal exposure and placement, and benefit the building aesthetic with integrated design elements much like skylights, that add visual interest.

## Integrated Solar/Energy Building Elements –

Not all integrated energy applications must encompass entire roofs on a monolithic building block. Buildings derive aesthetic interest from component elements like clerestorey windows, chimney structures, overhangs and facial designs, and from building massing and variations in wall planes.

The integrated solar energy building incorporates solar equipment and applications. North facing rooftop clerestories can provide structure for south facing solar equipment on the back side, thereby combining two functions - one of introducing daylight - the other of producing hot water and/or electricity, within the same structural element.

This solar/day lighting element can also include operable windows and glazing to facilitate building natural ventilation exhaust of unwanted interior heat. Now there are four functions for one building element.

It provides natural illumination; it provides for natural ventilation and building cooling; it provides a place for solar water or photovoltaic panels, and it provides an interesting and dramatic building design element

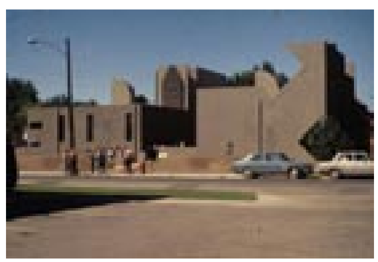
Multiple functional building elements are a strategy that lends itself to solar installations in existing buildings. While it may not be desirable to incorporate a solar device into an existing building because of installation costs related to that single action, it may be quite feasible and desirable to do a specific modifying action that has multiple benefit providing energy free illumination by day lighting; no-energy cooling by ventilation; no energy venting of undesirable hot air, and low energy water heating with the integrated solar equipment.

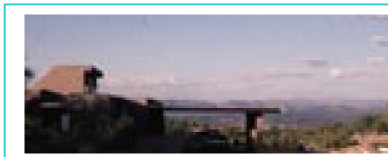
The integration approach meets multiple needs in a single action, and the energy efficiency/solar equipment savings realized will pay for itself and the construction in reduced energy bills and increased property value.

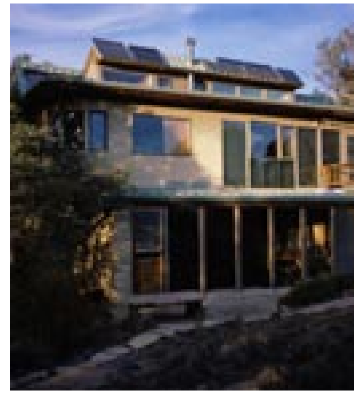
Solar applications are a growing reality in the building landscape. Traditional perceptions of aesthetics, appropriateness, and value are changing in response to the realities of energy and environmental considerations, need for energy security, and desire for energy stability and self-sufficiency.

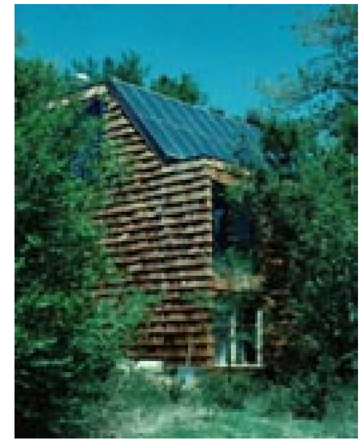
Buildings are incorporating environmental design strategies in response to site conditions, and available natural resources, and are incorporating solar strategies and equipment, which in turn affect building design and construction. Solar architecture is evolving as integrated energy buildings that define themselves in a form and expression that reflects local conditions and resources – a local environmental vernacular

The careful and considerate integration of solar, energy and environmental elements into the building, whether existing or new, is a benefit that manifests itself as the basis of a truly indigenous and local architecture.









This information was prepared by the Arizona Solar Energy Association & the Arizona Solar Center Inc. for the Arizona Department of Commerce Energy Office under a contract from the U.S. Department of Energy Million Solar Roof Program

NOTE: Financial support for this presentation has been provided by the Arizona Department of Commerce (Energy Office) and the U.S. Department of Energy through (DOE) Grant No. DE-FG51-01R021250. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of the Energy Office or U.S. DOE. The State of Arizona and U.S. DOE assume no liability for damages arising from errors, omissions or representations contained in this presentation.