Solar Ready Building Design Guidelines

Solar Ready Building Design Guidelines for the Twin Cities, Minnesota

What I'm going to conclude . . .

1. **The choice is ours.** Solar energy can be a major component of Minnesota's energy mix in the near term, if we make the choice
2. **Buildings are infrastructure.** The design choices we make today can constrain or enable future market opportunities. Design to accommodate the future.

What is ‘Solar America Communities’?

- Twenty-six cities across the nation serving as laboratories of solar market transformation tools. Cities included a wide variety of local circumstances:
  - Outstanding, good, and adequate solar resources
  - Expensive, average, and low electricity costs
  - Social/political environments committed to climate protection, and social/political environments in denial

Solar Cities

Minneapolis Saint Paul

- Program goals were to promote market expansion of solar technologies through deployment of solar systems in visible locations, market identification, and technical outreach.

  - Build a solar infrastructure leading to a quintupling of market penetration of solar electric capacity in the Twin Cities by 2010
  - Develop a long-term strategic plan for the sustainable large-scale deployment of solar technologies in the Twin Cities by 2015
  - Demonstrate leadership by example by expanding the use of solar technologies in public buildings

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Solar Cities

Minneapolis Saint Paul

- Demonstrate leadership by example by expanding the use of solar technologies in public buildings

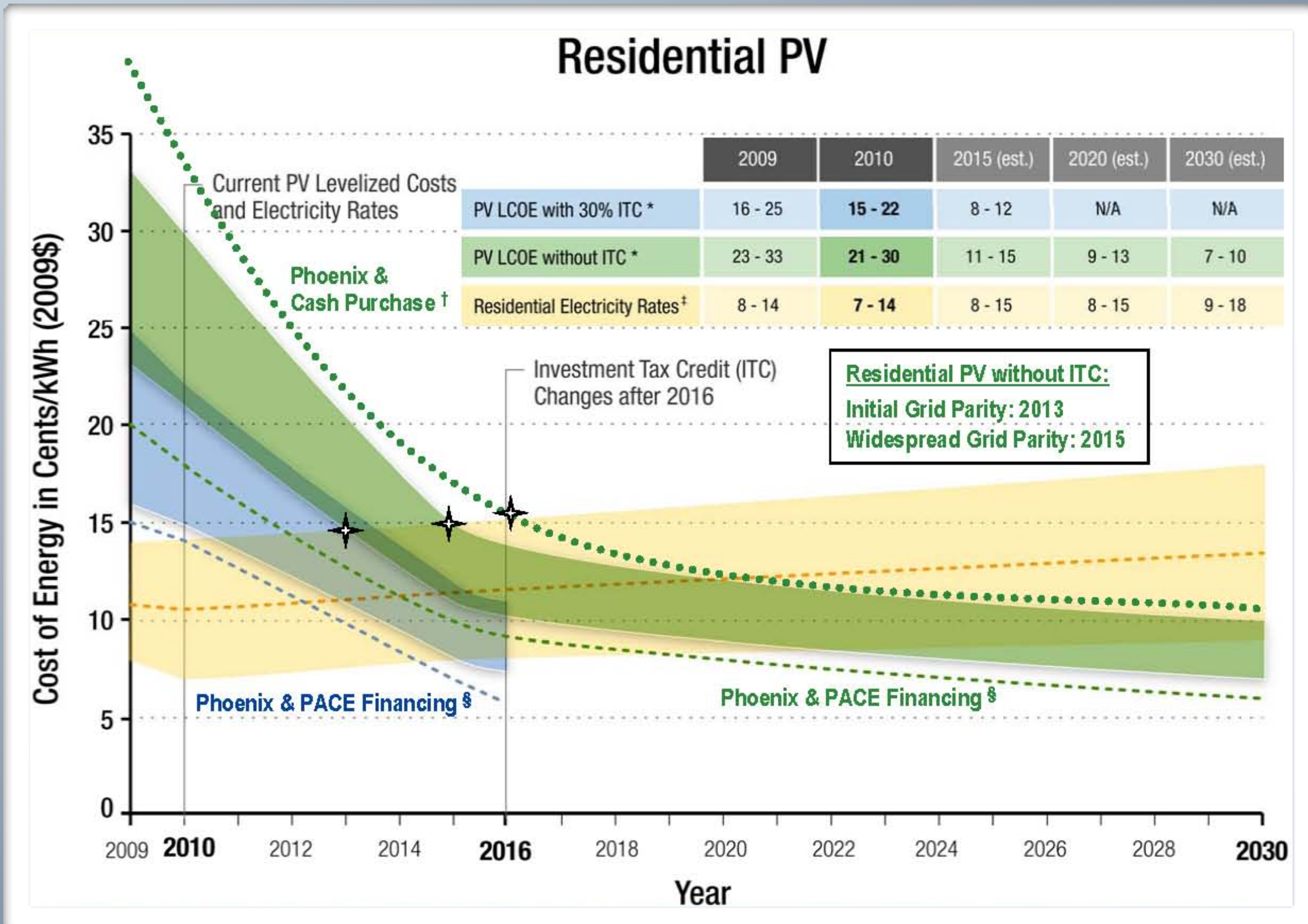
What Is Market Transformation?

- Changing the way the market for a particular good or service operates in order to better capture value or otherwise achieve societal benefit
  - Accelerating along the cost curve
  - Removing market barriers
  - Fixing market failures

What Is Market Transformation?

- The Solar America Cities market transformation efforts include creating tools to accelerate our movement along the declining cost curve . . .

What Is Market Transformation?



	2009	2010	2015 (est.)	2020 (est.)	2030 (est.)
PV LCOE with 30% ITC *	16 - 25	**15 - 22**	8 - 12	N/A	N/A
PV LCOE without ITC *	23 - 33	**21 - 30**	11 - 15	9 - 13	7 - 10
Residential Electricity Rates‡	8 - 14	**7 - 14**	8 - 15	8 - 15	9 - 18

What Is Market Transformation?

Residential PV: LCOE Targets

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

<u>Financing Mechanisms</u>

- Home Mortgage (80% financing, 6.0% interest, 30-year term)
- Home Equity Loan (100% financing, 7.75% interest, 15-year term)

<u>Geographic Locations</u>

- Phoenix, AZ
- Kansas City, MO
- New York, NY

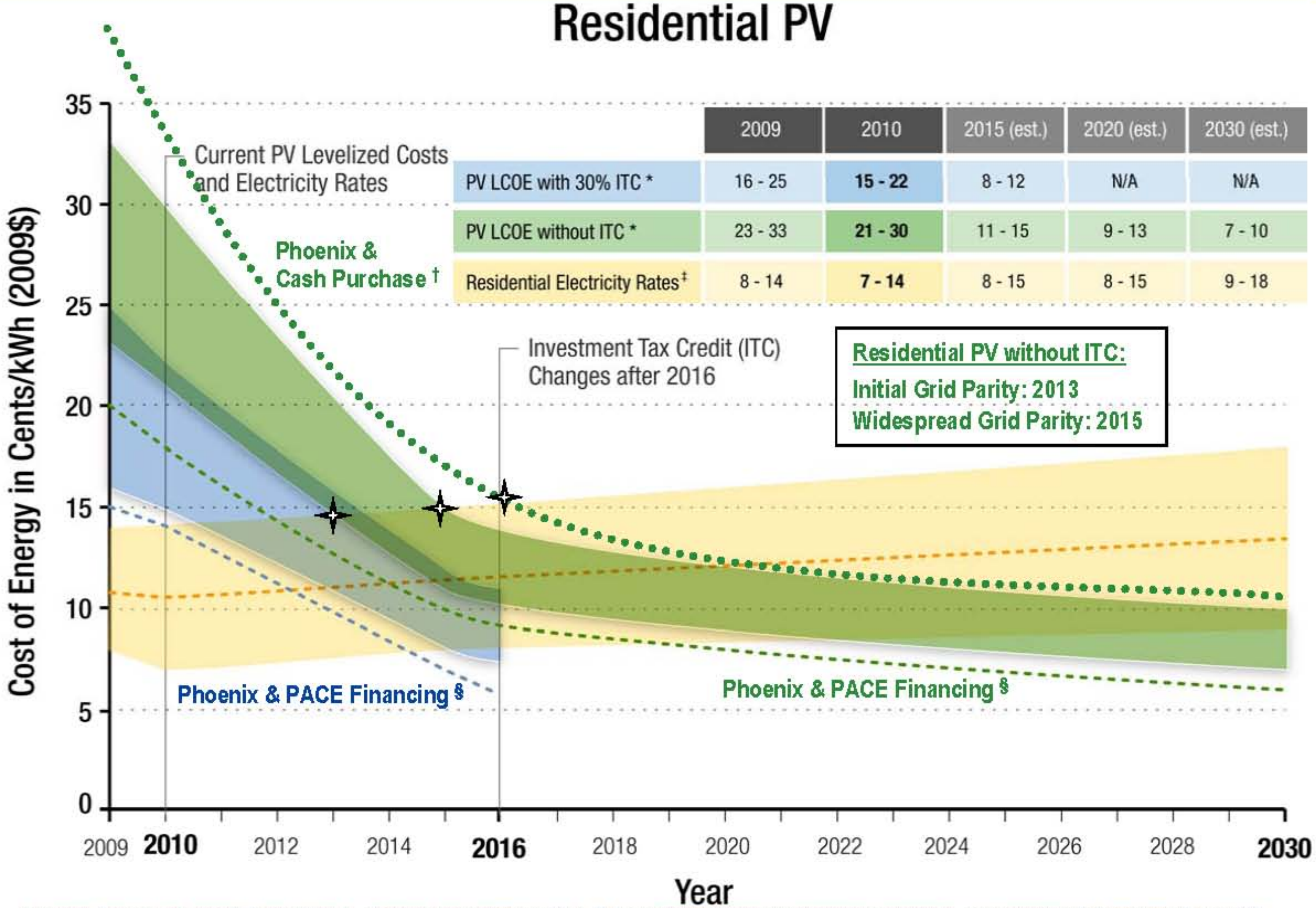
<u>2015</u>

- Without the ITC, PV is broadly competitive with residential electricity rates under all financing and insolation conditions

<u>2030</u>

- Without the ITC, PV has levelized costs that are lower than most residential electricity rates

Residential PV



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* No state, local or utility incentives are included. The range in residential PV LCOE is due to different insolation and financing conditions. For a complete list of assumptions, see DOE Solar Cost Targets (2009 – 2030), in process.

‡ The electricity rate range represents one standard deviation below and above the mean U.S. residential electricity prices.

§ Property Assessed Clean Energy (PACE) Financing assumes 100% financing at 5.0% interest with a 20-year payback schedule

† Cash purchase assumes a discount rate of 9.2% (nominal), equal to the long term return on the S&P 500

What Is Market Transformation?

- BUT . . . The solar energy revolution will not occur when solar becomes a cost-effective resource.
- Energy efficiency, which has long been a cost effective resource, still requires market transformation efforts.
  - Market barriers
  - Market failures

What are Local Barriers?

- What are local barriers to wide-scale adoption of cost-effective solar energy?
  - Barriers in the physical landscape
  - Barriers in the economic landscape
  - Barriers in the social/political landscape

Physical Barriers

- The Minneapolis Saint Paul area has lots of empty roof space for capturing our solar resource.

However . . .

- Building roofs were not been designed to accommodate solar technologies.
- Buildings and infrastructure were not placed on the landscape (subdivision, site design, etc) to accommodate solar energy capture.



Removing Physical Barriers

- The Minneapolis Saint Paul area has lots of empty roof space for capturing our solar resource.

However . . .

- Streamline the process and reduce costs for retrofitting buildings that can accommodate solar
- Investigate structural building modifications that will allow solar installations to be placed on buildings that cannot readily accommodate solar
- Create a "solar-ready" building specification geared to Minneapolis and Saint Paul housing and small commercial construction, to limit future physical barriers to solar installation

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Removing Physical Barriers

- Create a “solar-ready” building specification geared to Minneapolis and Saint Paul housing and small commercial construction, to limit future physical barriers to solar installation

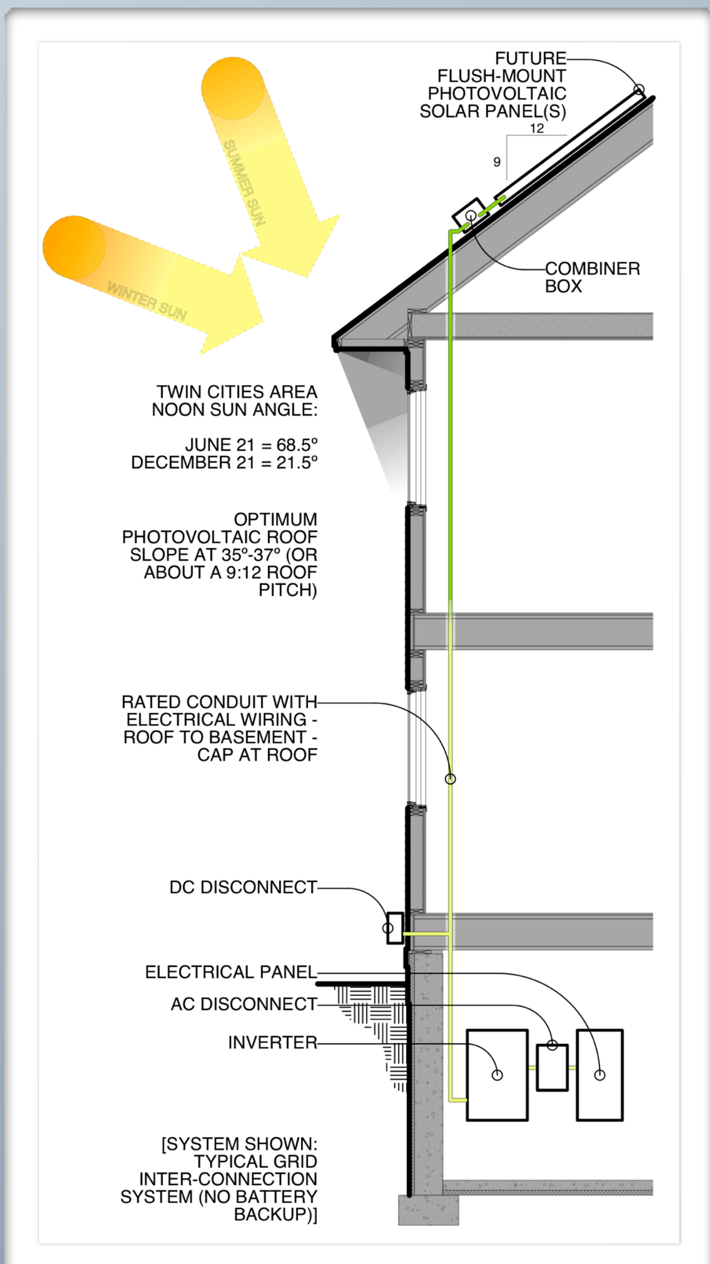
1. Understand why existing buildings create a market barrier

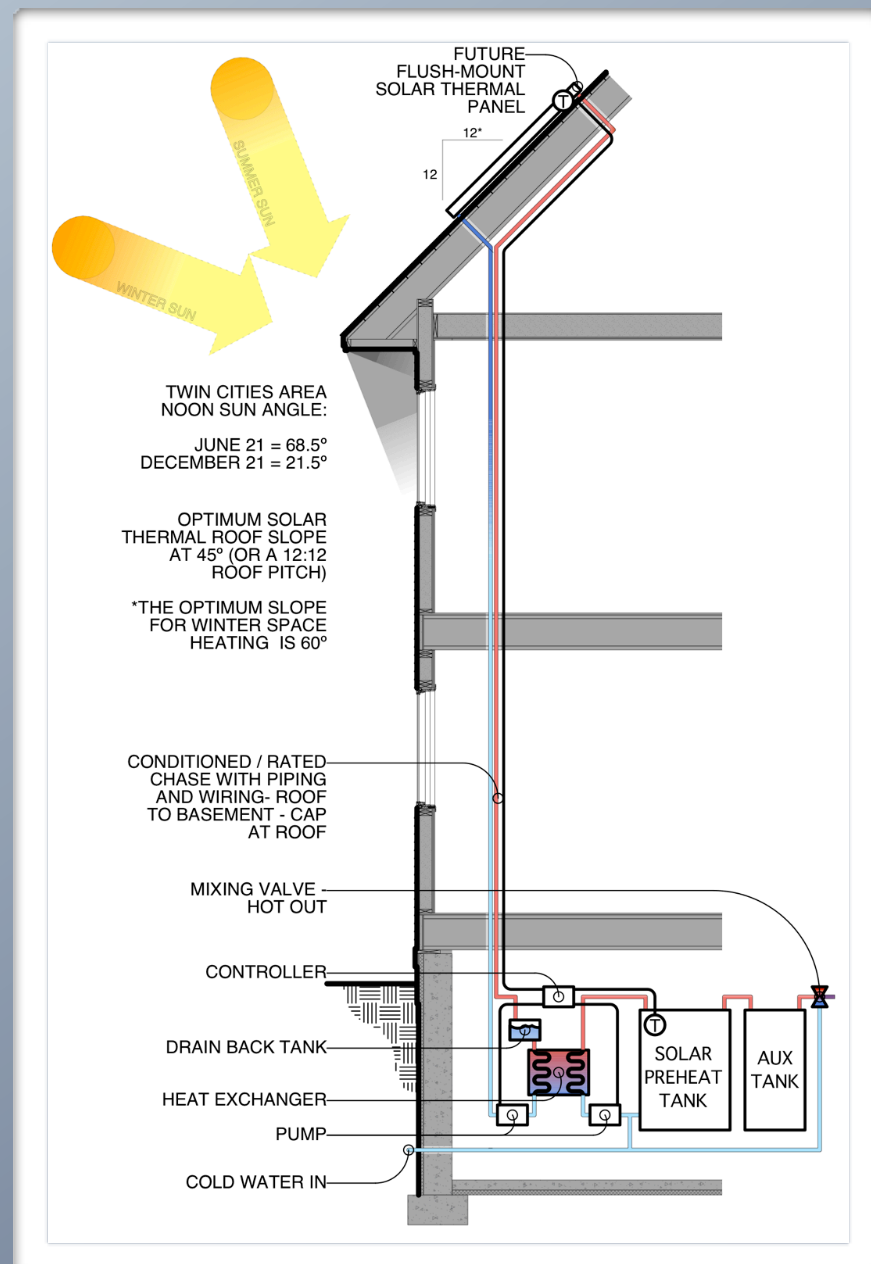
- Define “solar ready” in the context of problems with existing buildings
- Provide guidance to incorporate solar ready concepts in the design process and the construction process

Solar Ready Building Design Guidelines

Solar Ready Building Design Guidelines for the Twin Cities, Minnesota

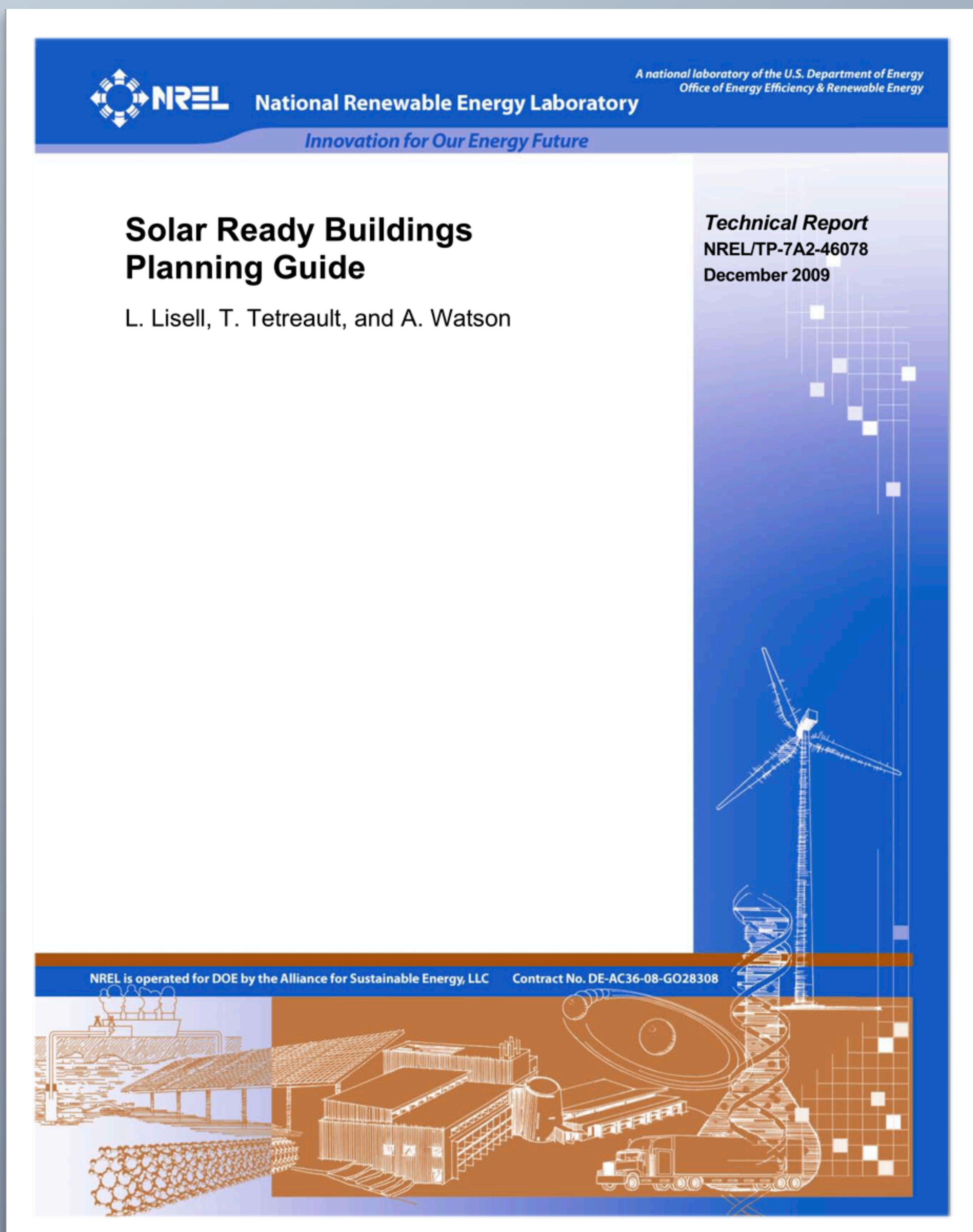
Solar Ready Building Design Guidelines Objectives:





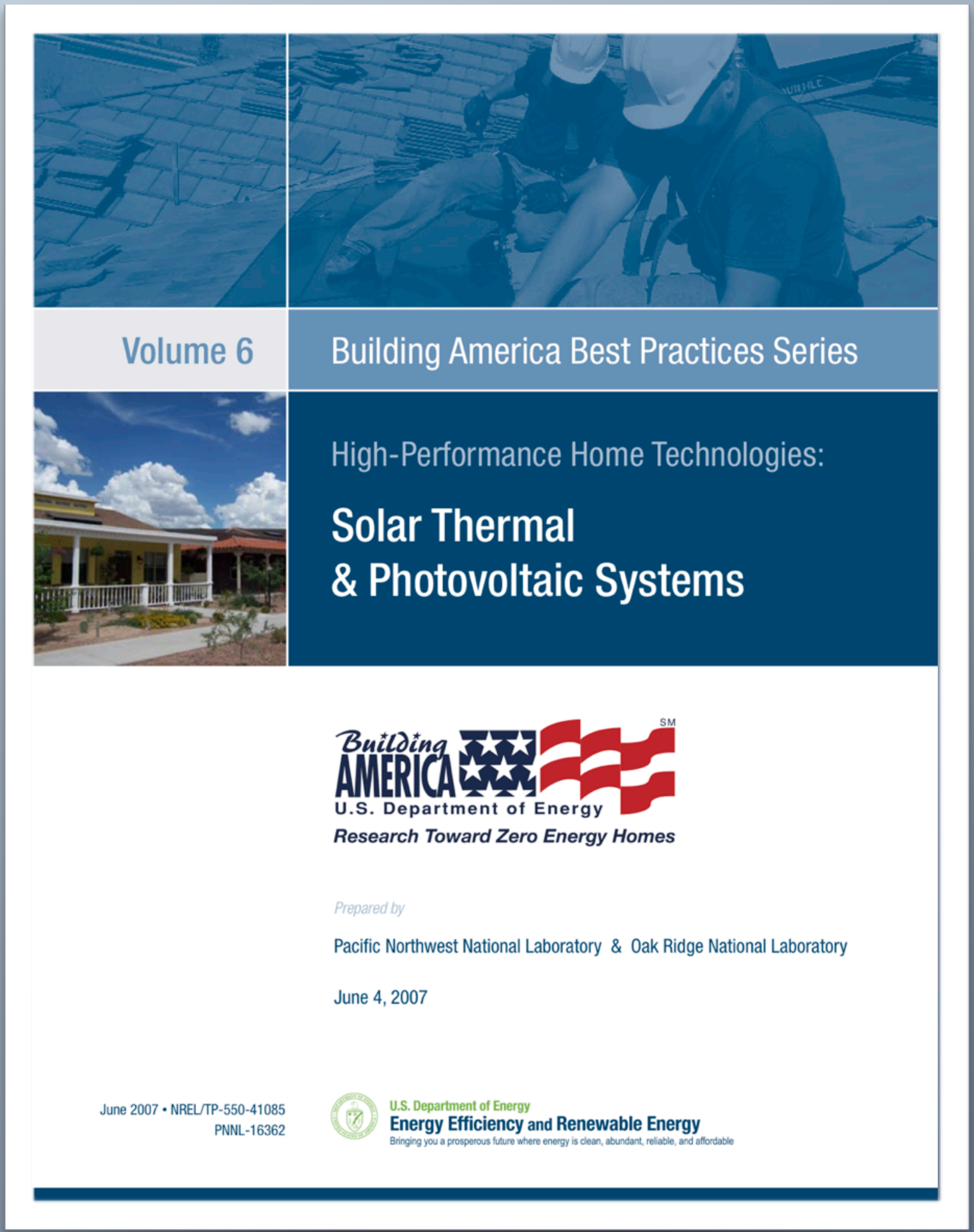
- Illuminate the cost benefit and simplify the requirements of solar ready construction for residential and commercial buildings
- Inform team members of available reference documents
- Make the process and technologies more transparent
- Give an overview of the decision points
- Create a clear path for decision-making
- Describe the responsibilities of team members

Reference Documents:



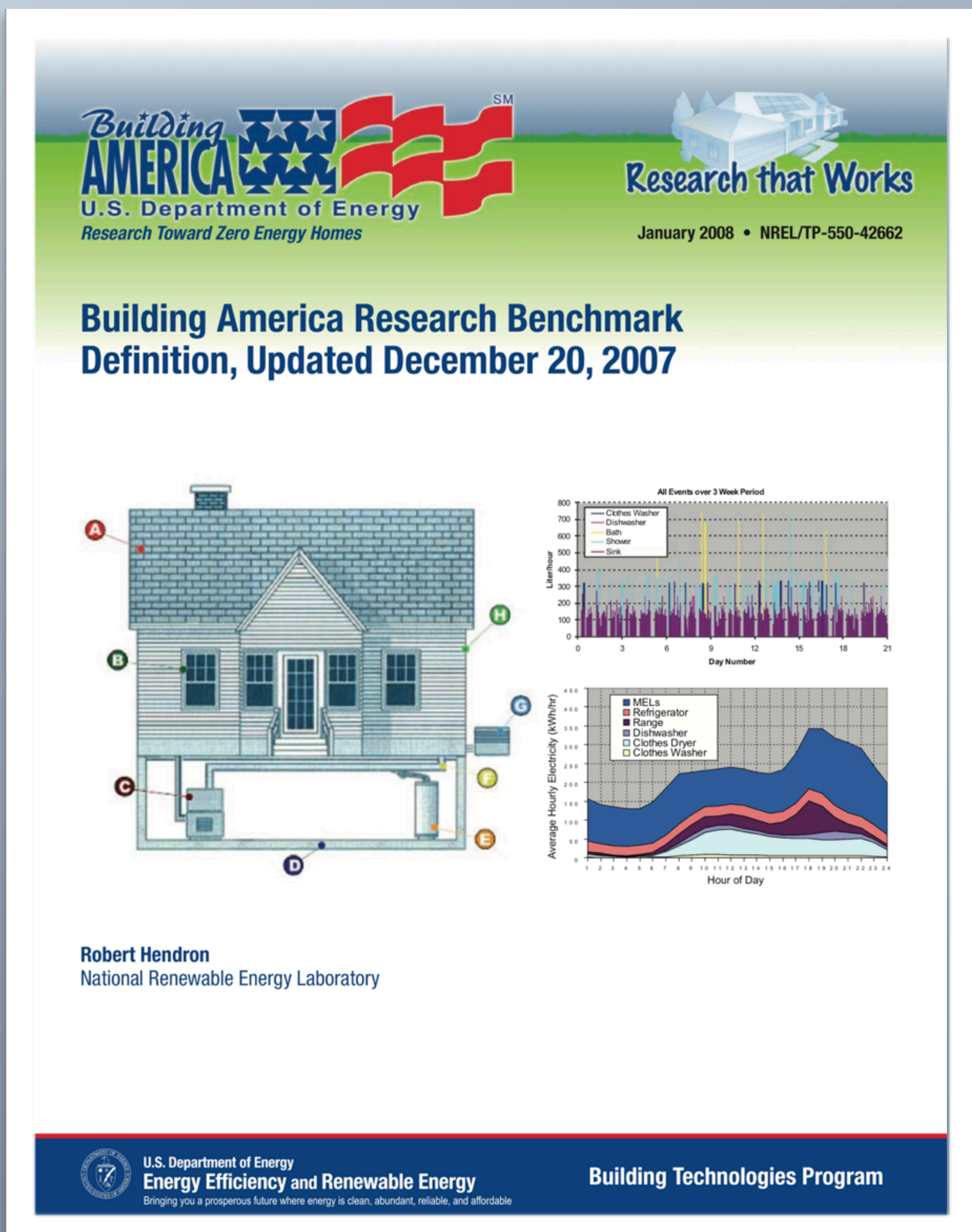
- Solar Ready Buildings Planning Guide – 2009
  - Detailed background on elements of solar ready construction
  - System requirements to consider in the planning and design phases
  - Guidance in developing building code and community regulations

Reference Documents:



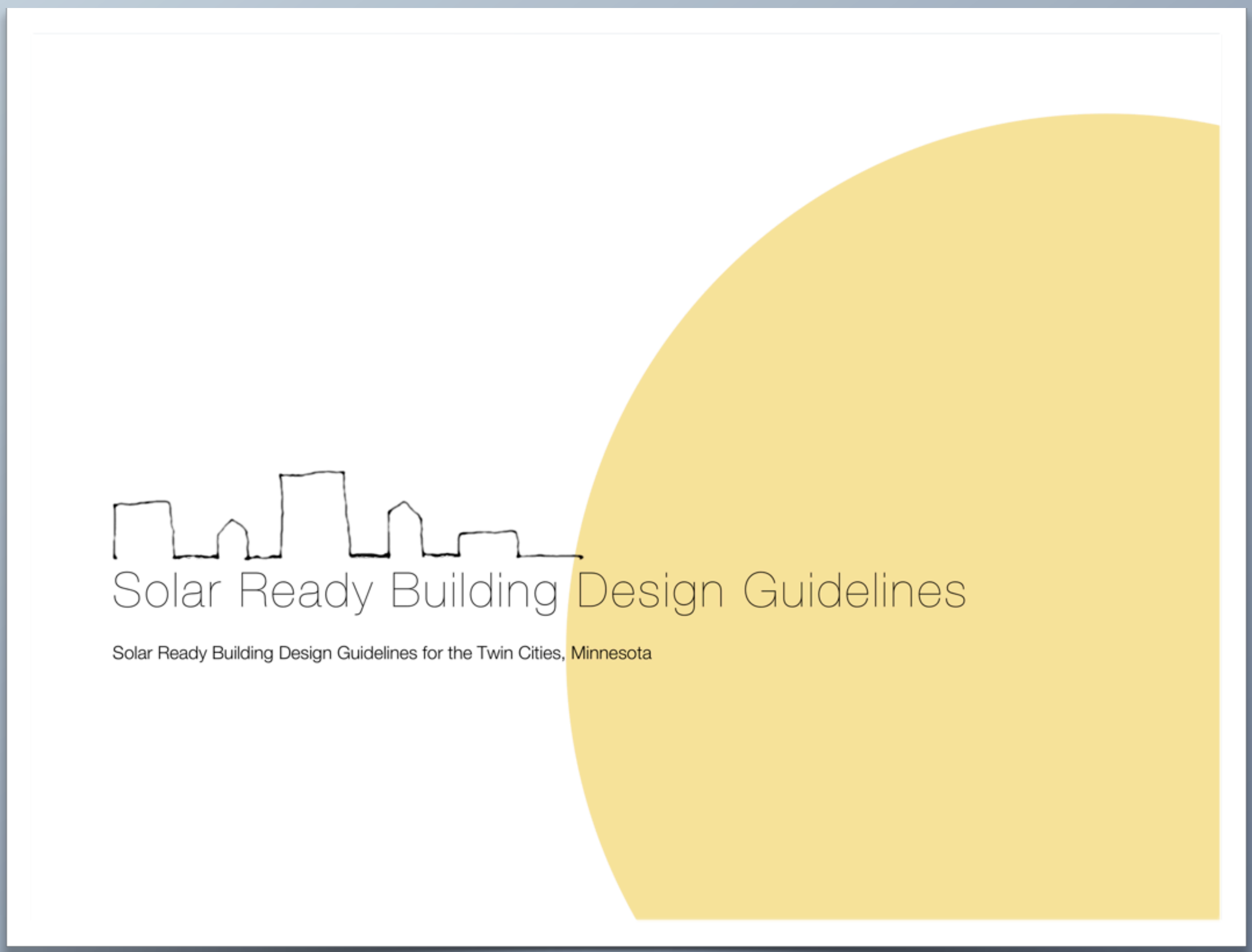
- Solar Thermal & Photovoltaic Systems – 2007
  - Identifies solar system engineering issues
  - Addresses affordability and marketability of zero net energy houses
  - Includes detailed descriptions of ST & PV systems
  - Includes case studies of various scale installations

Reference Documents:



- Building America Research Benchmark – 2007
  - Tracks progress of zero net energy homes
  - Provides benchmarks developed with industry teams
  - Extension of Home Energy Rating System (HERS)

Solar Ready Building Design Guidelines Content:



- Site Planning
- Building Form Planning
- Space Planning
- Roof Planning
- Mechanical & Electrical System Planning

How the Guidelines are Organized

Building Form Planning

To define the building form requirements for Photovoltaic and/or Solar Thermal System, the following documentation will be needed:

Dimensioned Site Plan with roof plan and location of solar array; show adjacent properties, buildings and vegetation.
Building Elevations
Building Section through solar array, show relationship to adjacent properties.
Three-dimensional representations may be useful.

Documentation needed

Site & Plan Organization

Starting Point: Think of the area for the solar array as an essential space in the building's program.

Rules of Thumb: In general, 100-150 square feet of roof area is needed for 0.8-1.0kW of solar modules depending on racking technology. A moderate-sized single-family residential sized solar thermal system has approximately 65 square feet of solar collector area and may need 100 square feet of roof area.

A contiguous rectangle of the required size works best.

Like a kitchen, the solar array has a size and function to be included early in the building's design process.

Decision points

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Site the building and arrange the building plan with solar access as a design criteria so that the location of the solar array is an integral element of the building design, not an afterthought	Same.	Determine the size of the solar array, optimize its location on the site, and evaluate building plan options with this in mind to minimize the length of the electrical feed.	An initial step in the Building Planning Process.	Architect or Builder with input from Solar Consultant.
The location of the solar array on the roof has consequences for the location of and distance to the inverter, the electrical meter, and for the routing of the solar electric feed.	The location of the solar array on the roof has consequences for the location of and distance to the storage tanks and for the routing of the pipes from the array to the tanks.	Develop the early building plan and proximity diagrams with this relationship in mind.		

Decision responsibilities

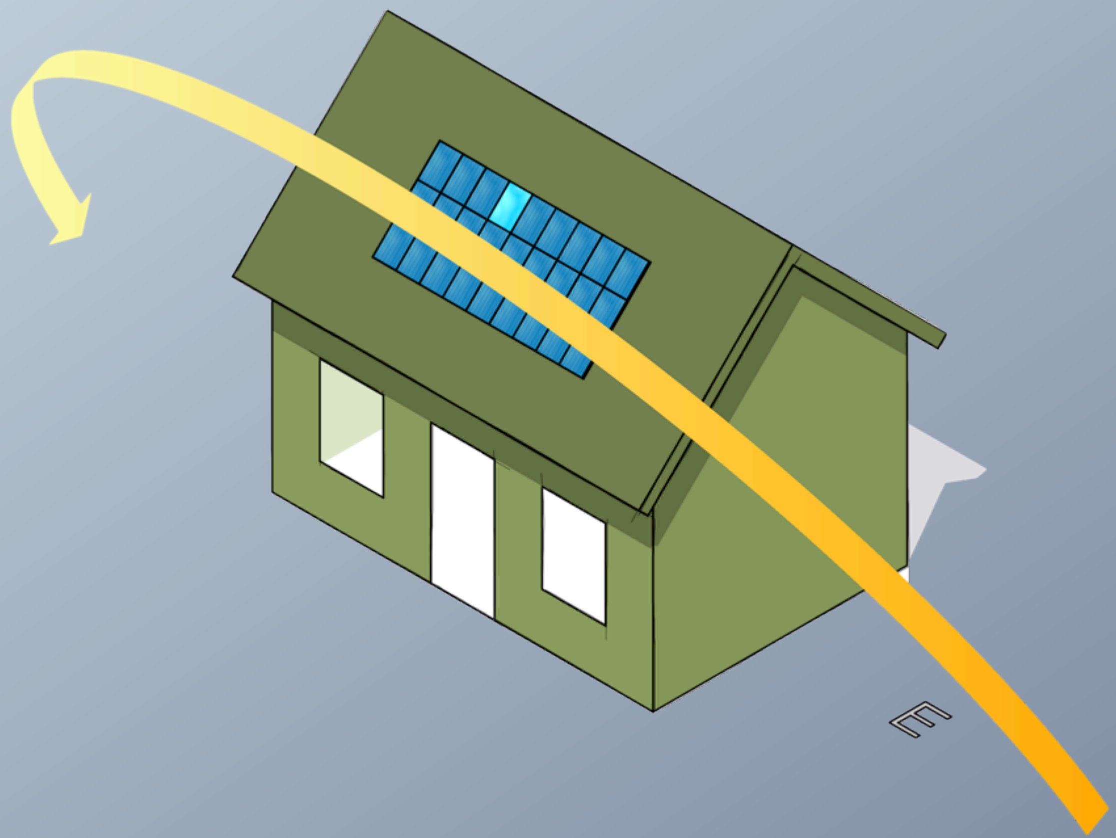
Decision-making

System requirements

Site Planning

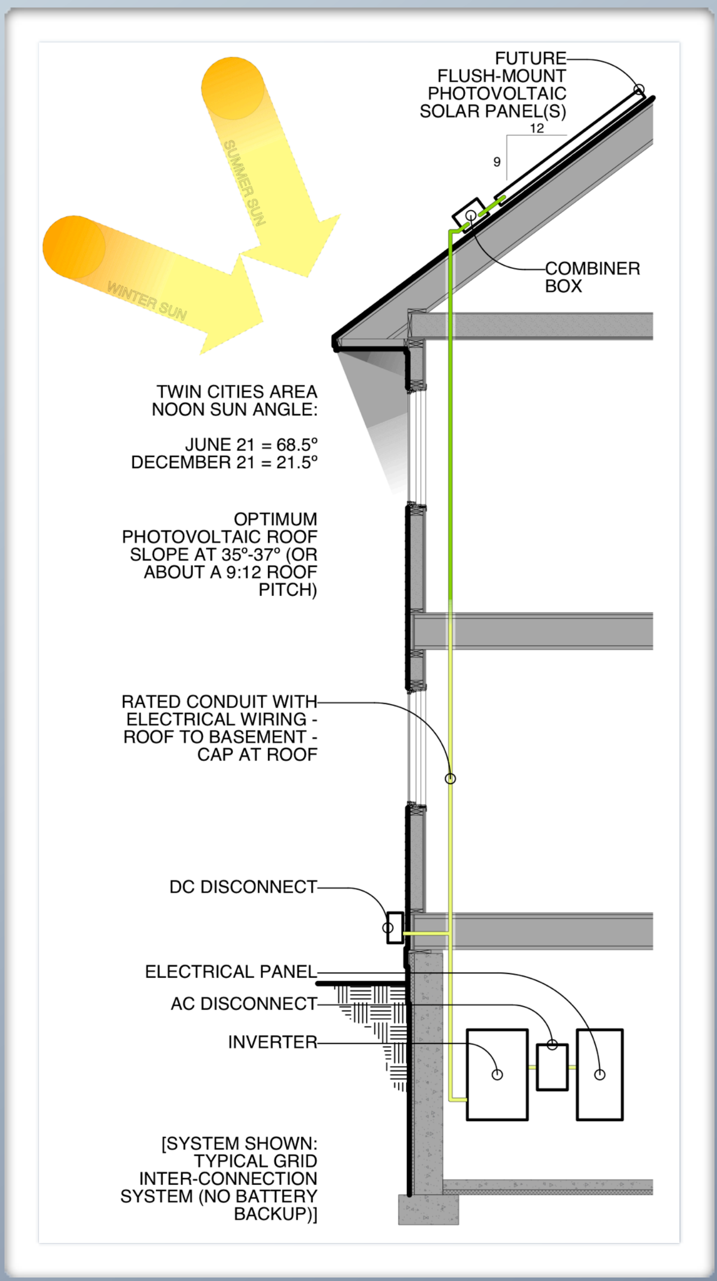
- City Plat and Ordinance Variations
- Planning for Solar Access
- Aesthetic Considerations
- City Regulatory Issues

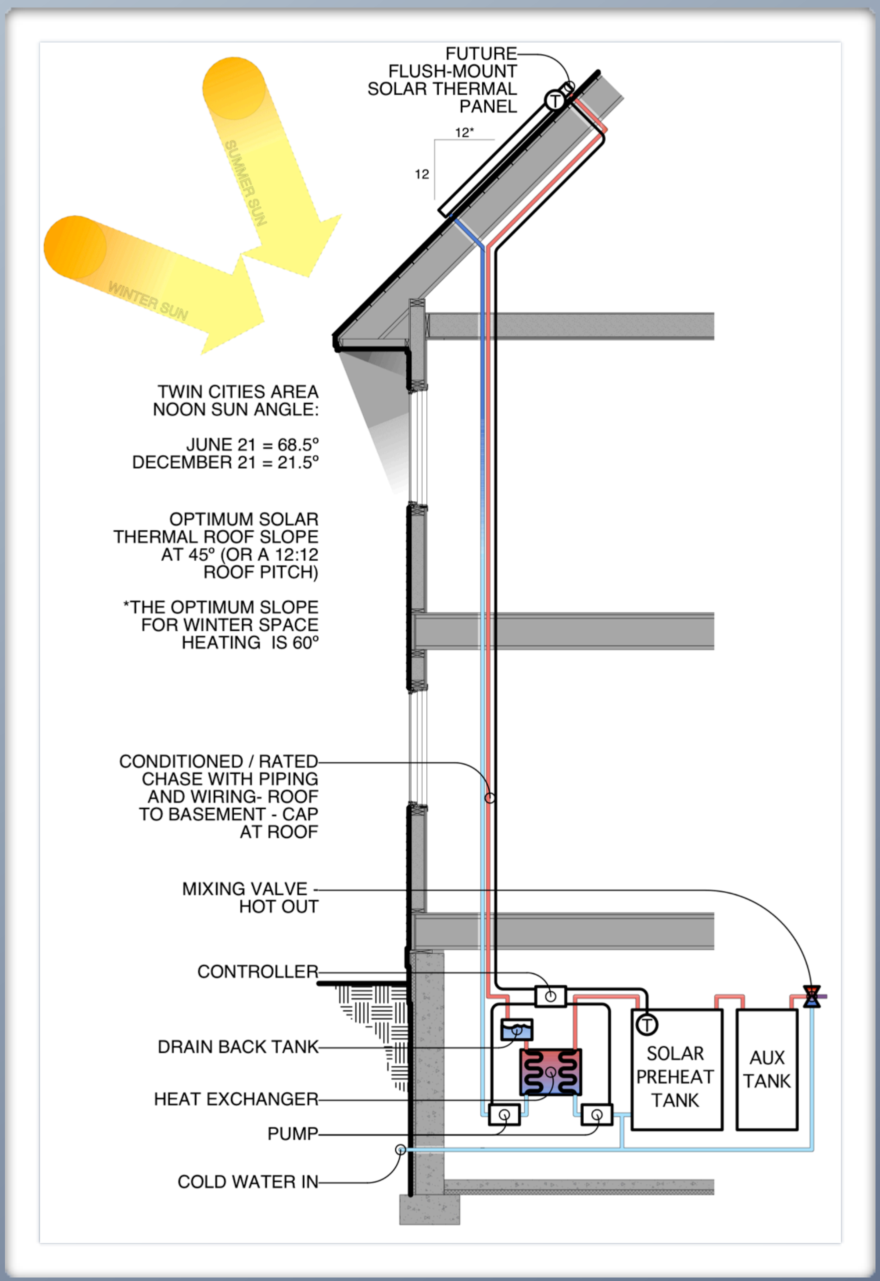
Building Form Planning



- Site & Plan
- Organization
- Building Massing
- Orientation
- Roof Form

Space Planning





- Space for Inverters & Disconnects
- Distance from Solar Array to Inverter
- Space for Water Storage Tanks
- Space for Valves, Pumps, Heat Exchangers, Expansion Tanks, Etc.
- Chase from Solar Array to Mechanical Space for Piping

Roof Planning

www.treehugger.com/20081126-solar-panels-roof.jpg

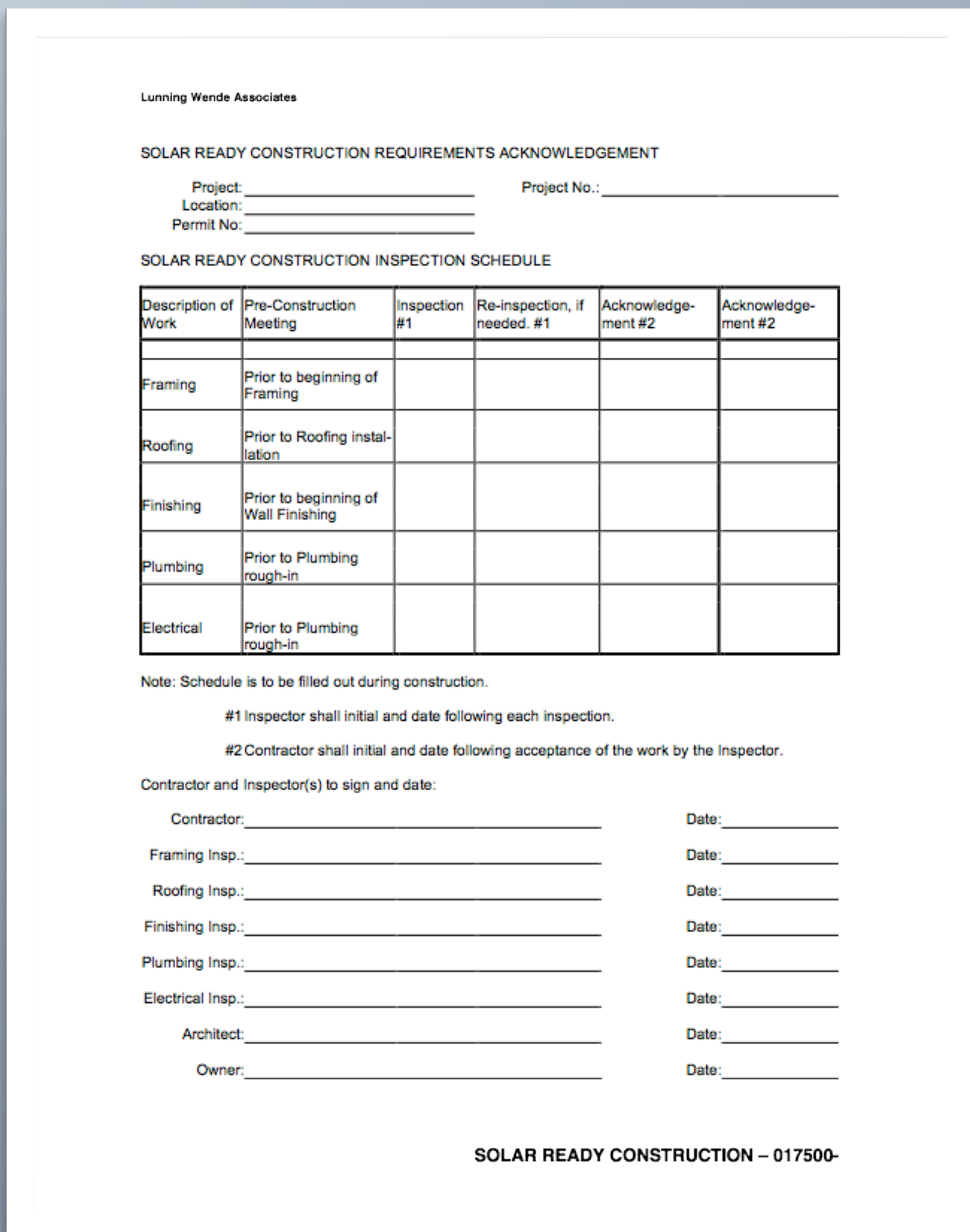
- Area
- Materials
- Roof
- Pitch
- Obstructions
- Structure
- Mounting Systems
- Roof Warranty

Mechanical & Electrical System Planning


http://www.powertripenergy.com/

- Empty metal conduit from roof to main service panel
- Electrical panel space for power input breaker
- Space in breaker box for the solar electric feed
- Production Meter
- Ground solar electrical system
- Pipes from roof to tank location
- Insulate and cap pipes
- Sensor wire parallel to water pipes

Specifications for Solar Ready Construction Requirements



Lunning Wende Associates

SOLAR READY CONSTRUCTION REQUIREMENTS ACKNOWLEDGEMENT

Project: ____________________ Project No.: ____________________
Location: ____________________
Permit No: ____________________

SOLAR READY CONSTRUCTION INSPECTION SCHEDULE

Description of Work	Pre-Construction Meeting	Inspection #1	Re-inspection, if needed. #1	Acknowledge-ment #2	Acknowledge-ment #2
Framing	Prior to beginning of Framing				
Roofing	Prior to Roofing instal-lation				
Finishing	Prior to beginning of Wall Finishing				
Plumbing	Prior to Plumbing rough-in				
Electrical	Prior to Plumbing rough-in				

Note: Schedule is to be filled out during construction.

#1 Inspector shall initial and date following each inspection.

#2 Contractor shall initial and date following acceptance of the work by the Inspector.

Contractor and Inspector(s) to sign and date:

Contractor: ____________________ Date: __________
Framing Insp.: ____________________ Date: __________
Roofing Insp.: ____________________ Date: __________
Finishing Insp.: ____________________ Date: __________
Plumbing Insp.: ____________________ Date: __________
Electrical Insp.: ____________________ Date: __________
Architect: ____________________ Date: __________
Owner: ____________________ Date: __________

SOLAR READY CONSTRUCTION – 017500-

- Intent and Conditions
- Requirements
- Responsibilities
- Inspections and Reports
- Protection and Repair

A Few Thoughts:

- Solar Ready Construction…
  - Adds a building system
  - Adds a new program element
  - Requires an integrated approach
  - One part of a complex puzzle of building better buildings

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Structural Aspects for Solar Array Support

- Structural Basics
- Retrofit Installations
- New/Solar Ready Installations

Applications

- Low-Rise Commercial
- Residential

Environmental Conditions

- Snow Effect
- Wind Effect

Structural Basics

- MSP Metro Area
- Typical Roof (approximate)
  - Snow Load = 35 psf
  - Self Weight DL = Weight of the structural system
  - Superimposed DL (SIDL) = Accommodate roofing, ceiling, lights, mechanical, etc. = 15-25 psf

    [Snow + SIDL = 50 – 55 psf (typical)]

Structural Basics

- Solar Array
  - Self weight Load = 3-6 psf
  - Wind induces sliding and uplift/downward loads
    - Steeper angle = more wind load
  - Ballast (if required) = 20 – 30 psf (or more)
  - Load for Ballast + Array is well in excess of typical SIDL allowance of 15 – 25 psf
- Still need to support roofing, M/E/P, ceiling, etc.
- Panel supports induce point and line loads

Roof Obstructions

- Potential for additional snow load
  - Due to “sheltering” effect if several rows of arrays are present
  - Due to sliding snow off collectors to low-side roof
  - Due to “projection” drifting

[Ref. ASCE 7-05 *Minimum Design Loads for Buildings and Other Structures*, Appendix C7.8.]

Roof Projections

- Code Requirement
  - Snow drift if above 2’ height and 15’ length
  - Could be nearly 100 psf snow load at peak

Retrofit Installations

- Earlier Codes for MSP generally required 40 psf snow load
- Current Code typically requires 35 psf snow load
- Result is potential 5 psf for Solar Array weight
- May have 2-5 psf reserve for additional SIDL
    - Residential - assuming one layer of shingles present
    - But not likely enough for ballast!
    - Highly unlikely enough for drift + ballast!
    - Still need to consider non-uniform loading
    - Upward or downward wind loads may govern

Retrofit Installations

- Minimize snow and wind effect
  - Match roof slope (primarily residential)
    - Reduced solar efficiency
  - “Flatten” panel slope on flat roof
    - Less than 2’ height - no drift and reduced wind
  - Arrange in less than 15’ lengths and space segments at least 15’ apart (no drift)
  - Raise array approximately 4’ (no drift, but more wind uplift)
  - Non-ballasted system

Retrofit Installation Options

- Low-slope Layout

Photographs courtesy of Wellington Management

- Non-ballasted System

Retrofit Installation Options

- Other Methods:
  - Construct new/independent structure above existing roof
  - Strengthen existing roof
    - Occupancy disruptions
    - M/E/P/Ceiling conflicts
  - Both options can be cost-prohibitive!

New / Solar Ready

- Pre-planning will minimize future costs
- Systems are evolving:

For Commercial Consider:

- Locate away from other drift zones
  - No cost
- Include stand-off posts extending above roof
  - Minimal cost
  - Issues with location, waterproofing, maintenance, thermal bridging
- Design designated area of roof for additional 20 - 40 psf for potential ballasted system and/or drift and consider non-uniform load potential
  - Modest cost – less than $1/sf
  - Provides future options
- Include layout and loads on A/E drawings for future engineer's benefit!

New / Solar Ready

- For Residential Consider:
  - Locate away from other drift zones
  - South facing exposure
  - Flat roof
    - Design designated area for additional 25-30 psf and consider non-uniform load potential
    - Area can be small - solar thermal usually 2 - 4'x8' collectors, PV varies
  - Sloped roof:
    - Design steeper roof at select area for direct mount
    - Design for additional 10-15 psf and add blocking between joists/trusses
  - Include layout and loads on Architectural drawings
  - Accomplish at modest up-front cost
  - Provides future options

Additional Considerations

- ✤ Roof service life typically 15-20 years
- ✤ Solar panel service life typically 30-40 years
  - Need plan for roof replacement
- ✤ Evaluate roof design / warranty issues
  - Loadings / punctures during installation
  - Changes in foot traffic after installation
  - Changes in expansion / contraction / runoff patterns
  - Wear / abrasion due to racking / support system "walking"

Source: *Great Expectations - Considerations before rooftop solar power generation*, The Construction Specifier, October 2010

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