Life Cycle Cost Analysis

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Registered Waterproofing Consultant (RWC), Roof Consultants Institute

OVERVIEW:

- Former Turner Construction Employee (Project Engineering and Superintendent)
- Over 20 years experience providing superior technical standards in all aspects of building technology and energy efficiency.
- Principal consultant in forensic investigations of building assemblies, failure analysis, evaluation and design of building infrastructure and building envelope evaluation and design.
- Expert in all aspects of building envelope technology.
- Completed numerous new construction, addition, rehabilitation, remodel and modernization projects for public and private sector clients.
- Specialization in siding, roofing, cement plaster, wood, water intrusion damage, window assemblies, storefronts, below grade waterproofing, energy efficiency, solar engineering and complex building envelope and mechanical assemblies.

Presentation Objectives

- Develop a better understanding of the average longevity of major building components managed by community managers
  - Roofs, lighting, HVAC, landscaping, plumbing, on site drainage, pavement, solar, etc.…

  <u>AND LEARN WHY COMPONENTS FAIL EARLY!</u>

- Learn some basic techniques for the correct evaluation of utility bills and the associated savings from typical water conservation or electricity generation measures.

- Learn some tips including financial and practical calculations, for deciding whether to perform major maintenance, to replace major building components, or to provide other alternatives…
  <u>LIFE CYCLE IS ALL ABOUT FINANCING, PROPER DESIGN, QUALITY INSTALLATION, AND MAINTENANCE.</u>

Life Cycle Costing Rules of Thumb

- The Life cycle costing process is an algorithm.
- Life cycle costing is closely tied to sustainability.
- Life cycle costing is NOT value engineering, and is LONG TERM.
- Greatest positive, AND negative, impacts on Life Cycle Costing, are found in the planning stages.
- But, life cycle costing techniques applied to maintenance can still address what are often severe, underlying, design issues.
- Unfortunately, many factors that impact life cycle costing are not visible.
- Adding a new system in a building with underlying problems may not be the best solution.
- Be careful of maintenance recommendations that play to what is offered by the repair person.

How Long ***SHOULD*** Components Last?

Typical Component Life Expectancies*

***Subject to regional variations and subject to quality of original construction**

Roofs:	
“Package” HVAC units:	
Central HVAC units:	
Variable Refrigerant Flow HVAC systems:	
Solar PV modules and inverter:	
Solar Thermal systems:	
Sealants:	
Below-grade waterproofing:	
Windows:	
Window gaskets:	
Stucco:	
Painting:	
Wood siding:	
Trees and landscaping:	
Asphalt Pavement:	
Concrete Sidewalks:	
Sewer and Storm Lines:	

Some Fundamental Issues:

Low Slope Roof: *Built-Up*

Advantages

- Very tough.
- Redundant protection.
- Excellent longevity.
- Many contractors.
- Well understood.
- Maintenance "easy."

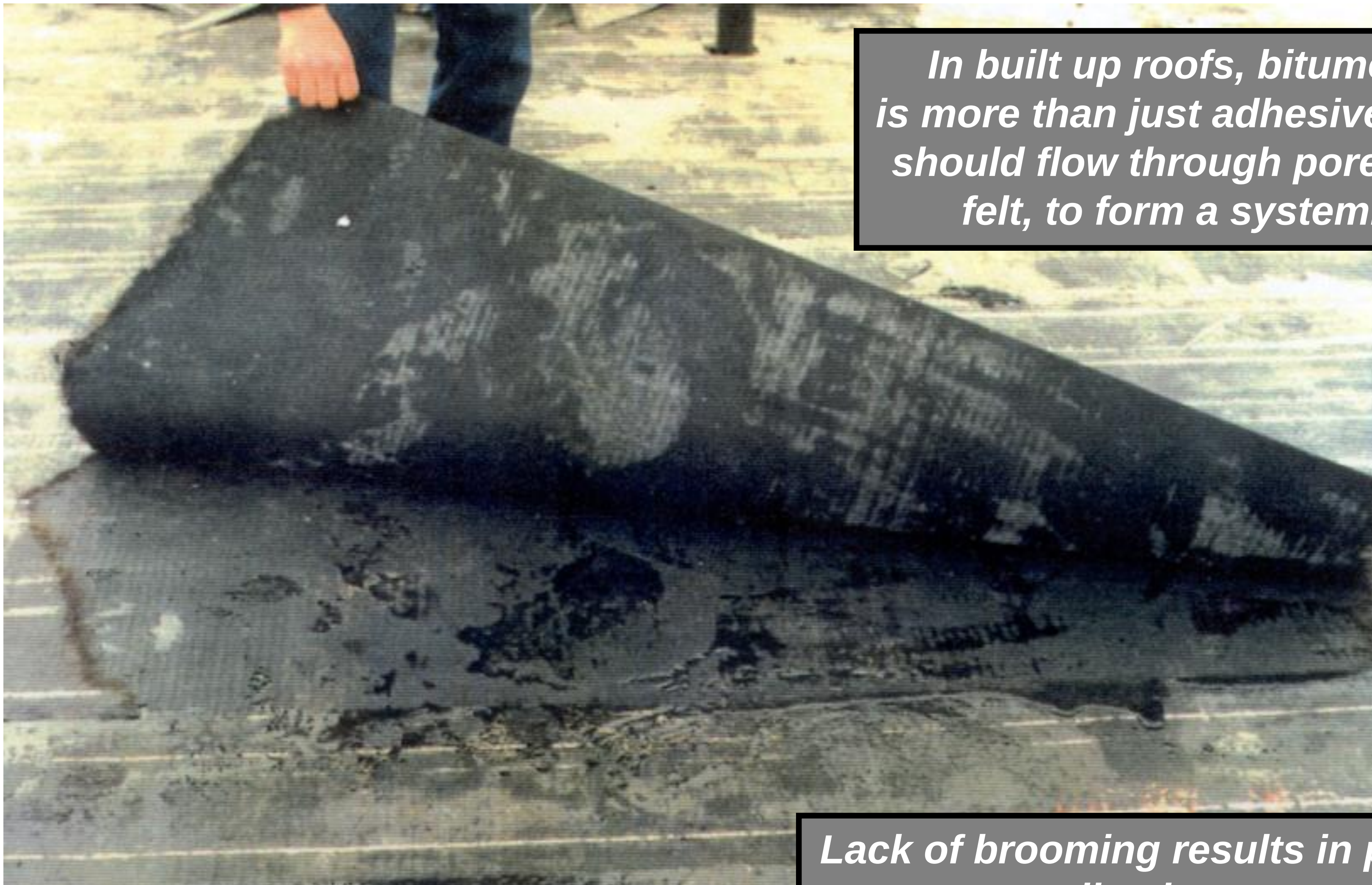
Disadvantages

- "Dirty" application for new and repair applications.
- Smell.
- Cost, especially tear off.
- Craftsmanship in complicated roofs.
- Repair hassle.

Low Slope Built Up Roof Issues

Brooming and full coverage are imperative.

Low Slope Built Up Roof Issues



In built up roofs, bitumen is more than just adhesive – it should flow through pores in felt, to form a system.

Lack of brooming results in poor adhesion.

Steep Slope: *Composite Shingles*

Advantages

- Install quickly.
- Beautiful aesthetics.
- Outstanding longevity.
- High fire resistance.
- Large contractor base.

Disadvantages

- Install too quickly.
- Easily damaged.
- Difficult to repair.
- Require vented decks.
- Subject to wind damage if not installed properly.
- Maintenance may not resolve all problems.

Steep Slope: *Composite Shingles*

Composite Shingles

Composite Shingles must match area's wind load, or they will fail.

Example of Underlying Issues

Example of Underlying Issues

Steep Slope: *Wood Shakes*

Advantages

- Beautiful aesthetics.
- Fair to lengthy longevity.
- Natural product.

Disadvantages

- Expensive installation.
- Repairs have limited life and are difficult.
- High Fire Risk.
- Easily damaged.
- Require vented decks.
- Questionable sustainability.

Steep Slope: *Wood Shake*

Steep Slope: *Concrete Tile*

Advantages

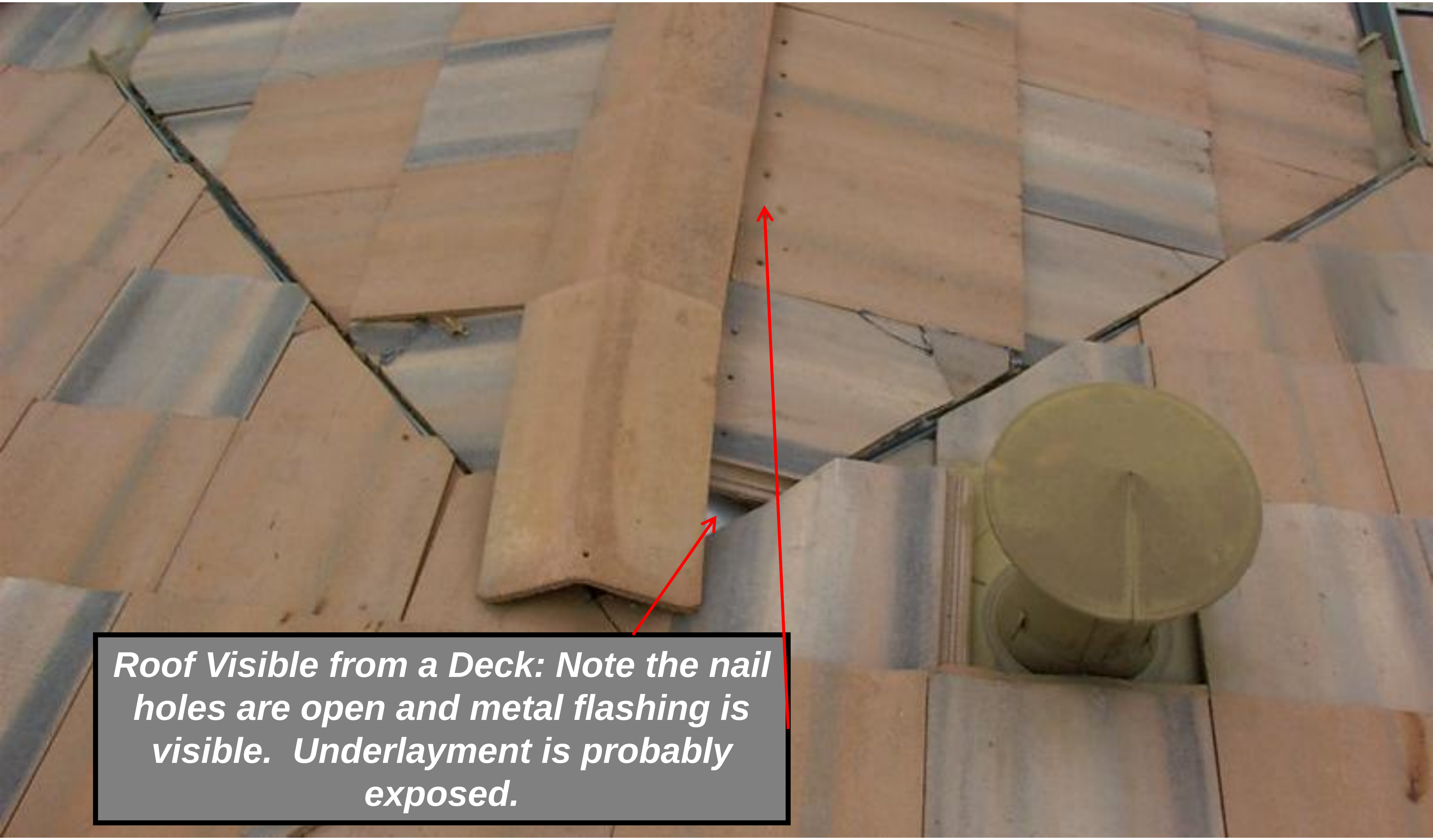
- Beautiful aesthetics.
- Fair to lengthy longevity.
- Some are natural product.
- Can allow natural ventilation.
- When underlayment fails, tiles can be removed and replaced.

Disadvantages

- Expensive installation.
- Repairs have limited life and are difficult.
- Can not walk on for other maintenance.
- Easily damaged.
- Underlayment must be protected.


How do you walk on this? Where would a leak be found?

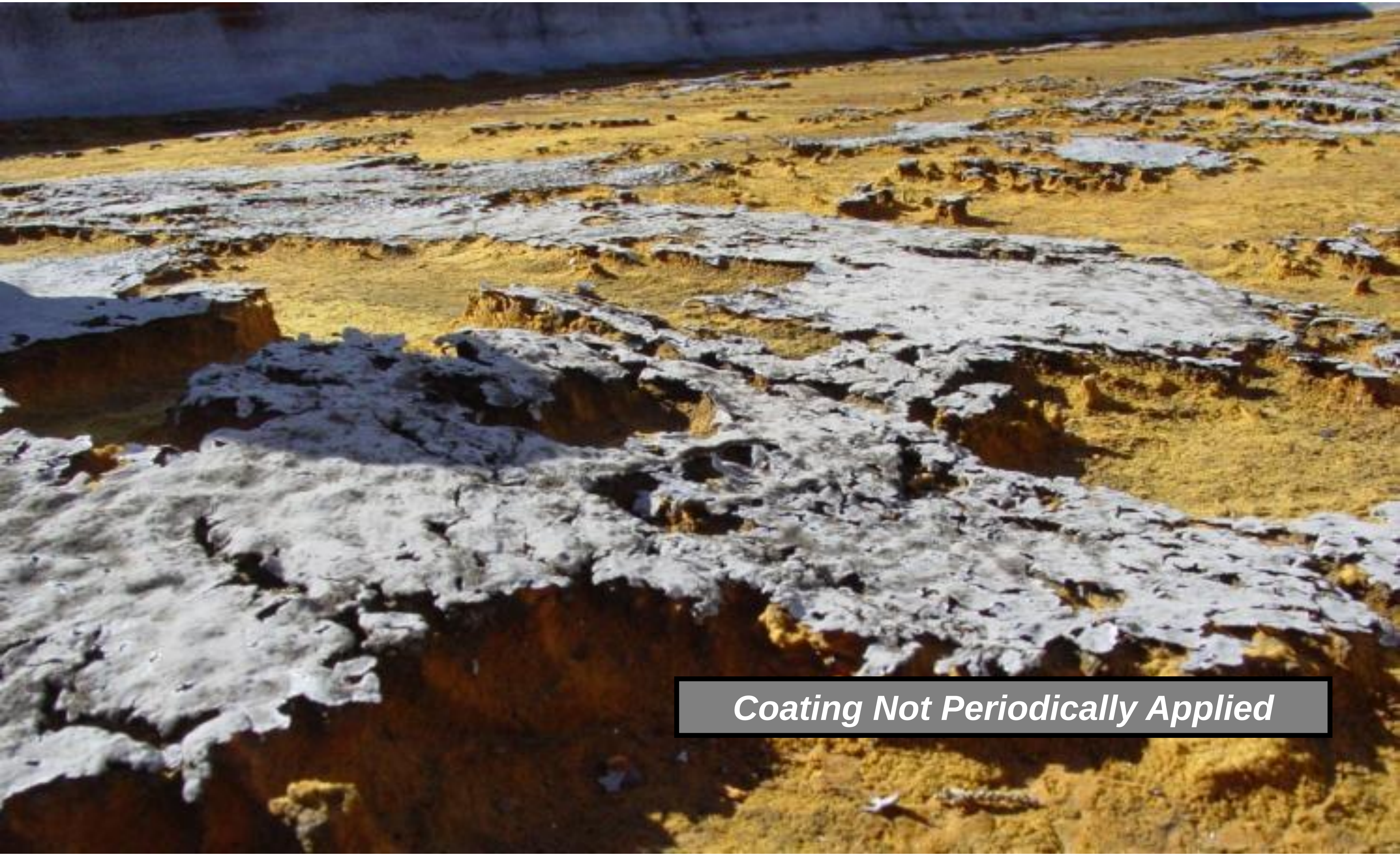
Concrete Tile Roof



Foam Roofs

Coating has delaminated after only a few years, exposing the foam to water intrusion. For foam roofs especially, recoating is essential, every five years. Surface of this roof may have been wet when coating was applied.

Degraded Foam Roof



“Foam” Roofs

An example of a pipe penetration system that was not designed properly.

“Maintenance” to Lengthen Life

Finished Cool Roof Project

Roof Replacement and Repair Alternatives

- **BUR Life: 10 – 30+ Years.**
  - BUR Repairs: Complicated and temporary.
  - Repair cost comparison to replacement: Repairs are less expensive than replacement, but typically only temporary.
  - Fix the underlying flaws for greatest impact: such as flashings, crickets, sealants, gutters.

- **Composite Life: 10 – 30+ Years.**
  - Composite Repairs: Complicated.
  - Repair cost comparison to replacement: Repairs are less expensive than replacement, but typically only temporary.
  - Fix the underlying causes, some similar to BUR, and: venting and uplift.

- **Shake Shingle Life: 20 – 30+ Years.**
  - Shake Repairs: Quick but not long lasting.
  - Repair cost comparison to replacement: Repairs are less expensive than replacement, but typically only temporary.
  - Fix the underlying causes, such as flashings, valley gutters, etc.

- **Foam roofs must be recoated on at least a 5 year schedule.**
  - Foam roofs are quick fixes that do not fix underlying problems.
  - Foam roofs are VERY difficult and messy to remove.
  - Fix the underlying causes: insulation, venting, etc.

Typical Component Life Expectancies*

***Subject to regional variations and subject to quality of original construction**

Roofs:	**10 - 30+ Years**
“Package” HVAC units:	
Central HVAC units:	
Variable Refrigerant Flow HVAC systems:	
Solar PV modules and inverter:	
Solar Thermal systems:	
Sealants:	
Below-grade waterproofing:	
Windows:	
Window gaskets:	
Stucco:	
Painting:	
Wood siding:	
Trees and landscaping:	
Asphalt Pavement:	
Concrete Sidewalks:	
Sewer and Storm Lines:	

Well Designed, Well Installed Roofs Can Last 30 Years, With:

- **Good Design.** Details such as drains, sleepers, base flashings, etc., all designed to last 30+ years, with clear construction details.
- **Good UV protection:** Evenly applied gravel surfacing, renewable acrylic coating, etc.
- **Good drainage.** Proper slope to drain, with clear construction details.
- **Properly secured.** Proper securement of roof and insulation, designed by the roof consultant, not just the contractor.
- **Appropriate substrate.** Stable substrate such as concrete, Lt Wt Insulating Concrete, or insulation over plywood or metal.
- **Design protection.** Protection from physical damage, excessive traffic, hail, etc.
- **Installation protection.** Protection from physical damage during construction, materials are protected from the weather, etc.
- **Construction Administration:** Interpretation of field conditions by designer, and review of construction in progress.
- **And many more…**

Roof Life Cycle Cost Calculations

LIFE CYCLE COSTING DECISION TOOL

To make decisions on any major building expenditure, you need to know:

- **The cost of the component each year, that is: *EQUIVALENT ANNUAL COST, and***
- **The *TOTAL LIFE CYCLE COST* during the Life of the component.**

Life Expectancy of a Buildilng Component, in Years:	**Cost Factor Per Year, Assuming Various Interest Rates:**				
	2%	3%	4%	5%	10%
10	0.1113	**0.1172**	0.1233	0.1295	0.16274
15	0.0778	0.0838	0.0899	0.0963	0.13147
20	0.0612	0.0672	0.0736	0.0802	0.11745
30	0.0446	0.0510	0.0578	0.0651	0.10607
Assume cost of :				$ 100,000	
Assume Life Expectancy in years:				10	
Assume Interest Rate 3%				**0.1172**	
Equivalent Annual Cost				**$ 11,723**	
Total Life Cycle Cost of Component over 10 year life expectancy				**$ 117,230**	

http://formularium.org/en/10.html?go=82.301

ROOFING LIFE CYCLE COSTING DECISION TOOL

Life Cycle of Roof in Years:	Cost Factor Per Year, Assuming Various Interest Rates:				
	2%	3%	4%	5%	10%
10	0.1113	0.1172	0.1233	0.1295	0.16274
15	0.0778	**0.0838**	0.0899	0.0963	0.13147
20	0.0612	0.0672	0.0736	0.0802	0.11745
30	0.0446	**0.0510**	0.0578	0.0651	0.10607
			Roof Field Designed by Contractor	**With Design by Roof Consultant**	
Assume cost of :			$ 100,000	$ 125,000	
Assume Life Expectancy in years:			15	30	
Assume Interest Rate 3%			**0.0838**	**0.0510**	
Equivalent Annual Cost			**$ 8,380**	**$ 6,376**	
And, you could add:		Yearly Maintenance Expense of Old Roof			
		Loss in Property Value			
		Cost of Homeowner Complaints			

15 Year Roof Life Cycle Cost

- Cost of 13,000 square foot roof by contractor, without construction details and design documents: **$100,000** capital cost for a roof with a 15 year life expectancy.

- $100,000 x factor of 0.838 = **$8,380** Equivalent Annual cost

- **$8,380 X 15 years = $125,700**

- At the end of 15 years, install another roof, with inflation: Approximately **$135,000**

- Total cost of two 15 year roofs: **$260,700**

30 Year Roof Life Cycle Cost

- Cost of 13,000 square foot roof built by contractor, with construction details and design documents prepared by a consultant:
  $100,000 + 12% + 12% = approximately $125,000

- $125,000 x factor of 0.05101 = **$6,376** Equivalent Annual cost

- $6,376 X 30 years **= $191,280**

- Total cost of one 30 year roof: **$191,280**

15 vs. 30 Year Roofs

- Total Cost of two 15 year roofs: $260,700
- Total cost of one 30 year roof: $191,280
- Net savings: $ 69,420
- Savings not quantified in this example: lower maintenance costs, happier homeowners, perceived higher values.

Roof Comparison – Concrete vs. Clay Tile

- Installation cost for a 10,000 s.f. concrete tile roof, with design:
  - $7/s.f. for tile plus $4/s.f. for underlayment = $110,000.
  - Replace roof in 30 years for $110,000 in today's dollars.

- Installation cost for a 10,000 s.f. clay tile roof, with design:
  - $10/s.f. for tile plus $4/sf for underlayment = $140,000.
  - Replace underlayment and some tile in 40 years at a cost of approximately of $70,000

LIFE CYCLE COSTING DECISION – CONCRETE OR CLAY TILE?

To make a decision regarding a major expenditure, such as a roof replacement, you want to know the equivalent annual cost

Life Cycle of Roof in Years:	**Cost Factor Per Year, Assuming Various Interest Rates:**				
	2%	3%	4%	5%	10%
30	0.0446	**0.0510**	0.0578	0.0651	0.10607
40	0.0366	**0.0433**	0.0505	0.0583	0.10225
			Concrete Tile	**Clay Tile**	
Assume cost of :			$ 110,000	$ 140,000	
Assume Life Expectancy in years:			30	40	
Assume Interest Rate 3%			**0.0510**	**0.0433**	
Equivalent Annual Cost			**$ 5,611**	**$ 6,056**	
				Initial cost	**Equivalent Annual Cost**
But for the next cycle:		New Concrete Tile Roof:		$135,000	$ 6,886
		Refurbished Clay Tile Roof:		$70,000	$ 3,028

Concrete vs. Clay Tile

- Total cost of 40 year clay tile roof:

  40 years X equivalent annual cost of $6,056 = **$242,240**

- Total cost of 30 year concrete tile roof over 40 year period:

  30 years X equivalent annual cost of $5,611 = **$168,330**

  plus 10 years X $6,886 (**$68,860**) = **$237,690**

- But for the next 20 years: Total cost of concrete tile is **$137,720** and total cost of clay tile is **$60,560**

- Moral of the story: clay tile is less expensive over the very long term (60 years)

Decision Matrix

HOA Roof Replacement - Evaluation Matrix

Selection Criteria

- A. Lowest Installation Cost
- B. Ability to install during normal operations (noise and fumes)
- C. Potential for Impact Damage
- D. Ease of Maintenance
- E. Cost of Maintenance
- F. Energy Efficiency
- G. Lowest Life Cycle Cost (if installed properly)
- H. Reliability (long term proven performance)

Alternative Roofing System	A	B	C	D	E	F	G	H	TOTAL
Importance	8	10	8	9	7	8	8	10	
1 Built Up Roofing – Hot Process	5 / 40	5 / 50	2 / 16	5 / 45	4 / 28	5 / 40	2 / 16	5 / 50	285
2 Built Up Roofing – Cold Process	4 / 32	4 / 40	2 / 16	4 / 36	4 / 28	5 / 40	4 / 32	3 / 30	254
3 Single Ply	4 / 32	3 / 30	5 / 40	2 / 18	5 / 35	1 / 8	5 / 40	3 / 30	233
4 Metal	4 / 32	4 / 40	1 / 8	4 / 36	2 / 14	3 / 24	4 / 32	1 / 10	196
5 Composite Shingle	4 / 32	2 / 20	2 / 16	3 / 27	4 / 28	2 / 16	2 / 16	4 / 40	195
6 Wood Shingle	1 / 8	2 / 20	2 / 16	2 / 18	3 / 21	2 / 16	5 / 40	4 / 40	179
7 Foam	2 / 16	2 / 20	5 / 40	1 / 9	2 / 14	1 / 8	4 / 32	4 / 40	179

MS Excel copy of this spread sheet available from CACM at www.cacm.org

Typical Importance Scoring*

10 – Significant Preference
9
8
7
6
5
4
3
2
1 – No preference

*Scores Will Vary Based on HOA Preference

Alternative Roofing Systems Typical Rating Scores*

5 – Excellent
4 – Very Good
3 – Good
2 – Fair
1 – Poor

*Subject to Regional and Other Variations

Mechanical Life Cycle Cost Example

Replacement of Chiller

- **New Variable Refrigerant Flow Chiller.**
- **Replaced Constant Refrigerant Flow Chiller.**
- **Cost: $950,000.**
- **Greatly reduced electricity usage for chilled water.**
- **Savings come from:**
  - New, more energy-efficient *environmentally sensitive equipment and controls.*
  - Demand based operation, not constant operation, utilizing new, variable speed pumps, chillers, and cooling towers.
  - Electronic control system that carefully optimizes system components for energy efficiency without compromising comfort.
  - Non-chemical filtration system providing environmental protection and water conservation.

Savings Funded the Project

- **Cost of new, higher efficiency chiller: $950,000**
- **Life expectancy of new chiller: 20 years.**
- **Electricity Reduction:**
  - Electricity reduction per month: 39,074 kWh
  - Dollar savings per month: $ 12,894
  - Approximately $155,000 per year
- **Simple payback period:** 6.5 years
- **Total savings after 6.5 years:**
  - $155,000 X per year X 13.5 = $2,092,500

New High Efficiency Chiller

State of the Art Variable Frequency Drives

Life Cycle Cost Analysis - CACM Facilities Management Conference May 10, 2011

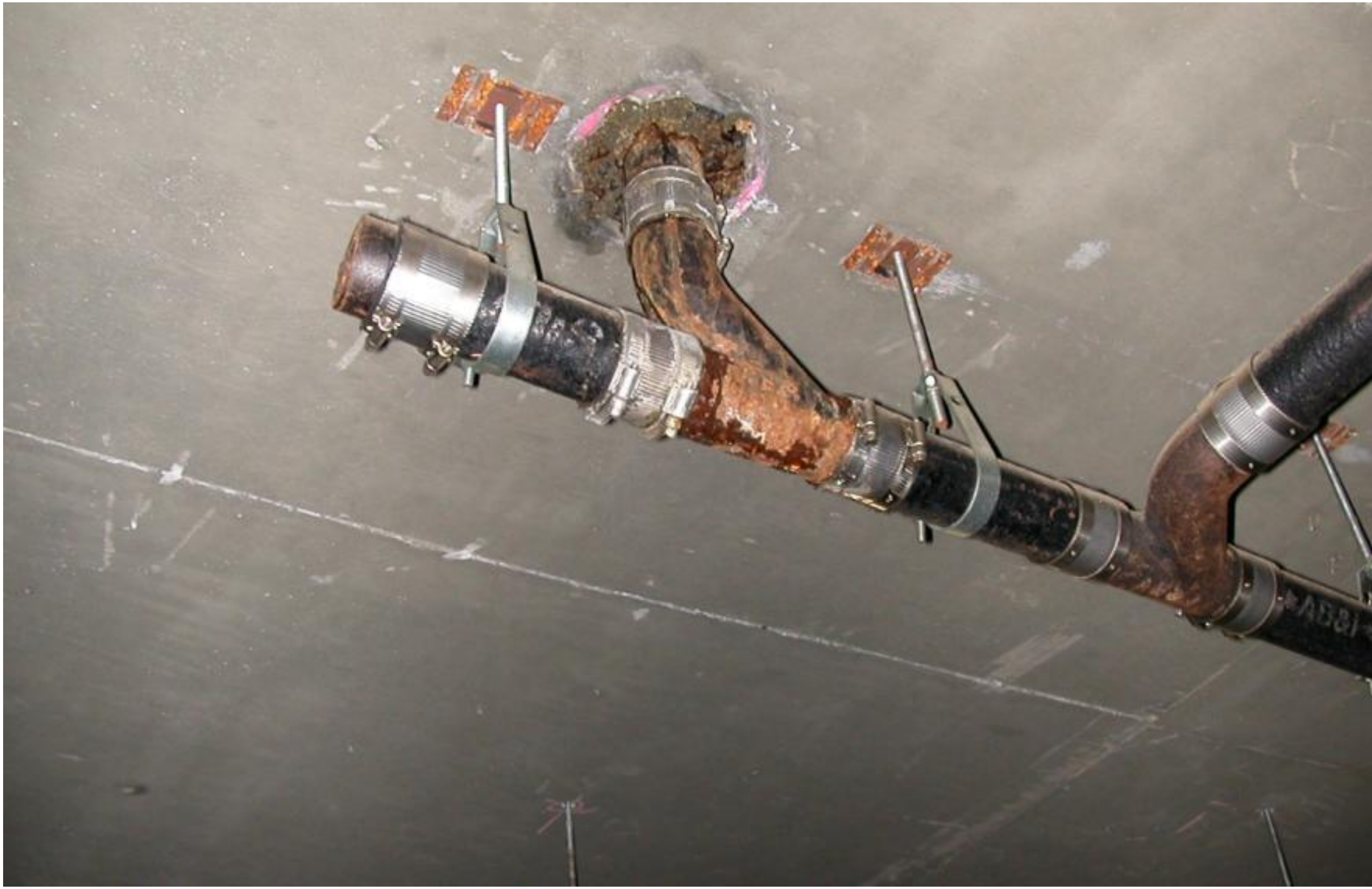
New, Remotely Programmable Controls

Non-Chemical Water Conditioning System

Mechanical System Failures

- **Where failures are typically found:**
  - "Package units" (an alternative is to install central system or VRF – Variable refrigerant flow).
  - Pool and specialized equipment, pipe penetrations.
  - Flashings around roof mounted equipment.
  - Curbs at roof mounted equipment.
  - Fix underlying issues first.

Possible Leaking Plaza Above



Plumbing Issues in Common Areas

- Pipe leaks.
- Angle stop leaks.
- "Darkened areas."
- Poor repairs.

Typical Component Life Expectancies*

*Subject to regional variations and subject to quality of original construction

Roofs:	10 - 30+ Years
"Package" HVAC units:	5 - 15 Years
Central HVAC units:	15 - 30 Years
Variable Refrigerant Flow HVAC systems:	15 - 30 Years
Solar PV modules and inverter:	
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Sealants:	
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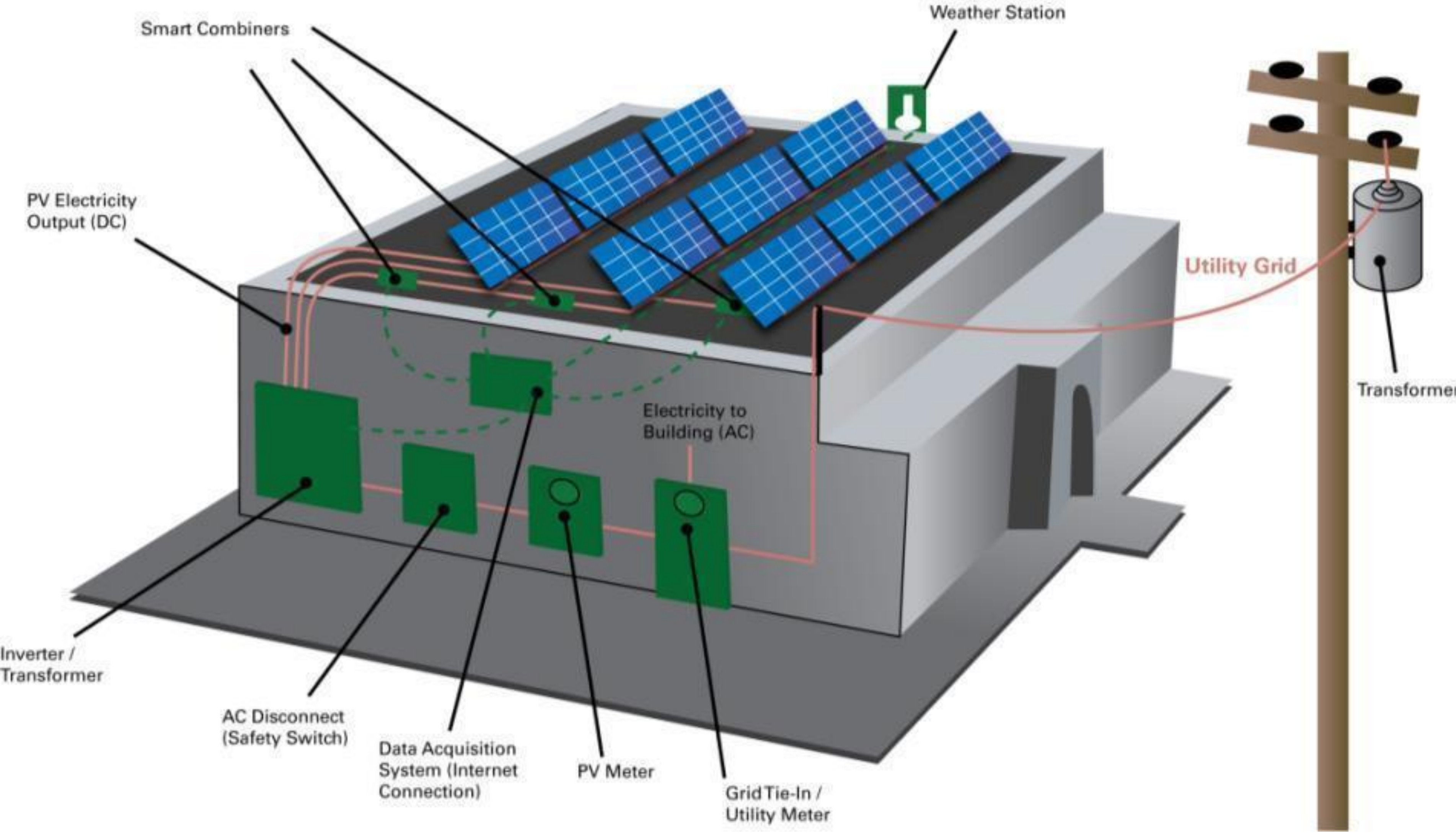
Alternative Energy

- Solar PV and analysis for solar.
- Solar Thermal.
- Wind.
- Biomass.
- Energy savings:
  - Retrofit mechanical equipment.
  - Coat roofs.
  - Insulate crawl spaces.

Costs of Solar and Other Information

- Price per watt: $4 to $6 to compete.
- 100 KW system = $400,000 to $600,000
- System weight, including racking = 3 - 6 lbs per sq. ft.
- Coverage: approximately 8-12 watts per sq. ft. for flat roof and 15 watts per sq. ft. sloped roof, depending on solar system efficiency.
- Roof area, 100 KW system: 7,000 to 10,000 square feet.
- Costs vary based on solar module efficiency, and mounting type.

Solar Roof PV Installation Basics



Additional Solar PV Components

- Inverters
  - PV modules generate direct current (DC) electricity.
  - The current is fed through an inverter to produce alternating current (AC) that can be used to provide energy to your buildings' common areas.

Solar PV Rooftop Design Considerations

- Proper utility bill analysis.
- Roof assessment.
- Physical constraints.
- Remaining roof life and sustainability of solar PV system over time.
- Structural loads created by the solar PV system.
- Wind uplift.
- Mounting.
- Thermal movement of PV components.
- Electrical, mechanical and other disciplines.
- Fire code.
- Maintenance of the PV system and the roof.

Roof Assessment

- Existing age and condition of roof.
- Remaining roof service life.
- Impact to existing warranty.
- Flashings.
- Drainage.
- Chemical compatibility.
- Impact on structural load?

Remaining Roof Service Life

- Will the roofing last the term of the Solar PV financing?
  - Most PPA's (financing) last 15 – 20 years.
  - The life of solar panels and components is 30 years or more.
  - But the roof life is limited, and could be less than the financing or the solar PV system.
  - So the life cycle cost of the Solar PV or Solar Thermal system may not matter!

- Will the Solar PV and all associated systems withhold its integrity and last the term of the Solar PV financing or warranty?

- What minimal maintenance requirements of the roof and PV systems will assist in having the lives of the roof and PV systems run concurrently?

Longevity

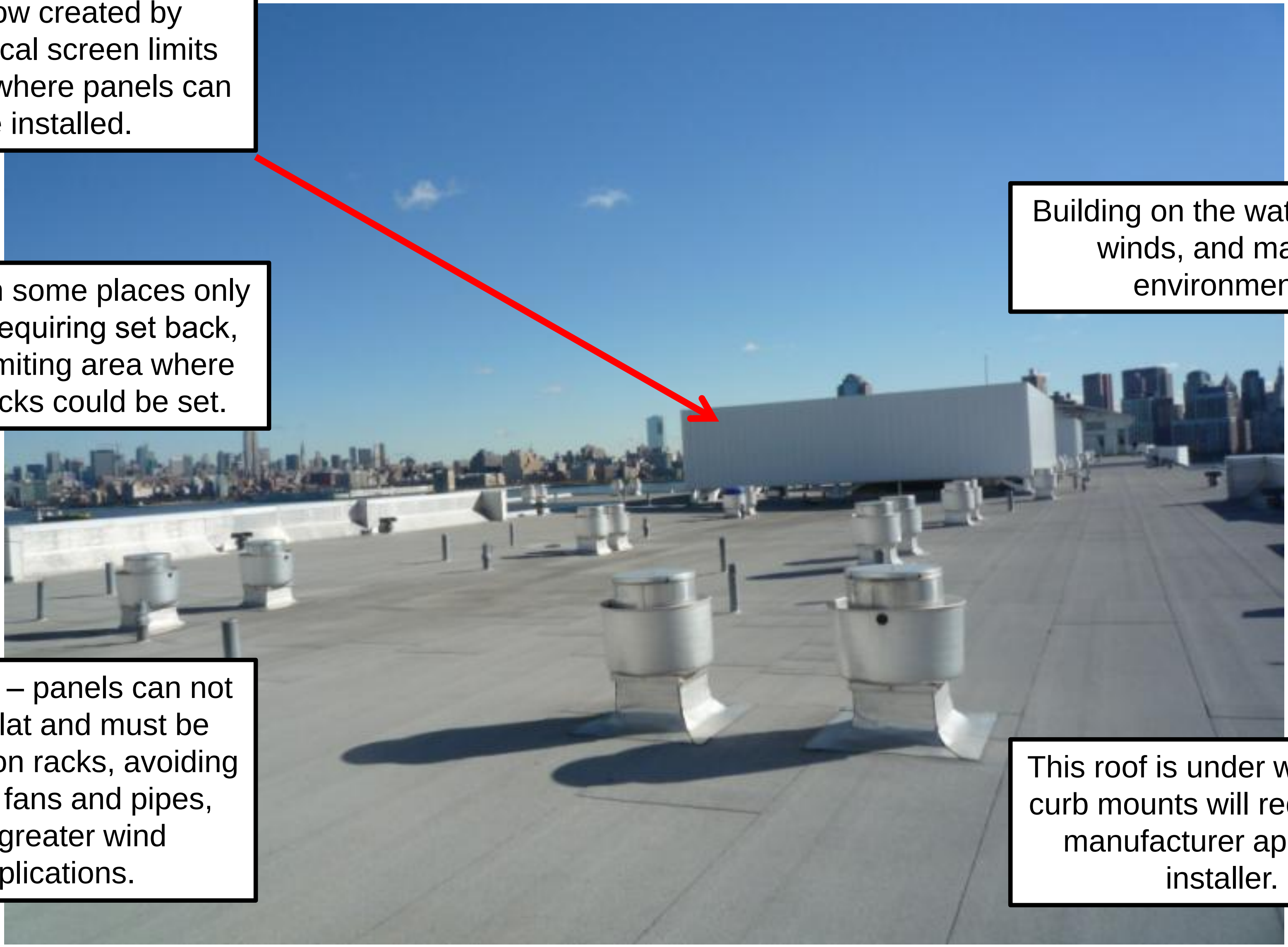
- Marine grade materials – aluminum is very susceptible to damage from salt air.
- Solar panels absorb heat and transmit it to the roof, potentially damaging the roof membrane.
- Some solar panels use EPS insulation – but this is not compatible with some single ply roofs (PVC).
- Value proposition of entire project?
- PV system built to stand the test of time?

Roof Top Assessment – New Jersey

Shadow created by mechanical screen limits the area where panels can be installed.

Parapet in some places only 6” high, requiring set back, further limiting area where panel racks could be set.

Busy roof – panels can not be laid flat and must be mounted on racks, avoiding exhaust fans and pipes, with greater wind implications.



Building on the water – high winds, and marine environment.

This roof is under warranty – curb mounts will require roof manufacturer approved installer.

Roof Assessment - Hawaii

Roof needs to be replaced before solar can be installed. Note the many repairs.

Notice drainage patterns – valleys and crickets which could have an impact on solar PV placement.

Wind blown debris could cover the new panels.

Solar Life Cycle Example

Multi-Family Property

- Located in Northern California
- Approximately 25 years old
- 500± units
- 10 buildings
- No solar currently
- But a fairly typical project

System Description

System Size (kW DC)	206.08
Annual kWh Production (Year 1)	305,741
Solar Module Information	896 230W
Inverter Information	Multiple Inverters
Tilt	10 degrees
Azimuth	207 degrees
Shading Percentage	0%
Type of Mount	Roof
Racking / Mounting System	Custom High Rack
Projected In-service date	**7/29/2011**

System Assumptions

System Life	35 Years
Annual PG&E Rate Increases	5.80%
Solar Electricity Value $/kWh	$0.2320
Annual Production Degradation	0.70%
Annual Operations & Maintenance (Year 1)	$4,122
Discount Rate	*7.0%*

Costs and Savings

Installed System Cost Total	**$1,041,619**
30% Federal Tax Credit or Grant	-$312,486
State/Utility Incentive (After Tax)	$0
Federal & State Depreciation Savings	$0
Cost After Incentives and Tax Benefits	**$729,133**
Lifetime O&M Costs	$74,416
Other costs	N/A
Utility Savings (35 Years)	-$1,713,795
Net Present Value of Cash Flows (After Tax)	**$910,246**

Life Cycle Savings

- **Installed cost: $1,041,619**
- **Yearly electricity bill before solar: $93,820**
- **First year savings in electricity costs: $71,121**
- **Cumulative savings over 35 years: $5,430,148 (assuming rate increases)**
- **Net present value of savings: $917,462**
- **Payback (Years): 8.8**

Unique Features

- **Cash funded**
- **Return on investment: >10%**
- **Possible model for HOAs with cash!!**
- Solar projects and mechanical upgrades, with could possibly pass the fiduciary responsibility smell test.

How Do You Pay for Solar?

- Many Solutions.
- Depends on your goals.
  - Because you are an enlightened sustainability advocate.
  - Dramatically reduce utility costs.
  - Predictability.
  - Use Capital Investment to Lower Operating Costs.
  - Tax Management.

How Do You Pay for Solar?

- Federal and State Incentives.

- Traditional financing:
  - Loan / Lease – Varies,
  - Municipal Lease,
  - Municipal Bond,
  - ARRA Stimulus Funds.

- Financing Solutions:
  - Power Purchase Agreement.

- Cash Purchase:
  - Great…if you have the money.

Power Purchase Agreement

- You’re buying energy not equipment.

- Private entity - installs, owns, operates and maintains solar system on your site.

- You buy electricity from the system through a Power Purchase Agreement.

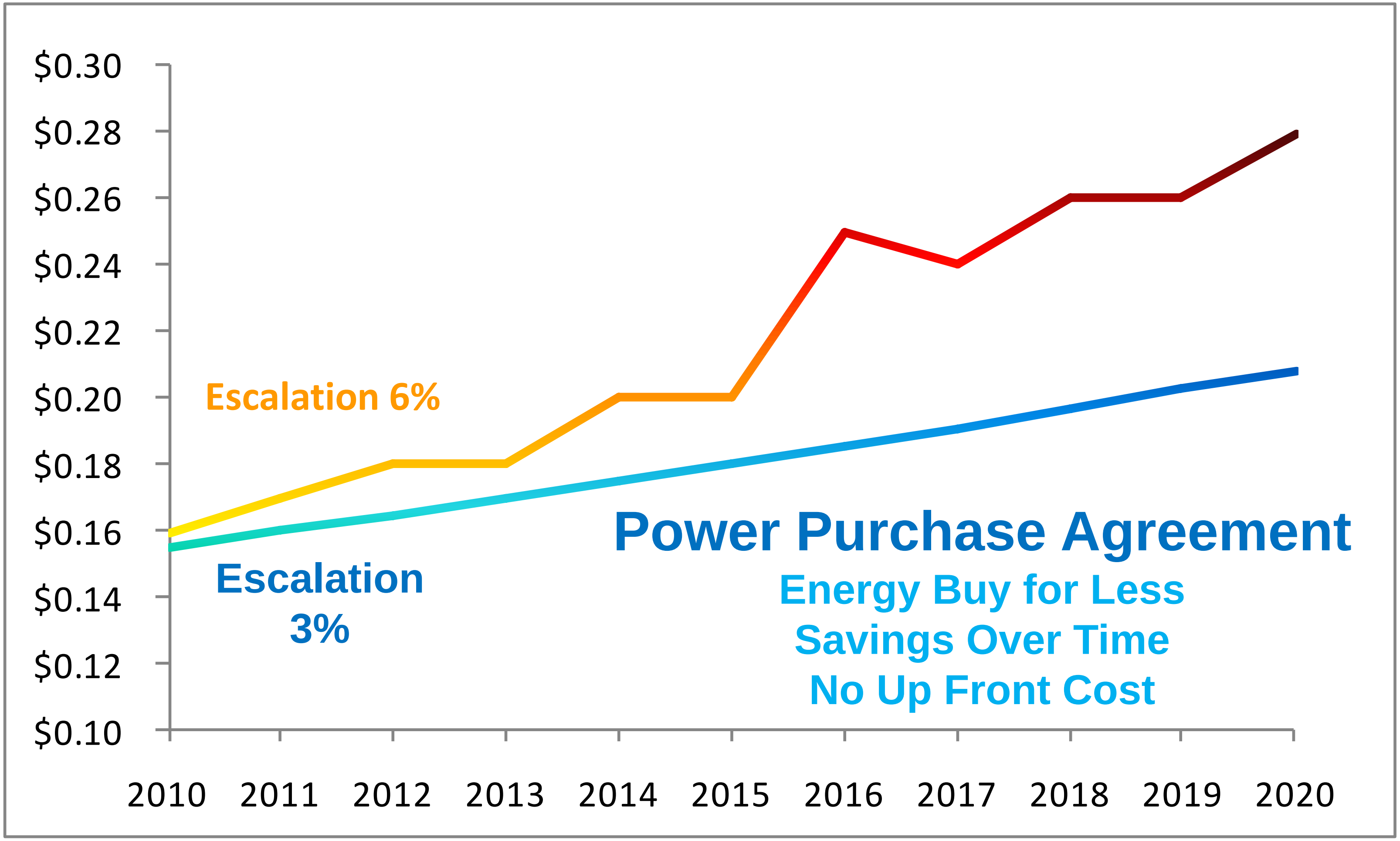
- No up front costs, no down payments, no maintenance costs.

- Credit quality is important.

Power Purchase Agreement (PPA)

- PPA Length: 15 – 25 years.
- Useful System Life: up to 40 Years.
- Optional Buyout – Fair Market Value.
- End of contract: System removal and site restored to original condition.

PPA Costs Are Predictable



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As-Built Stucco Problem that Reduces Longevity

Note that stucco was applied after the gutters – a scheduling problem by the sheet metal subcontractor, that will lead to significant problems.

Stucco Failures

Excessive stucco cracking

Design or Installation Problem?

How Many Life Cycle Problems?

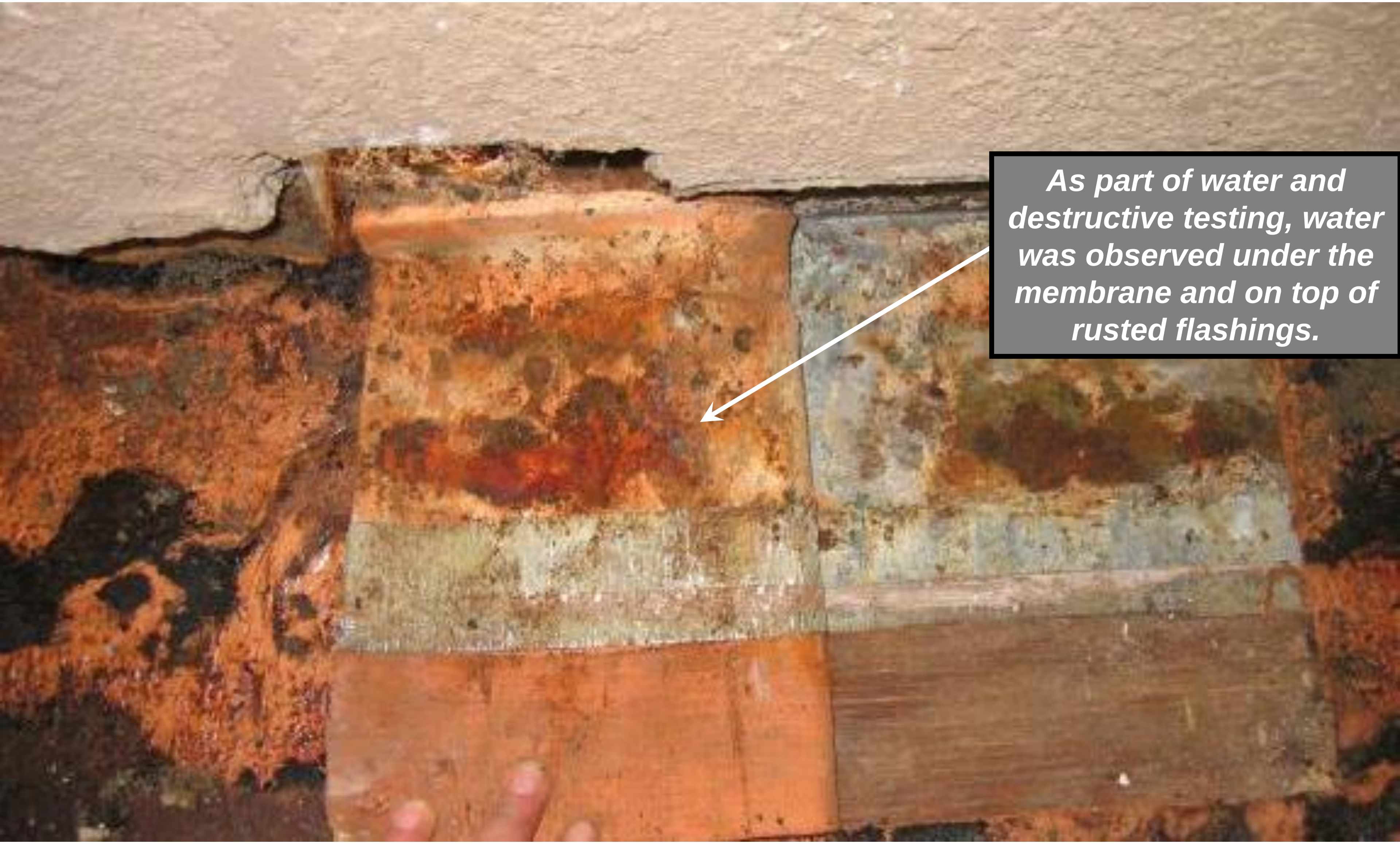
Stucco Repair Alternatives

- Elastomeric paint – won't address all cracks
- Patch?
- Replace with siding?
- Replace stucco in kind?
- Issues
  - Still need to resolve underlying issues
  - Expensive
  - Messy
  - Could change the structural load of the building
  - Aesthetics may change

Sealants and Flashings

Cracked and separated sealants; sealant and siding problems.

Hidden Balcony Waterproofing Issue



Electrical

What Can Be Done for Long Term Life Cycle Cost Reduction?

Landscaping – Invasive Roots

Don't My Dues Include Water?


LIVING ROOM
MEDIA ROOM
Landscaping should not be here.

Hardscape - Failed Pavement

- Weight damage.
- “Alligatoring” due to:
  - Poor design.
  - Water intrusion,
  - Standing water, or
  - Irrigation water.
- Slurry seal is only temporary!

Safety Issues

- Sidewalks – design issue most likely.
- Many experts recommend no more than a ¾" height differential.


Owners saved a lot of money by not paying a consultant to check for PT cable location via X-ray.

Spalled Concrete

Wood to Wood Contact
Traps Water and Promotes Decay

Typical Component Life Expectancies*

***Subject to regional variations and subject to quality of original construction**

Roofs:	10 - 30+ Years
"Package" HVAC units:	5 - 15 Years
Central HVAC units:	15 - 30 Years
Variable Refrigerant Flow HVAC systems:	15 - 30 Years
Solar PV modules and inverter:	20+ Years
Solar Thermal systems:	20+ Years
Sealants:	10 - 25 Years
Below-grade waterproofing:	Life of the building
Windows:	Life of the building
Window gaskets:	10 - 20 Years
Stucco:	Life of the building
Painting:	5 - 7 Years
Wood siding:	15 - 40 Years
Trees and landscaping:	15 - 40 Years
Asphalt Pavement:	10 - 20 Years
Concrete Sidewalks:	15 - 25 Years
Sewer and Storm Lines:	40+ Years