

Peter Baker, P.Eng., Building Science Corporation

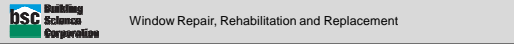
## Window Repair, Rehabilitation and Replacement

Building America Experts Meeting  
November 14, 2011, Minneapolis, MN



## Introduction


- Background
- System Interaction
- Cost and Performance
- Measure Implementation



## Background

Poor performing windows are one of the most significant performance issues for building enclosures

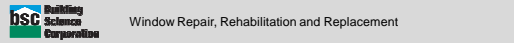
- Common location of water infiltration
- Common source of air infiltration
- Common source of significant space conditioning loads
- Common source of user comfort issues



## Background

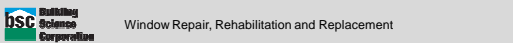
Multiple means to improve performance

- Repair and rehabilitate (add seals and gaskets)
- Coverings (awnings, shades, blinds, films, etc.)
- Additional glazing elements (exterior and interior storms and windows)
- Modification (retrofit existing sashes with IGU's)
- Sash replacement
- Window insert into existing frame
- Window replacement





## System Interaction

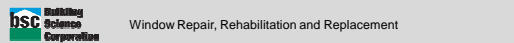
- It is important to understand the system components and connection/interaction details with the wall enclosure, as well as the functions of a traditional wood window in order to properly apply the various measure recommendations
- Water Management
- Air Infiltration
- Interstitial Condensation



## System Interaction

- Water Infiltration
  - Important to properly identify existing water infiltration concerns prior to window retrofit



### System Interaction

- Common water infiltration locations

Between the frame and rough opening  
At joints in the frame  
Between the sash and frame  
Between the glass and sash

**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 7

### System Interaction

- Water Management
  - Traditional windows use a shingle lapping approach

**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 8

### System Interaction

- Deteriorated Materials
  - Most of the retrofit measures require the existing window frame to be in good condition
  - Any damaged or deteriorated window sills will need to be replaced, unless a full window replacement is done

**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 9

### System Interaction

- Water Management - Jams
  - overlap of materials and/or use of sealants is generally required

**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 10

### System Interaction

- Water Management
  - Most window retrofit measures do not specifically address the interface of the existing window frame to the wall
  - If concerns exist regarding the performance of the existing window to wall, then a more extensive retrofit may be warranted
  - Full window replacement strategies provide the best means to integrate a window into an existing wall assembly.

**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 11

### System Interaction

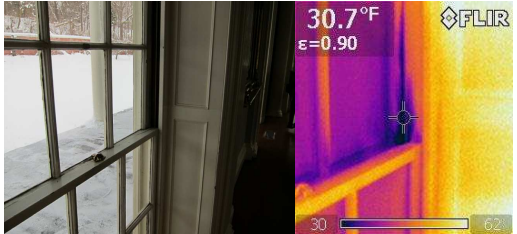
- Air Infiltration
  - Common pathways are at sash to frame interfaces

Air infiltration between sash and frame  
Air infiltration at the meeting rails

**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 12

### System Interaction

- Air Infiltration
  - Common pathways are at sash to frame interfaces



30.7°F  
ε=0.90

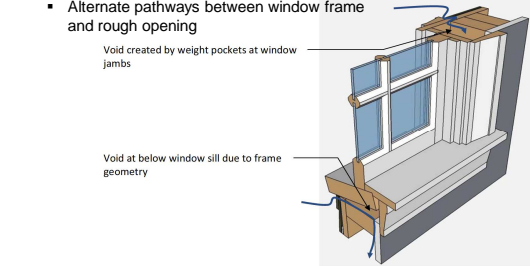
FLIR

30 62

**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 13

### System Interaction

- Air Infiltration
  - Alternate pathways between window frame and rough opening



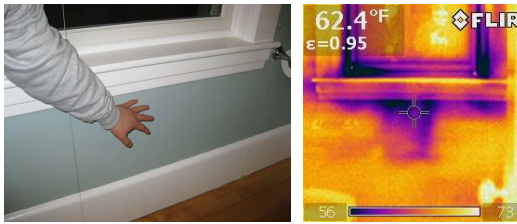
Void created by weight pockets at window jambs

Void at below window sill due to frame geometry

**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 14

### System Interaction

- Air Infiltration
  - Alternate pathways between window frame and rough opening



62.4°F  
ε=0.95

FLIR

56 73

**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 15


### System Interaction

- Air Infiltration
  - Infiltration between the sashes and the window frame are address with all window retrofit measures
  - Infiltration between the frame and the rough opening are only addressed as part of a complete window replacement
  - Additional air sealing outside of the window retrofit is generally needed – typically through the use of spray foam insulation

**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 16

### System Interaction


- Interstitial Condensation
  - Concern created by uncontrolled air leakage into space between original "prime" window and interior or exterior storm window



**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 17

### System Interaction


- Interstitial Condensation
  - Concern created by uncontrolled air leakage into space between original "prime" window and interior or exterior storm window



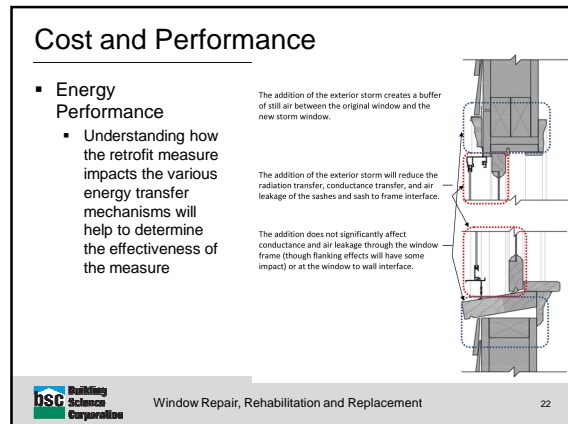
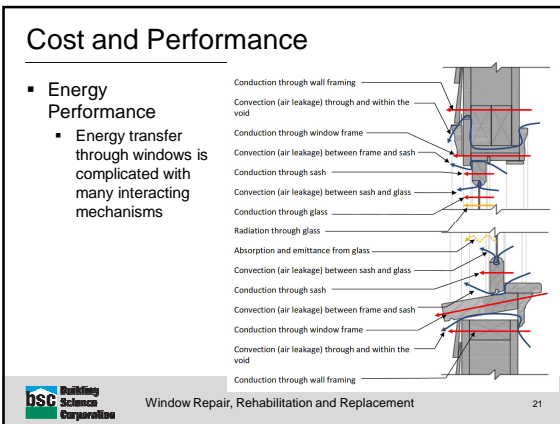
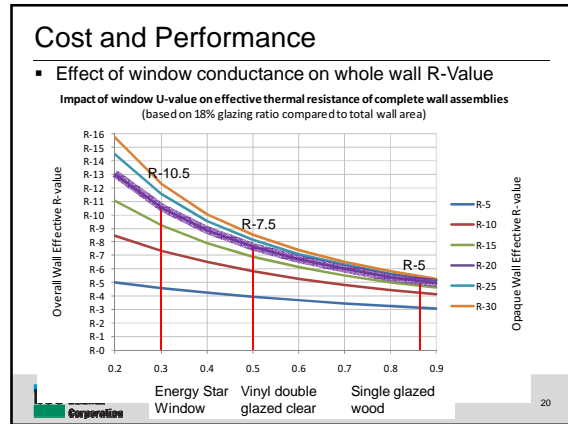
**BSC** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 18

### System Interaction

- Interstitial Condensation
  - For cold climates, the inner glazing element needs to be as air tight as possible (Drive is reversed for hot humid climates).
  - The exterior glazing element should be as air tight as possible to maximize performance.
  - If needed the exterior glazing element can be made incrementally more air leaky to help alleviate any condensation problems that may occur (increasing air leakage will reduce overall window energy performance).
  - Be aware of air by-pass through elements such as sash weight pulleys




Window Repair, Rehabilitation and Replacement 19



### Cost and Performance

NFRC Documentation relating performance of window attachment products




National Fenestration Rating Council Incorporated

NFRC 100A-2010

Procedure for Determining Fenestration Attachment Product U-factors

© 2010 NATIONAL FENESTRATION RATING COUNCIL, INC.

PREPARED BY:  
National Fenestration Rating Council  
6700 W. Linn, Suite 100  
Overland Park, MO 66212  
Phone: (913) 552-1774  
Fax: (913) 552-3884  
Email: info@nfrc.org  
Website: www.nfrc.org



Window Repair, Rehabilitation and Replacement 23

### Cost and Performance

Existing Window Types	U-factor	SHGC
Single-pane clear window (metal frame)	1.18	0.78
Single-pane clear window (non-metal frame)	0.86	0.68
Double-pane clear window (metal frame)	0.80	0.70
Double-pane clear window (non-metal frame)	0.49	0.60


  

New Window Options	U-factor	SHGC
Highly-insulating window	0.22	0.30
ENERGY STAR window for northern climates	0.30	0.30
Double-pane low-E window (non-metal frame)	0.35	0.25
Double-pane clear window (non-metal frame)	0.49	0.60

Storm Window Options	Primary Window Types	U-factor	SHGC
Low-E Storm Window	Single-pane clear window (metal frame)	0.70	0.61
	Single-pane clear window (non-metal frame)	0.40	0.52
	Double-pane clear window (metal frame)	0.63	0.57
Clear Glass Storm Window	Double-pane clear window (non-metal frame)	0.34	0.48
	Single-pane clear window (metal frame)	0.79	0.70
	Single-pane clear window (non-metal frame)	0.49	0.60
	Double-pane clear window (metal frame)	0.67	0.64
	Double-pane clear window (non-metal frame)	0.38	0.55


Window U-value and SHGC for various windows systems and exterior storm configurations (source US DOE "Highly Insulating or Low E Storm Windows Energy Savings Estimator")



Window Repair, Rehabilitation and Replacement 24

### Cost and Performance

- Modification or replacement of existing single glazed windows is generally cost effective in every climate zone.
- Cost of each measure is highly variable depending on existing conditions, retrofit measure chosen, and products used.
- Cost optimization should be done on a project by project basis.




Window Repair, Rehabilitation and Replacement 25

### Cost and Performance

Parametric step	Cost/ft <sup>2</sup>
Benchmark = single glazed wood (U=0.87, SHGC=0.62)	N/A
Single glazed wood + clear exterior storm (U=0.49, SHGC=0.60)	\$7.81
Single glazed wood + lowE exterior storm (U=0.40, SHGC=0.52)	\$12.14
Double Glazed LowE Energy Star Window (U=0.30, SHGC=0.30)	\$40.73
Single glazed wood + interior Double Glazed LowE Energy Star Window (U=0.25, SHGC=0.25) <sup>1</sup>	\$40.73
Triple Glazed LowE Window (U=0.20, SHGC=0.20)	\$77.76


<sup>1</sup>Values were assumed due to unavailability of actual modeled or measured values for this configuration



Window Repair, Rehabilitation and Replacement 26

### Measure Implementation

- Several options for improving the performance of existing windows was used
- Stepping through the various strategies using a single starting condition as a baseline in order to illustrate the differences in the various strategies
- Highlighting potential durability concerns as part of the individual strategy




Window Repair, Rehabilitation and Replacement 27

### Measure Implementation

List of Measures

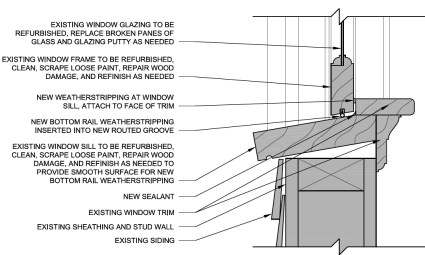

- Window Rehabilitation
- Exterior Storms
- Interior Removable Storms
- Interior Permanent Storms
- Window Sash Modification
- Window Sash Replacement
- Insert Replacement Window
- Complete Replacement Window



Window Repair, Rehabilitation and Replacement 28

### Measure Implementation

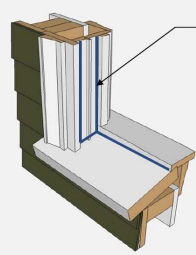

#### Window Rehabilitation

Window Repair, Rehabilitation and Replacement 29

### Measure Implementation

#### Window Rehabilitation

Window Repair, Rehabilitation and Replacement 30

### Measure Implementation

#### Exterior Storms

- NEW SINGLE GLAZED PERMANENT OPERABLE EXTERIOR STORM WINDOW. SEAL AT HEAD AND JAMBS. SILL EXTENSION TO BE LEFT UNSEALED TO ALLOW SILL TO DRAIN TO EXTERIOR
- EXISTING WINDOW GLAZING TO BE REFURBISHED. REPLACE BROKEN PANE OF GLASS AND GLAZING PUTTY AS NEEDED
- EXISTING WINDOW FRAME TO BE REFURBISHED. CLEAN. SCRAPE LOOSE PAINT. REPAIR WOOD DAMAGE. AND REFINISH AS NEEDED
- NEW WEATHERSTRIPPING AT WINDOW SILL. ATTACH TO FACE OF TRIM
- NEW BOTTOM RAIL WEATHERSTRIPPING INSERTED INTO NEW ROUTED GROOVE
- EXISTING WINDOW SILL TO BE REFURBISHED. CLEAN. SCRAPE LOOSE PAINT. REPAIR WOOD DAMAGE. AND REFINISH AS NEEDED TO PROVIDE SMOOTH SURFACE FOR NEW BOTTOM RAIL WEATHERSTRIPPING
- NEW SEALANT
- EXISTING WINDOW TRIM
- EXISTING SHEATHING AND STUD WALL
- EXISTING SIDING

**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 31

### Measure Implementation

#### Interior Removable Storms

- NEW SINGLE GLAZED REMOVABLE FIXED INTERIOR STORM WINDOW. WINDOW TO HAVE METAL TRACK WITH MAGNETIZED FRAME. SEAL TRACK TO TRIM AT WINDOW PERIMETER
- EXISTING WINDOW GLAZING TO BE REFURBISHED. REPLACE BROKEN PANE OF GLASS AND GLAZING PUTTY AS NEEDED
- EXISTING WINDOW FRAME TO BE REFURBISHED. CLEAN. SCRAPE LOOSE PAINT. REPAIR WOOD DAMAGE. AND REFINISH AS NEEDED
- NEW WEATHERSTRIPPING AT WINDOW SILL. ATTACH TO FACE OF TRIM
- NEW BOTTOM RAIL WEATHERSTRIPPING INSERTED INTO NEW ROUTED GROOVE
- EXISTING WINDOW SILL TO BE REFURBISHED. CLEAN. SCRAPE LOOSE PAINT. REPAIR WOOD DAMAGE. AND REFINISH AS NEEDED TO PROVIDE SMOOTH SURFACE FOR NEW BOTTOM RAIL WEATHERSTRIPPING
- NEW SEALANT
- EXISTING WINDOW TRIM
- EXISTING SHEATHING AND STUD WALL
- EXISTING SIDING

**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 32

### Measure Implementation

#### Interior Permanent Fixed Storms

- NEW SITE BUILT DOUBLE GLAZED PERMANENT FIXED INTERIOR INSULATING GLASS UNIT (IGU). WINDOW TO BE SEALED AT PERIMETER TO PREVENT AIR LEAKAGE INTO INTERSTITIAL SPACE
- EXISTING WINDOW GLAZING TO BE REFURBISHED. REPLACE BROKEN PANE OF GLASS AND GLAZING PUTTY AS NEEDED
- EXISTING WINDOW FRAME TO BE REFURBISHED. CLEAN. SCRAPE LOOSE PAINT. REPAIR WOOD DAMAGE. AND REFINISH AS NEEDED
- NEW GLAZING TAPE (BUTYL)
- NEW WEATHERSTRIPPING AT WINDOW SILL. ATTACH TO FACE OF TRIM
- NEW SEALANT
- NEW BOTTOM RAIL WEATHERSTRIPPING INSERTED INTO NEW ROUTED GROOVE
- EXISTING WINDOW SILL TO BE REFURBISHED. CLEAN. SCRAPE LOOSE PAINT. REPAIR WOOD DAMAGE. AND REFINISH AS NEEDED TO PROVIDE SMOOTH SURFACE FOR NEW BOTTOM RAIL WEATHERSTRIPPING
- NEW SEALANT
- EXISTING WINDOW TRIM
- EXISTING SHEATHING AND STUD WALL
- EXISTING SIDING

**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 33

### Measure Implementation

#### Sash Modification

- NEW DOUBLE GLAZED INSULATING GLASS UNIT (IGU) INSTALLED IN EXISTING WINDOW FRAME. IGU TO BE SET ON SETTING BLOCKS. 1/2" HIGH
- NEW GLAZING TAPE (BUTYL)
- NEW WEEP HOLES IN BOTTOM RAIL ALLOWING GLAZING POCKET TO DRAIN TO EXTERIOR
- EXISTING WINDOW FRAME TO BE REFURBISHED. CLEAN. SCRAPE LOOSE PAINT. REPAIR WOOD DAMAGE. AND REFINISH AS NEEDED
- NEW WEATHERSTRIPPING AT WINDOW SILL. ATTACH TO FACE OF TRIM
- NEW BOTTOM RAIL WEATHERSTRIPPING INSERTED INTO NEW ROUTED GROOVE
- EXISTING WINDOW SILL TO BE REFURBISHED. CLEAN. SCRAPE LOOSE PAINT. REPAIR WOOD DAMAGE. AND REFINISH AS NEEDED TO PROVIDE SMOOTH SURFACE FOR NEW BOTTOM RAIL WEATHERSTRIPPING
- NEW SEALANT
- EXISTING WINDOW TRIM
- EXISTING SHEATHING AND STUD WALL
- EXISTING SIDING

**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 34

### Measure Implementation

#### Sash Modification

- INSULATING GLASS UNIT
- SILICONE SEALANT CAP BEAD
- EXTERIOR STOP
- GLAZING POCKET WEEPED TO EXTERIOR
- PRE-SHIMMED BUTYL TAPE INTERIOR AND EXTERIOR SEALS

**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 35

### Measure Implementation

#### Sash Replacement

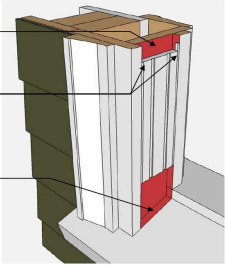
- NEW TRIPLE GLAZED REPLACEMENT SASH. EXISTING WINDOW SASH TO BE REMOVED
- NEW WEATHERSTRIPPING AT WINDOW SILL. ATTACH TO FACE OF TRIM
- NEW BOTTOM RAIL WEATHERSTRIPPING AT NEW WINDOW SASH
- EXISTING WINDOW SILL TO BE REFURBISHED. CLEAN. SCRAPE LOOSE PAINT. REPAIR WOOD DAMAGE. AND REFINISH AS NEEDED TO PROVIDE SMOOTH SURFACE FOR NEW BOTTOM RAIL WEATHERSTRIPPING
- NEW SEALANT
- EXISTING WINDOW TRIM
- EXISTING SHEATHING AND STUD WALL
- EXISTING SIDING

**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 36

### Measure Implementation

#### Sash Replacement

- Paint window jamb with liquid applied waterproof membrane
- Caulk sides of jamb liner to outer casing and interior stop
- Extend liquid applied water proof membrane down onto window sill (jamb liner not shown for clarity). Do not caulk bottom edge of jamb liner to sill.

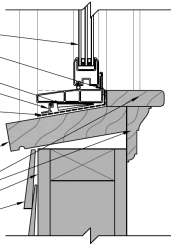


**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 37

### Measure Implementation

#### Insert Replacement Window

- NEW TRIPLE GLAZED REPLACEMENT WINDOW, EXISTING WINDOW TO BE REMOVED
- NEW SEALANT
- NEW PLASTIC SHIMB AT WINDOW 1/4 POINTS (2 LOCATIONS PER WINDOW)
- NEW SILL EXTENSION, DO NOT CAULK AT SILL
- NEW LIQUID APPLIED OR SHEET MEMBRANE PAN FLASHING, TURN UP 2" AT JAMB, JAMB FLASHING TO SINGLELAP OVER TURNED-UP SILL FLASHING
- EXISTING WINDOW SILL TO BE REFURBISHED, CLEAN, SKIPE LOOSE PAINT, REPAIR WOOD DAMAGE, AND FINISH AS NEEDED TO PROVIDE SMOOTH SURFACE FOR NEW BOTTOM RAIL WEATHERSTRIPPING
- EXISTING WINDOW TRIM
- EXISTING SHEATHING AND STUD WALL
- EXISTING SIDING

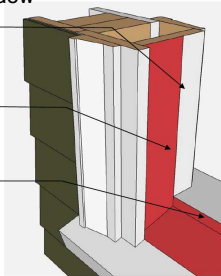


**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 38

### Measure Implementation

#### Insert Replacement Window

- Window sashes, parting beads, and interior stops removed. All gaps and hole in jambs patched and filled
- Liquid applied membrane or self adhered membrane waterproofing installed around rough opening
- Use existing stool as support for the membrane back dam



**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 39

### Measure Implementation

#### Insert Replacement Window

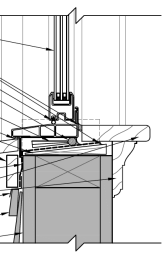


**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 40

### Measure Implementation

#### Complete Window Replacement

- NEW TRIPLE GLAZED WINDOW, EXISTING WINDOW AND FRAME TO BE REMOVED
- NEW SEALANT
- NEW WEATHERSTRIPPING AT NEW WINDOW
- NEW BACKER ROD AND SEALANT
- NEW PLASTIC SHIMB AT WINDOW 1/4 POINTS (2 LOCATIONS PER WINDOW)
- NEW SEALANT TO MINIMIZE WATER PENETRATION AT SILL
- NEW BEVELED SIDING
- NEW SILL EXTENSION AND TRIM BELOW
- NEW LIQUID APPLIED OR SHEET MEMBRANE PAN FLASHING, TURN UP 2" AT JAMB, JAMB FLASHING TO SINGLELAP OVER TURNED-UP SILL FLASHING, DOWNTURNED LEG OF FLASHING INSTALLED TO ACCOMMODATE FUTURE WALL RETROFIT
- NEW OR REINSTALLED EXISTING INTERIOR WINDOW TRIM
- NEW METAL FLASHING
- EXISTING SIDING, CUT TOP ROW TO ALLOW FOR SILL FLASHING
- EXISTING SHEATHING AND STUD WALL

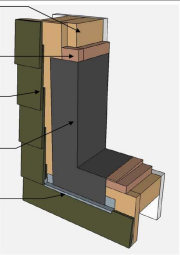


**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 41

### Measure Implementation

#### Complete Window Replacement

- Remove sashes, and window frame back to wall framing
- New blocking as needed
- Cut back siding as required to account for new replacement window dimensions
- Wrap rough opening with liquid applied or self adhered membrane flashing
- Lap bottom edge of membrane pan flashing over sheet metal flashing to shed water back out over the siding



**BSC Building Science Corporation** Window Repair, Rehabilitation and Replacement 42

### Measure Implementation

#### Complete Window Replacement

- CONTINUOUS SEALANT (AIR BARRIER SYSTEM)
- LOW EXPANSION FOAM SEALANT AT INTERIOR BETWEEN WINDOW AND PAN FLASHING (AIR BARRIER SYSTEM)
- PRE-MANUFACTURED PAN FLASHING WITH BACK DAM
- PLASTIC DAM
- SEALANT BETWEEN WINDOW AND SILL TRIM TO MINIMIZE WATER PENETRATION AT SILL JOINT
- SILL OF TRIM EXTENSION BOX
- DO NOT APPLY FLASHING MEMBRANE OVER BOTTOM FLANGE, ALLOW DRAINAGE, PLACE 3" WASHER UNDER EACH SCREW BETWEEN FLANGE AND FLASHING MEMBRANE FOR DRAINAGE SPACE
- FULLY ADHERED SHEATHING MEMBRANE EXTENDED INTO OPENING OVER BEVELED SILL (AIR BARRIER SYSTEM)
- WOOD FURRING STRIP
- (2) LAYERS OF 2" FOIL-FACED POLYISOCYANURATE INSULATING SHEATHING, JOINTS STAGGERED AND TAPED
- BEVELED SIDING SLOPED SILL
- FULLY ADHERED MEMBRANE OVER EXISTING SHEATHING TO FORM THE DRAINAGE PLANE AND PRIMARY AIR BARRIER

**b3c** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 43

### Measure Implementation

#### Complete Window Replacement

- LOW EXPANSION FOAM SEALANT AT INTERIOR BETWEEN WINDOW AND PAN FLASHING (AIR BARRIER SYSTEM)
- BEVELED SIDING SLOPED SILL
- PRE-MANUFACTURED PAN FLASHING WITH BACK DAM
- PLASTIC DAM
- SEALANT BETWEEN WINDOW AND SILL TRIM TO MINIMIZE WATER PENETRATION AT SILL JOINT
- SILL TRIM
- 2" POLYWOODSIB EXTENSION BOX CALLS INTERIOR CORNERS
- WOOD FURRING STRIP
- (2) LAYERS OF 2" FOIL-FACED POLYISOCYANURATE INSULATING SHEATHING, JOINTS STAGGERED AND TAPED; OUTER LAYER IS DRAINAGE PLANE
- CONTINUOUS SEALANT BETWEEN BACK DAM OF SILL PAN AND EXTENSION BOX (AIR BARRIER SYSTEM)
- FULLY ADHERED MEMBRANE OVER EXISTING SHEATHING TO FORM THE PRIMARY AIR BARRIER
- FULLY ADHERED SHEATHING MEMBRANE EXTENDED INTO ROUGH OPENING (AIR BARRIER SYSTEM)
- CONTINUOUS BEAD OF SEALANT BETWEEN EXTENSION BOX AND MEMBRANE (AIR BARRIER SYSTEM)

**b3c** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 44

# Questions?

Peter Baker  
pbaker@buildingscience.com

**b3c** Building Science Corporation  
Window Repair, Rehabilitation and Replacement 45