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PEER – Prefabricated Exterior Energy Retrofit

Building Capture Technology
13th Annual North American Passive House Conference, Boston, MA
2018.09.21



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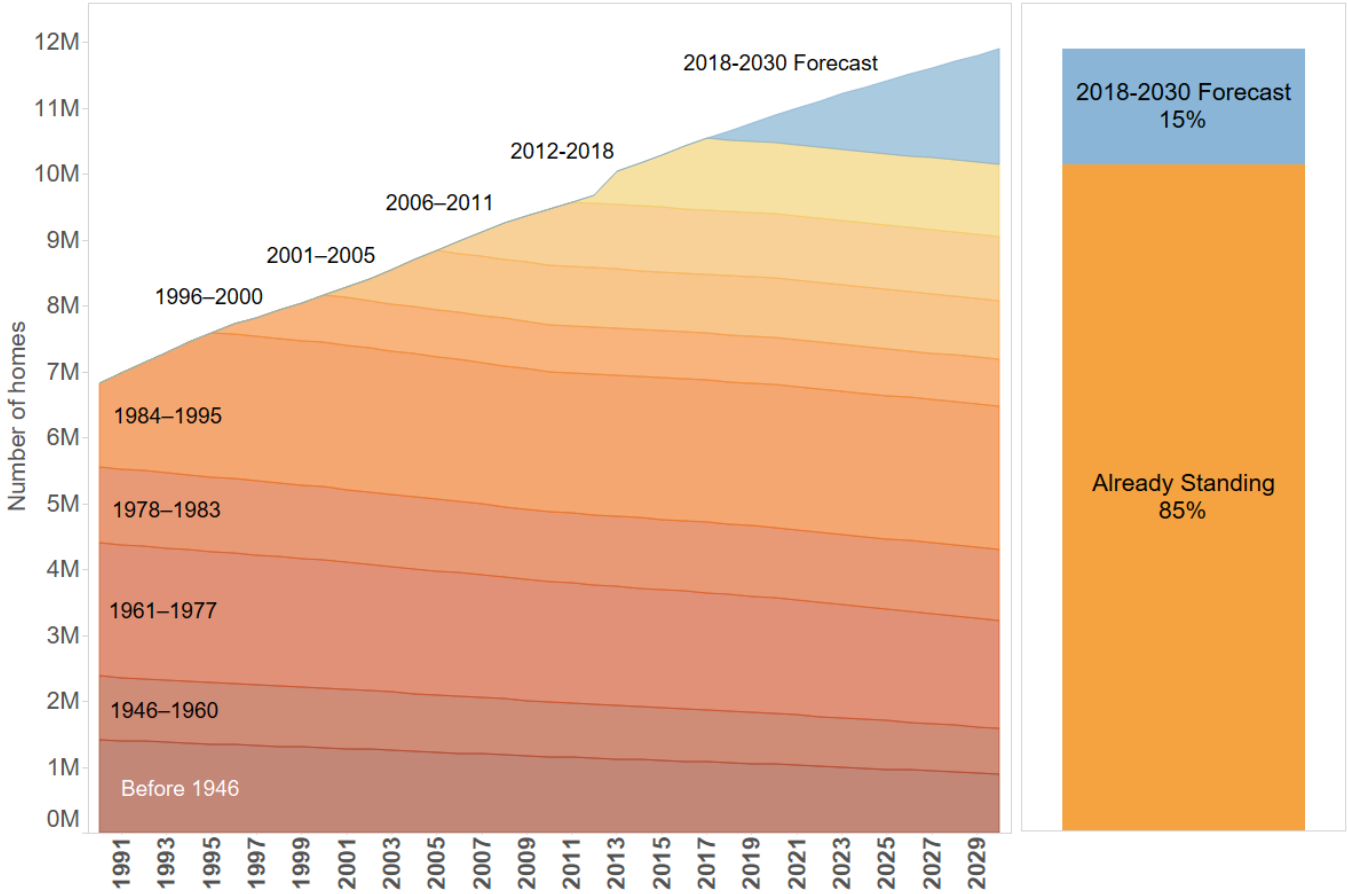
Outline

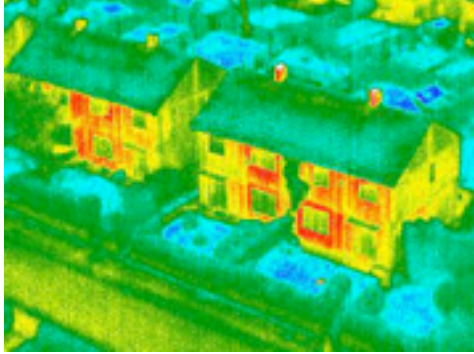
1 Canada's housing stock and retrofit activity
2 PEER project introduction
3 What is a prefab retrofit?
4 What challenges and opportunities do they present?
5 What is "Building Capture"?
6 What building info is required?
7 What technologies are available to obtain this info?
8 How do they compare?
9 Typical workflows

Canada's Housing Stock

- Replacement rates are slow in Canada.
- We estimate that >85% of the 2030 housing stock is already standing.



Retrofit efforts to date



Over the last 25 years >1M Canadian homes have received some type of energy retrofit.
Average annual energy savings – 21%

- HVAC system replacements (heating, cooling, hot water and ventilation) - **53%**
- Windows, interior insulation (mainly attics and foundations) and air-sealing – **43%**
- ***Exterior wall retrofits - 4%***

Barriers:

- Too expensive – perceived poor ROI
- Too disruptive – slow, noisy
- Too complicated – different trades involved
- Too much risk – technical and financial

Costs:

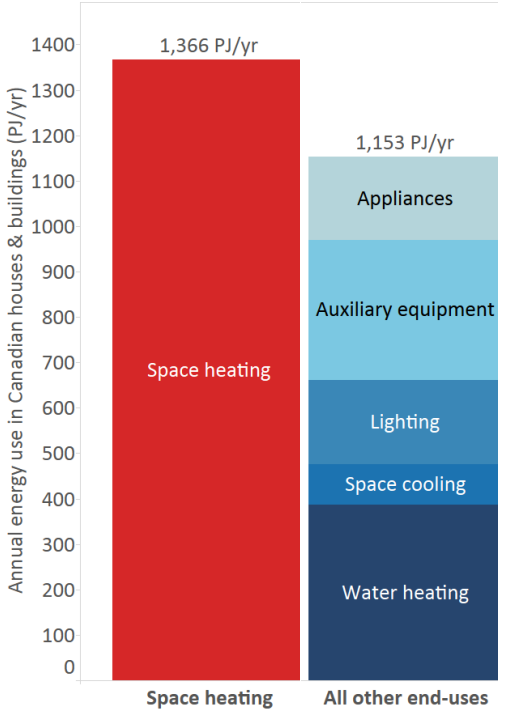
- 70 - 90% of the cost of an exterior wall retrofit is fixed (demolition, installing new cladding, etc.). 10% to 30% is R-value dependent. This may justify higher R-values than previously thought.

Opportunities:

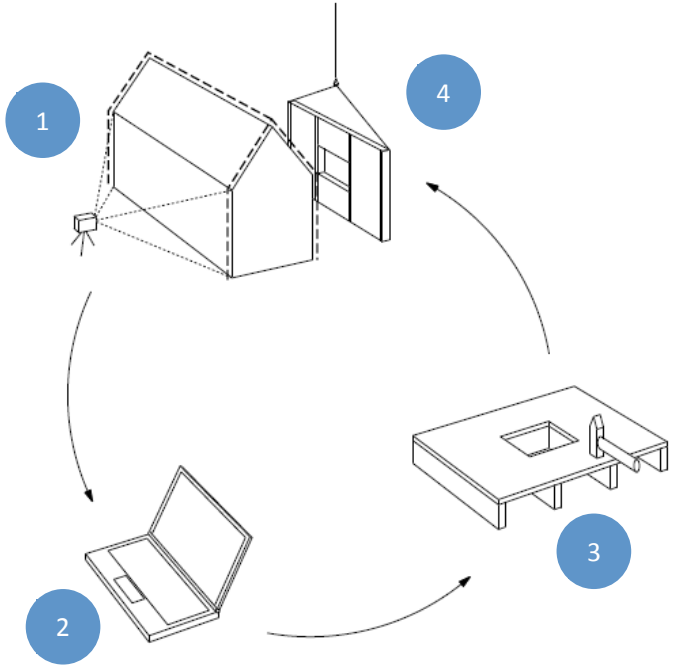
- Key time to retrofit is when cladding and/or windows need replacement
- Prefabrication can significantly reduce disruption

PEER Project (2016-2021)

- Goal: prefabricated building envelope solutions to achieve Net-Zero Ready
- Main research question:
  - Can factory-built, super-insulated, airtight panels be installed directly over existing walls? And if so, could that promise to be a cheaper and more effective way to conduct deep energy retrofits?
- 3 primary research areas:
  1. Building capture: rapid, accurate measurement
  2. Panel prototypes, fabrication and installation
  3. Building science: minimizing risks of failure

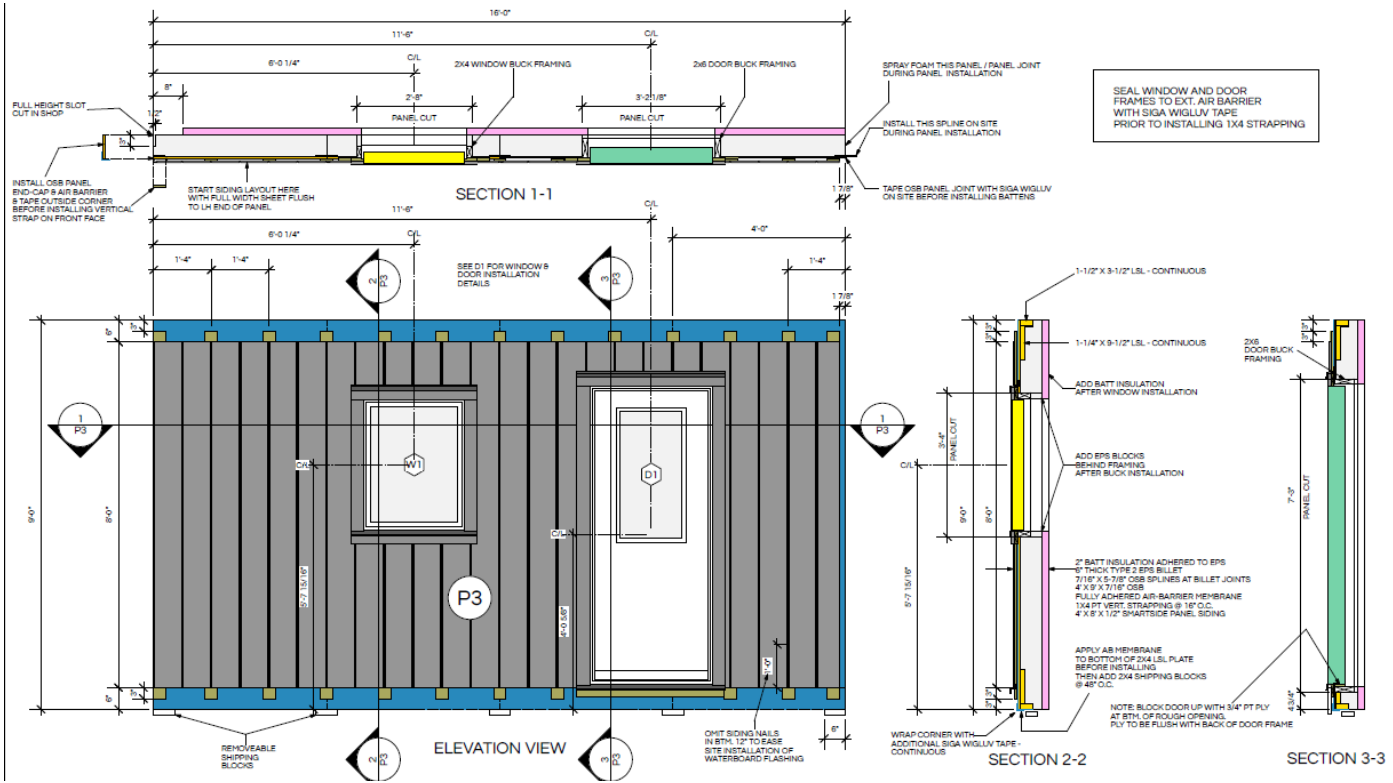


What is a prefabricated retrofit?

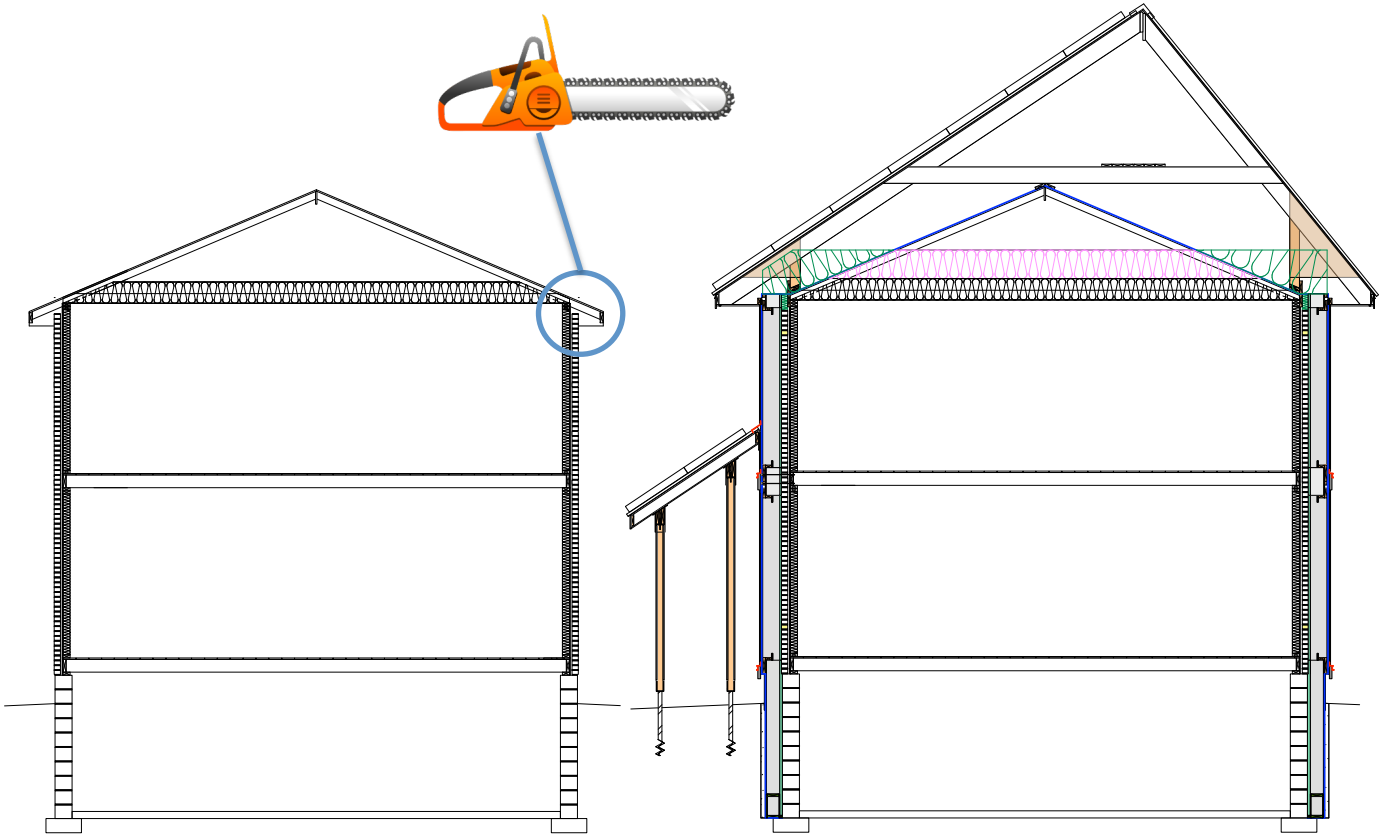


TES EnergyFacade, 2009

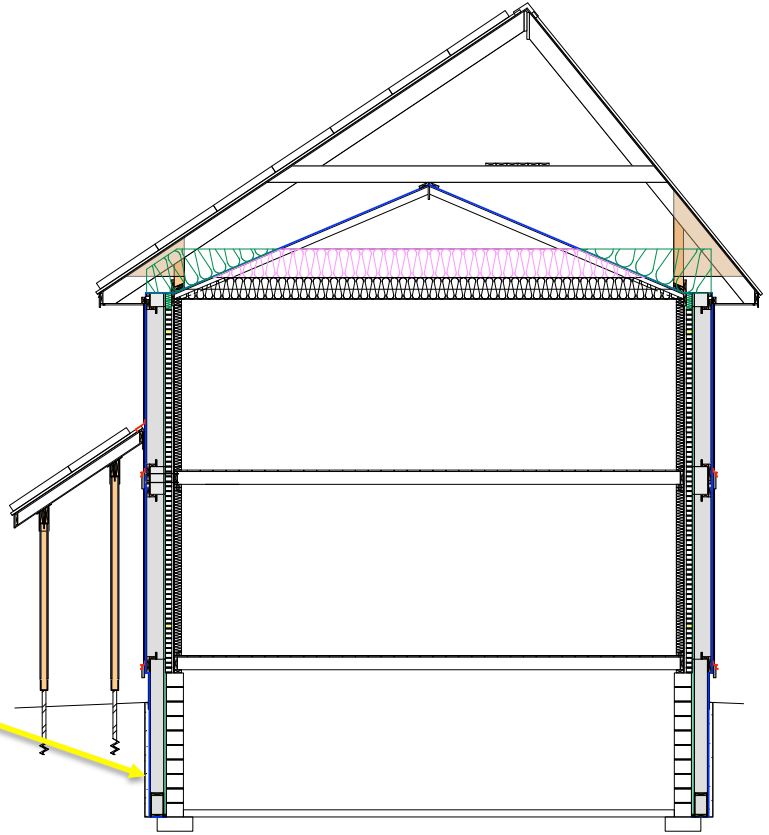
1. Scanning or measuring building (building capture)
2. Panel design
3. Off-site fabrication
4. Panel installation



Before



After



After

PEER Panel Prototypes

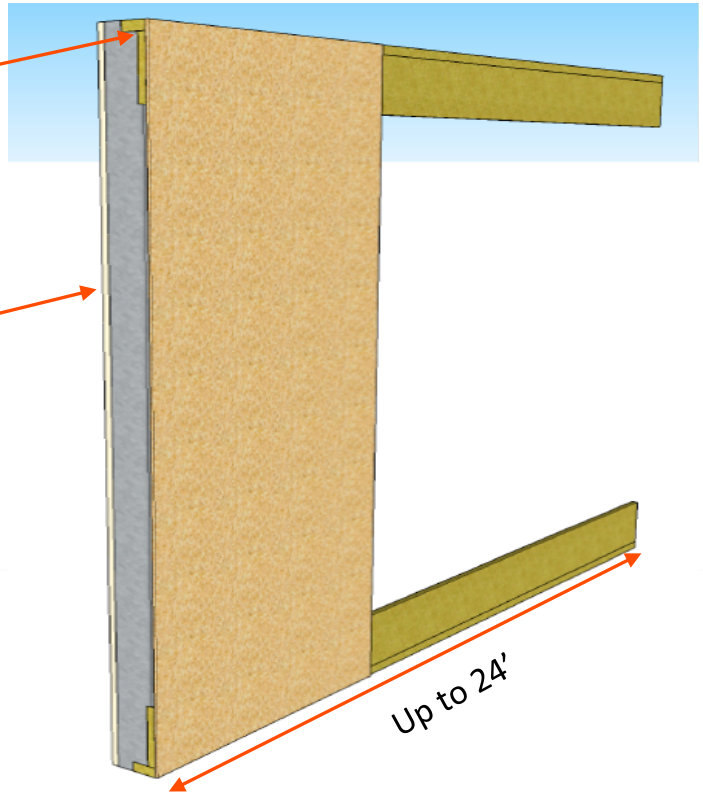
A. Rigid foam nail-base panel

Let-in structure

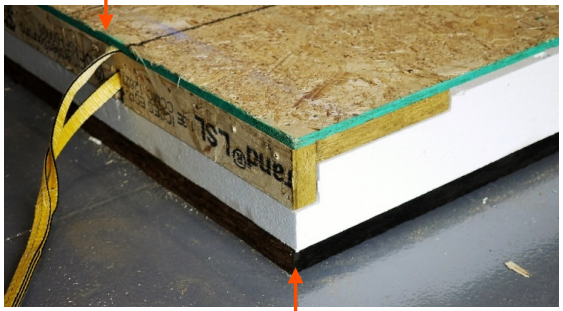
Ties sub-panels into superpanel
Stiffens superpanel and enables it to be lift into place

Squishy Layer

Helps with plumb/square
Absorbs surface irregularities
Provides dimensional tolerance
Vapour open

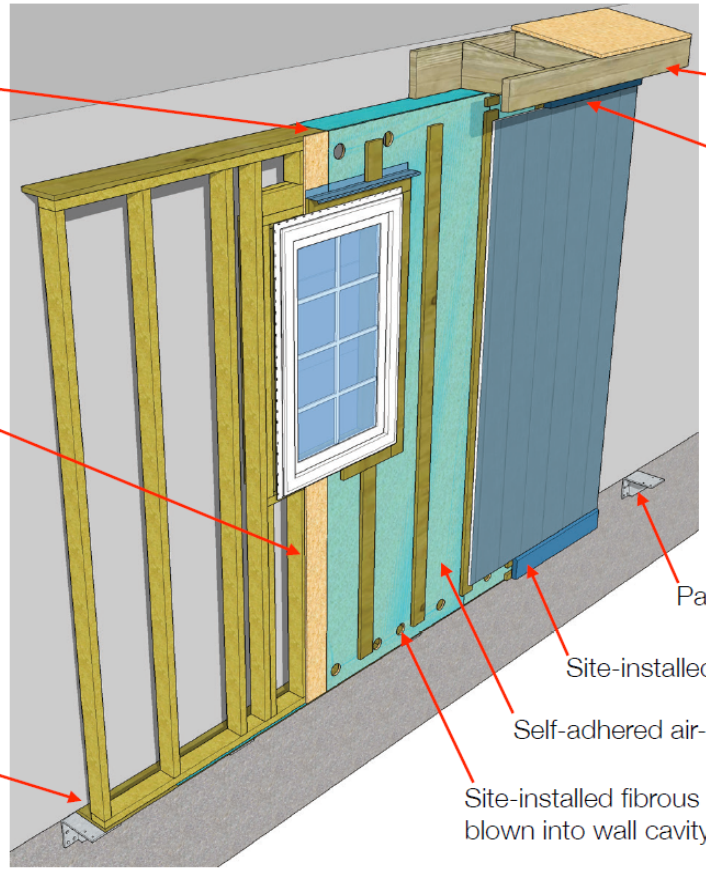


Integrated lifting straps



Squishy Layer

B. Woodframe Standoff Panel



Why? What are the advantages of prefabrication?

- Minimizes demolition and site prep
- Less time and disruption on site
- Less waste
- Improves quality control
- Materials stay dry and out of elements
- Lower risk of materials disappearing on site
- Helps address skilled labour shortage
- Solutions can be scaled and rapidly deployed
- *Maybe: cost savings at scale*

What is Building Capture?

The process of accurately recording existing 3D building and site conditions using static scanning and/or photogrammetry. *(Reality Capture for building applications)*

Using laser scanning and photogrammetry methods, millions of surface points are measured and mapped to create a textured, high-resolution, geometrically precise 3D model.

Advantages:

- Increased accuracy
- Comprehensive documentation
- Fewer trips to jobsite
- Begin designing in 3D

Panel fit strategies

Instrument uncertainty

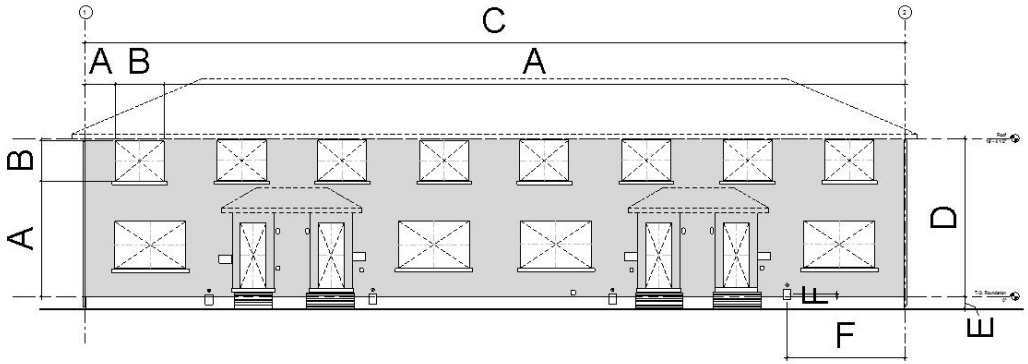
Interpretation error

Manufacturing tolerances

\+ Installation tolerances

Total Potential Error

What are our target levels of accuracy?



Measurement / Dimension		Tolerance	
		(in)	(mm)
A	Position of window in façade (X, Y)	1/4”	6mm
B	Window opening (height and width)	1/4"	6mm
C	Overall building width	1/4"	6mm
D	Overall building height from top of foundation to underside of soffit	1”	25mm
E	Average grade level to top of foundation	1”	25mm
F	Centreline of building penetrations, utility meters, and service entrances	1”	25mm

What measurement methods are available?

- Hand measurements
- Theodolite total station
- 3D laser scanning
- Photogrammetry

Measure by hand

Pros

- Low cost of entry for training and equipment
- Only important/relevant measurements are recorded

Cons

- Accessibility challenges (measuring above reach, or around obstructions)
- The surveyor will only capture what and where they measure and are unlikely to catch small imperfections and peculiarities
- Measurements and transcription prone to human error. Such errors can occur in the field or at the office
- Difficult and time consuming to measure and record complex building geometry

Total Station Theodolite

Pros

- Equipment and operators widely available
- Just the facts
- Instruments are extremely accurate with long range capabilities
- Data easy to manage and import into CAD

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Cons

- Somewhat expensive equipment ($7-20k CAD)
- Operator needs to know exactly what measurements are required
- Finite number of points captured, higher risk of points being missed
- Field time (and therefore cost) is comparable with laser scanning but only capturing a small fraction of the information
- Time-intensive to “re-section” (moved the total station around a building) and to produce a detailed and finished plan

3D Photogrammetry

Pros

- Hi-res cameras widely available
- Software is inexpensive
- Able to add extra detail in areas of interest
- Everyone's a photographer

Cons

- Lower accuracy, precision and more distortion
- Requires a lot of photos and processing
- Requires decent lighting conditions which are difficult to control outdoors
- Some training and experience required for processing
- Results cannot be determined until back in office; high likelihood of missing information
- Not all points may be visible from multiple angles
- Difficult and complicated to make corrections if software generates poor results

3D Laser Scanning

Pros

- Detailed and comprehensive datasets; minimal risk of missing key measurements
- High degree of accuracy and reliable results when done properly
- Reduced trips to site; information is useful to various members of project team
- Technician doesn't need to know what measurements are required

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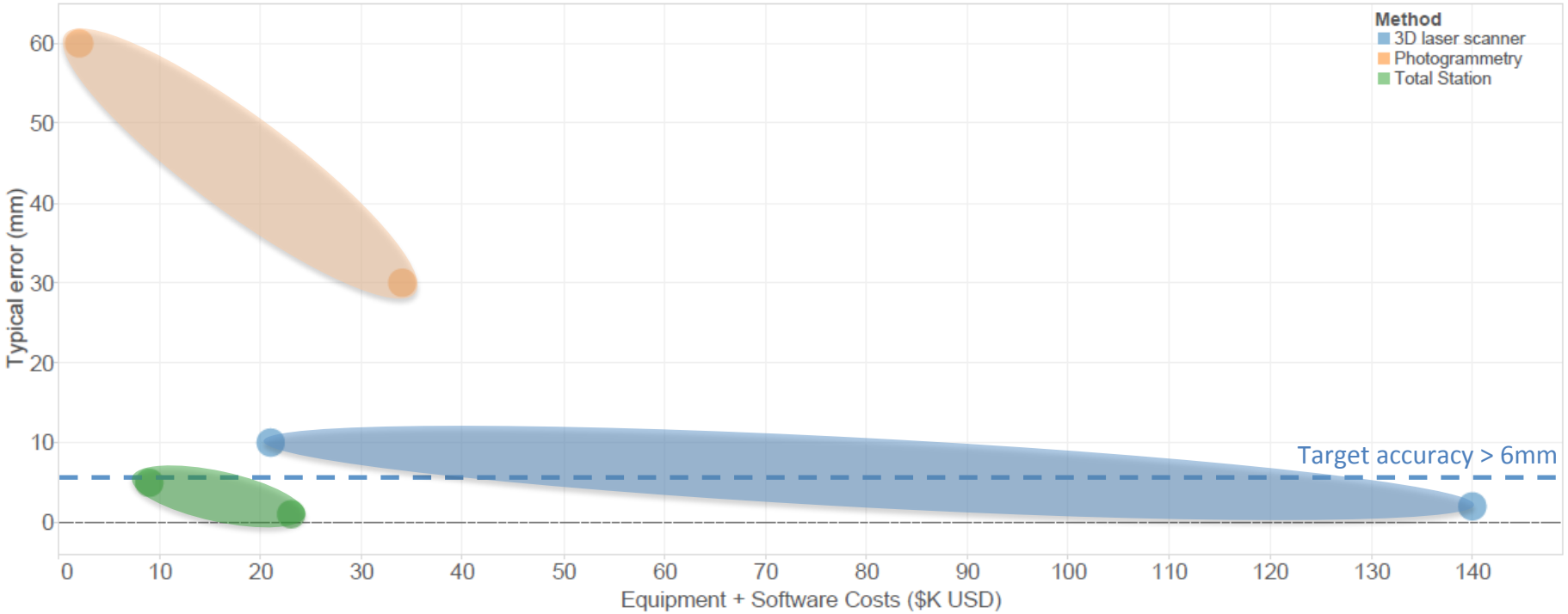
Cons

- Software required to view and utilize the data
- Only records measurements within line of site
- Possibility of cumulative error in scan registration
- Difficulty capturing very dark or reflective surfaces
- Extremely large data sets can be difficult to work with

Cost vs Accuracy

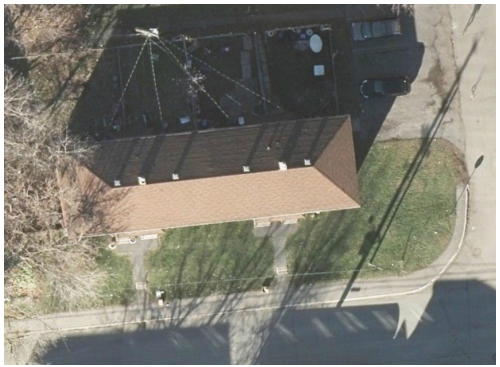


Comparison Matrix

	3D Laser Scanning	Photogrammetry	Total Station Theodolite
Equipment Cost (USD)	$20-120k scanner, tripod, accessories	$1-2k camera, lens, tripod, accessories	$8-20k TS, tripod, accessories
Software Cost (USD)	$1-10k	$1k-4k	$1-5k
Typ. field work (hours)	2.5	2 (photo survey) 1 (reference measurements)	2
Typ. office work (hours)	2.5 (point cloud cleaning +registration) 4 (producing measured drawings)	4 (photo orientation, point marking and 3D model)	3 (3D model)
Typ. error	~ 2 – 10mm	> 0.5% (based on test results with calibrated camera setup. ie, 60mm error over 25m measurement)	~ 1 – 5mm
Conclusions	Current state of the art, best practice for application.	Nascent technique with potential to disrupt, but currently not ready for production applications.	Dependable legacy approach. Least software and computer intensive.

3D Laser Scanning Workflow

Planning → Field Work → Office Work (Data Processing) → Office Work (Data Extraction)



- Review site photos, aerial imagery, etc.
- Determine number and location of scan stations
- Determine appropriate quality and resolution
- Determine best time for field work; minimal traffic, obstructions, etc.
- Notify tenants

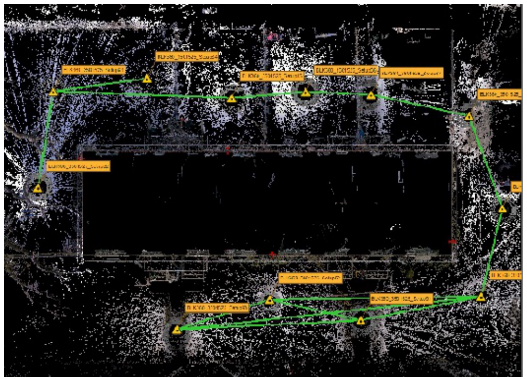
3D Laser Scanning Workflow

Planning → Field Work → Office Work (Data Processing) → Office Work (Data Extraction)

- Set up targets and control points
- Set up scan stations
- Level instrument
- Capture scan data
- Capture photographs to colorize point cloud

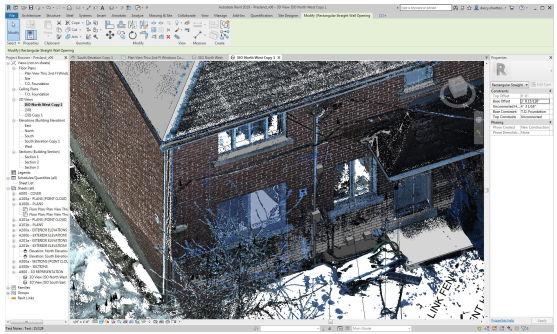
3D Laser Scanning Workflow

Planning → Field Work → Office Work (Data Processing) → Office Work (Data Extraction)



- Download data from equipment and import into database
- Map color data (photographs) onto point clouds
- Register scans together into one coordinate system
- Remove unwanted data.
- Export point cloud (.pts, .ptx, .e57, .las)

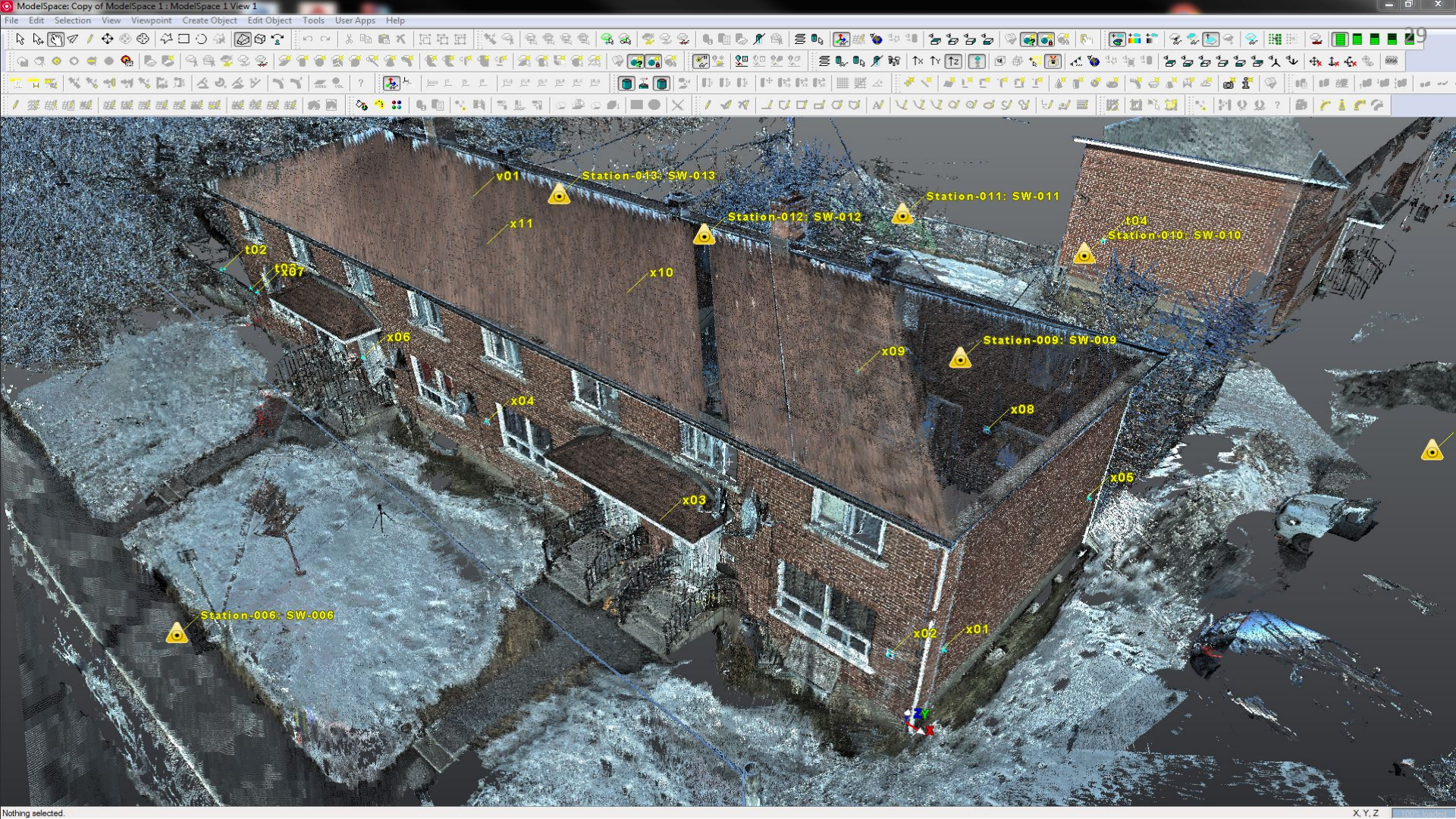
3D Laser Scanning Workflow



- Import point cloud into CAD software (AutoCAD, Revit, etc.)
- Use specialized tool sets to extract geometry of point cloud, or ‘trace’ over data to create 2-dimensional representations
- Add dimensions and annotations

OR

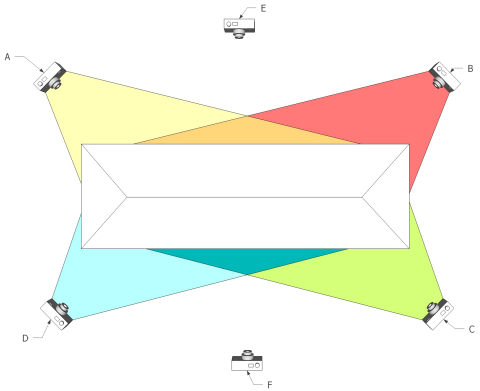
- Develop shop drawing directly on point cloud


ModelSpace: Copy of ModelSpace 1 : ModelSpace 1 View 1
File Edit Selection View Viewpoint Create Object Edit Object Tools User Apps Help
v01
Station-013: SW-013
Station-012: SW-012
Station-011: SW-011
Station-010: SW-010
t04
x11
t02
t03
x10
x06
x09
Station-009: SW-009
x04
x08
x05
x03
Station-006: SW-006
x02
x01
Nothing selected.
X, Y, Z

Photogrammetry Workflow

Photogrammetry Workflow

Planning → Field Work → Office Work



- Camera + lens selection and calibration
- Determine approximate number and location of photo stations
- Determine appropriate file format of photos
- Determine best time for field work; minimal traffic, obstructions, etc.
- Notify tenants

Photogrammetry Workflow

- Conduct photo survey
- Take reference measurements

Photogrammetry Workflow

Planning → Field Work → Office Work

- Import photos into photogrammetry software
- Mark reference points to orient photos
- Build wireframe model of relevant geometry from referenced points
- Establish scale based on reference measurements
- Export 3D model or point cloud (.dxf, .pts, .las)
- Import model into CAD or BIM and develop shop drawings

PhotoModeler Scanner [64-bit]: 2018.07.17 Presland Manually Marked.pmr

File Edit View Marking Referencing Project Window Options Dense Surface Help

Update Available

34

Default White

Photo Windows

Photo17 : dsc_0221 : 15%

Photo2 : dsc_0228 : 15%

Photo1 : dsc_0211 : 15%

3D View Windows [Floating]

3D

Visibility

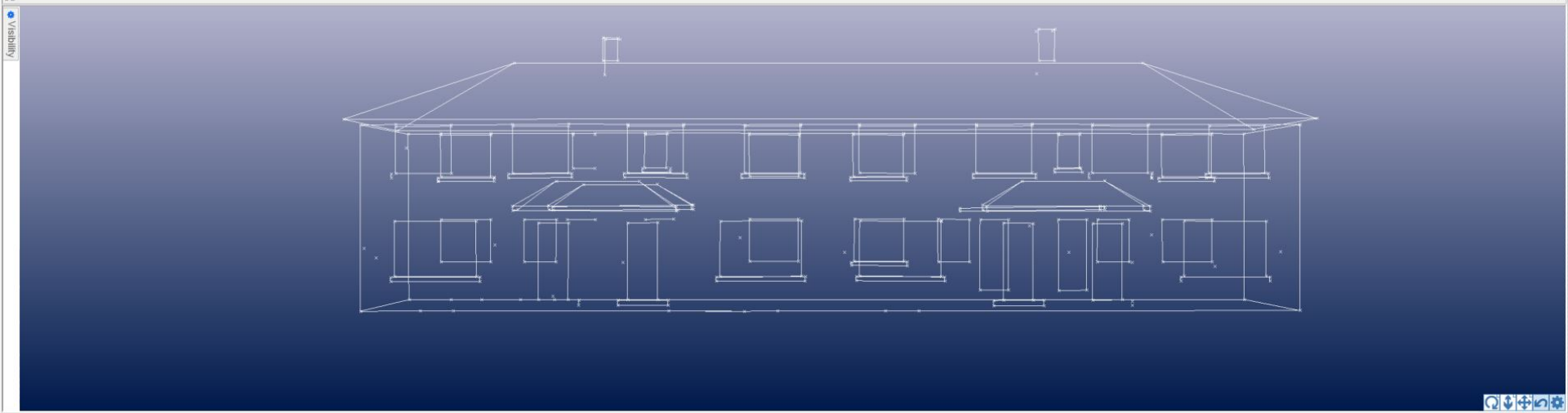


Photo List Photo Windows

[Select] Click on an item to select it and to perform various actions or view information.

Max. Residual: 14.02 pt: 1155 Photo: 2

Last A

Thanks!

For more info, please visit:

http://www.nrcan.gc.ca/energy/efficiency/housing/research/19406

or contact:

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