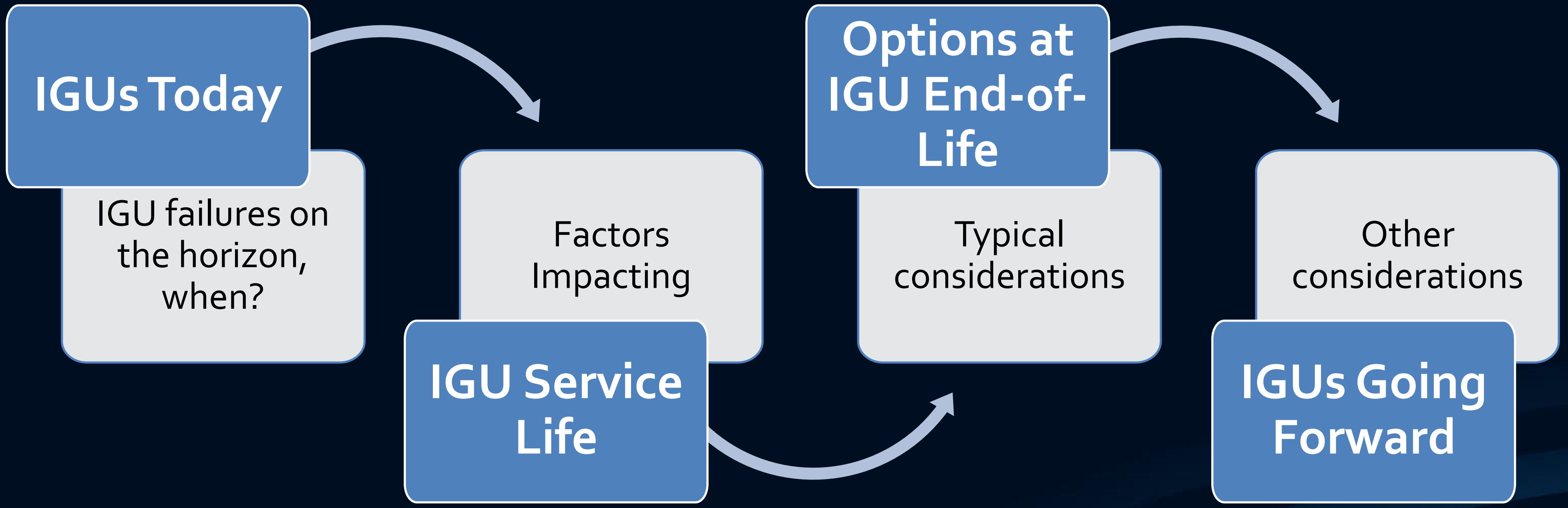
GLAZING RENEWAL

The Finite Life Of IGUs…
Like Death And Taxes – You Can't Avoid It!

sense engineering

ENGINEERING THAT MAKES SENSE.

CONCEPTUAL SUMMARY:



IGUs Today

- Early adoption IGUs of 70-80s will run their course…
- Are IGUs of 90s & early 2000s also subject to failure?
- Is there a tsunami on the horizon?

In 2000, 280 million m2 of IGUs
manufactured globally – >80% in NA & Europe

IGUs Today

- Early adoption IGUs of 70-80s will run their course…
- Are IGUs of 90s & early 2000s also subject to failure?
- Is there a tsunami on the horizon?

Failure:

***Moisture, fog or dirt collection** on glass surfaces located within air space…**permanent material obstruction of vision** through unit due to accumulation of dust, moisture or film on internal surface of glass*

IGUs Today

Condensation accumulation within IGU – between glass lites

IGUs Today

Condensation accumulation within IGU – between glass lites

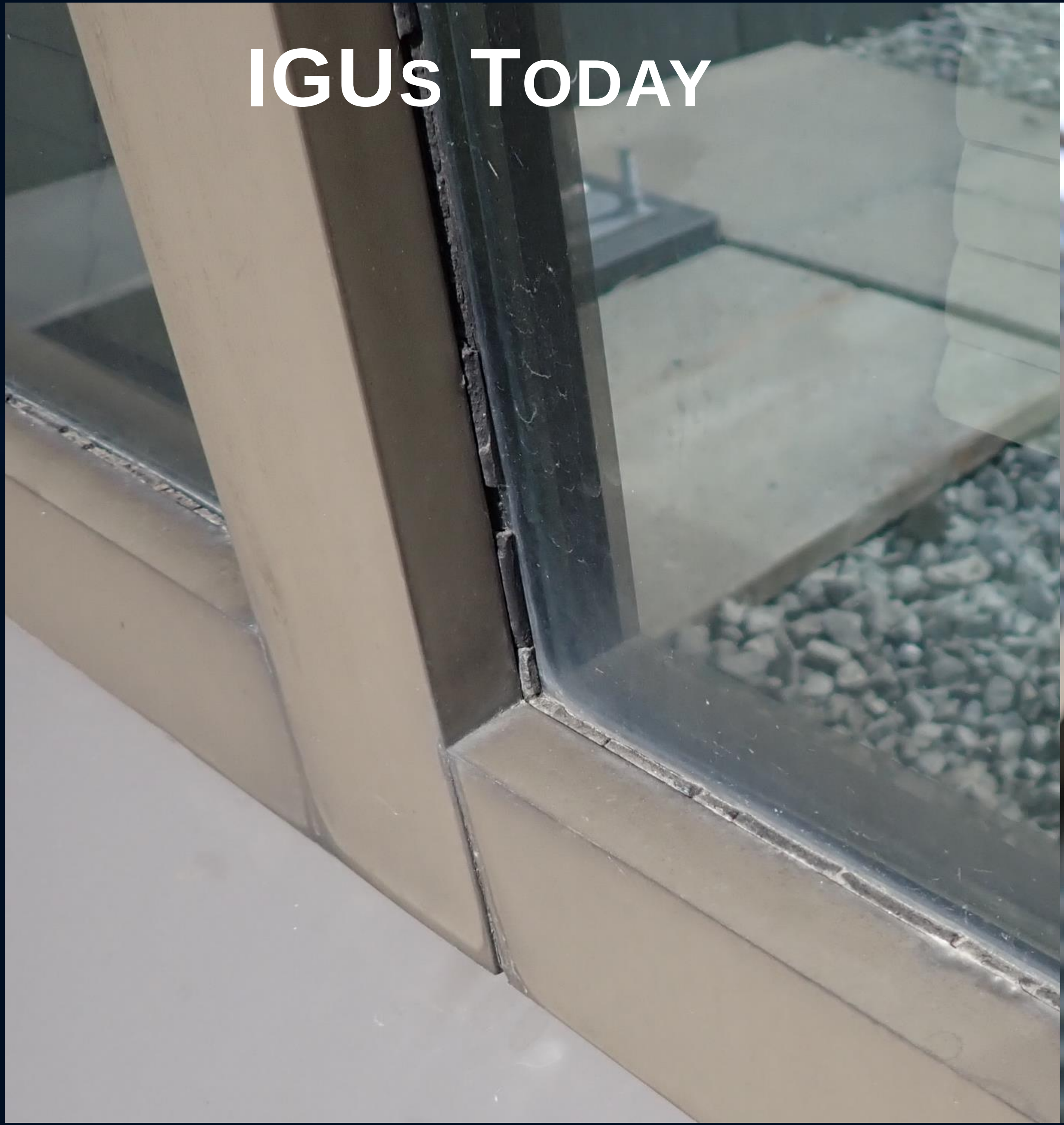
IGUs Today

Deteriorating reflective coating (aesthetic anomaly = pending failure)

IGUs Today

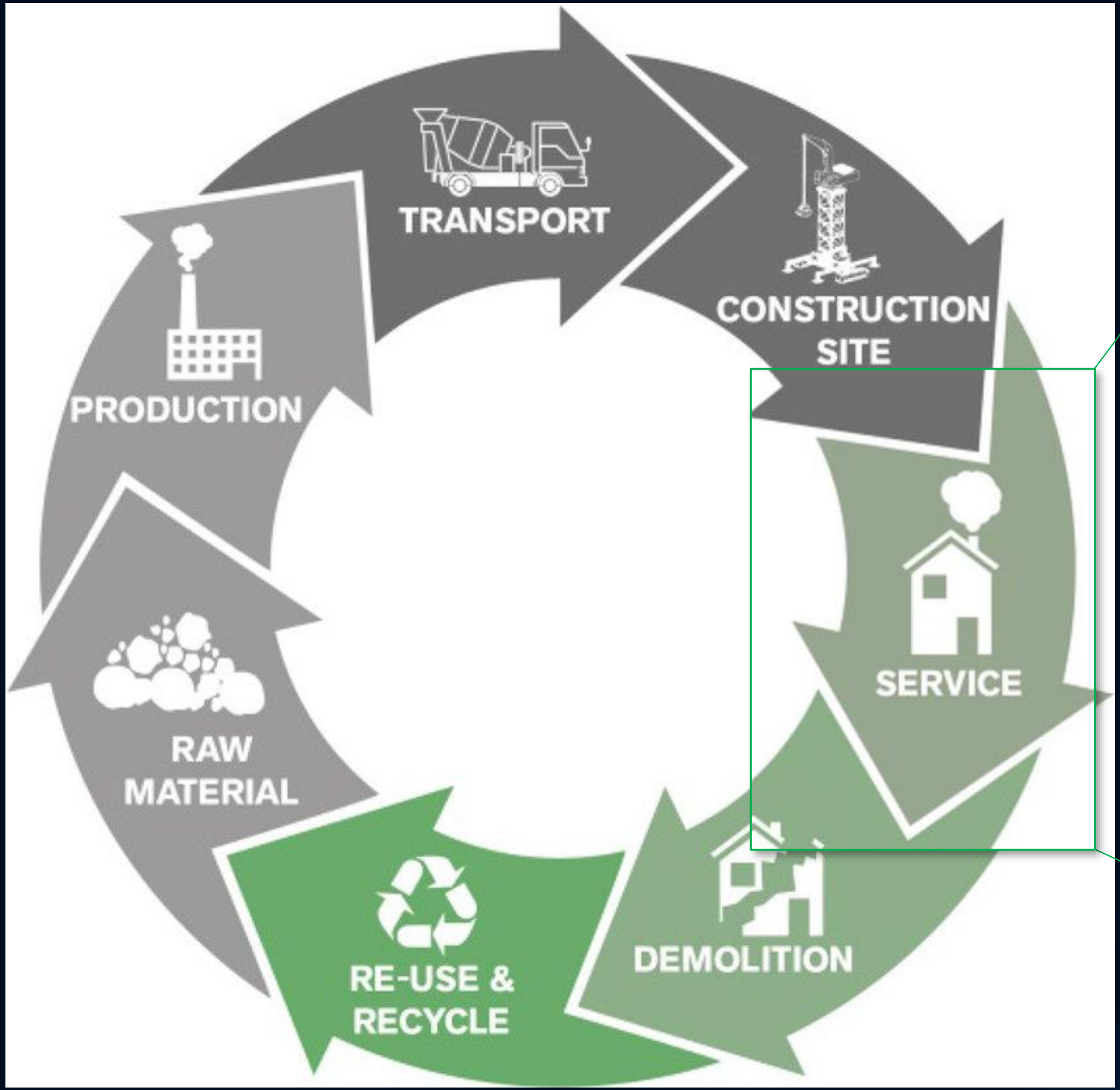
Deteriorating reflective coating (oily appearance)

IGUs Today



Deteriorating and aging exterior seals

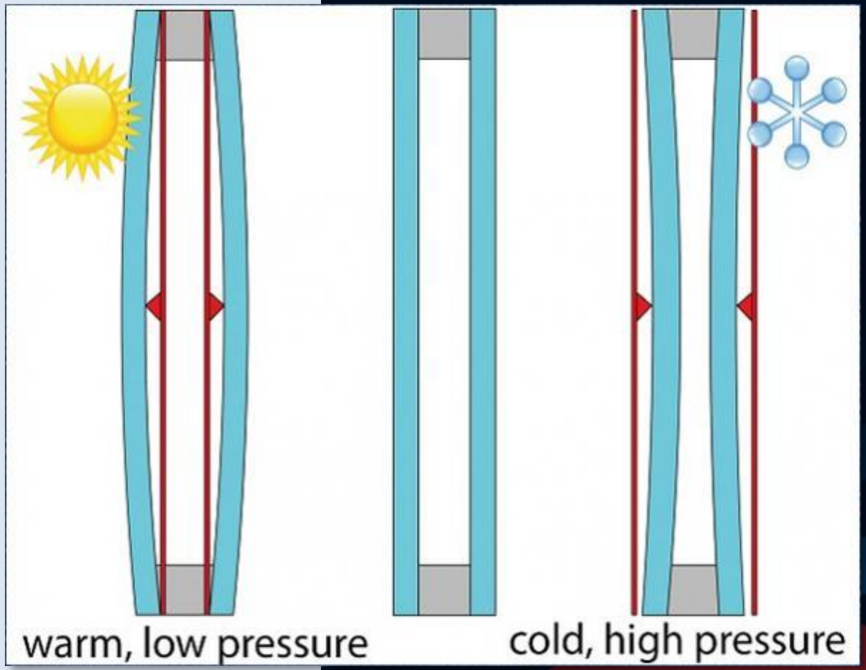
IGU Service Life Study Findings



IGU Service Life Study Findings

- "Design & Material Selection Factors That Influence The Service-Life & Utility Value Of Dual-Sealed Insulating Glass Units" (2001)

*"…**service lives of more than 25 years** can be obtained, **if** units are properly designed, manufactured & installed for given service environment."*



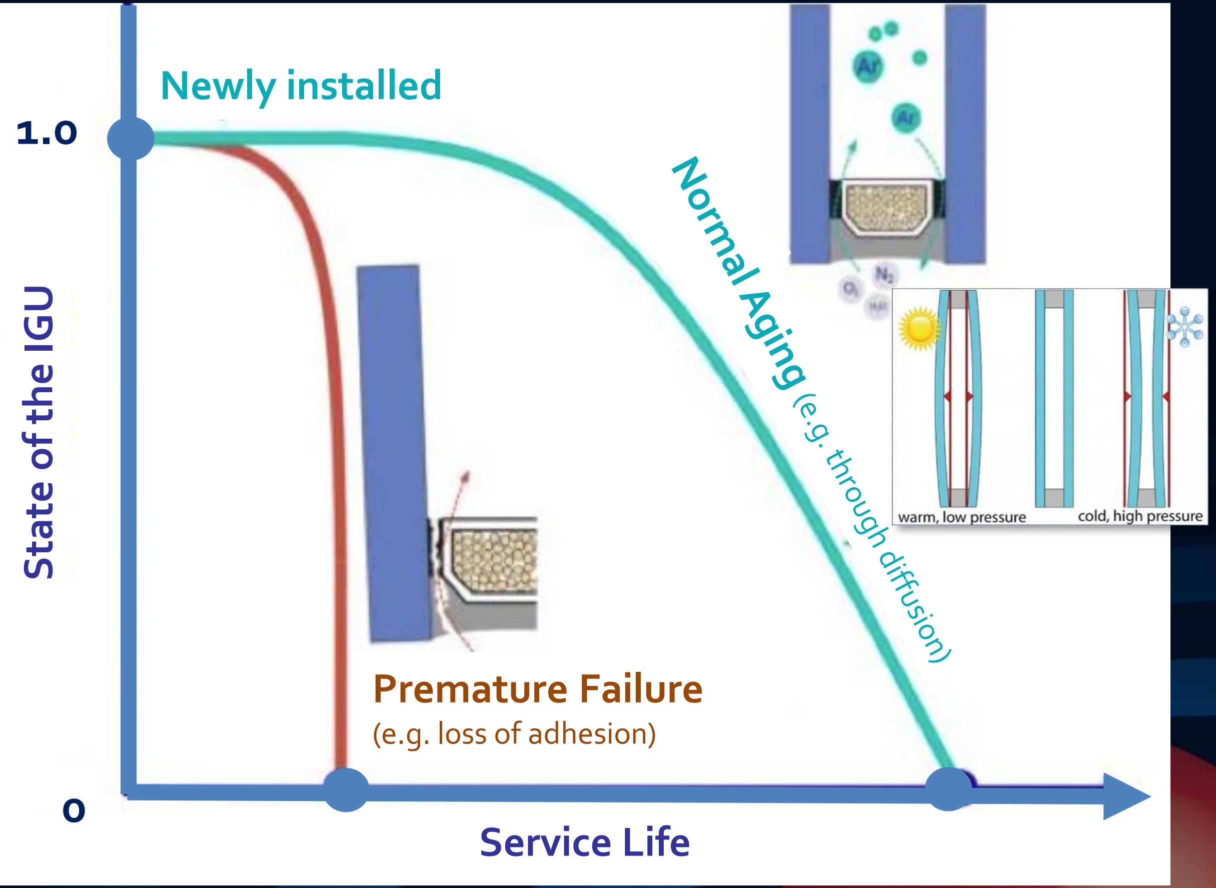
https://www.irbnet.de/daten/iconda/CIB9944.pdf

IGU Service Life Study Findings

- “Design & Material Selection Factors That Influence The Service-Life & Utility Value Of Dual-Sealed Insulating Glass Units” (2001)

Factors impacted service life:

- **Service Environment** (temp, RH, wind loads, sun exposure, micro-climate across assembly)
- **Spacer** (thermal resistance, bond with seal)
- **Desiccant** (quantity, type, initial loading)
- **Sealants** (Frame-IGU, Glass-Spacer – Primary & Secondary Seals)
- **Diffusion Resistance** (water vapour/gas, across entire edge assembly)
- **Coating Properties** (heat-reflecting)
- **Gas Fill** (type, initial amount, loading method)
- **Manufacture Conditions** (air/gas temp. & RH)

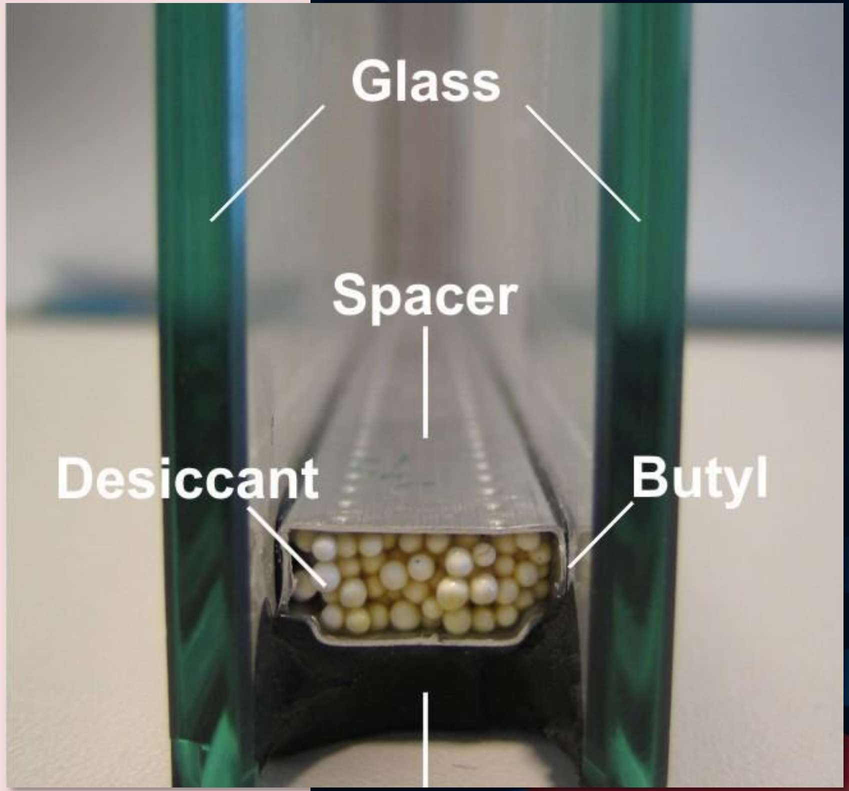


https://www.irbnet.de/daten/iconda/CIB9944.pdf

IGU Service Life Study Findings

- “Studies into the Life Expectancy of Insulating Glass Units” (200?)

“The service life of a sealed IGU critically depends on ***perfect functioning of the edge seal*** *under environmental stresses.”*



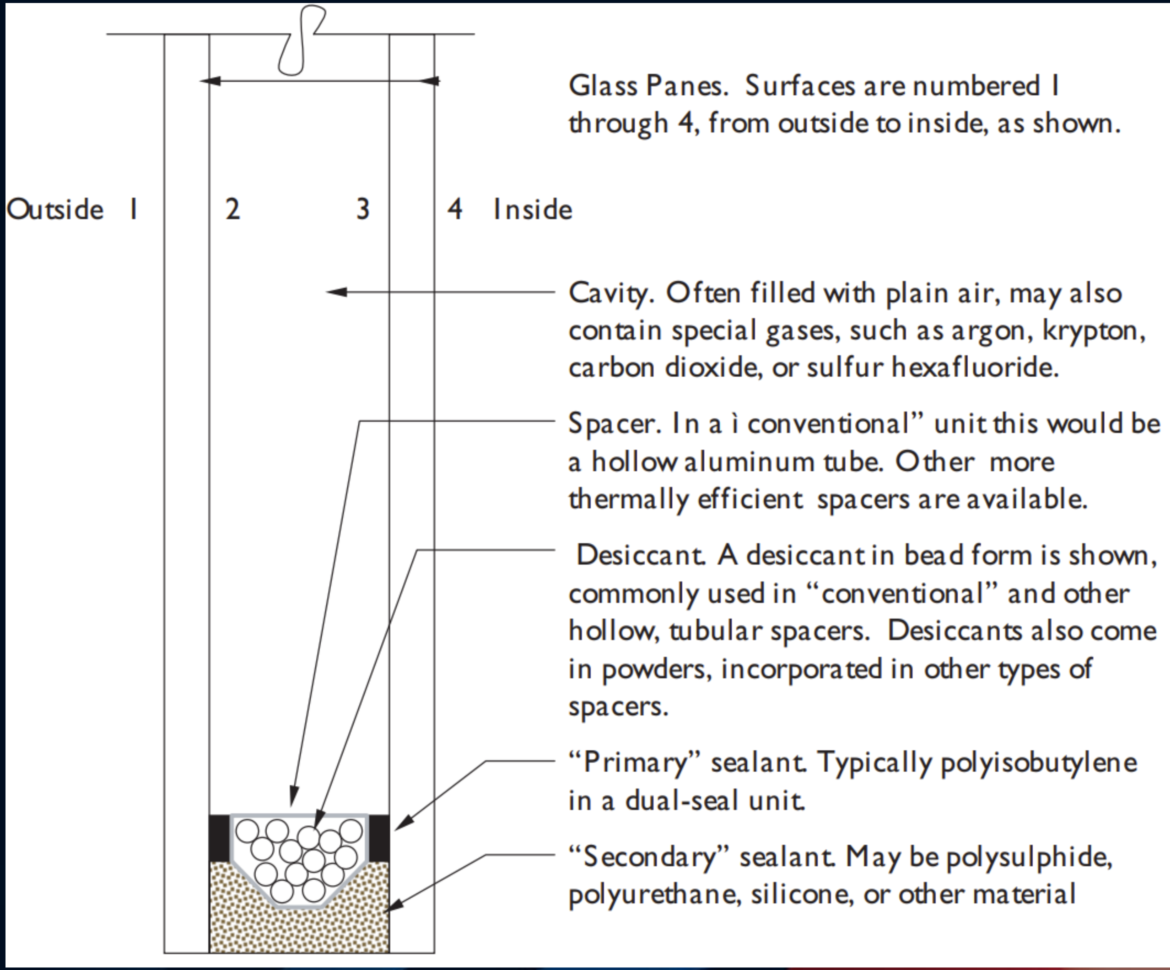
https://www.sciencedirect.com/science/article/abs/pii/036013239290032K

IGU Service Life Study Findings

- "Studies into the Life Expectancy of Insulating Glass Units" (200?)

Factors impacting edge seal functioning:

- Water vapour permeability of secondary sealant not critical, since that of PIB primary seal is very low
- Tensile strength & elastic recovery of secondary glass sealants of great importance, as they impact primary seal functioning
- For gas-filled IGUs, gas permeability of primary & secondary sealants are approx. equal & hence each exert great influence on gas leakage rate
- Silicone sealants for gas-filled IGUs, necessitate additional measures to ensure a gas-tight edge seal



https://www.sciencedirect.com/science/article/abs/pii/036013239290032K

IGU Service Life Study Findings

- "Field Correction of the Performance of Insulating Glass Units in Buildings – A Twenty-Five Year Study" (1980-2005)

In 25-year correlation study of IGU failure to ASTM E 774 standard, the ***more stringent CBA Class demonstrated lower failure rates*** *than C & CB Classes*

https://web.ornl.gov/sci/buildings/conf-archive/2007 B10 papers/066_Lingnell.pdf

IGU Service Life Study Findings

- "Field Correction of the Performance of Insulating Glass Units in Buildings – A Twenty-Five Year Study" (1980-2005)

Table 6. Summary Survey Failure Rates

	1980 Units				1990 Units
	25-year		15-year		15-year
	C+CB	CBA	C+CB	CBA	CBA
Failure Rate	14.0%	3.6%	5.9%	2.9%	1.0%
Units	917	797	786	760	10944

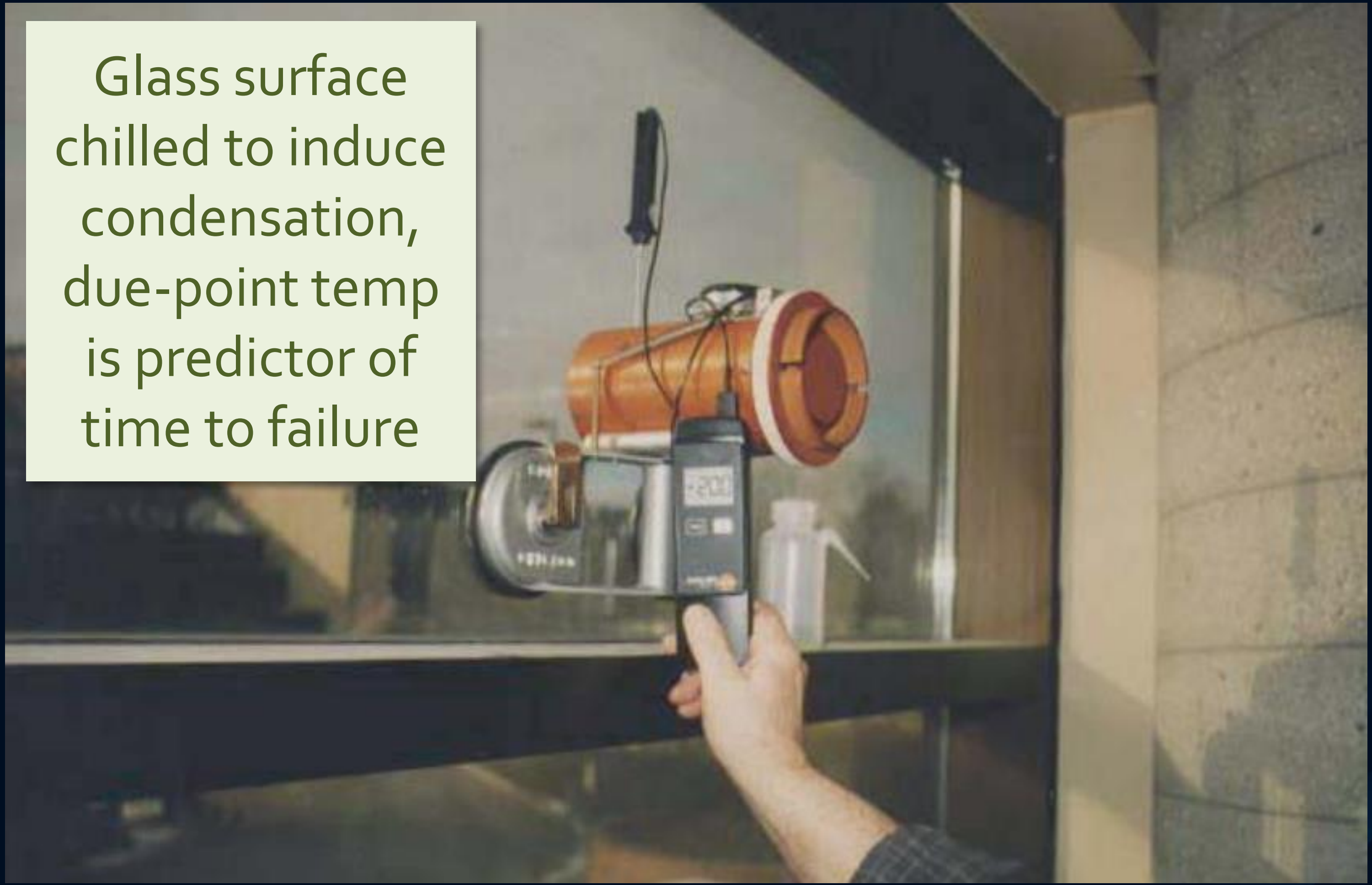
https://web.ornl.gov/sci/buildings/conf-archive/2007 B10 papers/066_Lingnell.pdf

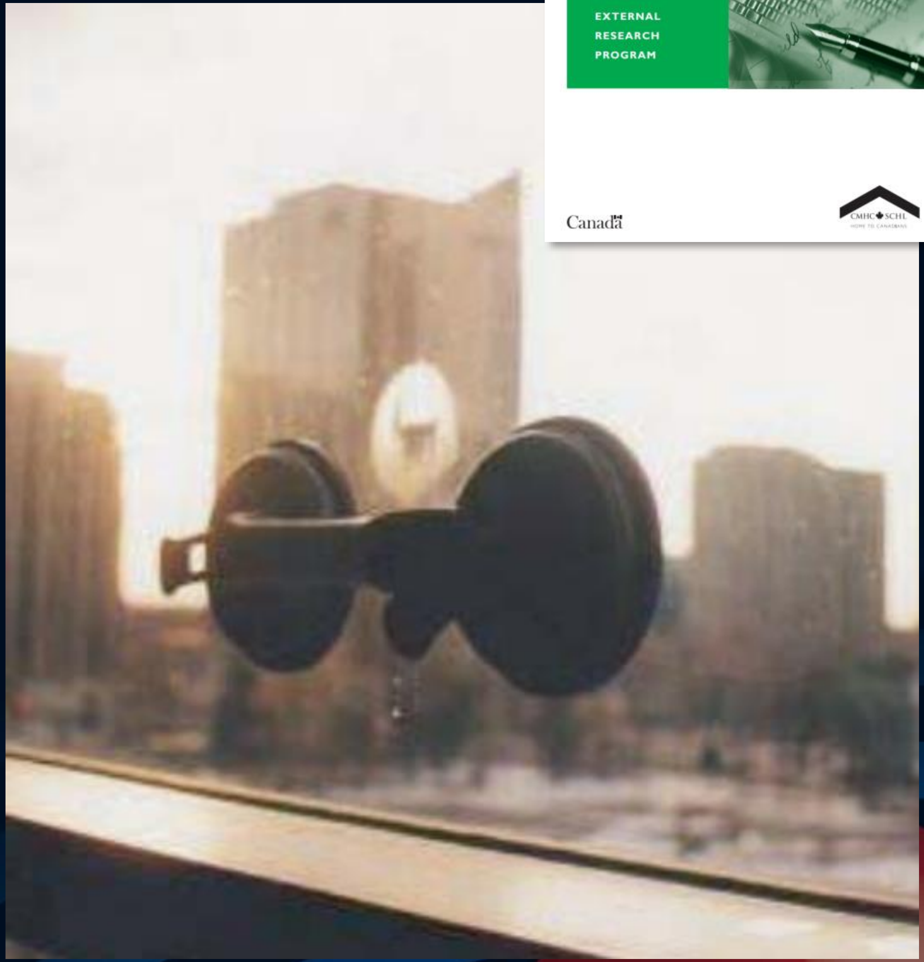
IGU Service Life Study Findings

- “Predicting Time to Fogging of Insulated Glass Units” (2005)


RESEARCH REPORT
PREDICTING TIME TO FOGGING OF INSULATING GLASS UNITS
EXTERNAL RESEARCH PROGRAM
Canada
CMHC SCHL

Glass surface chilled to induce condensation, due-point temp is predictor of time to failure





https://publications.gc.ca/collections/collection_2011/schl-cmhc/nh18-1-2/NH18-1-2-126-2005-eng.pdf

IGU Service Life Study Findings

- "Predicting Time to Fogging of Insulated Glass Units" (2005)

Pre-Study Method

- Relates dew-point temp to desiccant manufacturer's technical data
- Inability to predict failure beyond a two-year period

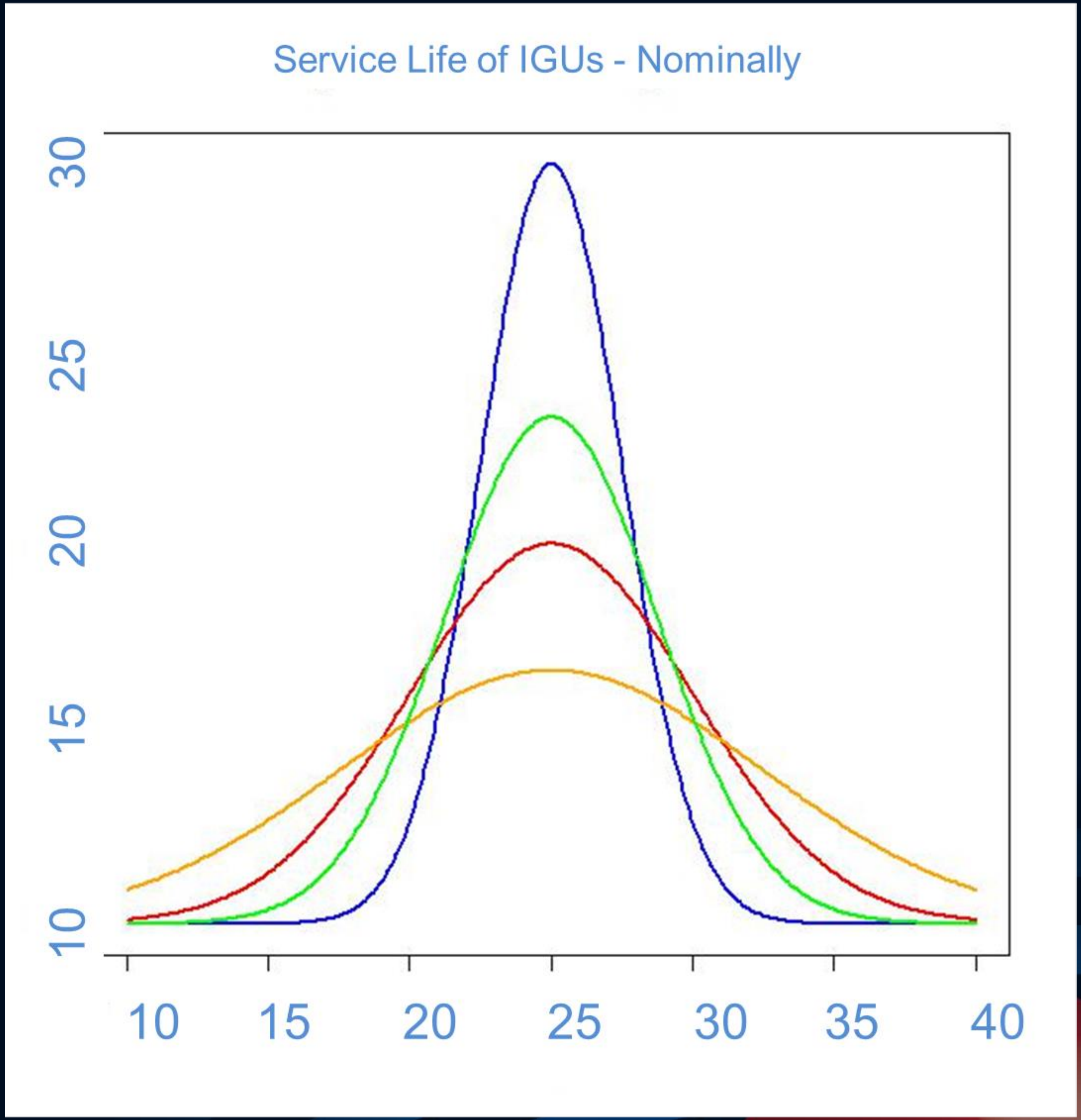
Study Proposed Modified Method

- Requires min. 3 sets of field measured dew-point temps over time
- Predication accuracy increased by comparing trends

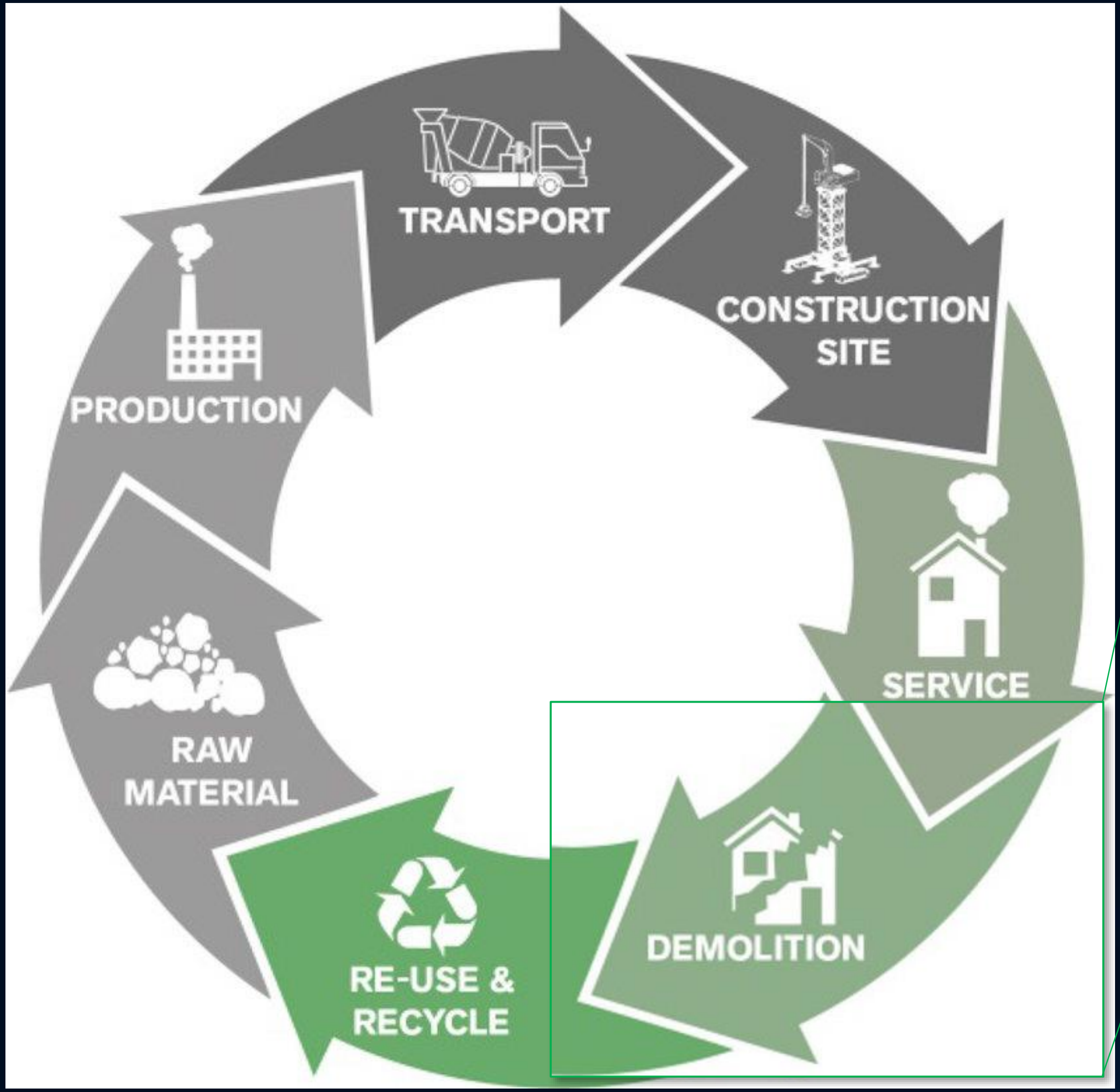
https://publications.gc.ca/collections/collection_2011/schl-cmhc/nh18-1-2/NH18-1-2-126-2005-eng.pdf

IGU Service Life Variables

- Median/average service life
- Frequency of outliers (early/late)
- Skewing is possible



Options at IGU End-of-Life



Options at IGU End-of-Life

I. **Continue Replacing** – like for like (or incremental change)

II. "**Repair**" units (?)

III. **Comprehensive** (possibly phased) glazing renewal

Considerations:

1. Upgrade IGU design/system
2. Framing seals renewal
3. Fenestration renewal – incremental or whole-scale

OPTIONS AT IGU END-OF-LIFE

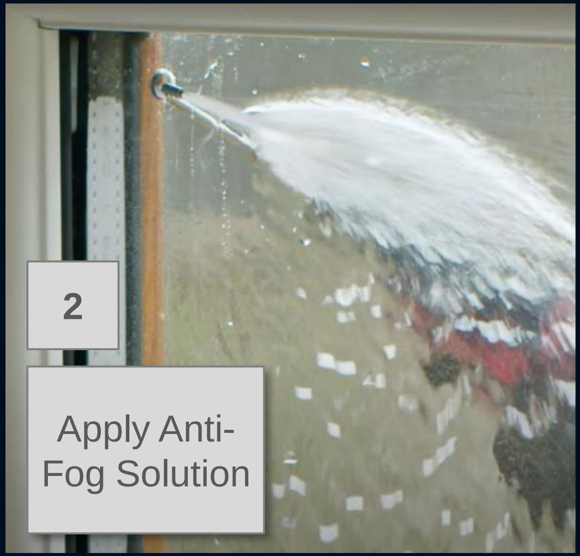
- Repair-in-Place (straw man)

Treated as Maintenance

- IGUs repaired as failures happen – see steps:

Band-Aid Approach

- Worse-than-Like
  - Lower thermal performance (no gas fill, breathes)
  - Potential impact on coatings
  - Drilling not possible if outer glass is coated &/or strengthened
- Extended life, huge $ savings
- Avoided Waste



Options at IGU End-of-Life

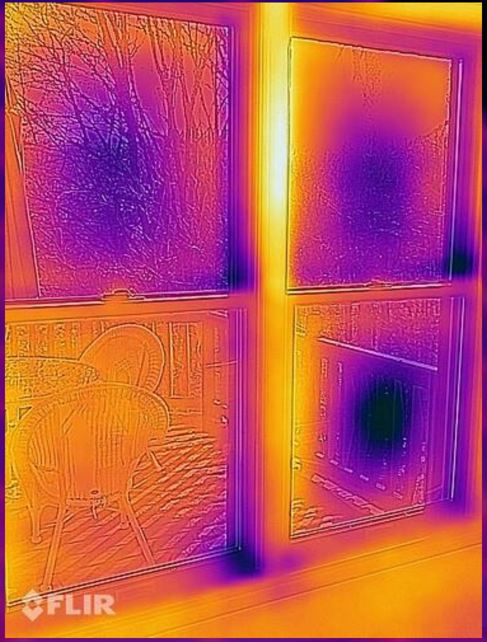
- Incrementally Replace

Treated as Maintenance

- IGUs replaced as failures happen

Status Quo Approach

- Like-for-Like or
- Better-than-Like



Options at IGU End-of-Life

- Fully Replace – Ontario Example

Options at IGU End-of-Life

Options at IGU End-of-Life

- Fully Replace – Ontario Example

Treated as Maintenance

- IGUs replaced as failures happen

Status Quo Approach

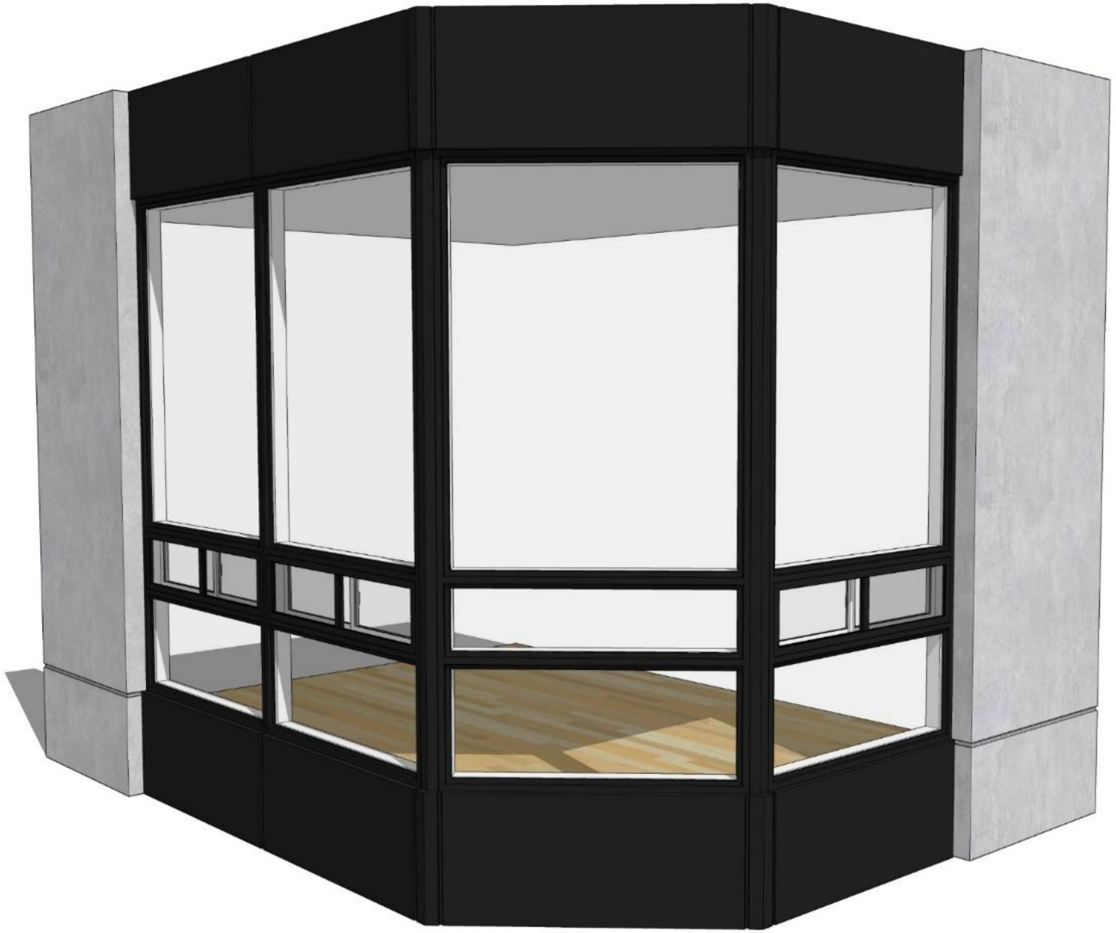
- Like-for-Like or
- Better-than-Like

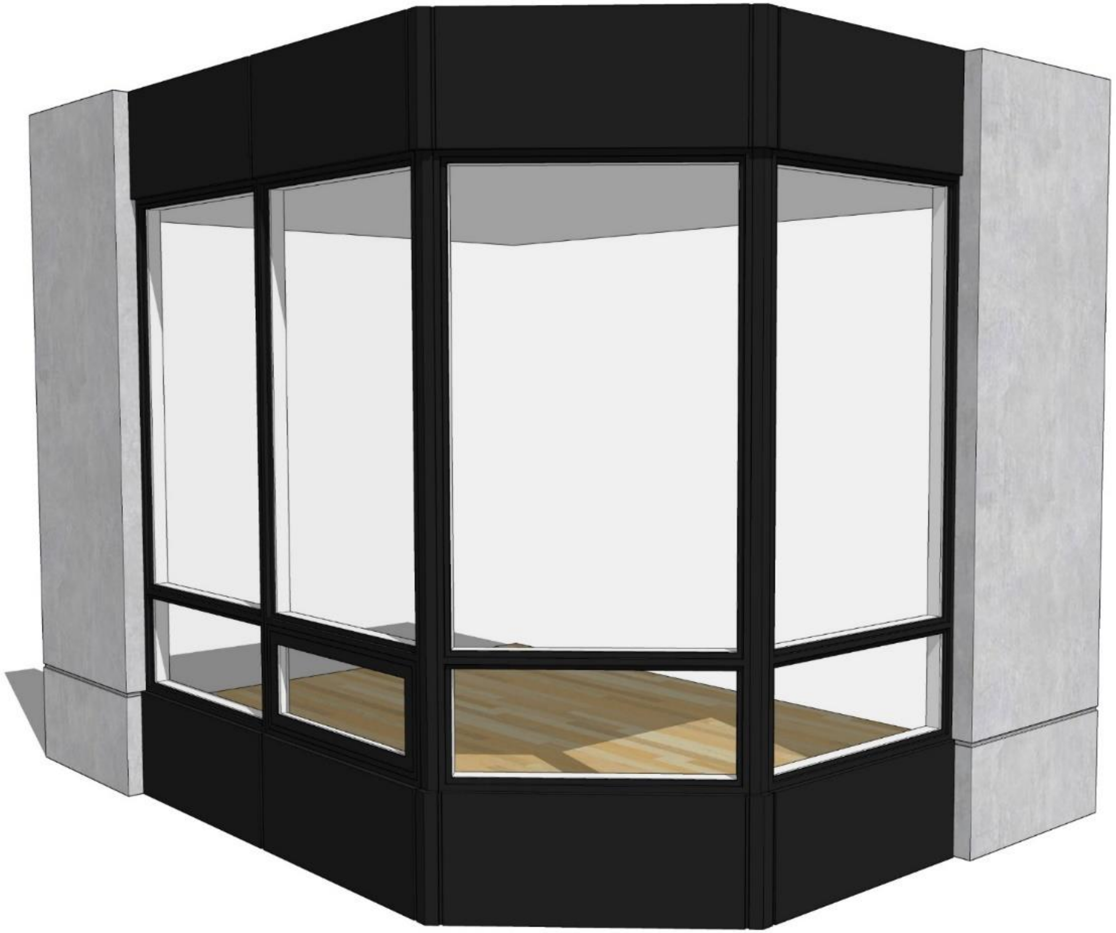
Better-than-Like Features:

- 1-coat low E (2 or 3 coat options)
- Warm edge spacers & Argon-filled
- Client decided to replace all at once

Options at IGU End-of-Life

- Fully Replace – Option to “reconfigure”?





Options at IGU End-of-Life

- Fully Replace

Treated under Capital Plan

- IGUs replaced entirely in advance of full failure; *or*
- Special assessment

Advanced Approach

- Better-than-Like or
- Energy Efficiency Optimized

Costly

- Hard to justify based on ROI / Simple Payback alone

Disruptive

- May require staging, impacts occupied space

Options at IGU End-of-Life

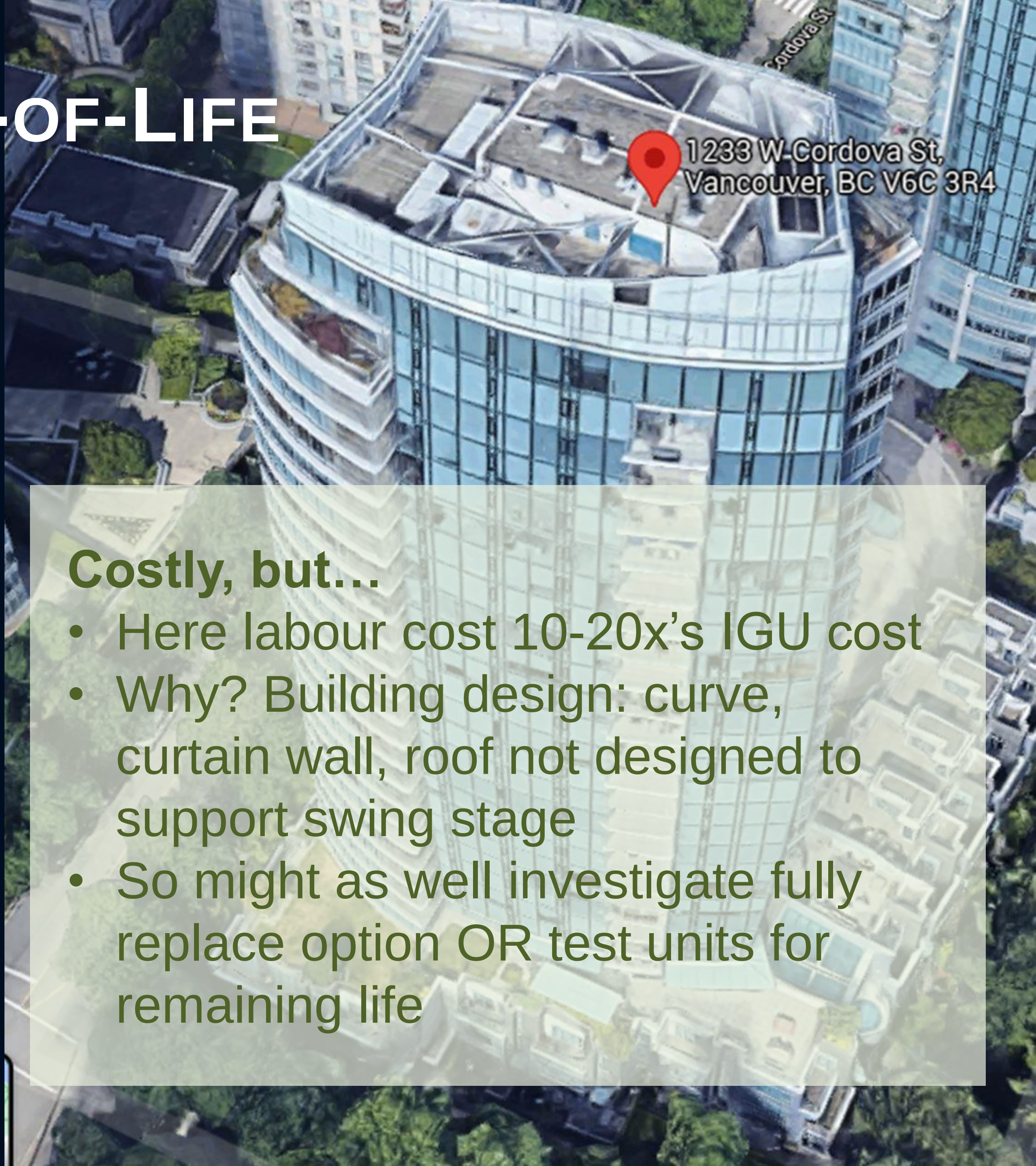
- Façade Challenges: Vancouver

Treated under Capital Plan

- Replace IGUs entirely in advance of full failure; or
- Test units to determine remaining service life

Advanced Approach

- Better-than-Like or
- Energy Efficiency Optimized



Costly, but…

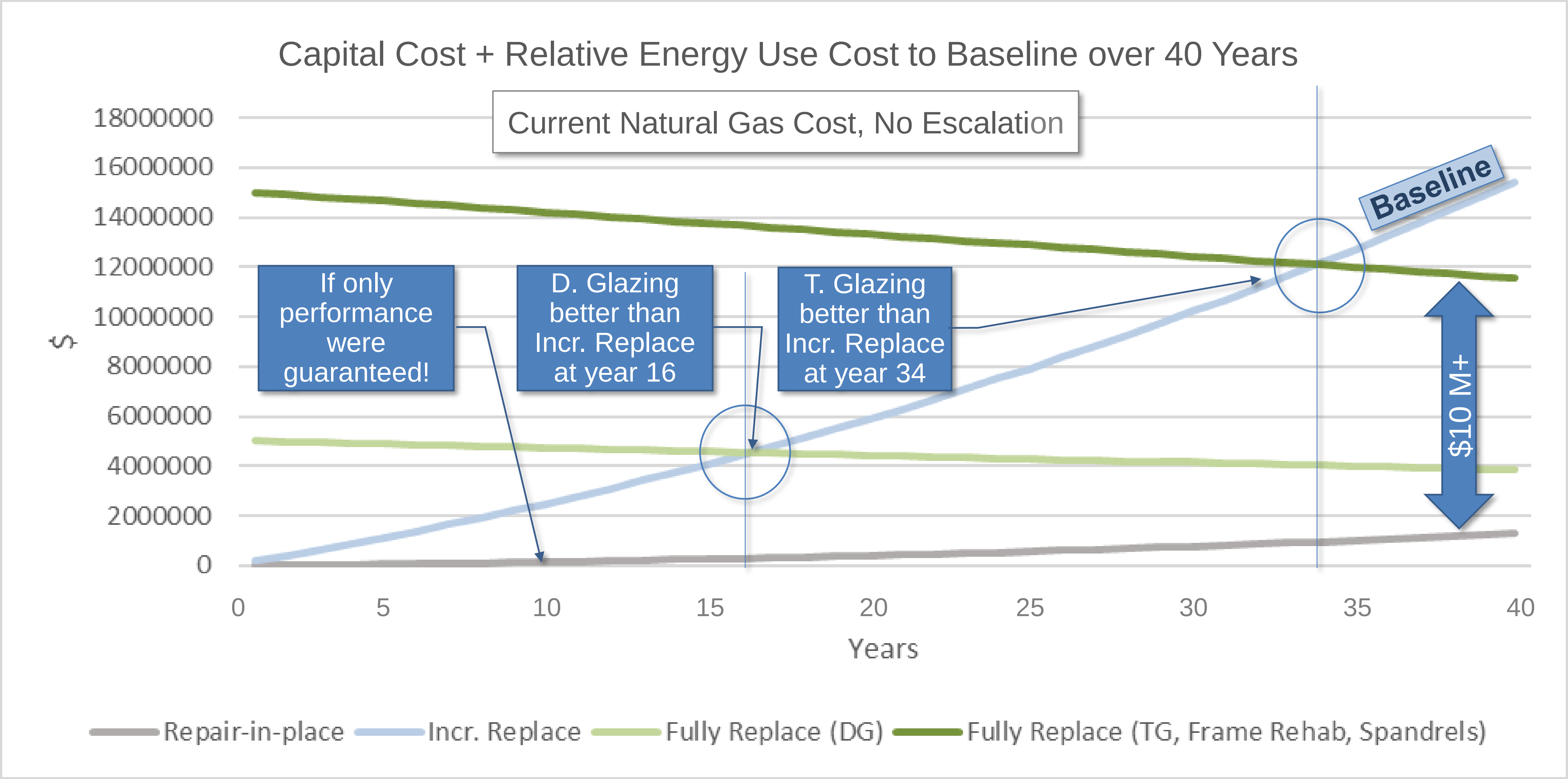
- Here labour cost 10-20x’s IGU cost
- Why? Building design: curve, curtain wall, roof not designed to support swing stage
- So might as well investigate fully replace option OR test units for remaining life

Options at IGU End-of-Life

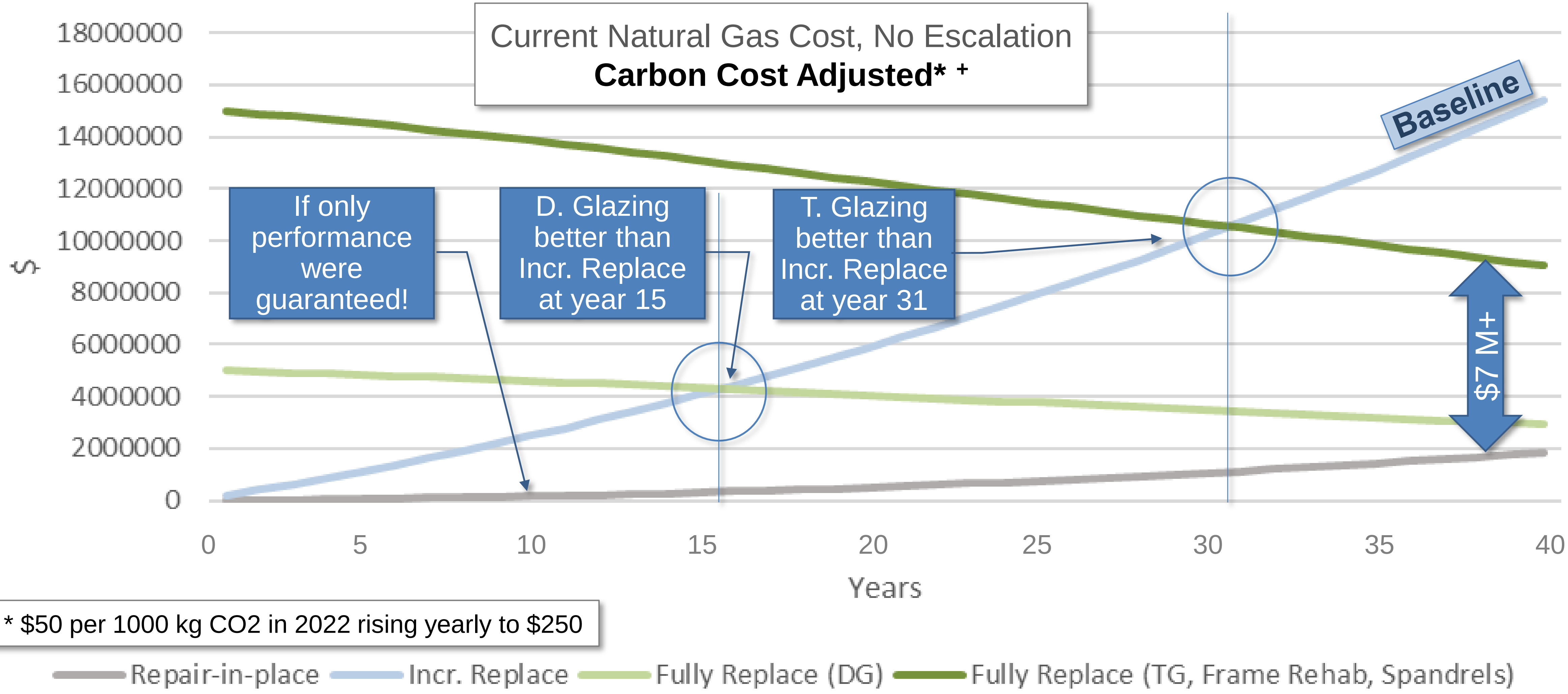
- Comparing Repair-in-Place, Incrementally & Fully Replace – Toronto

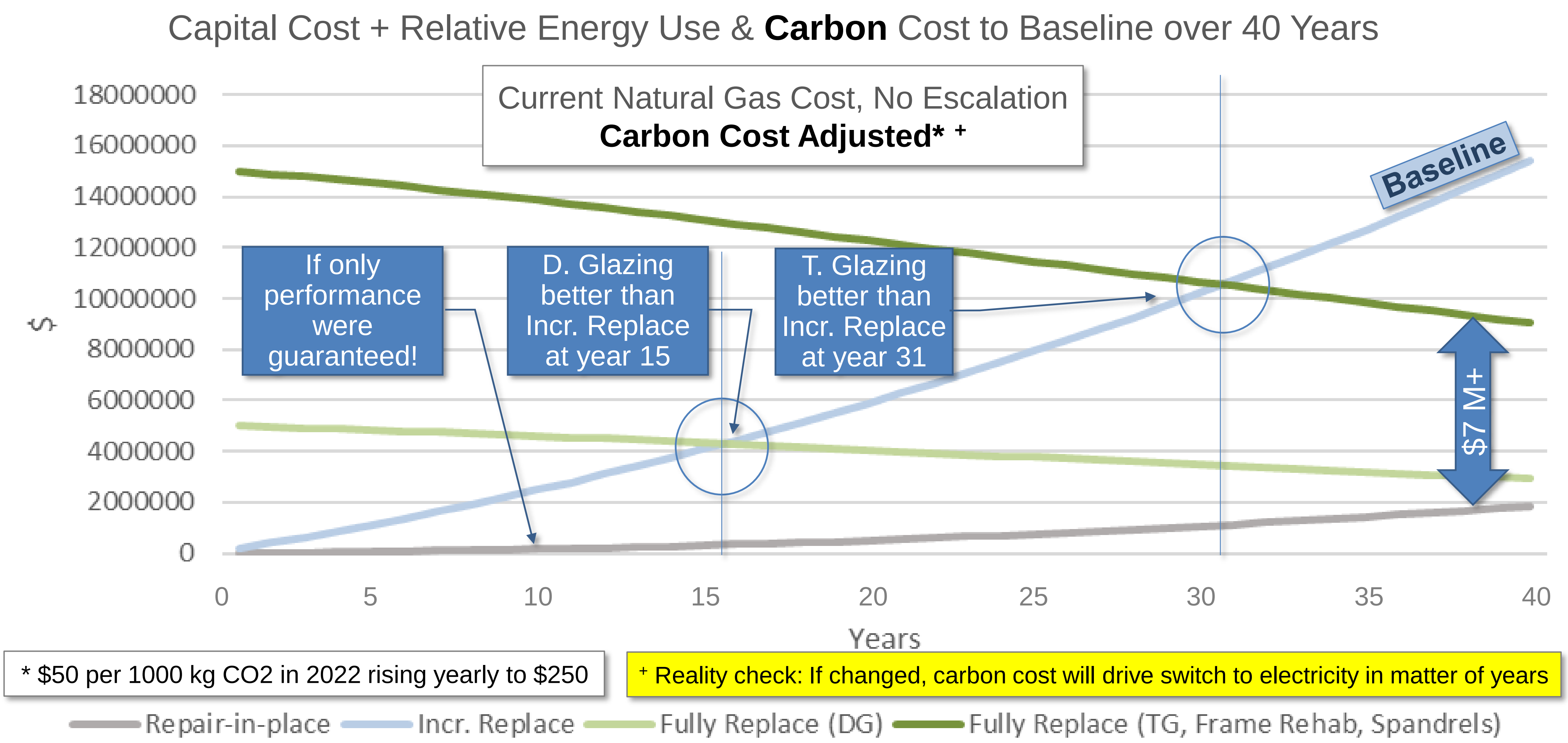
High Rise Office Building Glass Curtain Wall	
Repair-in-Place	Worse-than-Like (thermally) Replace 50 in year 1, increasing yearly to year 40
Incrementally Replace	Like-for-Like (thermally) Replace 50 in year 1, increasing yearly to year 40 **Baseline –** What Owner is Currently Doing
Fully Replace	Better-than-Like (thermally) Double Glazing, Low E Coat, Warm Edge Spacer
Fully Replace	Better-than-Like (thermally) Triple Glazing, Low E Coat, Warm Edge Spacer, Frame Rehab, Spandrels

High Rise Office Building Glass Curtain Wall	**Greenhouse Gas Intensity – GHGI** ($ekgCO_2/m^2/yr$)	**Total Energy Use Intensity – TEUI** ($ekWh/m^2/yr$)	**Thermal Energy Demand Intensity – TEDI** (ekWh/m2/yr)	**Orders of Capital Cost**	**Impact on Natural Gas Heating Cost** (compared to baseline, steady state fuel cost)
Repair-in-Place (Worse-than-Like, 50+/yr)	25.5 (year 1) 27.3 (year 40)	251 (year 1) 268 (year 40)	145 (year 1) 155 (year 40)	$10k/year (yr 1) $28k/year (yr 40)	+$1k/year (yr 1) +30k/year (yr 40)
Incr. Replace (Like-for-Like, 50+/yr)	25.5	251	145	$200k/year (yr 1) $560k/year (yr 40)	**Baseline**
Fully Replace (D. Glazing)	24.1 (-6% off baseline)	240 (-4% off baseline)	135 (-7% off baseline)	$5M upfront	-$30k/year (off baseline)
Fully Replace (T. Glazing, Frame Rehab, Spandrels)	21.7 (-15% off baseline)	221 (-12% off baseline)	115 (-21% off baseline)	$15M upfront	-$90k/year (off baseline)


Capital Cost + Relative Energy Use Cost to Baseline over 40 Years
Current Natural Gas Cost, No Escalation
18000000
16000000
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
$
If only performance were guaranteed!
D. Glazing better than Incr. Replace at year 16
T. Glazing better than Incr. Replace at year 34
Baseline
$10 M+
0
5
10
15
20
25
30
35
40
Years
Repair-in-place
Incr. Replace
Fully Replace (DG)
Fully Replace (TG, Frame Rehab, Spandrels)

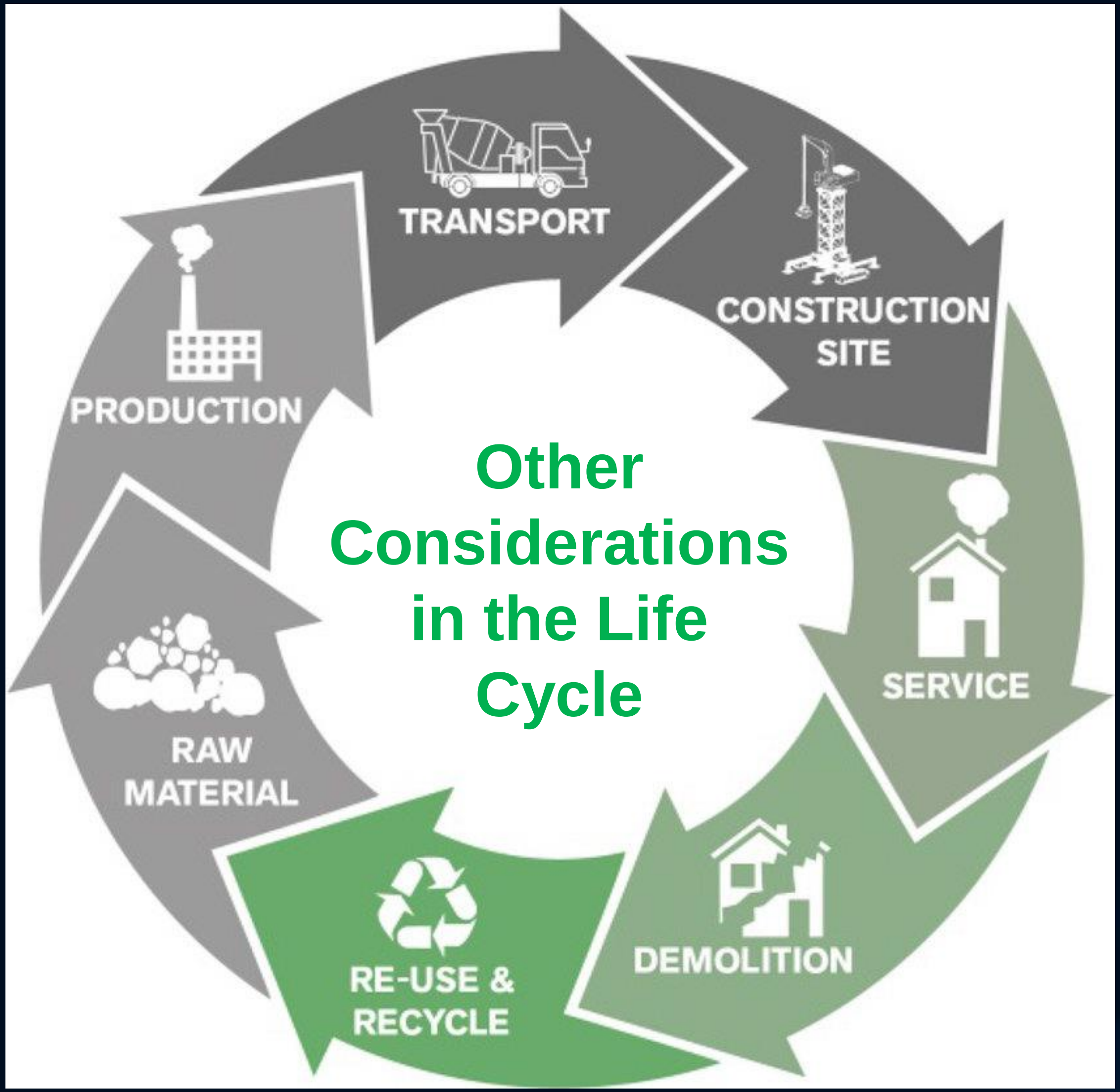
Capital Cost + Relative Energy Use & **Carbon** Cost to Baseline over 40 Years





Capital Cost + Relative Energy Use & **Carbon** Cost to Baseline over 40 Years
Current Natural Gas Cost, No Escalation
Carbon Cost Adjusted* +
18000000
16000000
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
$
0
5
10
15
20
25
30
35
40
Years
If only performance were guaranteed!
D. Glazing better than Incr. Replace at year 15
T. Glazing better than Incr. Replace at year 31
Baseline
$7 M+
* $50 per 1000 kg CO2 in 2022 rising yearly to $250
+ Reality check: If changed, carbon cost will drive switch to electricity in matter of years
Repair-in-place
Incr. Replace
Fully Replace (DG)
Fully Replace (TG, Frame Rehab, Spandrels)

IGUs Going Forward



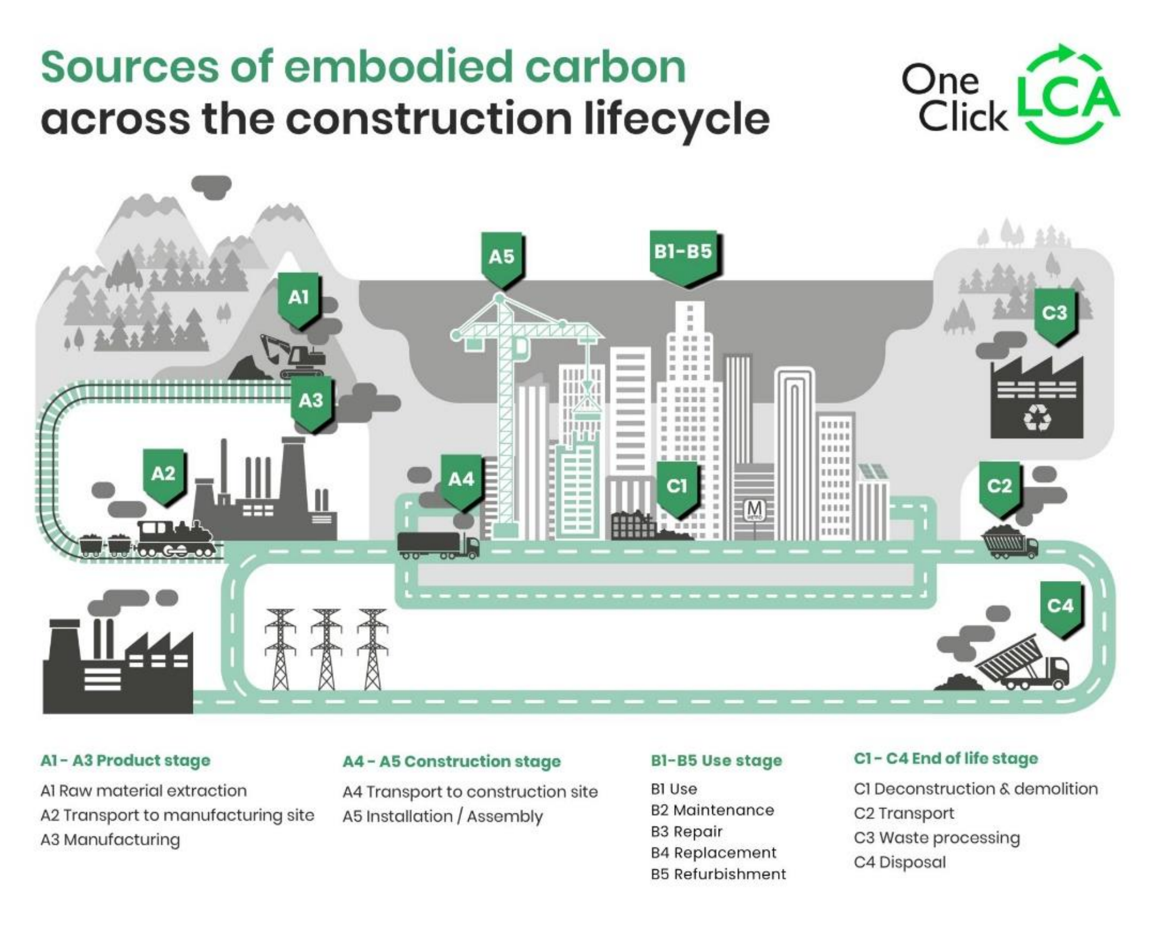
IGUs Going Forward

- Other Considerations in the Life Cycle

Embodied Carbon

- GHGs from extraction, manufacturing, transporting, installing, maintaining & disposing of materials

- What's the Embodied Carbon impact relative to potential performance improvements from replacement?



IGUs Going Forward

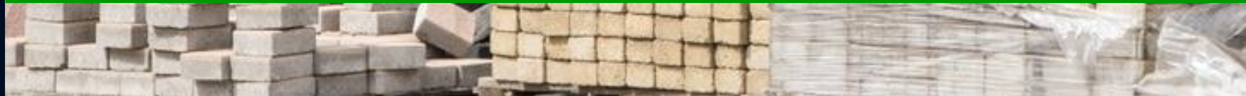
- Other Considerations in the Life Cycle

Recyclability

- Clear glass is infinitely reusable/recyclable
- However, measures intended to enhance performance in service (colour, coatings, lamination, etc.), render primary glass material unsuitable for recycling (in current recycling market)

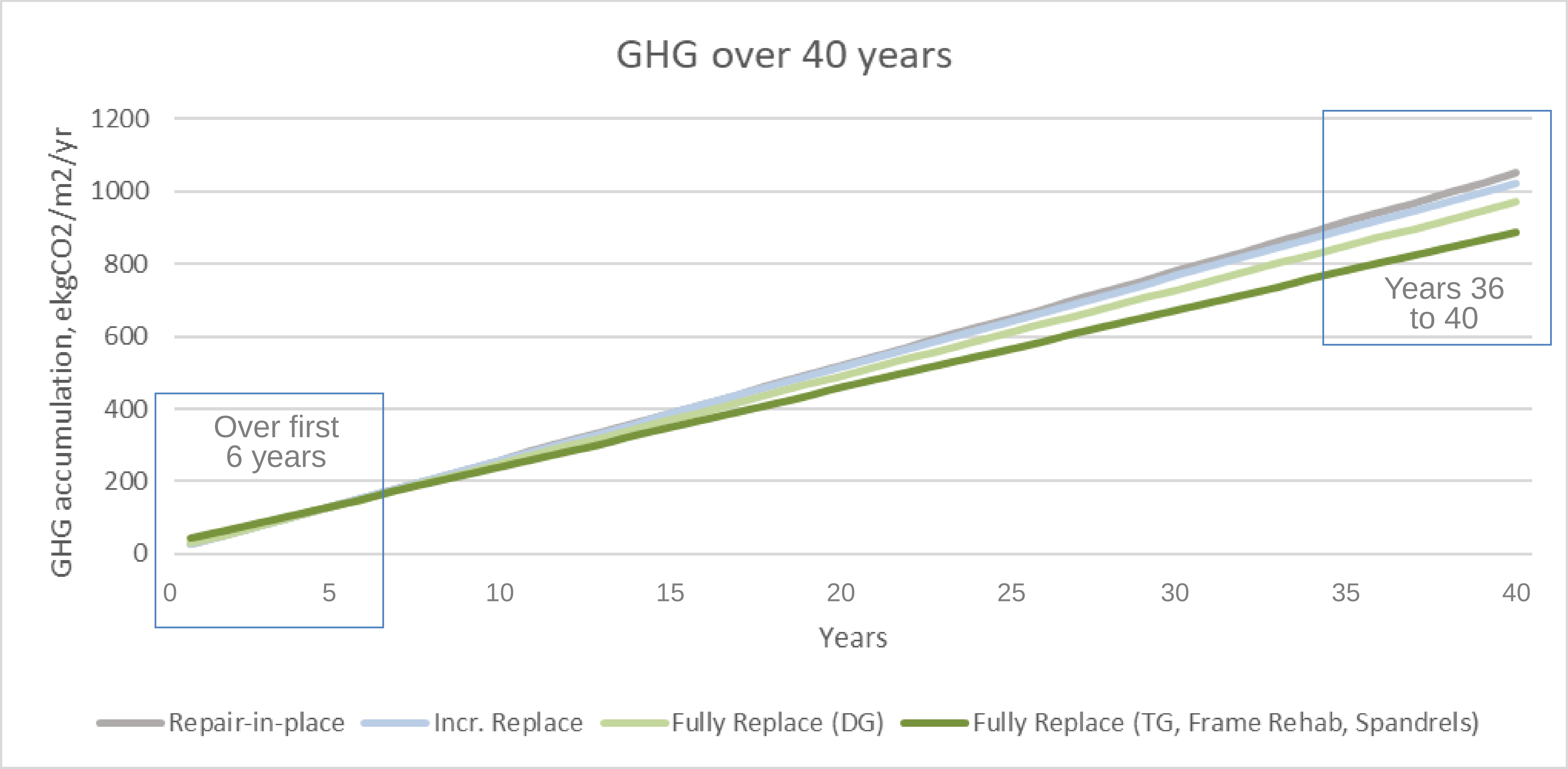
Future IGUs need to be optimized for both energy & eventual reuse of all components

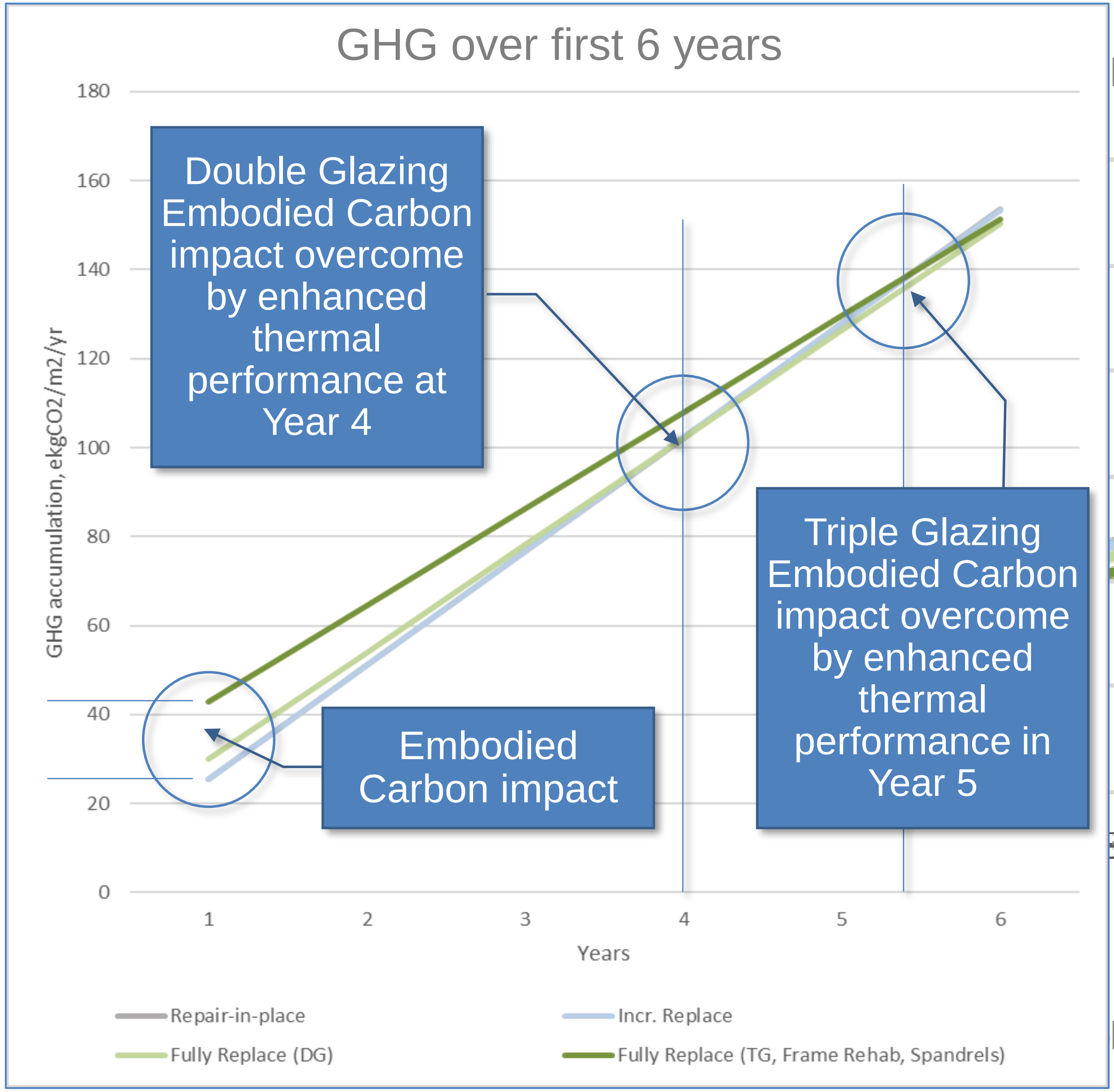
Future recycling markets need to better value non-clear &/or treated glass

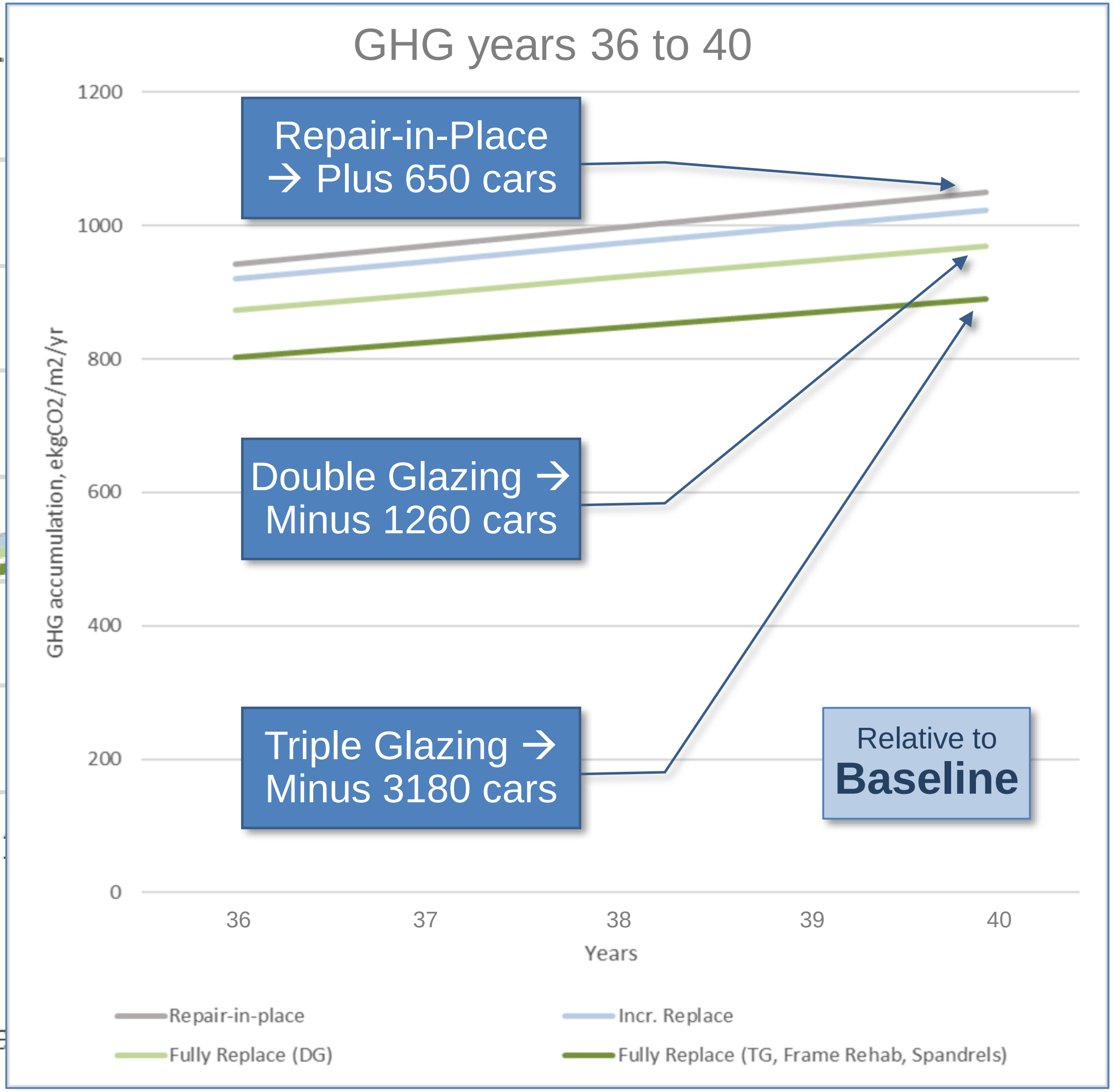


IGUs Going Forward

High Rise Office Building Glass Curtain Wall	Embodied Carbon Impact	Ongoing Impacts During Service Life			Embodied Carbon Impact
	Global Warming (kg CO_2e/m^2)	Greenhouse Gas Intensity – GHGI (ekgCO_2/m^2/yr)	Total Energy Use Intensity – TEUI (ekWh/m^2/yr)	Thermal Energy Demand Intensity – TEDI (ekWh/m2/yr)	Total use of primary energy (ekWh/m^2)
Repair-in-Place (Worse-than-Like, 50+/yr)	NA	25.5 (year 1) 27.3 (year 40)	251 (year 1) 268 (year 40)	145 (year 1) 155 (year 40)	NA
Incr. Replace (Like-for-Like, 50+/yr)	> 1	25.5 (year 1) 27.3 (year 40)	251 (year 1) 268 (year 40)	145 (year 1) 155 (year 40)	> 1
Fully Replace (D. Glazing)	6	24.1 (-6%)	240 (-4%)	135 (-7%)	29
Fully Replace (T. Glazing, Frame Rehab, Spandrels)	21	21.7 (-15%)	221 (-12%)	115 (-21%)	109


GHG over 40 years
GHG accumulation, ekgCO2/m2/yr
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
40
Years
Over first 6 years
Years 36 to 40
Repair-in-place
Incr. Replace
Fully Replace (DG)
Fully Replace (TG, Frame Rehab, Spandrels)


GHG over first 6 years
180
160
140
120
100
80
60
40
20
0
GHG accumulation, ekgCO2/m2/yr
Double Glazing Embodied Carbon impact overcome by enhanced thermal performance at Year 4
Triple Glazing Embodied Carbon impact overcome by enhanced thermal performance in Year 5
Embodied Carbon impact
1
2
3
4
5
6
Years
Repair-in-place
Incr. Replace
Fully Replace (DG)
Fully Replace (TG, Frame Rehab, Spandrels)


GHG years 36 to 40
1200
1000
800
600
400
200
0
GHG accumulation, ekgCO2/m2/yr
Repair-in-Place → Plus 650 cars
Double Glazing → Minus 1260 cars
Triple Glazing → Minus 3180 cars
Relative to Baseline
36
37
38
39
40
Years
Repair-in-place
Incr. Replace
Fully Replace (DG)
Fully Replace (TG, Frame Rehab, Spandrels)

Conclusions

- ✓ IGU failures (as defined) inevitable – there's a Tsunami coming
- ✓ Viable IGU Repair-in-Place solutions are needed – a potential game-changer, $ savings, avoided waste
- ✓ Replacements decisions – whether Incrementally or Fully need to consider the cost of carbon, fuel switch timing & embodied energy
- ✓ Where replacement continues, future IGUs need to be optimized for both energy and eventual recycling of all components
- ✓ Better recycling systems are required to enable processing and ease of reuse of all components
- ✓ And, we could avoid all of this if there were…

No windows…

TELEVISIONS

KEVIN DAY

MARK SALERNO

sense engineering

ENGINEERING THAT MAKES SENSE.