Misunderstanding Complexity: The Case of the Grenfell Tower

José L. Torero, A. James Clark School of Engineering, The University of Maryland

How could this happen?

- 100 + buildings tested – 100% failure
- 10 + buildings being evacuated in the UK
- 5 + buildings being evacuated in Germany
- Several buildings being investigated in the US (including several hotels)
- Several buildings being investigated in Australia (including hospitals)
- A class action law suit was launched in April 2018 against the construction companies and the cladding manufacturers in Australia …
- … this is only the beginning …


Hawaii, July 15th 2017
Rostov-on-Dom, September 29th 2017
Peru, July 20th 2017
Jecheon, December 22nd 2017
Dubai, August 4th 2017
Istanbul, April 6th 2018
Dublin, March 23rd 2018
Grenfell Tower, June 14th, 2017

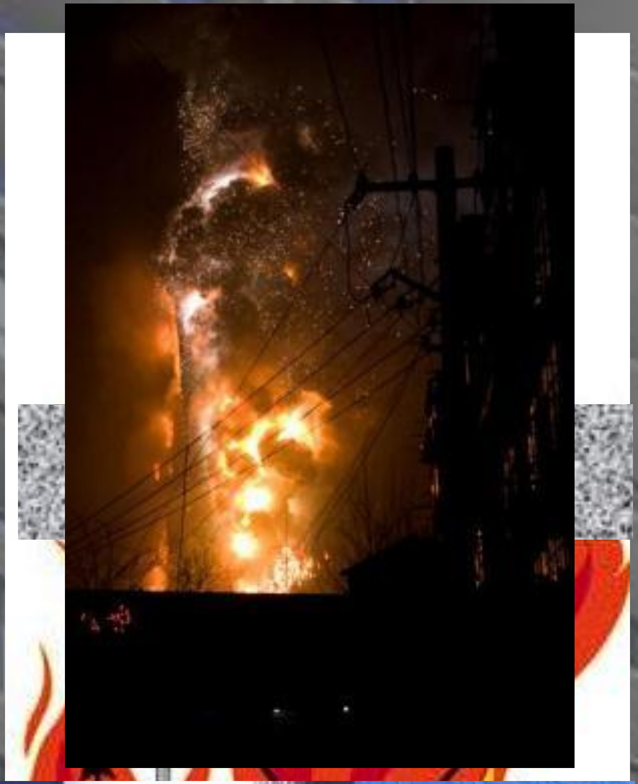
So … Are Façade Fires an Unavoidable Feature of Modern Architecture?

The Key Changes

- The building envelope
- New construction methodologies
- Flammable insulation materials – encapsulation
- etc …

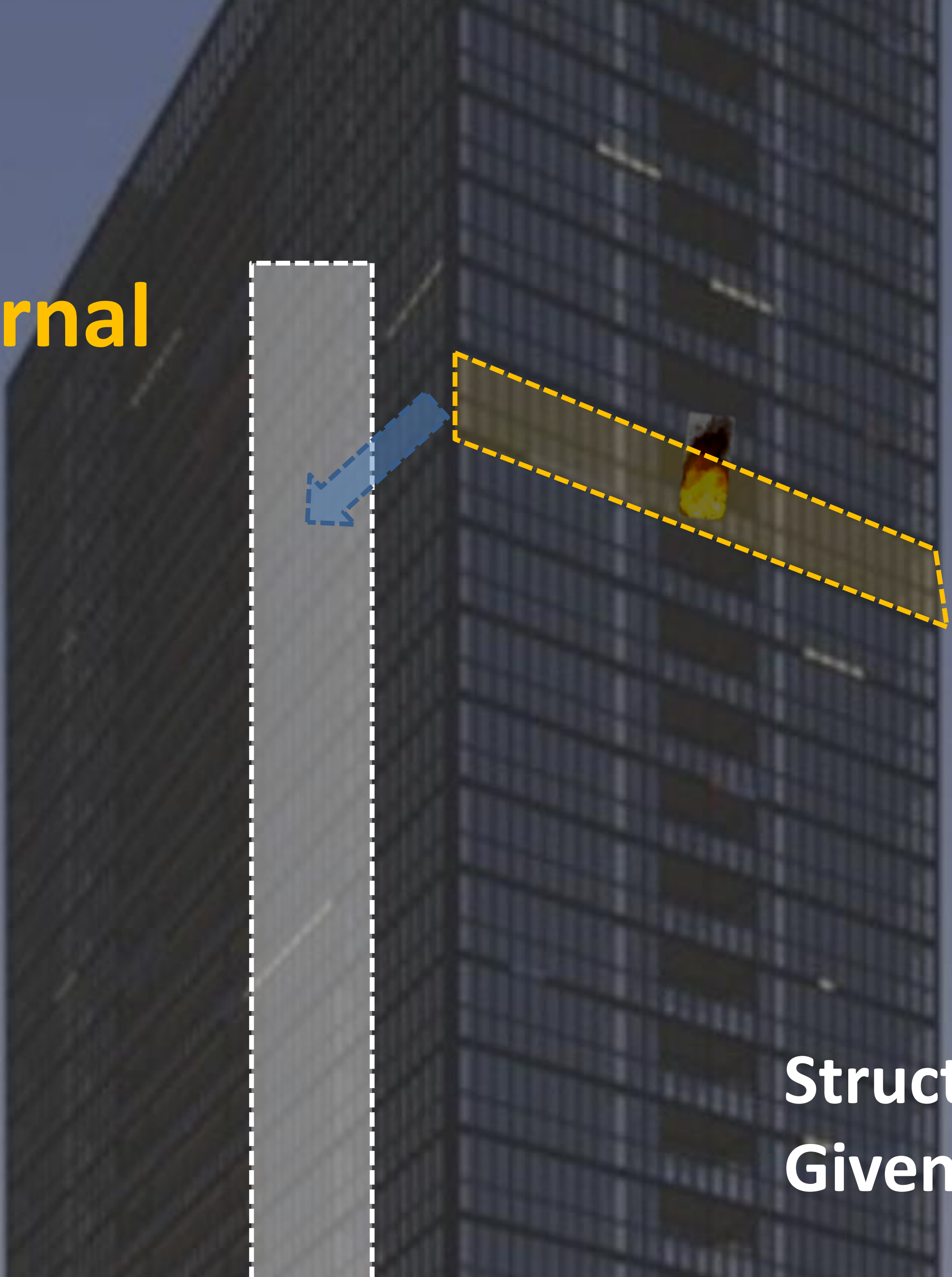
… it is not “one” problem!

The Building Envelope



Why is this important?

Impact of External Fire Spread



Effective Detection

Compartmentalization

Adequate Travel Distances

Protected Egress Paths

Fire Brigades: Defend in Place

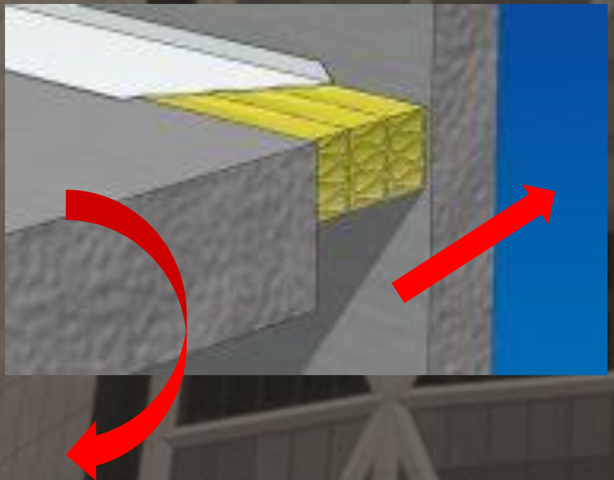
Structural integrity – Given a 1 Floor Fire

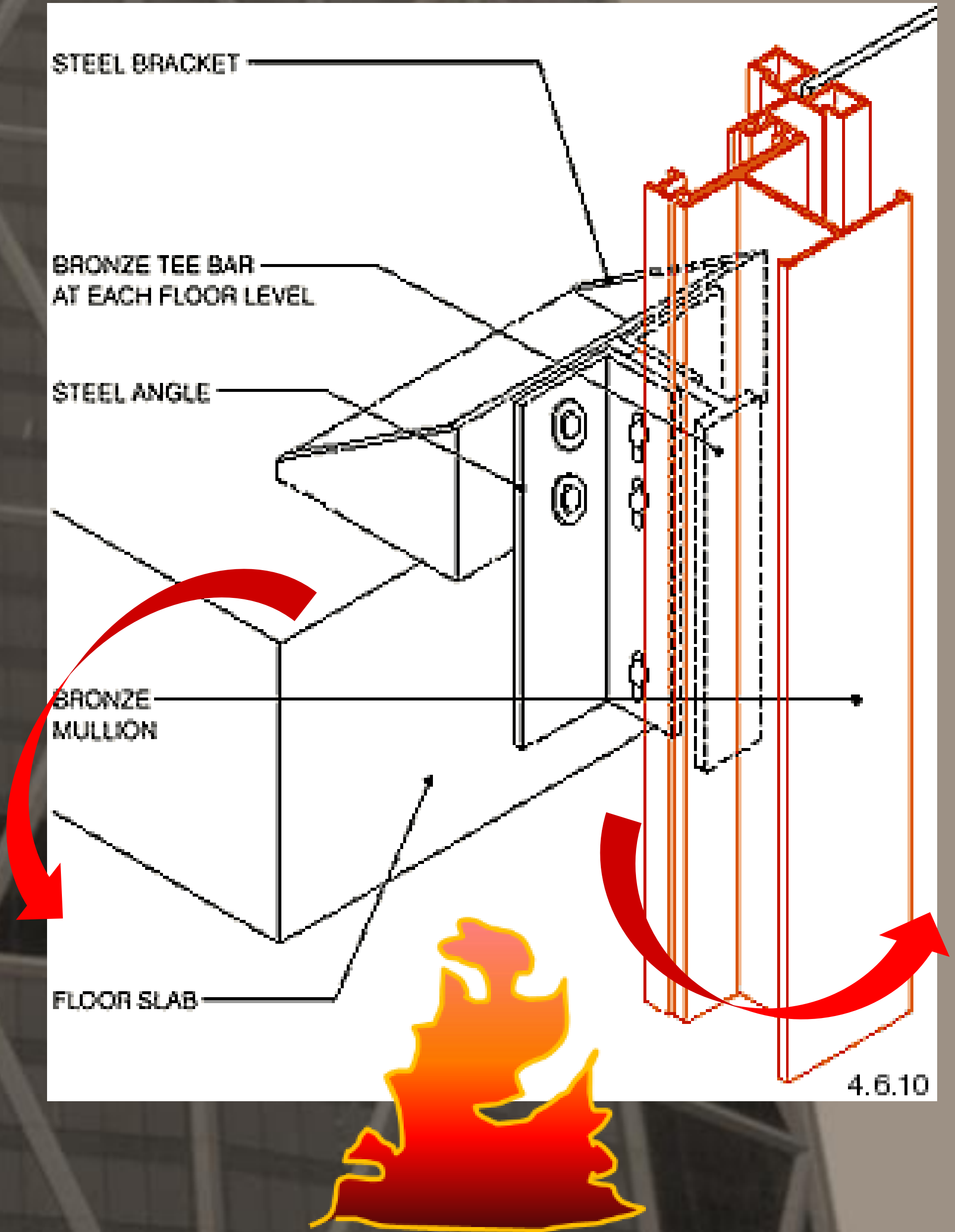
How do things change?

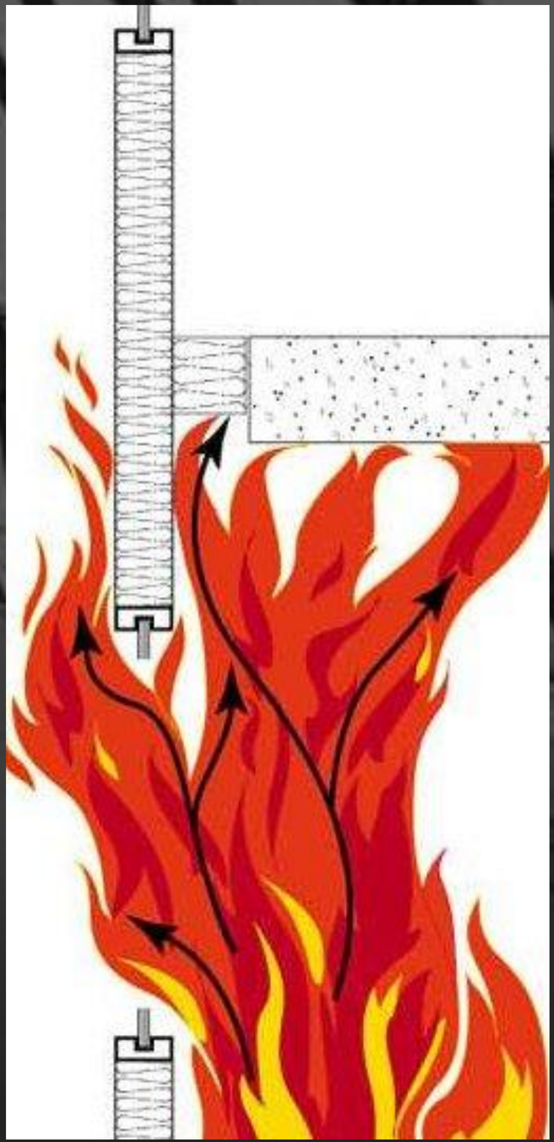
- Detection
- Egress
- Protection of egress paths – compartmentation
- Active fire suppression: Sprinklers
- Structural integrity
- Fire Brigade operations
- etc …


How did things changed?

A fundamental change of the problem …



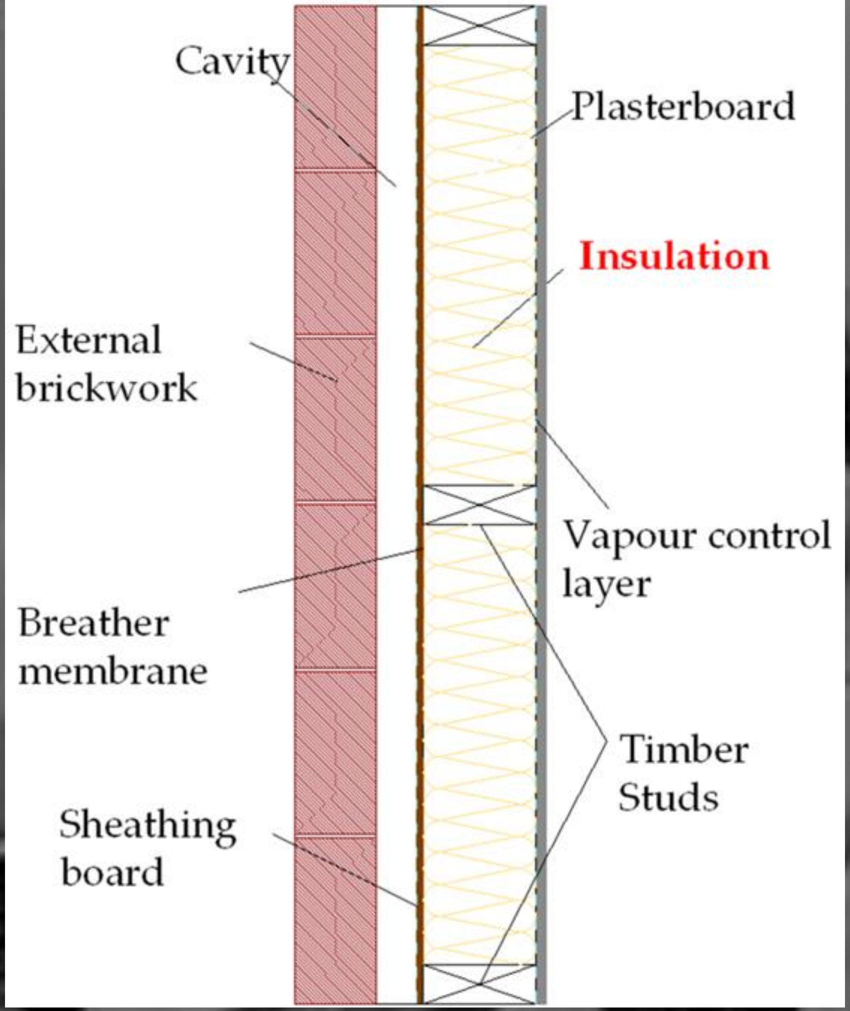




Filling the opening?

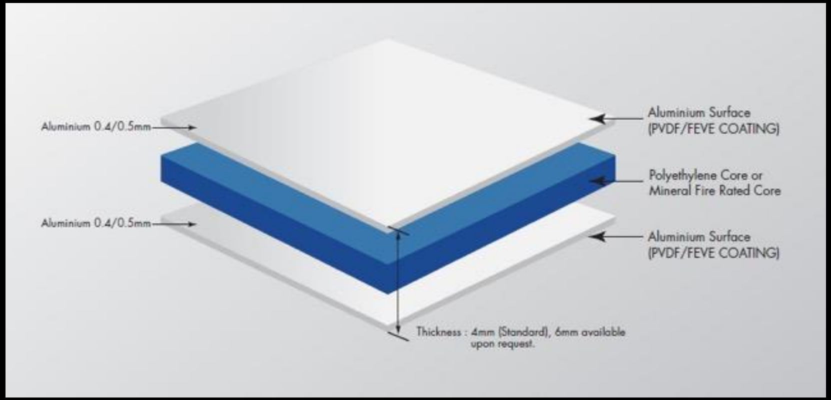
- Relative displacement
- Construction Detailing

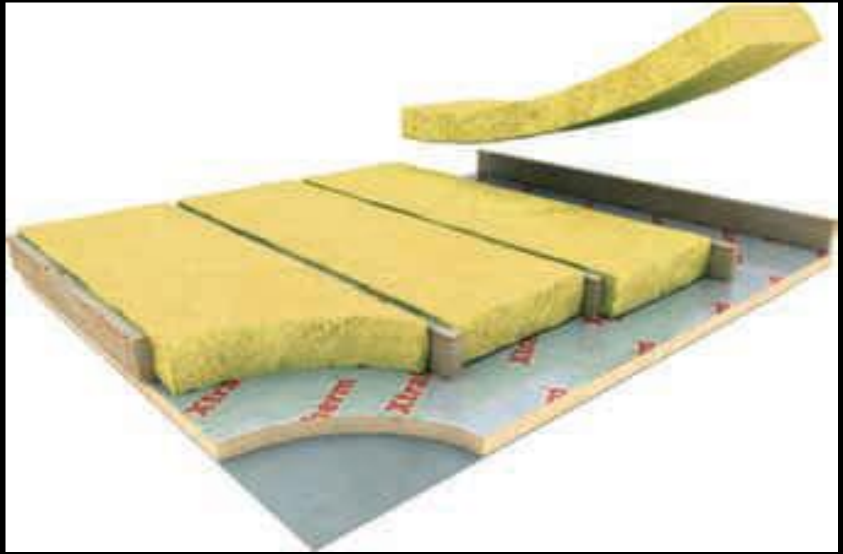
Complex Building Systems

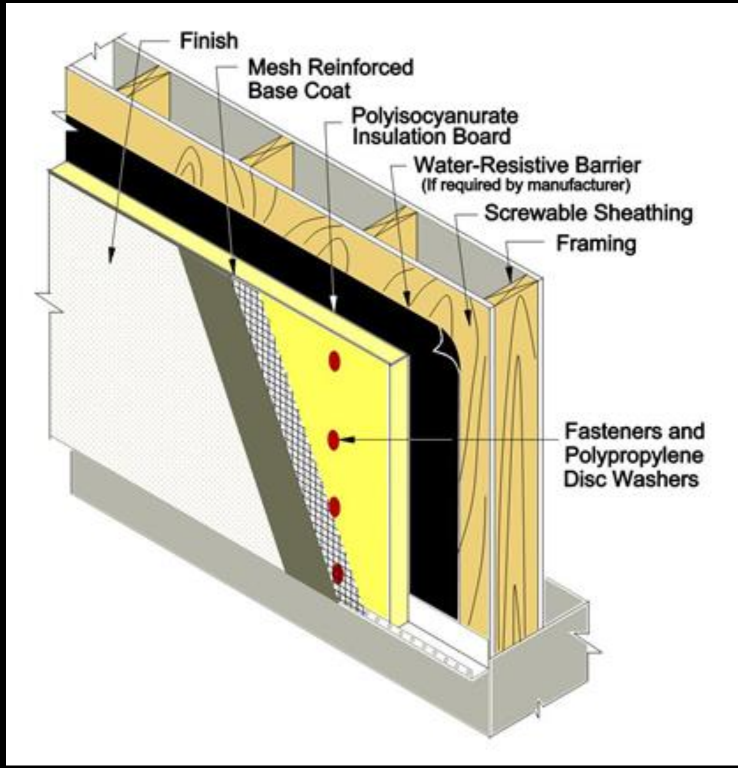


- **Complex:** Building systems are "multi-purpose" (energy, stability, durability, comfort, life cycle, fire barriers, etc.)
- **Dependent on labour skill and cost:** Tolerances, installation times, modification during construction, etc.
- If the objective is to guarantee encapsulation then this is the problem that needs to be solved!

Encapsulation







Encapsulation

Protective Layers

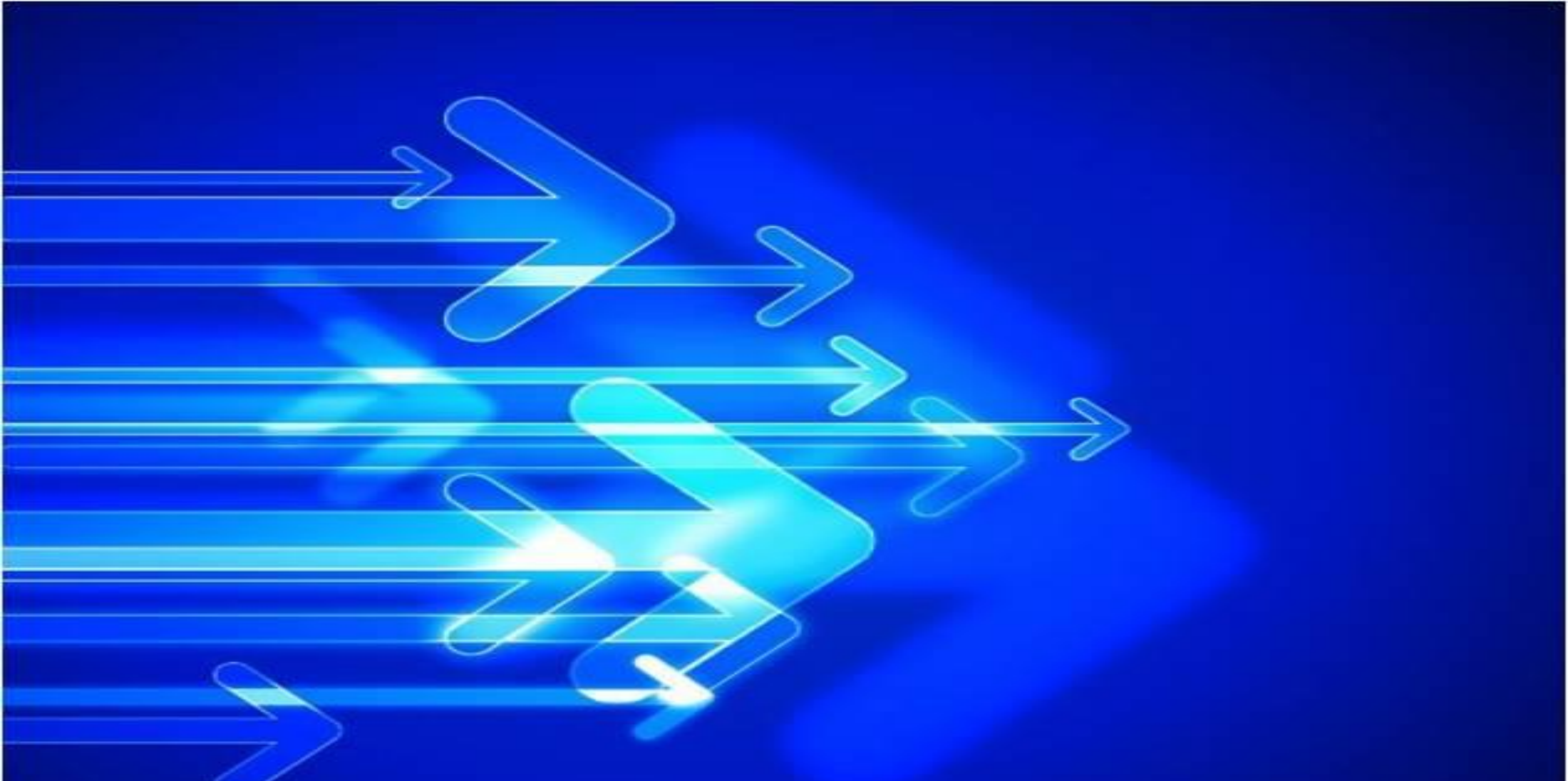
How do we establish performance for encapsulation/ protective layers?

Flammability to Encapsulation = Complexity

- Challenged our understanding of how to achieve quality, safe, robust, resilient infrastructure
  - Design principles
  - Design practises
  - Performance assessment
  - Regulatory frameworks
  - Professional boundaries
  - Integrated design
  - Definition of competence
  - … etc.

Why are we back to the 1970's?

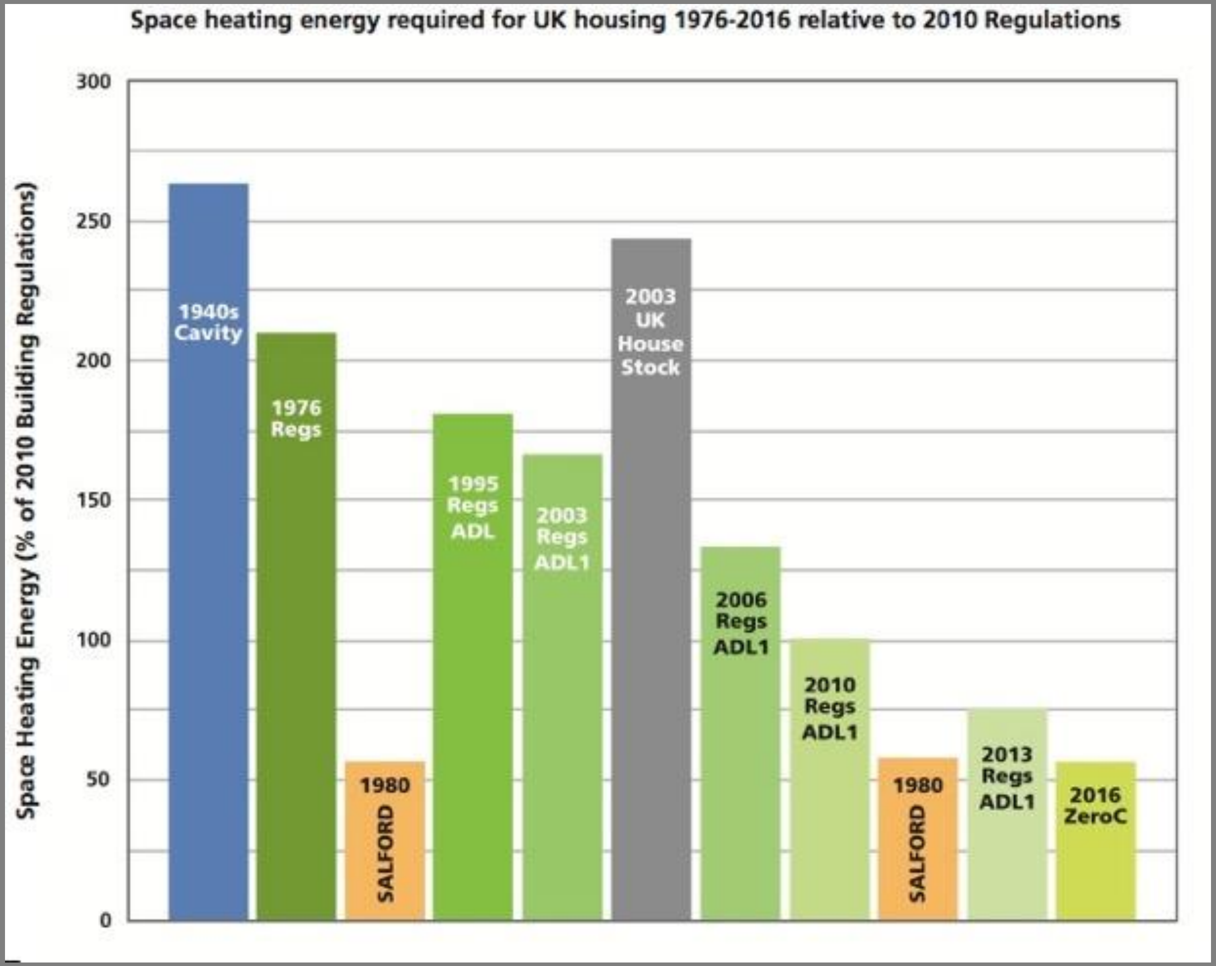
Joelma fire, Sao Paulo, Brazil,
Friday, February 1st, 1974

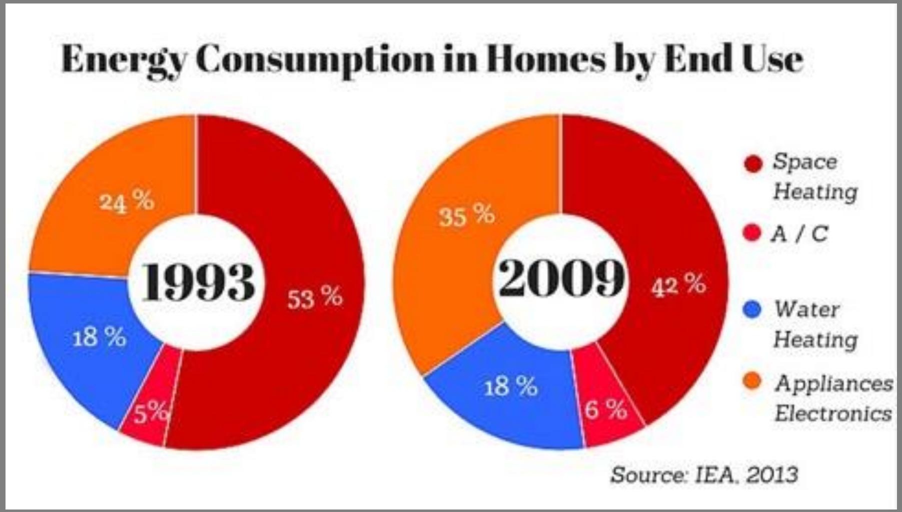


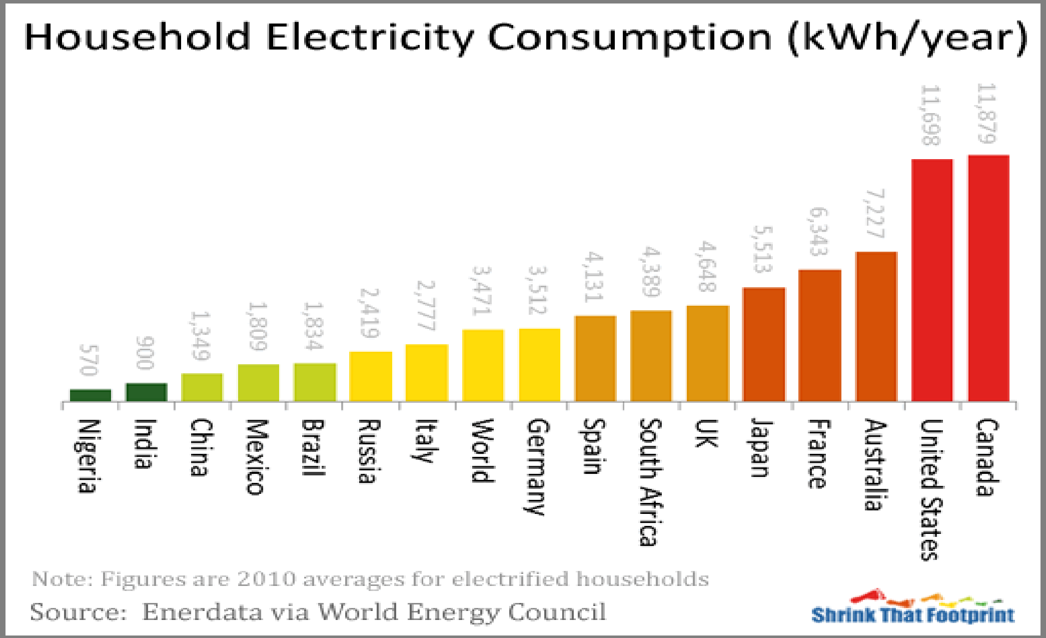
Drivers and Constraints

Energy: Quantifiable Performance

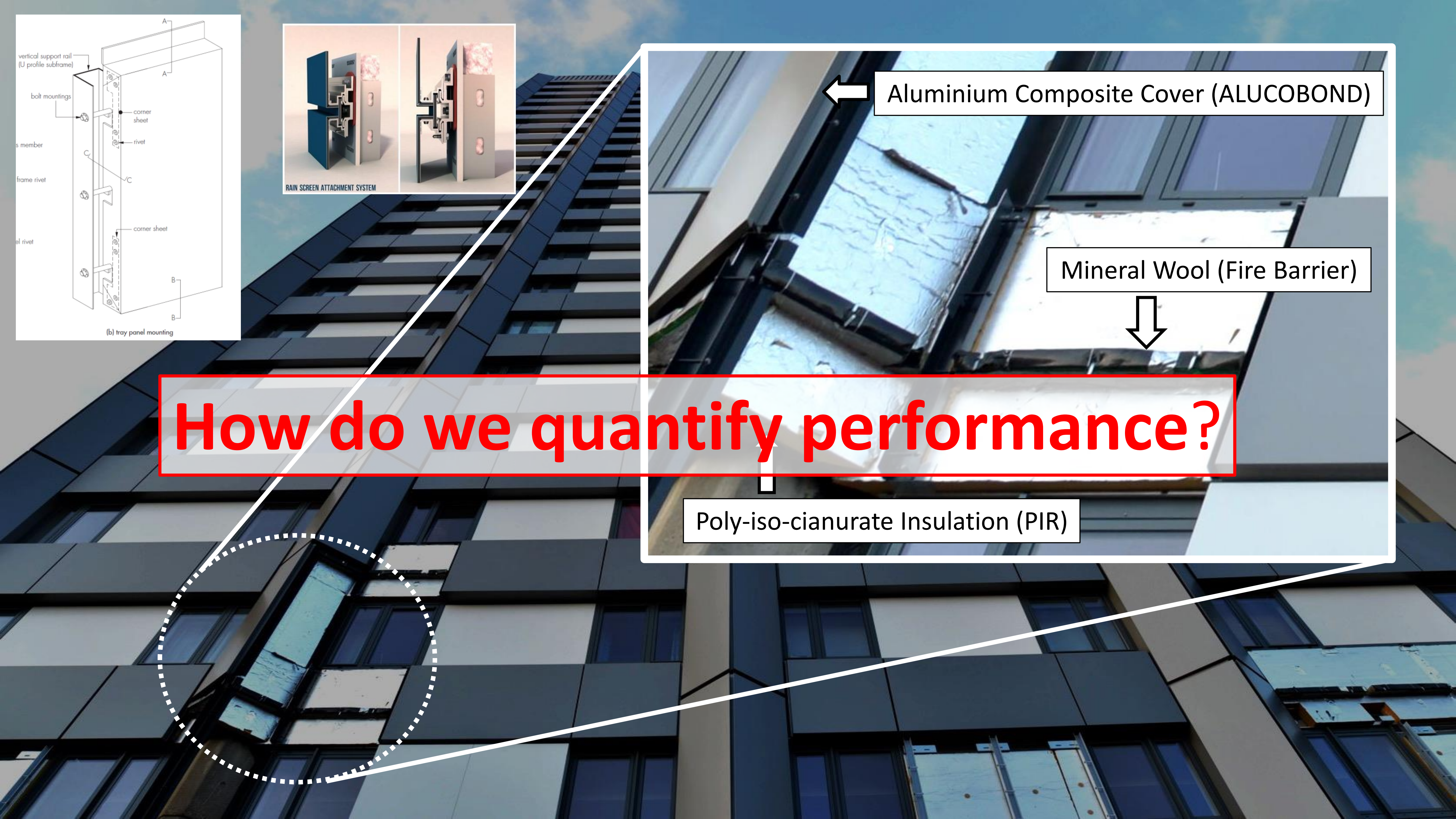
- Energy conservation targets







Social Housing: 1960's – 1970's


vertical support rail
(U profile subframe)
bolt mountings
corner sheet
rivet
corner sheet
(b) tray panel mounting
RAIN SCREEN ATTACHMENT SYSTEM
Aluminium Composite Cover (ALUCOBOND)
Mineral Wool (Fire Barrier)
How do we quantify performance?
Poly-iso-cianurate Insulation (PIR)

Insulation Materials/Products

12.7 In a building with a storey 18m or more above ground level any insulation product, filler material (not including gaskets, sealants and similar) etc. used in the external wall construction should be of limited combustibility (see Appendix A). This restriction does not apply to masonry cavity wall construction which complies with Diagram 34 in Section 9.

Materials of limited combustibility

9 Materials of limited combustibility are defined in Table A7:

a. (National classes) by reference to the method specified in BS 476: Part 11:1982; or

b. (European classes) in terms of performance when classified as class A2-s3, d2 in accordance with BS EN 13501-1:2007, *Fire classification of construction products and building elements,* Part 1 – *Classification using data from reaction to fire tests* when tested to BS EN ISO 1182:2002, *Reaction to fire tests for building products – Non-combustibility test* or BS EN ISO 1716:2002 *Reaction to fire tests for building products – Determination of the gross calorific value* **and** BS EN 13823:2002, *Reaction to fire tests for building products – Building products excluding floorings exposed to the thermal attack by a single burning item.*

Compliance

7 Behaviour in relation to fire

7.1 When tested to BS 476-6 : 1989, ALUCOBOND panel achieved a fire propagation index (I) of 0 with sub-indices (i_1), (i_2) and (i_3) also of 0 and when tested to BS 476-7 : 1997, the product achieved a Class 1 surface spread of flame.

7.2 When tested in accordance with BS EN 13501-1 : 2007, the ALUCOBOND plus panel,with outer aluminium sheet coated with primer and a two-layered finish coat, when tested for reaction to fire, achieved a classification of B-s1, d0.

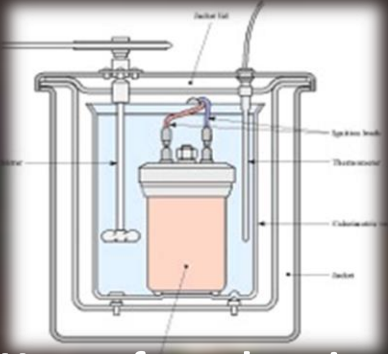
7.3 When tested in accordance with BS EN 13501-1 : 2007, the ALUCOBOND A2 panel when tested for reaction to fire, achieved a classification of A2-s1, d0.

7.4 The panels are capable of achieving Class 0 surface or a 'low risk' material in relation to the national Building Regulations.

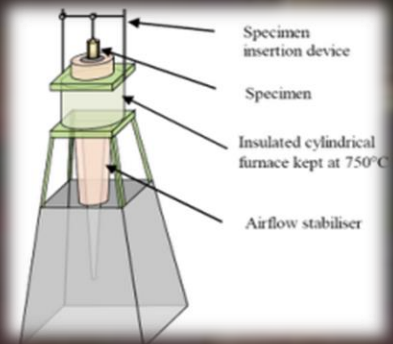

Is this a solely a material flammability issue?

Flammability Tests

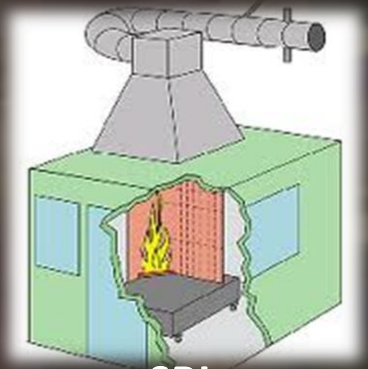
Reaction-to-fire Classification: A1, A2, B, C, D, E = f(…, FIGRA, SMOGRA, …)



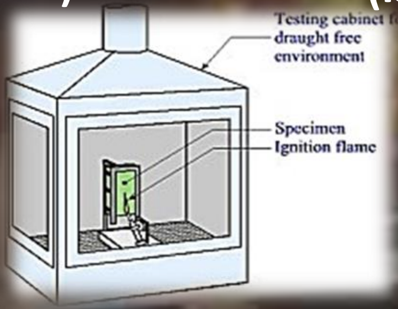
Heat of combustion
(ISO 1716)



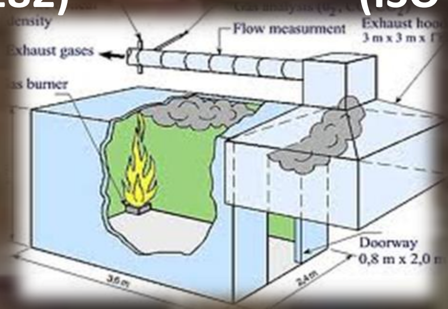
Non-combustibility test
(ISO 1182)



SBI
(ISO 13823)



Ignitability test
(ISO 11925-2)

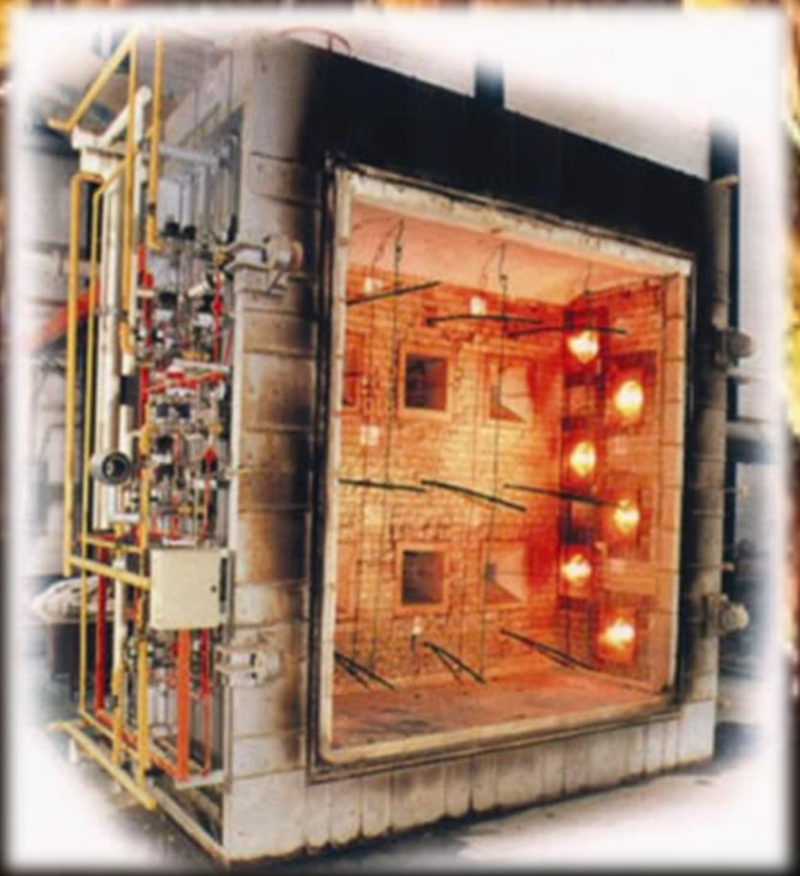


Room corner test
(ISO 9705)

Are we truly testing “system” behaviour?

Does this test provide system performance?

Does this test assess true mechanical behaviour?

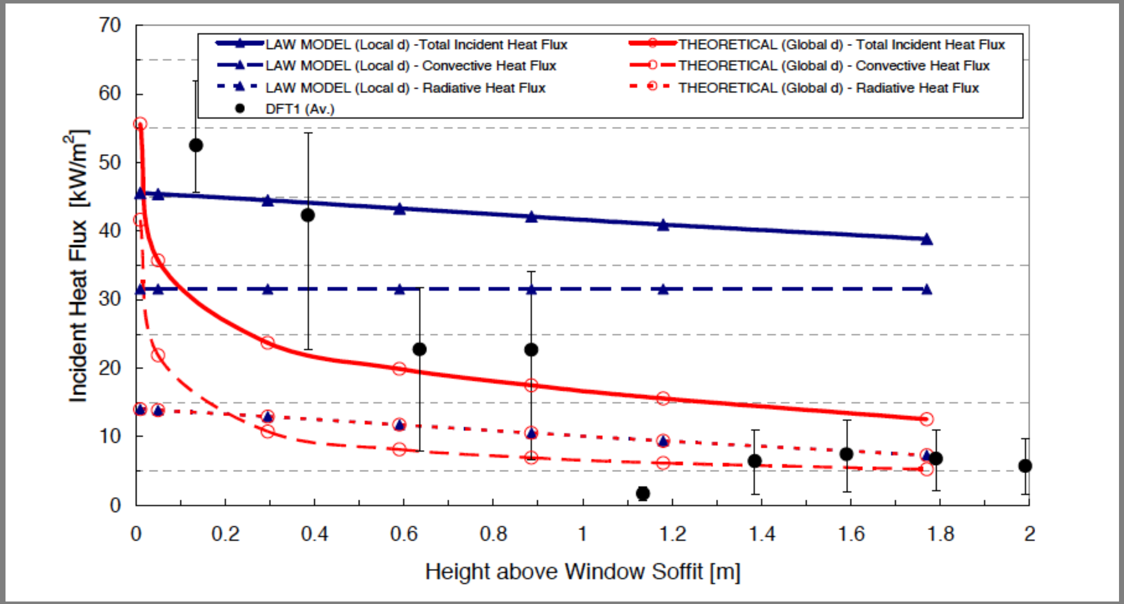


Fire-resistance

Pass-Fail

R,E,I

Spill Plumes



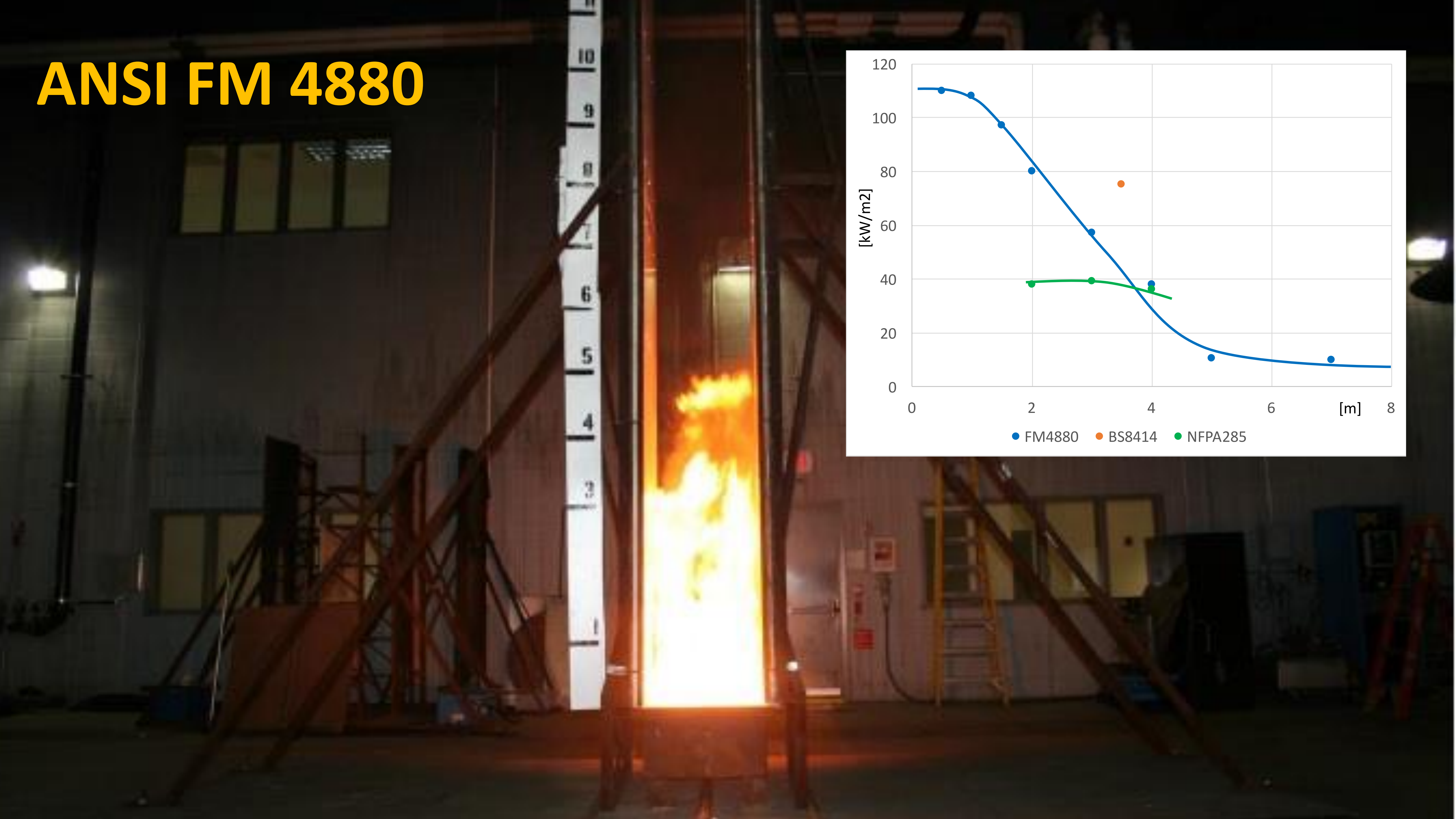
Are these the right tests?

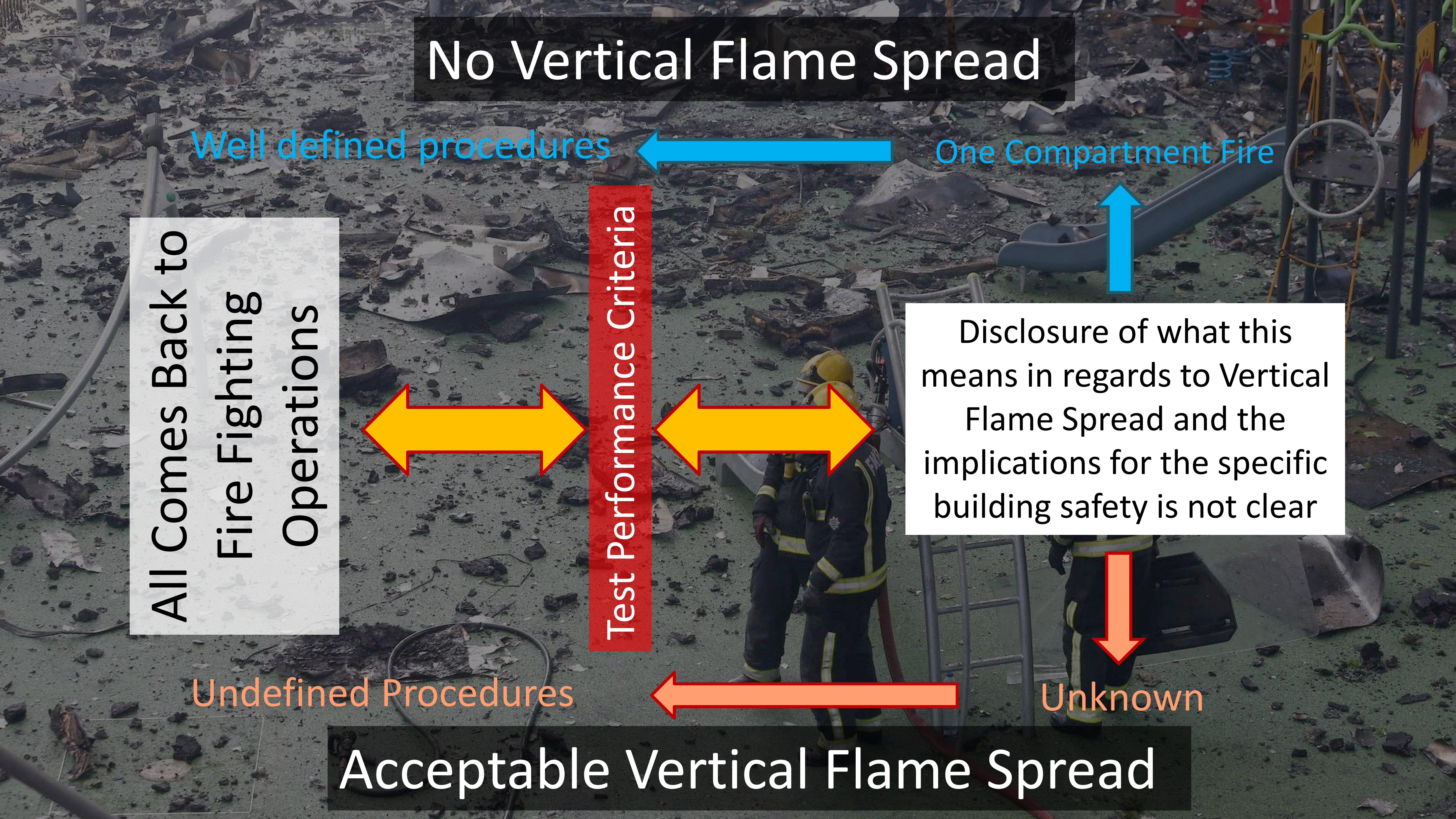
48.4.1.5 Wall Assembly Flammability.

48.4.1.5.1 The wall assembly shall be tested in accordance with, and the results shall comply with, the acceptance criteria of NFPA 285, *Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components.*

48.4.1.5.2 The requirement of 48.4.1.5.1 shall not apply to one-story buildings complying with 48.3.3.4(4).

ANSI FM 4880




No Vertical Flame Spread
Well defined procedures
One Compartment Fire
All Comes Back to Fire Fighting Operations
Test Performance Criteria
Disclosure of what this means in regards to Vertical Flame Spread and the implications for the specific building safety is not clear
Undefined Procedures
Unknown
Acceptable Vertical Flame Spread

Performance

… we know perfectly well how to do it …

… but it requires "bespoke" performance protocol for each particular system … there is no standardize test because we are testing "system behaviour": Building + Envelope

… Past: One test for all materials

… Today: A bespoke performance protocol for each system


What is the solution?

“The Wake Effect”

… or the unintended consequences of our actions


How do we bring attention to the “wake”?
o Safety is not a constraint
o It is not the bad test
o It is not the bad material
o It is the lack of understanding of the consequences of our actions

A viable technical proposition …
an enormous philosophical departure

Thank you!