Advanced Building Science

- Intro to Building Enclosures (Envelope)
  - Built facilities
  - Building enclosure functions

- Readings
  - HPE Chapter 2 (all) & 3 (p. 23-29 only)

Intro to Building Enclosure

Our Built Environment

- Human needs

- Functions of built facilities
  - support
  - distribute
  - control
  - finish

- Building attributes

Intro to Building Enclosure

Our Built Environment – Human Needs

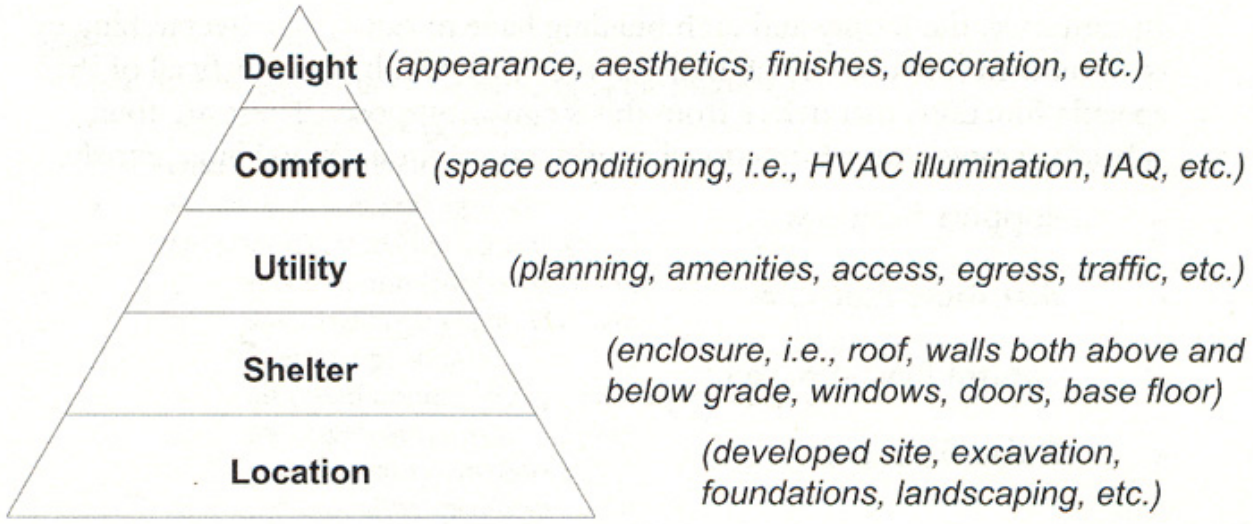
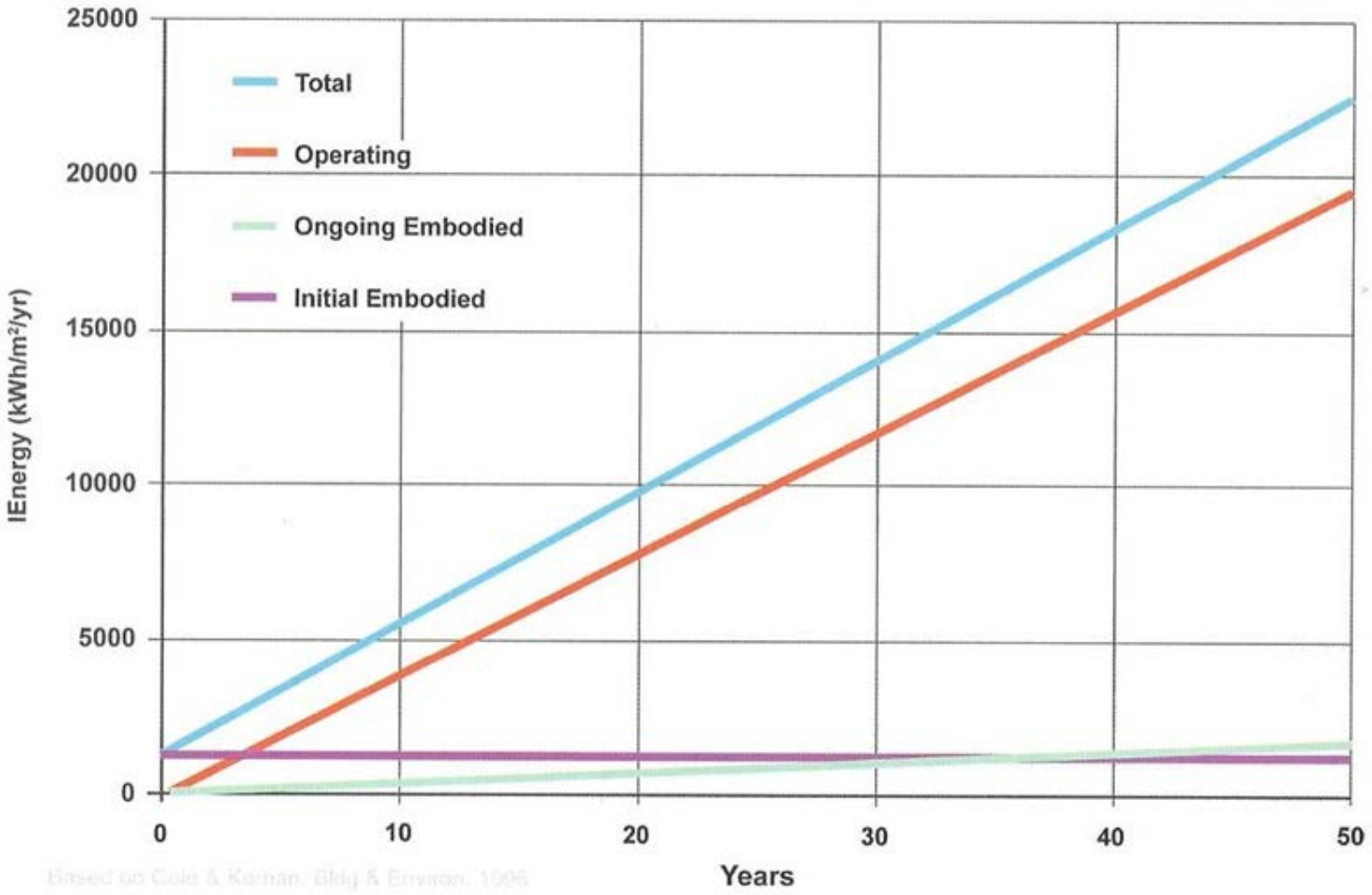


Figure 1.1: The five-step hierarchy of human needs for a built facility

Note: Inherent in all five fundamental levels of human need is the necessity for the appropriate superstructure in order to support the building enclosure, meet the need for internal structural separation (horizontal and vertical), and interface with the ground.

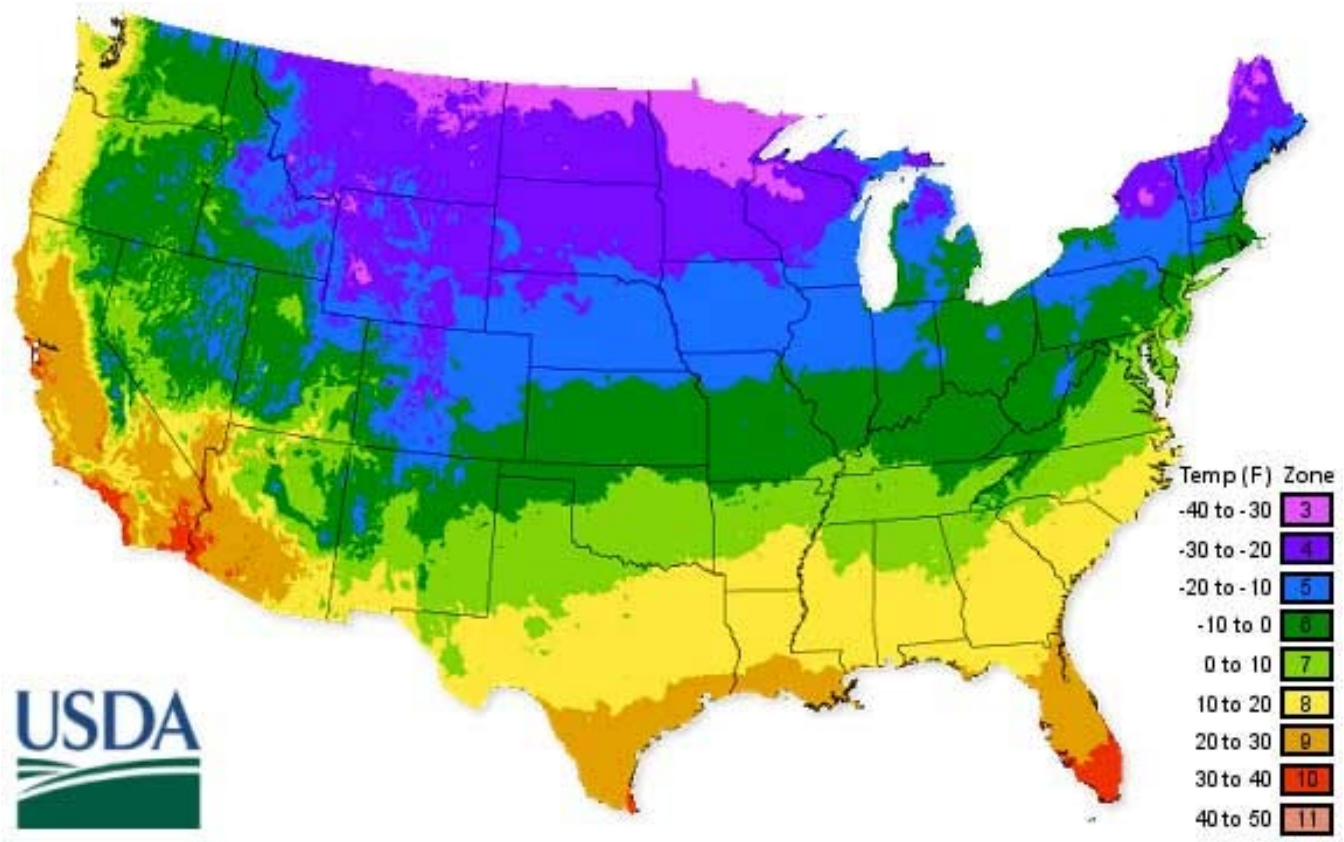
Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 1

Embodied & Operating Energy



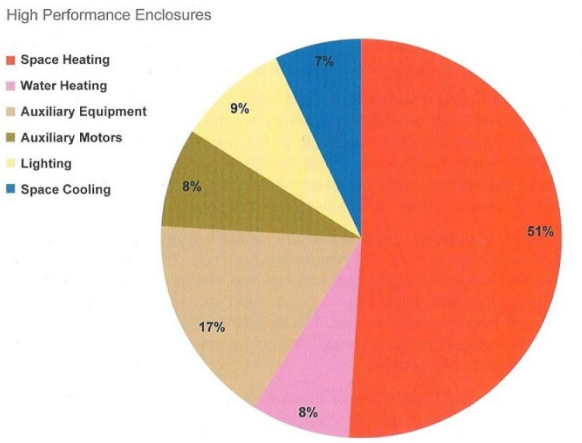
Straube: High Performance Enclosures, Chapter 1

Climate Zones

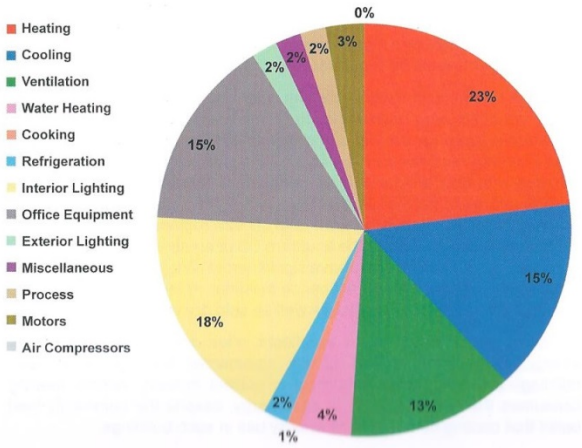


Energy Consumption by End-Use

- Canadian Office Buildings
  - NRCan 2007



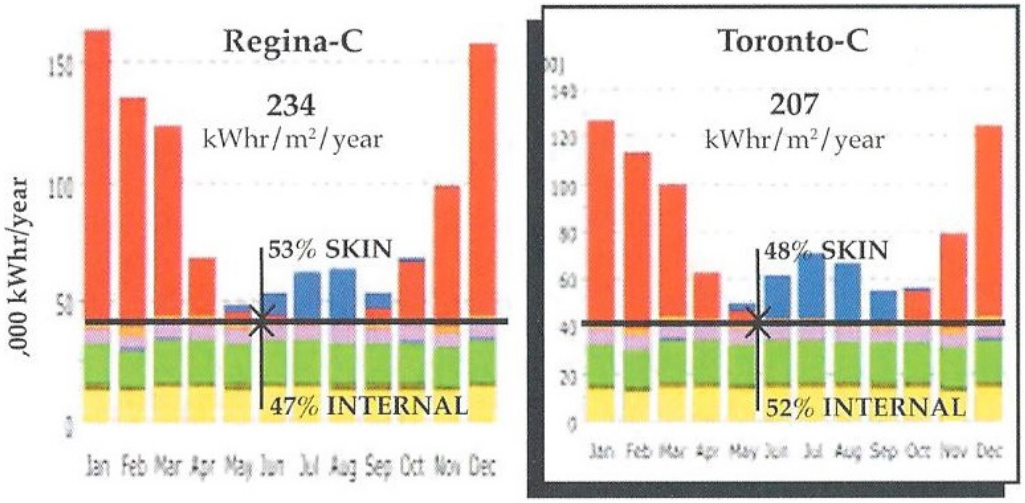
- California Office Buildings
  - CEC 2006



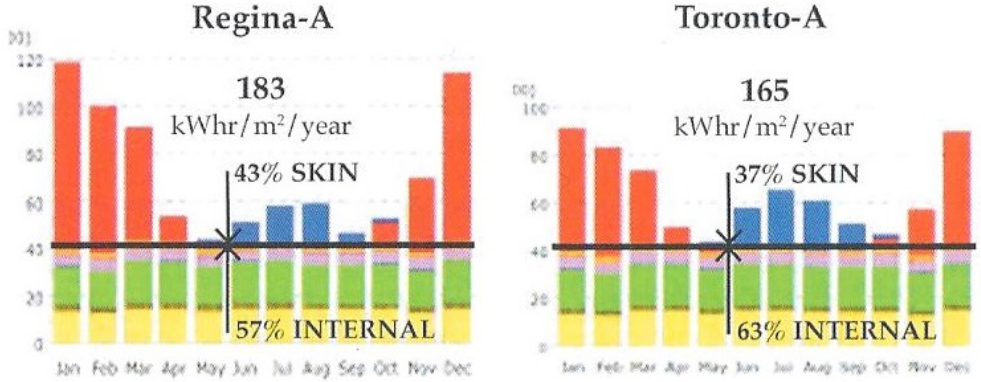
Straube: High Performance Enclosures, Chapter 1

Distribution of Energy Use

MD40SQ-C
- 4-storey, square floor plate
- 50,000 ft² GFA
- 40% WWR (N, S, E & W)
- Enclosure "C-Institutional"

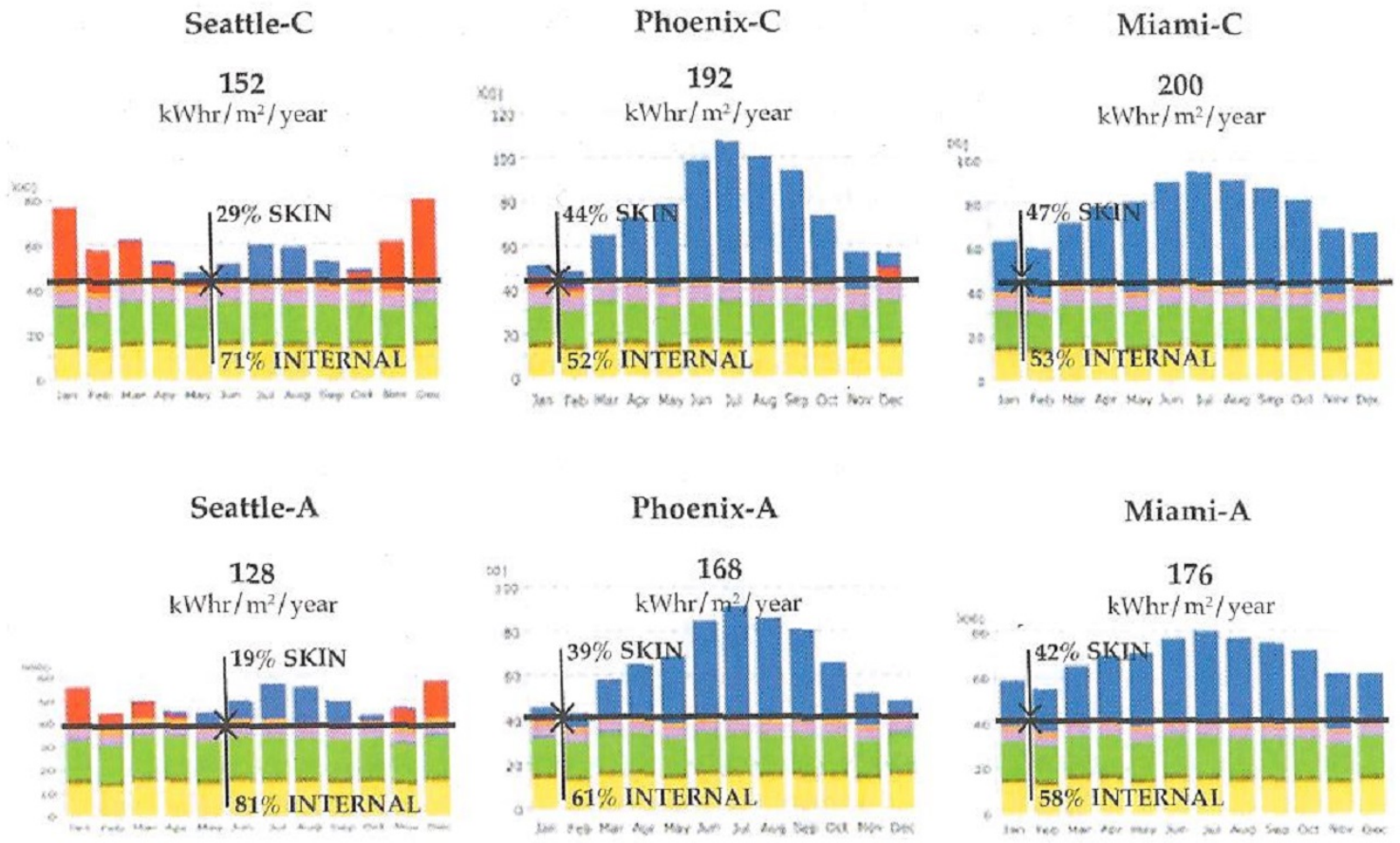


MD40SQ-C
- 4-storey, square floor plate
- 50,000 ft² GFA
- 40% WWR (N, S, E & W)
- Enclosure "A-Exemplary"



Straube: High Performance Enclosures, Chapter 2

Distribution of Energy Use



Straube: High Performance Enclosures, Chapter 2

Priorities for Low-Energy Commercial Buildings

- 1. Limit window to wall ratio to 30 to 40%
- 2. Increase window performance
- 3. Increase wall/roof insulation levels
- 4. Separate ventilation air from heating & cooling system
- 5. Use occupancy and daylighting controls
- 6. Reduce equipment, plug, and lighting loads
- 7. Use demand controlled ventilation with heat recovery
- 8. Improve boiler/chiller efficiency
    - Use low temperature hydronic heating and cooling, when possible
- 9. Use variable speed pumps and fans
- 10. Simple, compact building form

Straube: High Performance Enclosures, Chapter 2

Recommended Glazing System U-values

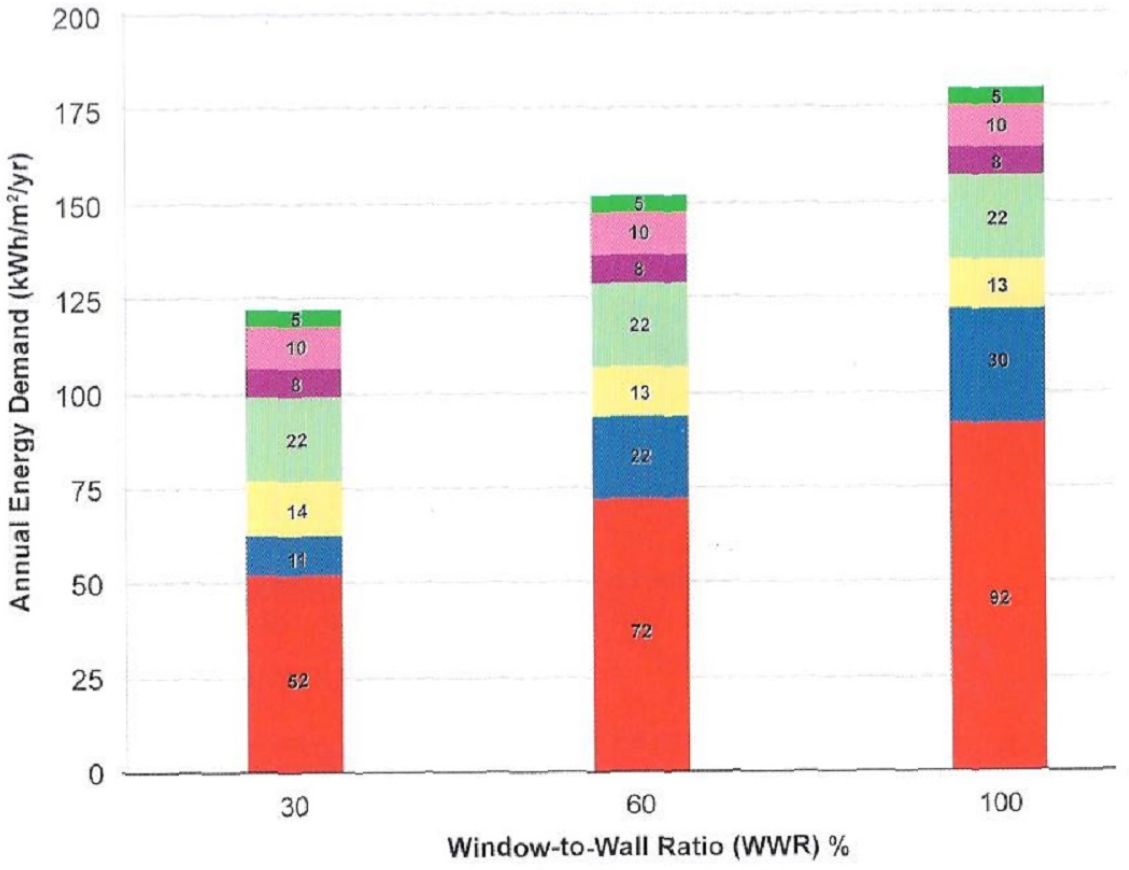
Zone	5	6	7	8	5	6	7	8
	Heating Degree Day (18 °C)				Heating Degree Day (65 °F)			
WWR	3000	4000	5000	6000	5400	7200	9000	10800
25	2.5	2.4	2.2	1.9	0.44	0.42	0.39	0.33
30	2.3	2.2	1.9	1.7	0.41	0.39	0.33	0.30
35	2.3	1.9	1.7	1.4	0.41	0.33	0.30	0.25
40	2.1	1.65	1.45	1.3	0.37	0.29	0.26	0.23
50	1.8	1.5	1.2	1.1	0.32	0.26	0.21	0.19
60	1.5	1.2	1.1	0.95	0.26	0.21	0.19	0.17
70	1.3	1.1	1	0.85	0.23	0.19	0.18	0.15
80	1.2	1	0.9	0.8	0.21	0.18	0.16	0.14

Straube: High Performance Enclosures, Chapter 2

Impact of Window-to-Wall Ratio

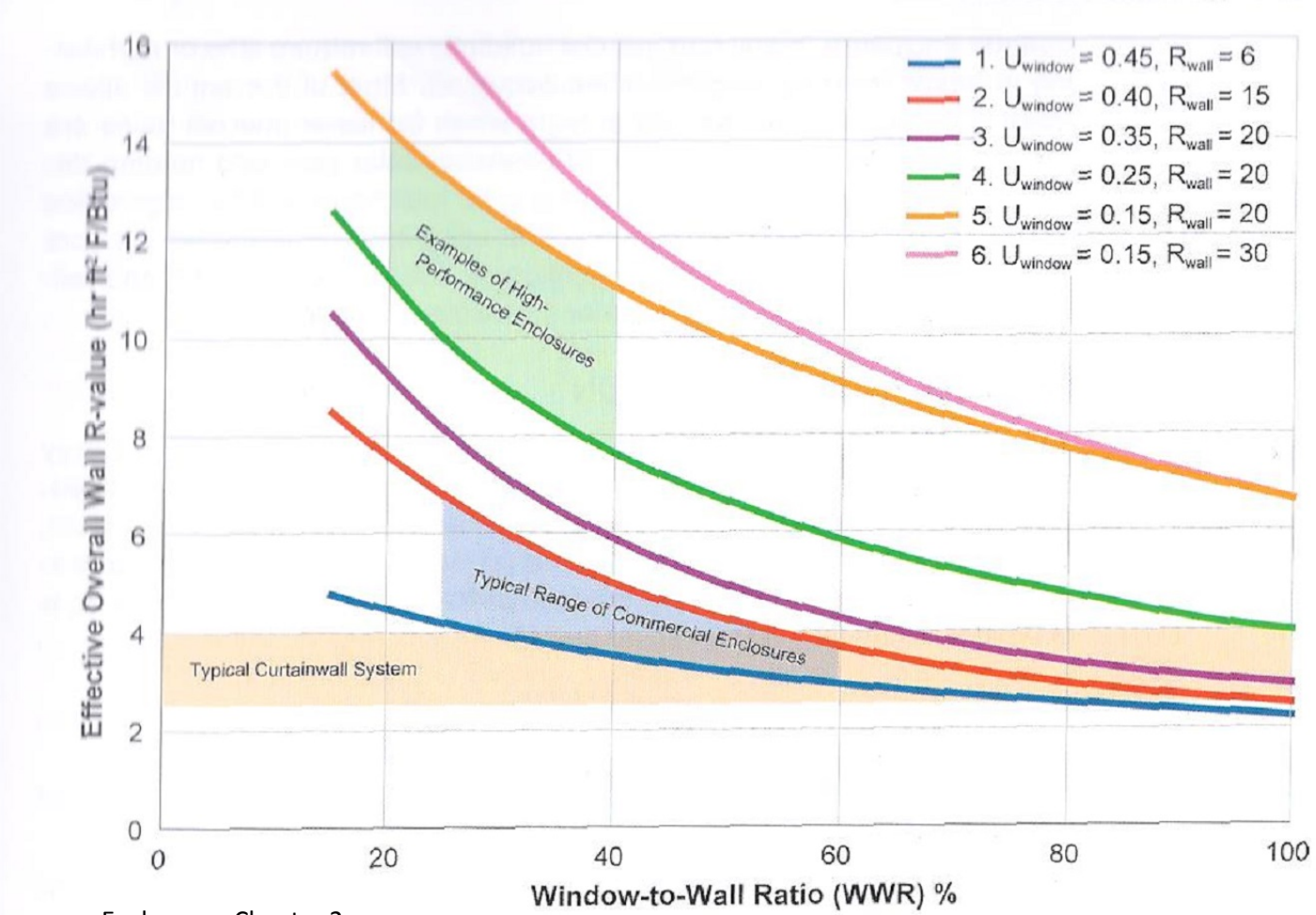
Mid-size Swedish Office

- R-20 walls
- R-3.5 windows
- w/daylighting controls & demand ventilation



Straube: High Performance Enclosures, Chapter 2

Window – Wall Relationship



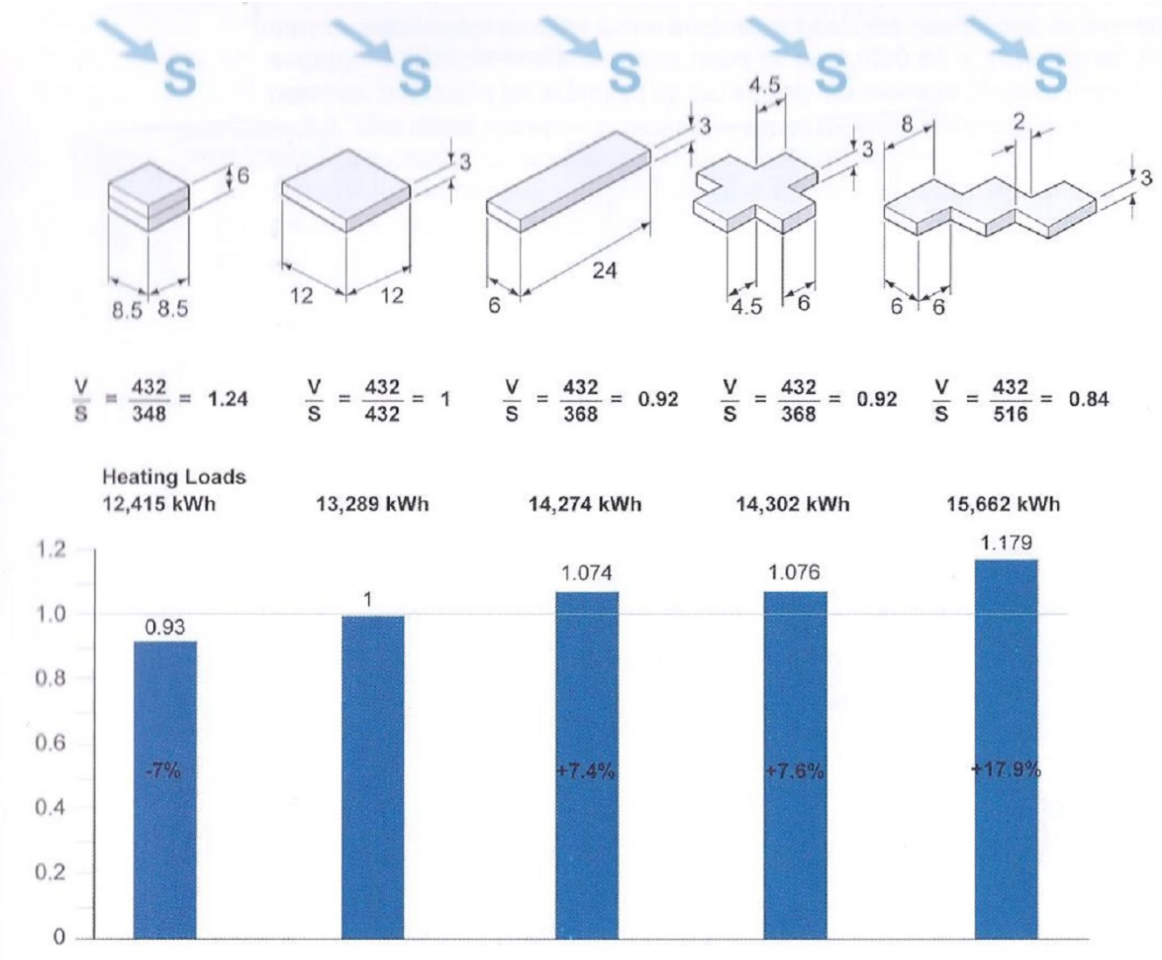
Straube: High Performance Enclosures, Chapter 2

Impact of Building Form

$$\text{Compactness Factor} = \frac{\text{Volume}}{\text{Surface Area}}$$

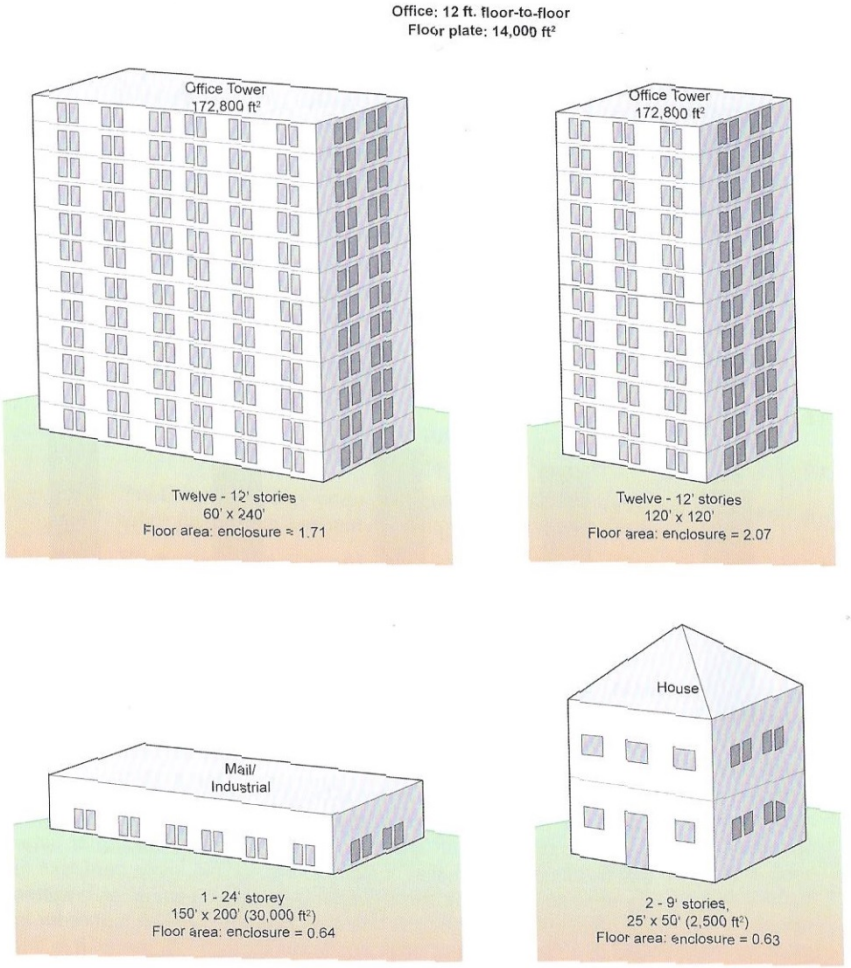
$$\text{Floor/Enclosure Ratio} = \frac{\text{Floor Area}}{\text{Enclosure Area}}$$

Impact of Building Form



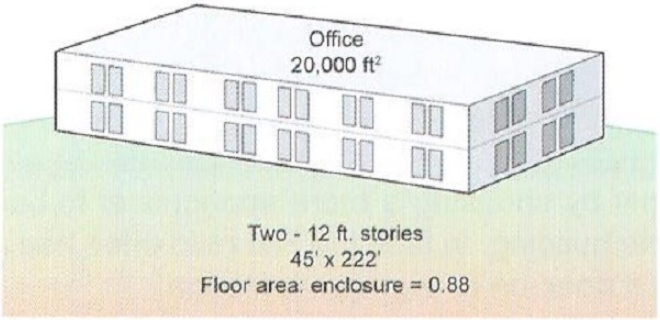
Straube: High Performance Enclosures, Chapter 2

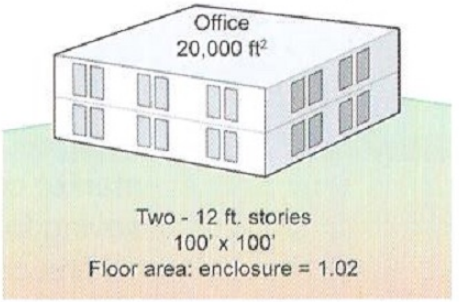
Form Factors Vary by Building Type

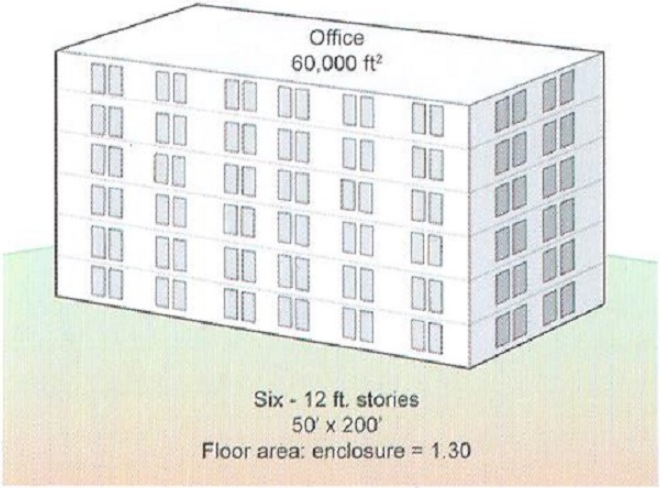


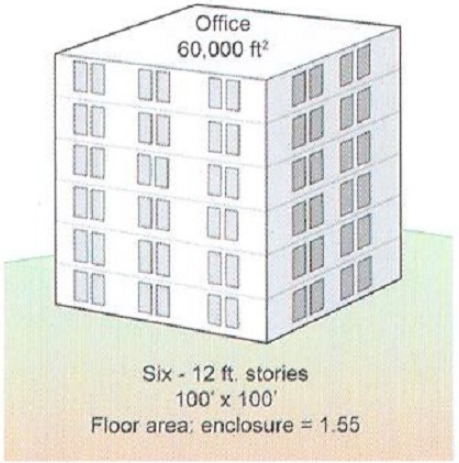
Straube: High Performance Enclosures, Chapter 2

Impact of Building Form









Straube: High Performance Enclosures, Chapter 2

Example of Modern Office Building

Straube: High Performance Enclosures, Chapter 1

Intro to Building Enclosure

Physical Functions – Support

- Accommodate, resist, distribute, and transfer all physical loadings
  - air pressure differentials
  - ground motion
  - fire
  - gravitational effects
  - impact
  - volume changes

Intro to Building Enclosure

Physical Functions – Control

- Into, within, and out of the building …
  - people & vehicles
  - animals, birds, insects
  - environmental loadings
    - precipitation
    - solar radiation
    - heat (temperature)
    - air
    - moisture (water, vapor)
    - sound
    - light
    - contaminants and particulates

Intro to Building Enclosure

Physical Functions – Finish

- Appearance or suitability of all relevant faces
  - color, speculance, reflectance, etc.
  - texture, pattern, relief
  - shape
  - proportion

Intro to Building Enclosure

Physical Functions – Distribute

- Transport or flow into, within, and out of the building
  - people
  - goods
  - vehicles
  - data
  - utilities
    - water
    - air
    - gas
    - electricity

Intro to Building Enclosure

Building Attributes

- buildability or constructability
- economic viability
- viewability
- utility
- sustainability
- serviceability
- safety
- productivity
- operability
- maintainability
- repairability
- durability
- disposability

Intro to Building Enclosure

Building Components

- Superstructure
- Enclosure
- Service systems
- Fabric

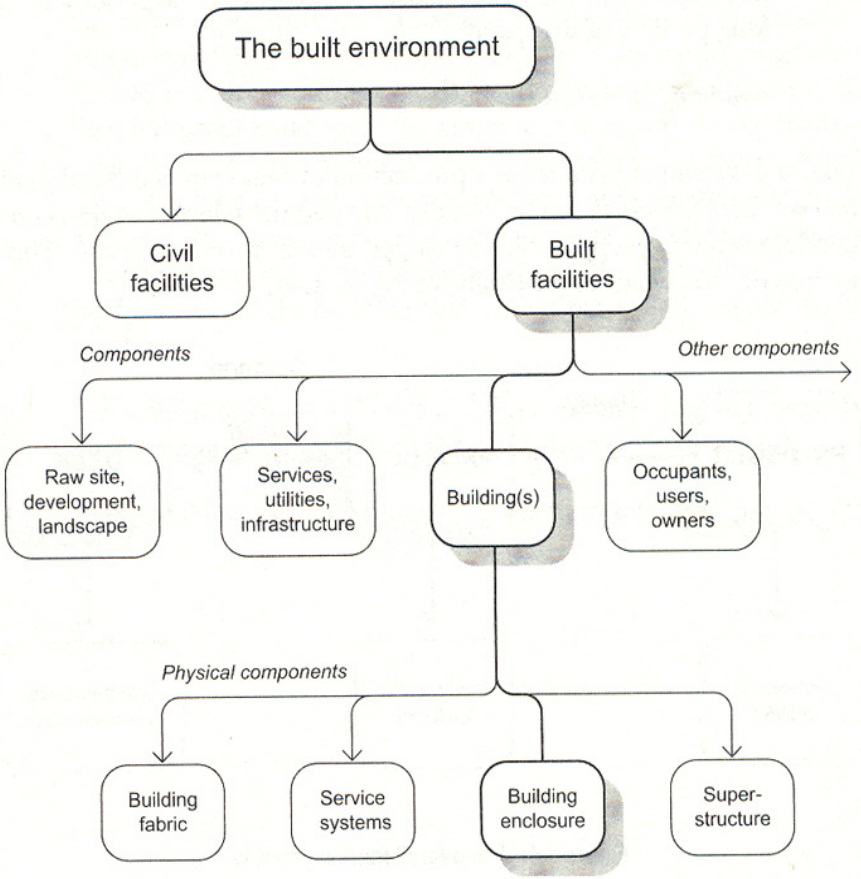


Figure 1.3: Components of built facilities and their buildings

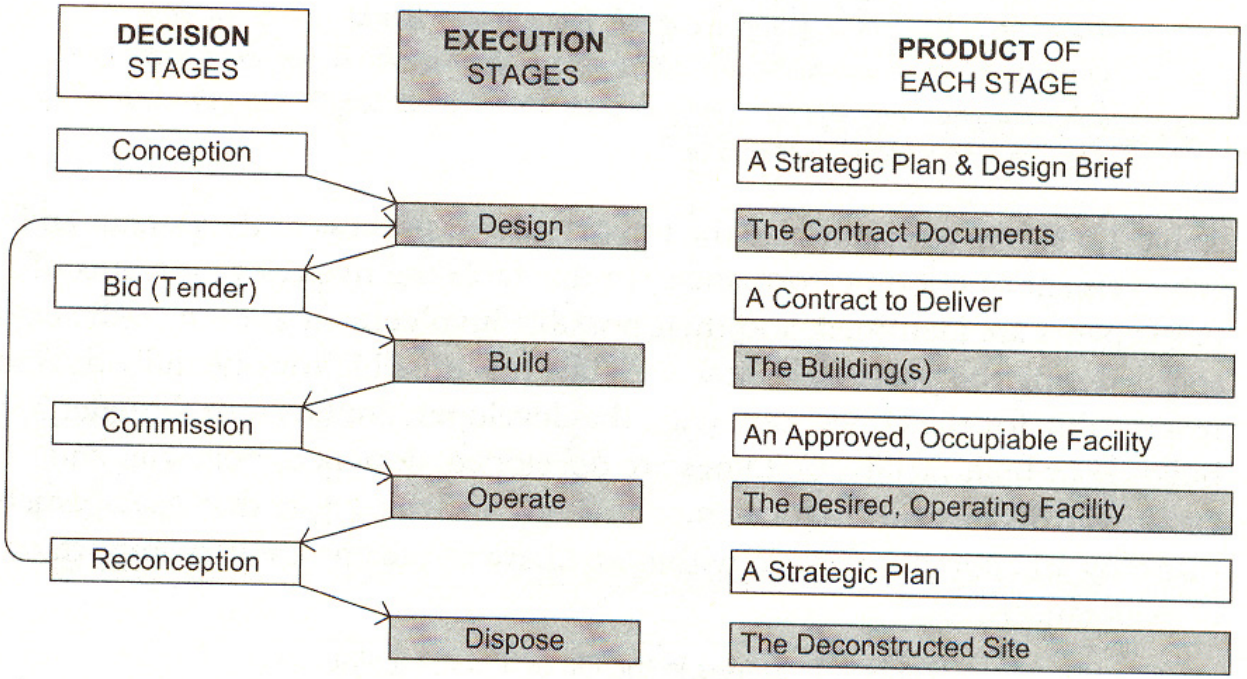
Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 1

Building Science for Building Enclosures

Intro to Building Enclosure

Life-Cycle of a Built Facility

Table 1.4: Stages in the life of a built facility and the related product



Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 1

Intro to Building Enclosure

Life-Cycle Costs (commercial building)

- Delivery costs
  - 2 - 4%
- Financing Costs
  - ???
- Operating costs
  - 2 – 6%
    - utilities - 20%
    - maintenance – 15%
    - admin, clean, etc. – 30%
    - fixed costs – 35%
- Occupant related costs
  - 90-96%

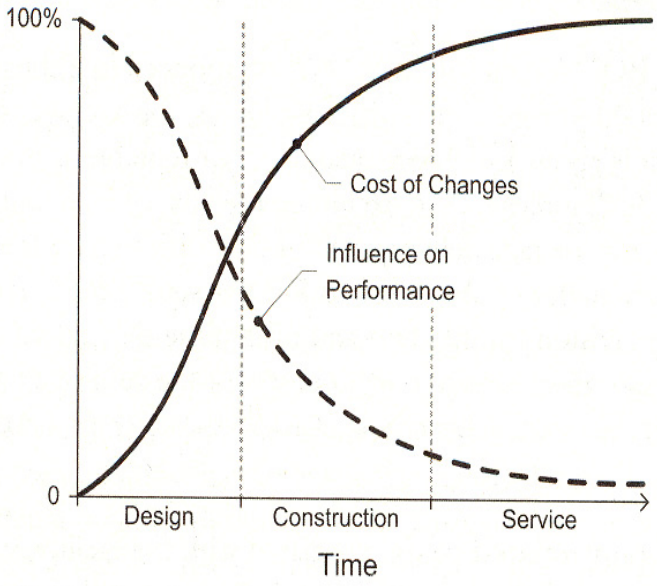


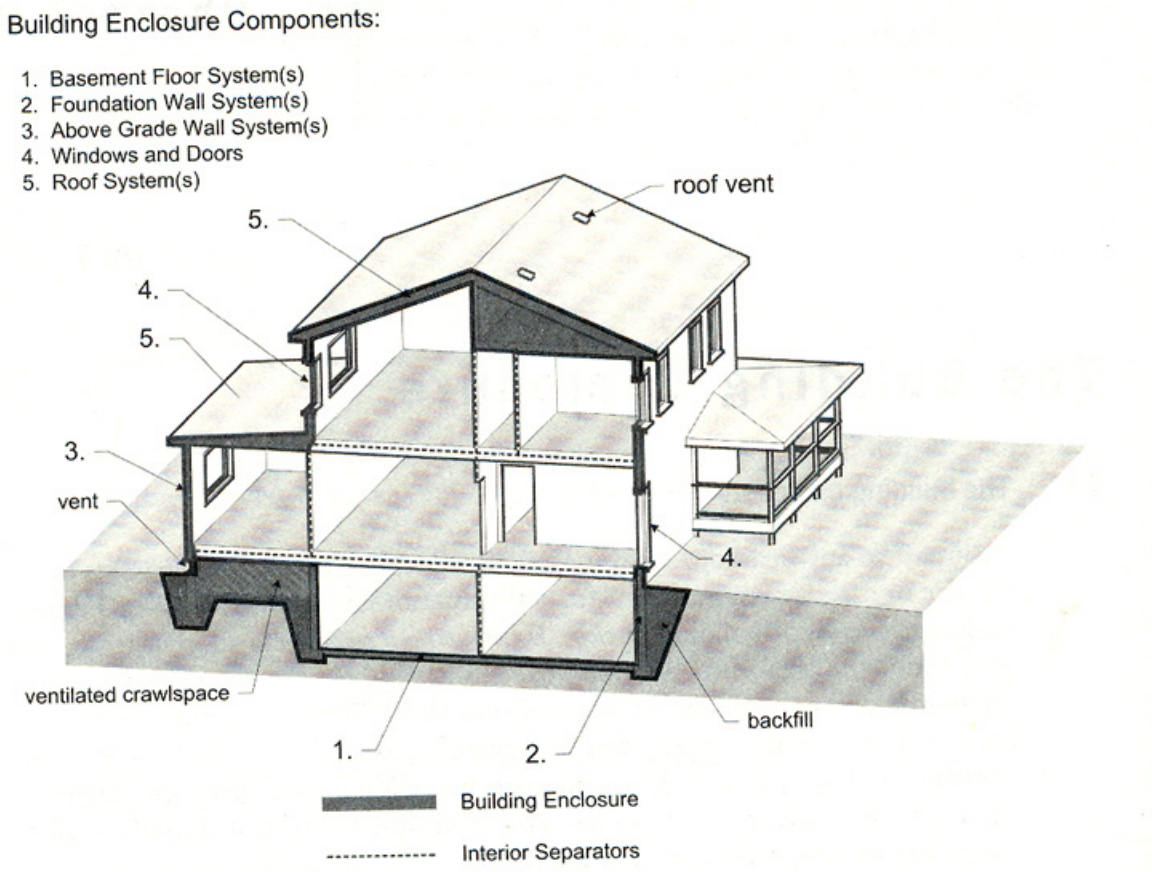
Figure 1.6: Opportunity to influence building performance

Building Science for Building Enclosures

Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 1

Intro to Building Enclosure

Building Enclosure – Definition



Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 2

Intro to Building Enclosure

Building Enclosure

- Base floor systems
- Below-grade wall systems
- Above-grade wall systems
  - windows and doors
- Roof systems
  - skylights

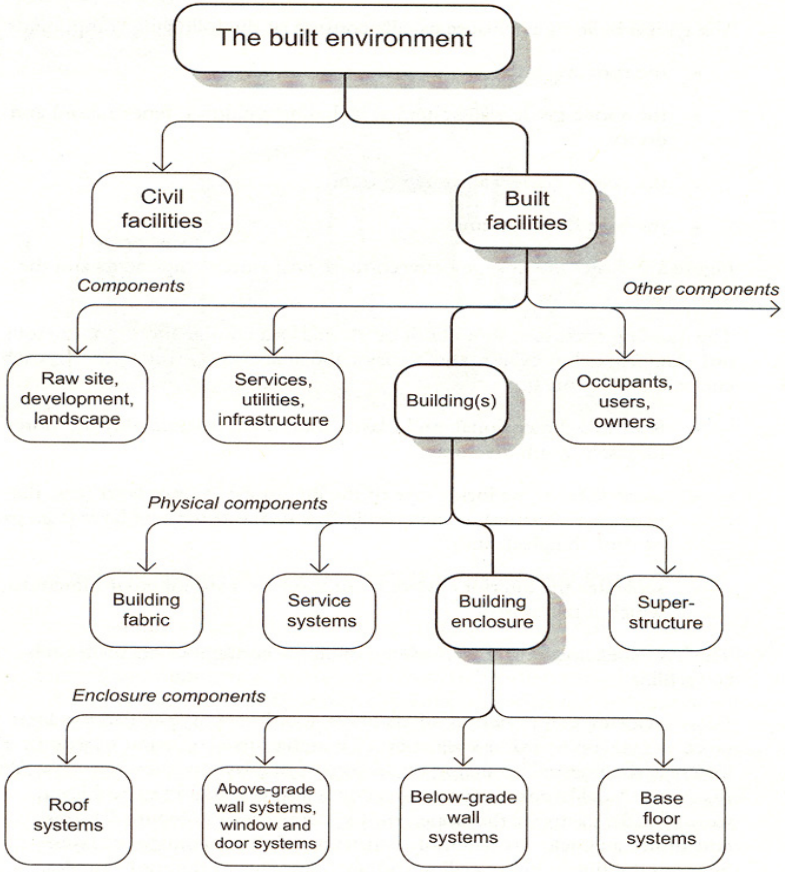


Figure 2.2: The linkage between the built environment and the physical components of the building enclosure

Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 2

Intro to Building Enclosure

Enclosure Loadings – From Exterior

Table 2.1: Loadings from the exterior environment

		Type				
		Heat related	**Moisture related**	**Air related**	**Ground related**	**Gravity related**
Source	**Weather or natural climate**	Ambient conditions, solar	RH, fog, rain, ice, snow	Barometric pressure, Wind		Water, snow, hail
	Abnormal climatic effects	Reflected solar, lightning	Tornado, hurricane, flooding	Tornado, hurricane	Frost heave, landslide	Wind-borne missile
	Natural phenomena	Fire, Ground water	Adfreezing, Freezing	Radon, methane, soil gas	Seismic, land- slide, settlement, termites, plants, etc.	Hydrostatic pressure, soil pressure
	Human-made weather	Global warming, city effect	Smog, Acid rain	Wind related vortex/swirl		
	Human-induced events	Fire	Fire (hoses, sprinklers, etc.)	Smoke, sonic boom, sound, explosion		Impact, wear and tear

Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 2

Intro to Building Enclosure

Enclosure Loadings – From Interior

Table 2.2: Loadings from the interior environment

		Type				
		Heat related	**Moisture related**	**Air-flow related**	**Ground related**	**Gravity related**
Source	**Interior Space**	Ambient conditions, solar	RH, water (sprinklers, etc.)	Barometric pressure, wind, stack, fan-induced		Water
	Natural phenomena	Fire	Fungal growth, mold	Radon, methane	Settlement, termites, plants, etc.	
	Human-induced events	Fire, people	People, flooding, combustion, equipment	Smoke, sound, explosion		Impact, wear and tear, dead & live loads

Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 2

Intro to Building Enclosure

Enclosure Loadings – From Enclosure

Table 2.3: Loadings from the enclosure

		Type				
		Heat related	Moisture related	Air-flow related	Ground related	Gravity related
Source	Element or component being considered	Volume change, shape change, fire	RH, built in moisture, volume change, fungal growth, mold, creep, shrinkage, etc.	Off-gassing, air flow, air pressure differentials		Self weight, live loads
	Adjacent Elements	Volume and shape change, fire	Volume change	Smoke		Dead loads, live loads

Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 1

Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 2

Intro to Building Enclosure

Enclosure and Its Functions

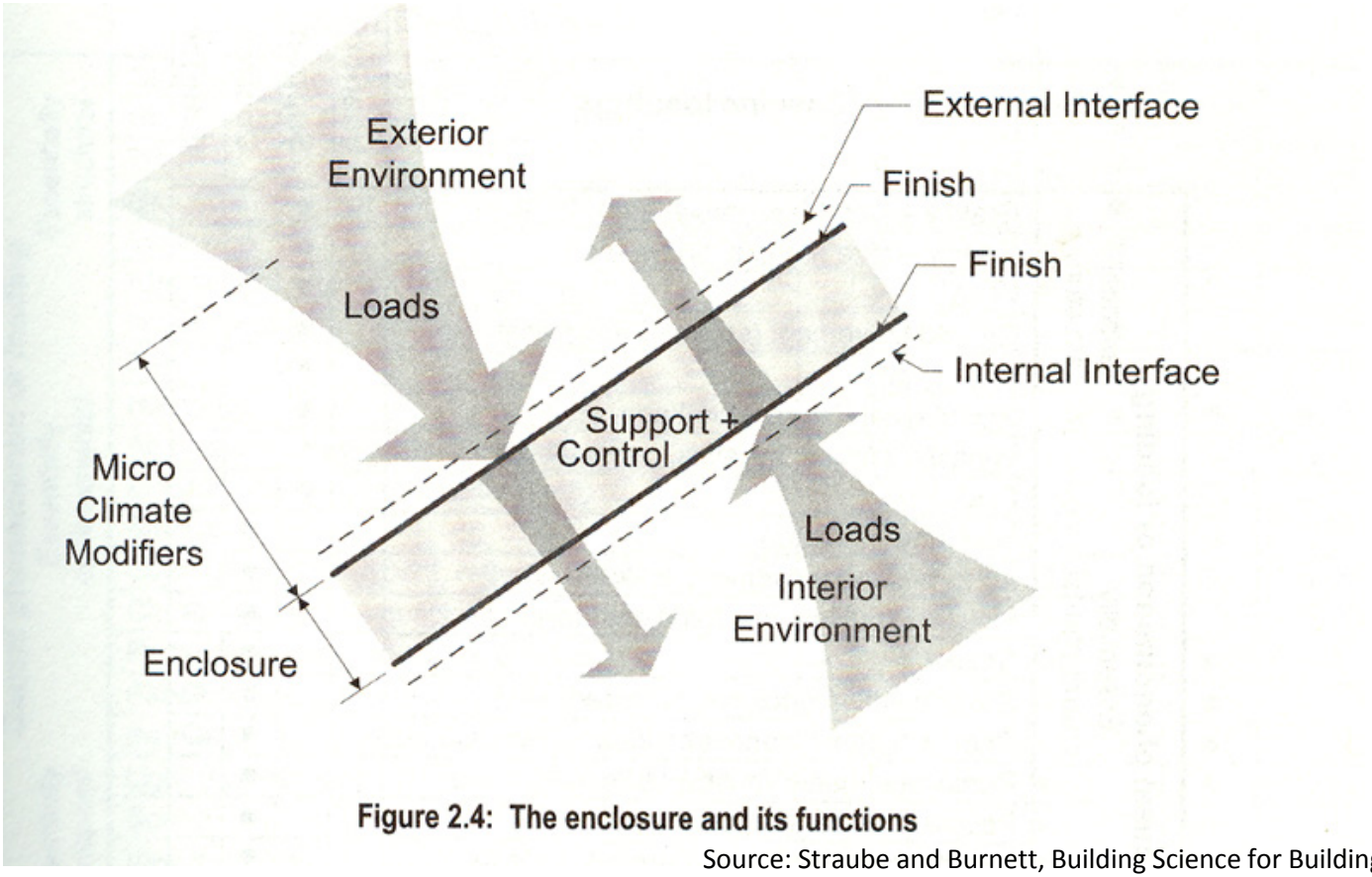


Figure 2.4: The enclosure and its functions

Source: Straube and Burnett, Building Science for Building Enclosures, Chapter 2

Intro to Building Enclosure

- There is hardly anything in this world that some man cannot make a little worse and sell a little cheaper.
  - and the people who consider price only are this man's lawful prey.

- It is unwise to pay too much, but it's more unwise to pay to little.
  - When you pay too much you lose a little money, that is all.
  - When you pay too little, you sometimes lose everything,
    - because the thing you bought was incapable of doing the very thing you bought it to do.

- John Ruskin (1819-1900)

In Summary

Questions and Discussion

Preview for Next Class

- Intro to Thermal Comfort
  - Interior design conditions
- Climate Summary
  - Exterior design conditions

- Readings
  - HF: Chapter 9.1 to 9.23
  - HF: Chapter 14
  - BSBE: Chapter 3