

The House As A System

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From Caulking Guns to Differential Manometers

- ▶ Boy, it was a lot simpler then
- ▶ We (thought we) knew what would happen, how much things would save
- ▶ We (thought we) were in the energy conservation business
- ▶ So we fixed some things
 - Insulated & vented some attics
 - Sealed up some holes

Turns Out Everything Works Together

- ▶ Can't insulate unless you air seal
- ▶ Can't air seal unless you insulate
- ▶ Can't air seal unless you have air for the fire
- ▶ Can't know if you have air for the fire until after you air seal
- ▶ If you air seal, you might need ventilation

Oh Yeah, There's Also This Other Stuff

- ▶ Formaldehyde
- ▶ Lead
- ▶ Radon
- ▶ Asbestos
- ▶ Carbon Monoxide
- ▶ Mold
- ▶ Volatile Organic Compounds
- ▶ Lawyers



Life is So Complicated!

- ▶ What to do?
- ▶ It ain't easy
- ▶ No substitute for understanding the interactions
- ▶ That's why you're here, right?
- ▶ A trade in search of its identity

System

- ▶ A regularly interacting or interdependent group of items forming a unified whole
- ▶ Harmonious arrangement or pattern

The Historical Perspective

- ▶ No control
- ▶ No options
- ▶ High bills
- ▶ Cold drafts
- ▶ Low indoor humidity
- ▶ The active chimney



How New Buildings are Different

- ▶ New construction
- ▶ Retrofit
- ▶ Indoor pollutants
- ▶ Indoor pressure
- ▶ Combustion safety





Building tune-Ups inc

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Cars Come with Owner's Manuals

- ▶ So do VCRs
- ▶ And watches
- ▶ But houses don't
- ▶ Why is that?

The Cost of Running a Fan

- ▶ Depends on:
 - How much air it moves
 - How it's installed
 - How much it runs
 - How much electricity it uses
 - How much the electricity costs
 - How cold (warm) it is outside
 - How much the heating (cooling) fuel costs
 - How efficient the heating (cooling) system is
 - How much the house leaks
 - How good the insulation & windows are

Heat

- ▶ Conduction
- ▶ Convection
- ▶ Radiation
- ▶ Always from hot to cold
- ▶ Quantity depends on temperature difference

Conduction

- ▶ Heat movement through a solid
- ▶ Quantity depends on temperature difference and characteristics of the material

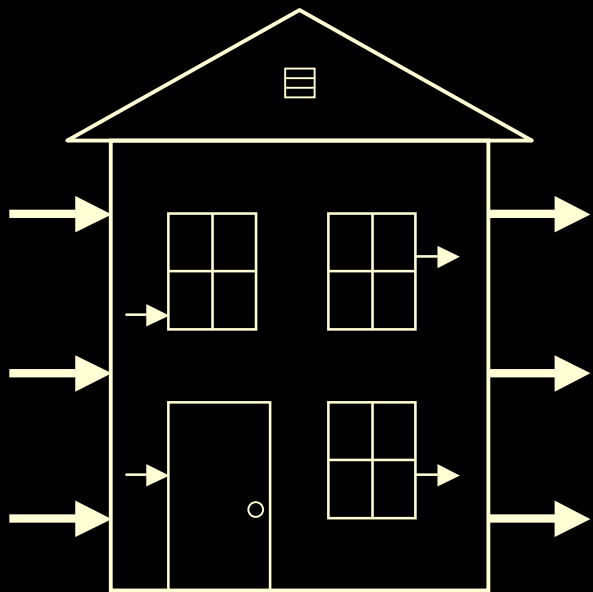
Convection

- ▶ Heat carried by a moving fluid
 - How furnaces and boilers get heat to the rooms
- ▶ Air leaving the building takes heat with it
 - Same amount of heat must be added to incoming air to maintain temp

Radiation

- ▶ Heat flow through empty space
 - More or less like light
- ▶ Hot Surfaces Warm You Up
 - You feel heat through space, even if the air is cold
 - You feel cold surfaces the same way
- ▶ Function of temperature difference, area, surface characteristics

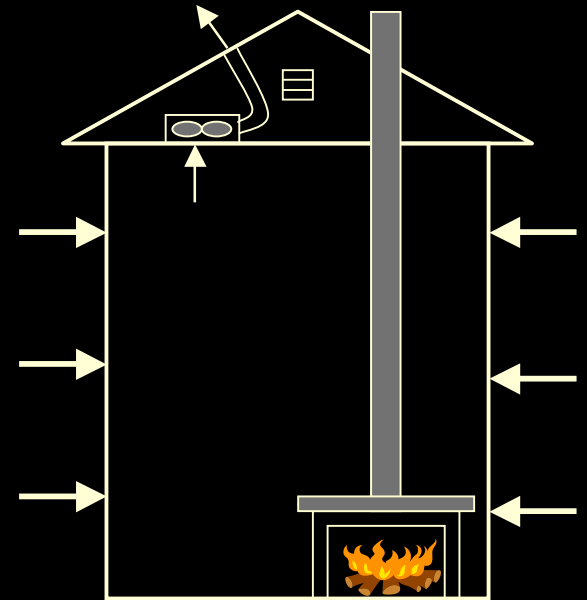
Air Flow



Wind



Temperature



Fans





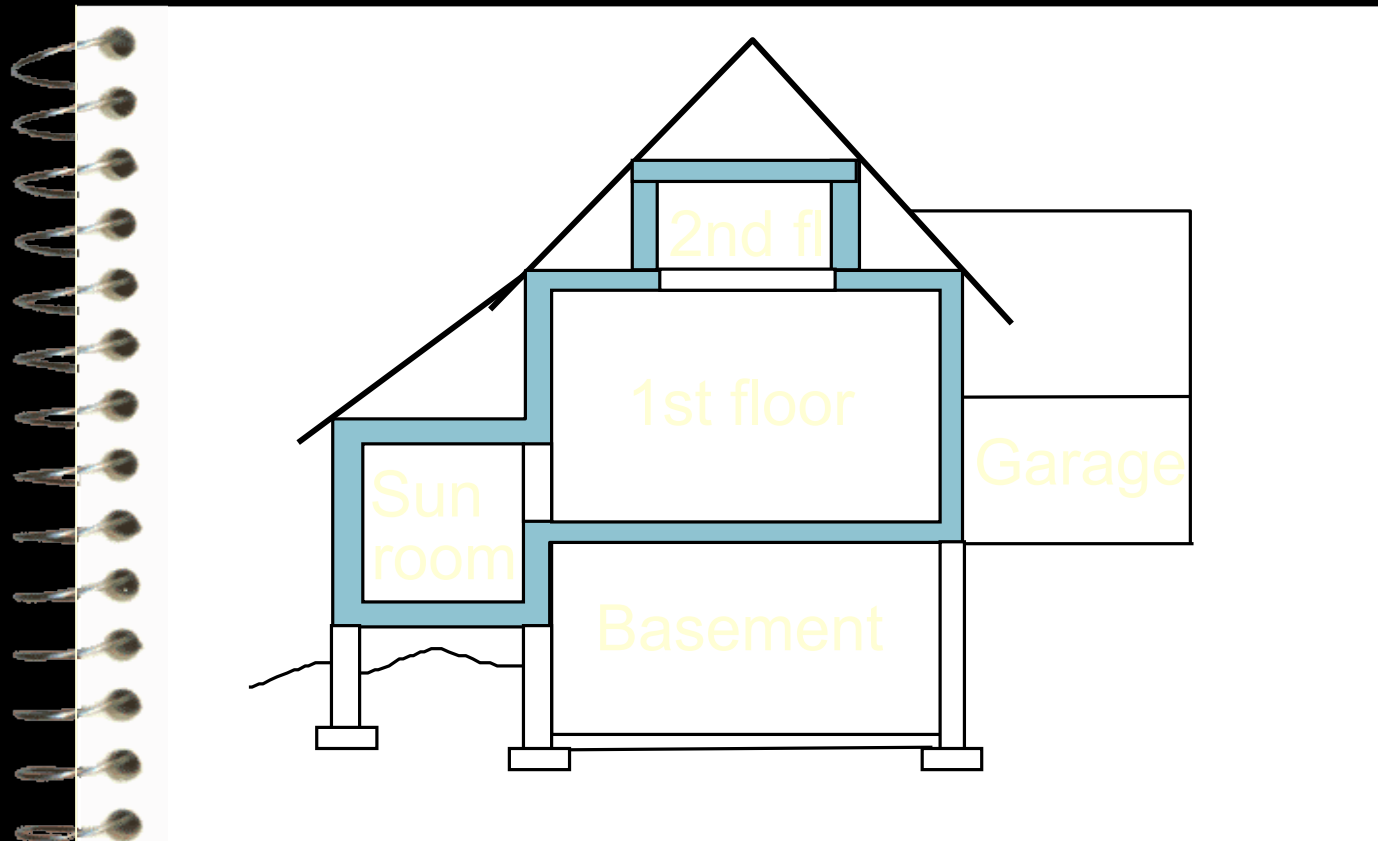




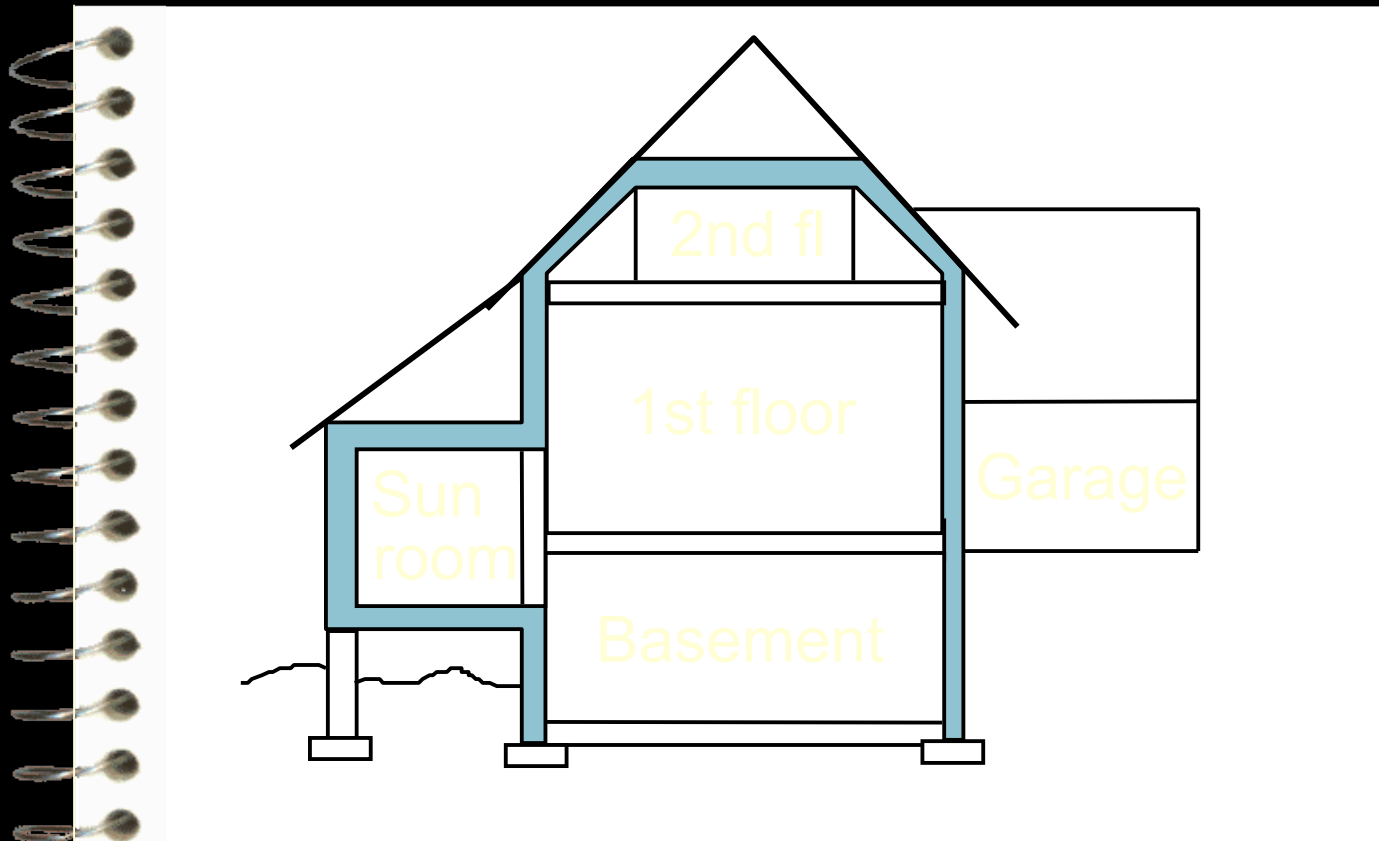
Air Under Pressure



Thermal Envelope



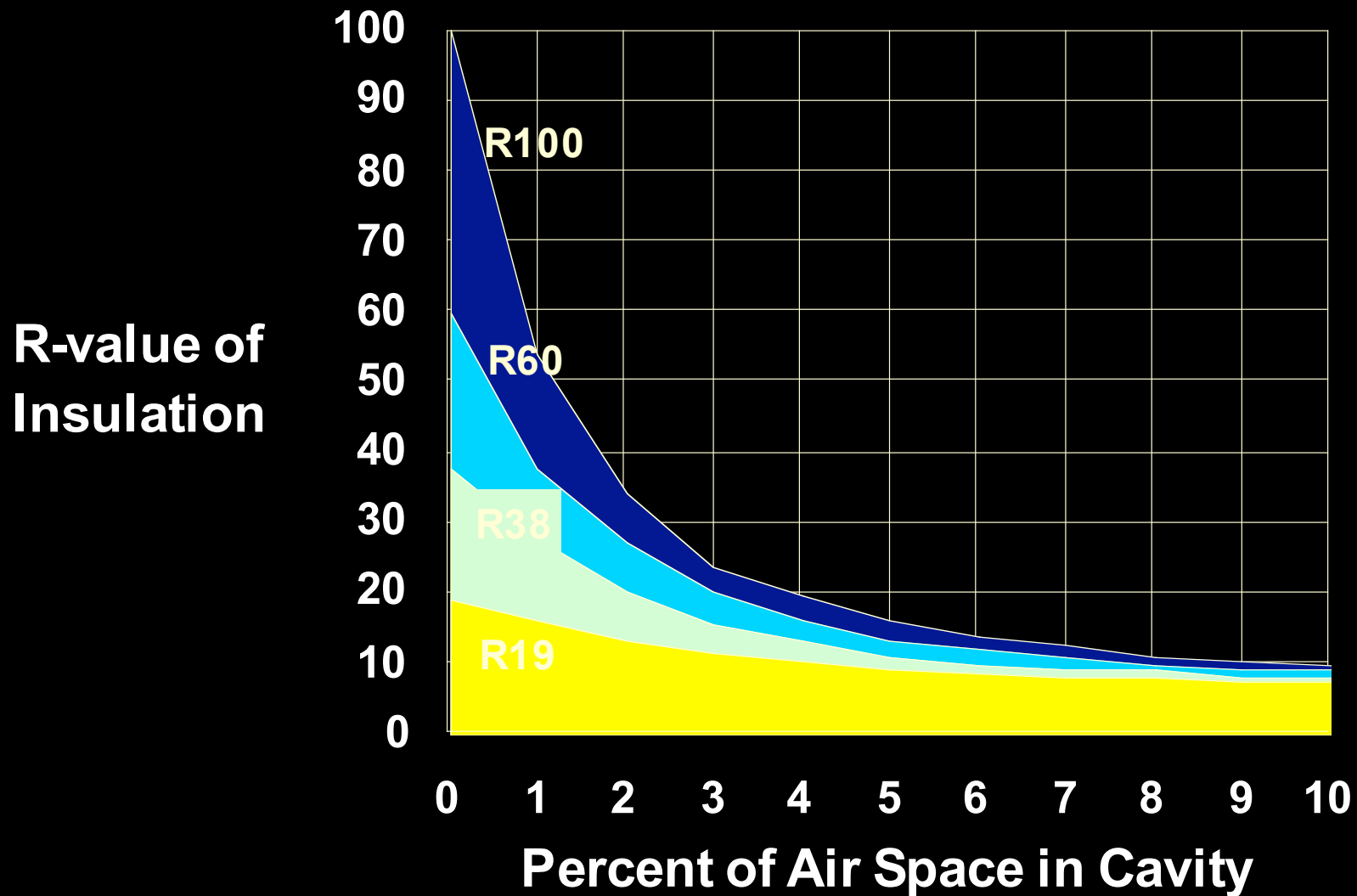
Thermal Envelope Alternate



How Insulation Works

- ▶ Trapped Air
 - Air flow through it reduces effectiveness
 - Air flow between it and the conditioned space prevents it from working
- ▶ Convective loops matter
- ▶ Missed areas matter a lot

Effect of Insulation Voids

















Moisture

- ▶ The biggest factor in building durability
- ▶ A major influence on indoor air quality



Moisture and Your Health

▶ High humidity

- Encourages mold and mildew growth
- Increases growth of fungi and dust mites
- Can worsen the effects of chemical contaminants

Moisture Transport

▶ Bulk Transport

- Solid or liquid, gravity

▶ Water Vapor

- Carried by air

▶ Capillarity

- Sucked through porous materials

▶ Diffusion

- Through a solid

Moisture Sources

- ▶ People, bath, kitchen (largest)
- ▶ Construction (tons in the first year)
- ▶ Special sources (pool, greenhouse, etc)
- ▶ Unvented combustion appliances
- ▶ Lack of moisture protection in building
 - Rainwater protection & drainage planes, foundations, crawlspace vapor retarders and capillary breaks

Relative Humidity & Condensation

- ▶ Warm air can carry more water than cold
- ▶ Relative Humidity = The amount of water in the air relative to the amount the air could hold at its current temperature
- ▶ 100% RH = dew point = condensation

Condensation

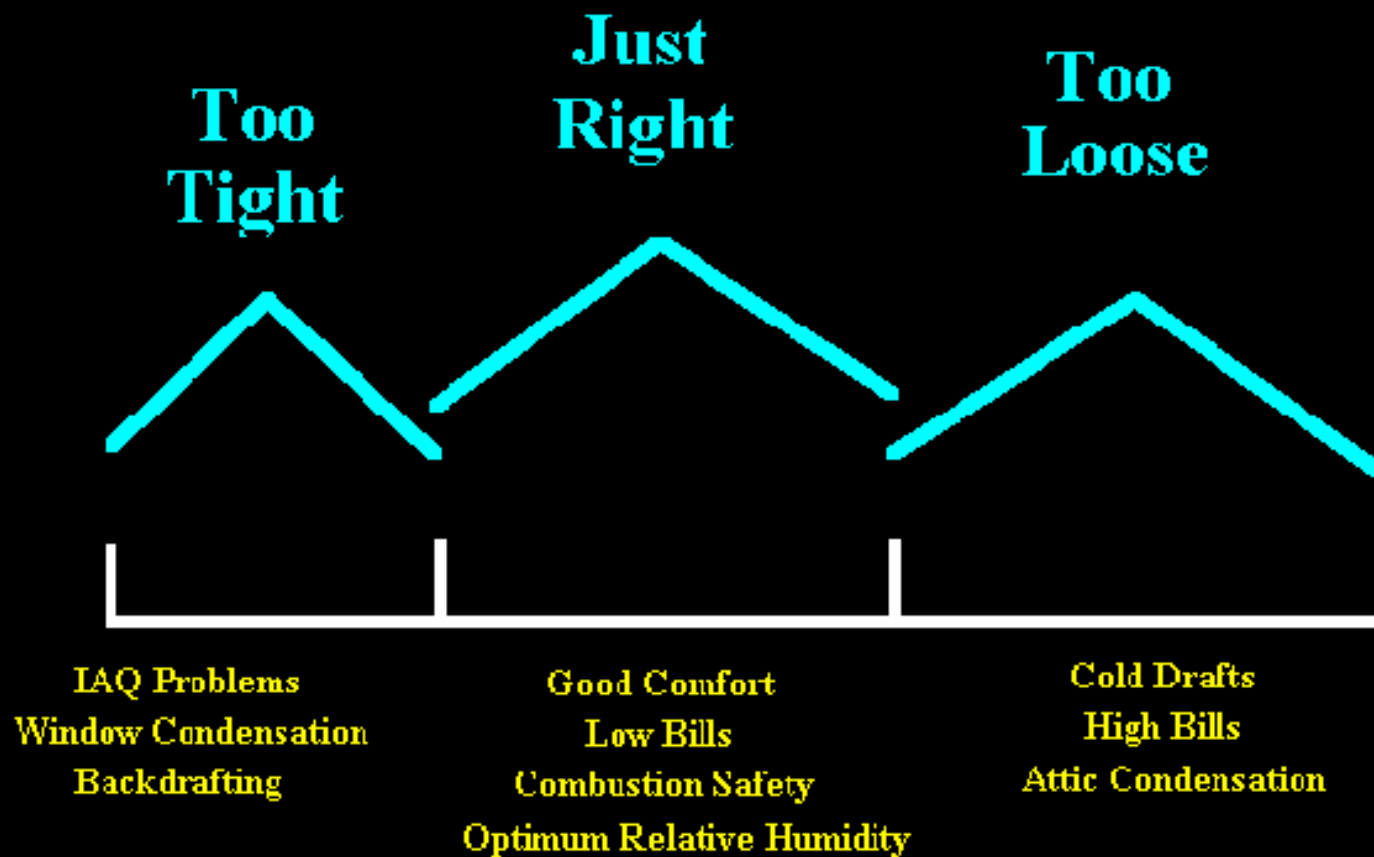
- ▶ Two control strategies:
 - Keep indoor relative humidity reasonable
 - Keep indoor air from contacting cold surfaces

Natural Ventilation

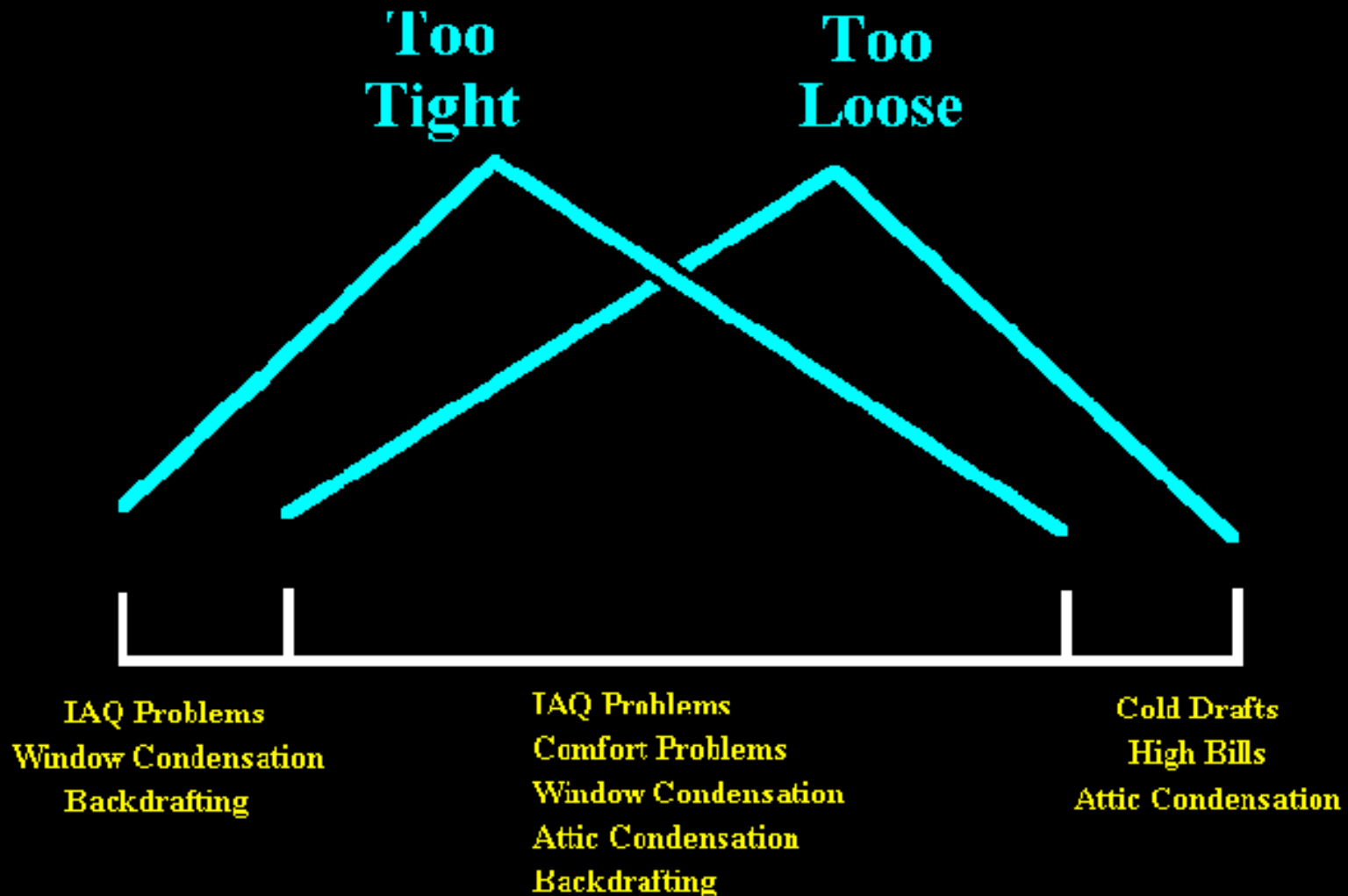
- ▶ Driven by the weather
 - Highly variable
 - Most when you want least, and vice versa
 - No correlation with need
- ▶ Where's it coming in?
- ▶ Where's it going out?



Relying on Natural Ventilation: The Concept



Relying on Natural Ventilation: The Real World

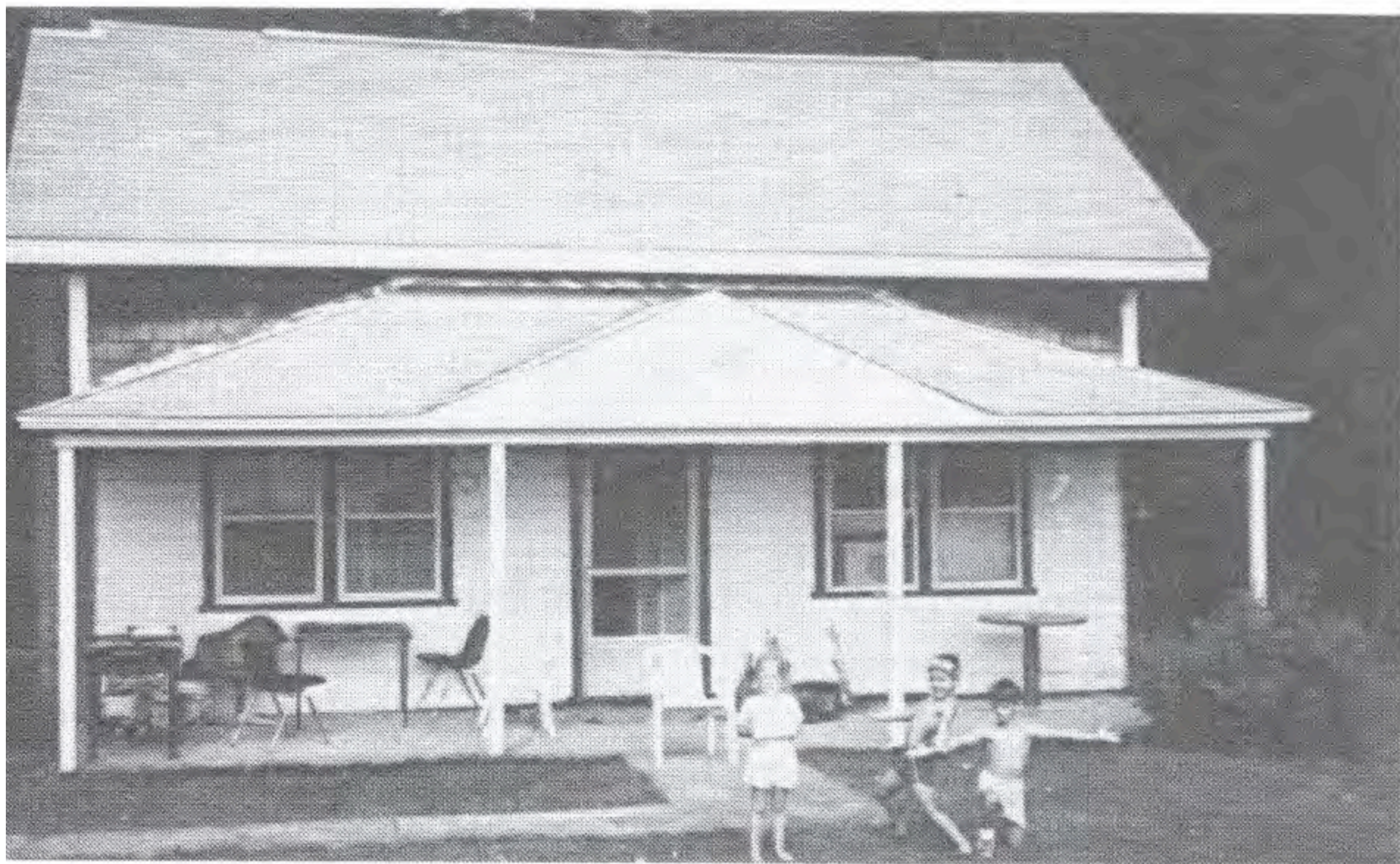


How Much Will It Save?

- ▶ Hard to predict
- ▶ Impossible to predict without understanding the building
- ▶ Occupants will often use the benefits for comfort at least as much as for heating cost

How Much Will It Save?

- ▶ Savings follows waste: you can't save big dollars by treating something that doesn't cost big dollars
- ▶ Shell treatments always have benefits other than fuel savings
- ▶ Your mileage may vary
- ▶ What's the payback on a couch?



**ne U.S. Department of Energy Weatherization Assistance Program
nd evaluation researchers were met with open arms by residents
f the house that had the highest fuel savings in the fuel-oil study.**





When It's Not a System

- ▶ When we insulate & vent the attic without air sealing
 - And rot the roof
- ▶ When we air seal without insulating
 - And grow mold on the drywall
- ▶ When we air seal without attention to the forced air system
 - And the pressures get out of control

When It's Not a System

- ▶ When we tighten up and get a new heating system
 - And end up with no fresh air
- ▶ When we do our air sealing and install a ventilation system
 - ...that the occupants don't understand or think they need

When It's Not a System

- ▶ When we do air sealing without combustion safety testing
 - And (sooner or later) hurt somebody
- ▶ When we install a clothes dryer in utility room
 - And backdraft the water heater
- ▶ When we install more heat to solve a heat loss problem

System Thinking

- ▶ Overpowering nature of pollutant sources
- ▶ Importance of the occupant
- ▶ Interrelationship of atmospherically-vented combustion appliances with the building shell and exhaust devices

System Thinking

- ▶ Importance of mechanical ventilation
- ▶ Forced air balancing the newly-tightened house
- ▶ Comprehensiveness in energy efficiency services













