
Energy and Indoor Environmental Quality (IEQ) Retrofits in Low-income Apartments

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Acknowledgments

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- U.S. Department of Energy – Building Technologies Department
- Technical Advisory Committee
- Collaborators
- Building Owner(s) and Occupants



Motivation

- 30% population lives in multifamily buildings

- Below-average incomes
- Potential IEQ problems
- Often subsidized (should use resources wisely)



- Buildings consume 40% all energy

- Need to improve existing buildings



- Retrofits: opportunity to improve IEQ & energy

Goals

Broad long-range goal

- Healthy, efficient & comfortable apartments

Project goals

- Develop protocols to select optimal package of retrofits
 - Considering both IEQ & energy
- Quantify & demonstrate energy & IEQ benefits
 - Communicate findings broadly



Project overview

- Develop protocols for selecting retrofits
 - Retrofit ranking based on
 - Initial conditions of apartments (inputs)
 - Predicted energy and IEQ benefits (analysis)
- Implement packages of retrofits
 - 15 – 18 apartments (5 - 6 each in 3 bldgs)
 - Different CA climates and seasons
- Quantify & demonstrate impacts on energy use & IEQ
 - Pre- and post- retrofit data
 - Retrofitted and un-retrofitted apartments



Retrofit Selection Protocol

■ Goals

- Provide rational method for selecting energy & IEQ retrofits
- Maximize total benefits w.r.t. to investment

■ Retrofit considered

- Ventilation
- Thermal comfort/heating & cooling
- Source control
- Appliances

■ Approaches for developing retrofit recommendations

- 1) A-priori list
- 2) Normalized impact score based on energy, IAQ, & comfort benefits



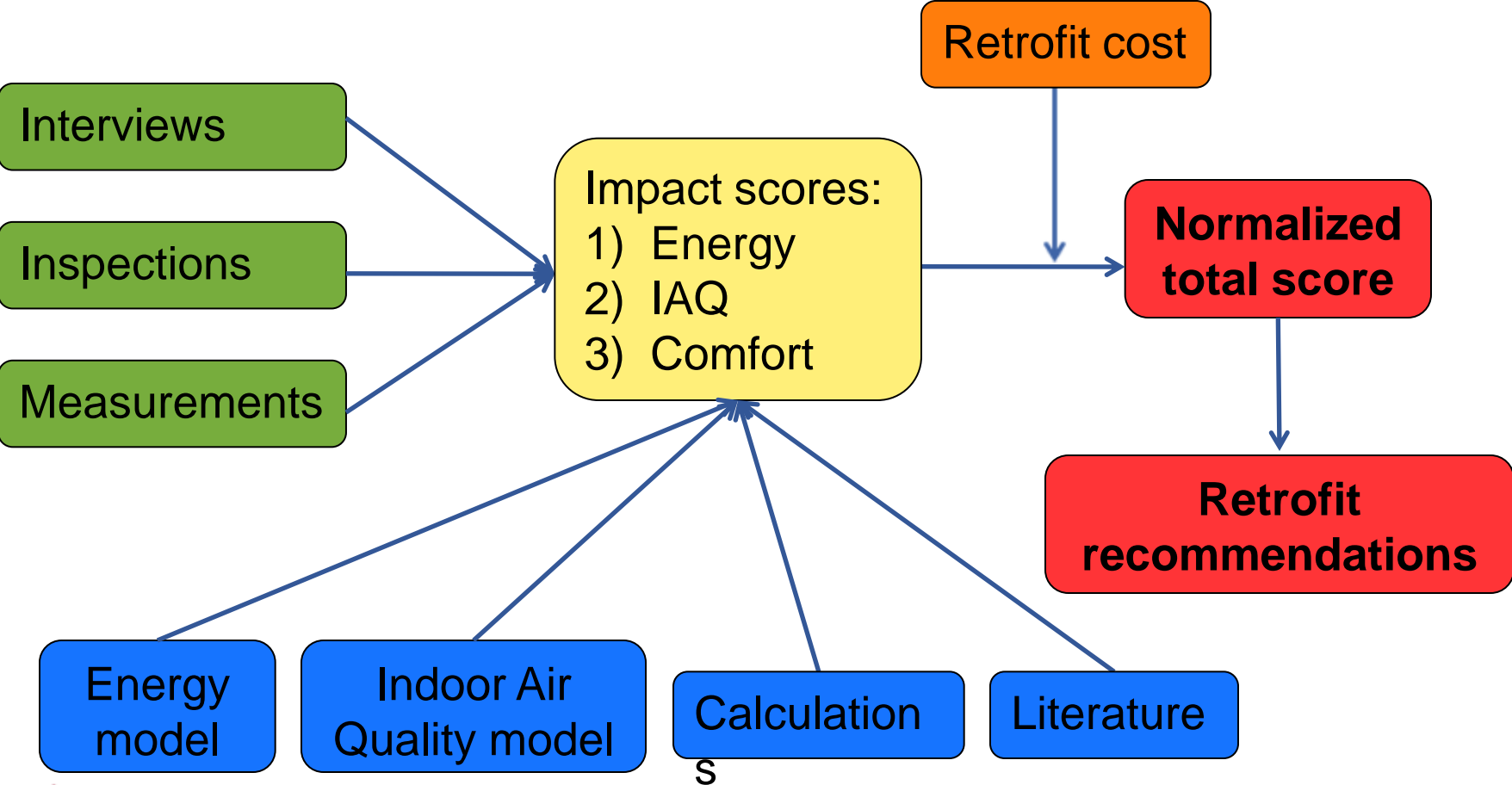
A-priori List

- **Air sealing**
 - Interior partitions priority
 - Exterior wall when mechanical ventilation is an option
- **Mechanical ventilation (ASHRAE 62.2)**
 - Whole unit: 150% of required by Standard 62.2
 - Local: kitchen and bath vented exhausts
- **Heating Ventilation Air Conditioning (HVAC) system filtration**
 - Reduce bypass & install a MERV 9-13 filter
- **Domestic Hot Water (DHW)**
 - Low flow showerhead, insulation to water tank and lines
- **Education**
 - Both general and retrofit-specific education



Benefit scale

- Many inputs & steps



Interview & inspections

- **Manager interview**
 - Interest in participation
 - Meet criteria for inclusion in study
 - Collect general information on equipment

- **Inspection of building & candidate apartments**
 - Gather specific information
 - Equipment & devices
 - Potential issues
 - Potential retrofit opportunities



Performance and diagnostics

- Objectives:
 - Characterize apartment & equipment impacting energy & IEQ
 - Identify where intervention is needed
 - Quality assurance for retrofit implementation
- Specifics
 - Air tightness of apartment
 - Insulation
 - Mechanical exhaust flow rates
 - Sound levels from use of mechanical ventilation
 - Combustion appliance backdrafting potential



Energy & IEQ impact models

- Energy: Home Energy Saver (HES) <http://hes.lbl.gov>
 - Input details for residence (town house)
 - Upgrade recommendations with yearly savings → energy score

- IEQ parameters

- Indoor Air Quality (IAQx) for well-mixed pollutants
- Simple calculations & literature
 - HVAC filtrations
 - Heat Recovery Ventilation (HRV) system
 - Air-moving devices: with & without AC
 - Insulation



- Normalized benefit score (total score/\$): Ranking

Scoring & Ranking

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Retrofit implementation: Overview

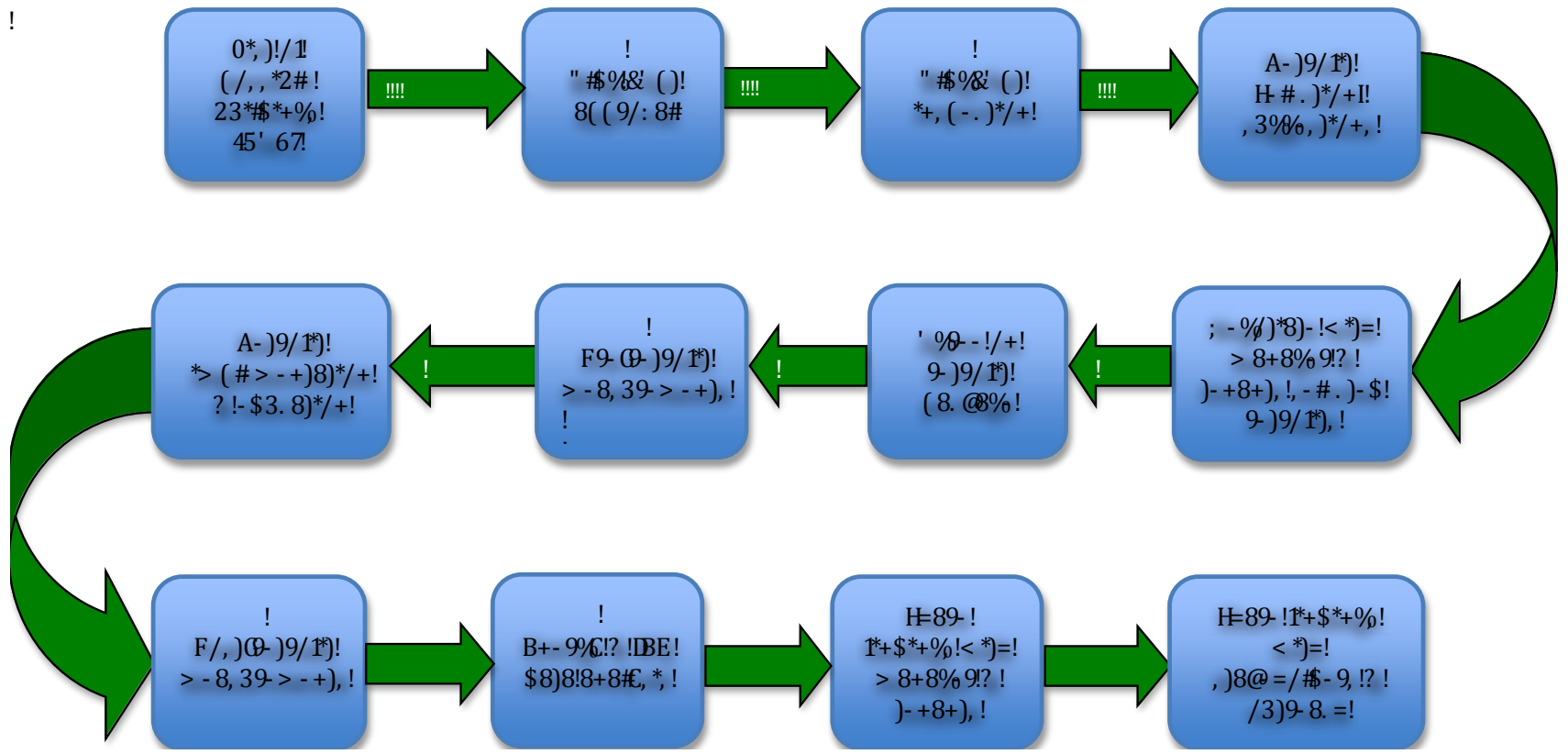
- Retrofit of 5 - 6 apartments each in 3 bldgs
 - Different CA climates and seasons
 - 1st bldg in summer 2011
 - 2nd & 3rd bldgs in winter 2011/12

- Objectives
 - Quantify effect on overall energy use & seasonal patterns
 - Quantify impact on specific IEQ and comfort parameters
 - Investigate benefits of specific measures



Retrofit implementation: Overview

- Many steps throughout the process



Implementation of retrofit packages

■ Building Criteria

- Serve low-income population: subsidized housing
 - e.g.,: HUD project-based section 8 or sec 236 (no energy rehab)
- Size: low-rise (< 3-4 stories)
- Age > 20 years
- > 15 apartments
- Existing electricity & gas meters for each apt
- Independent heating & air-conditioning (if present) for each apt
- No exhaust air system serving multiple apartments (preferred)
- Individual gas heating system (preferred)



Impact measurements

- Energy: 12 months before & after retrofits
 - Retrofitted and control apartments



- IEQ: 2 one-week period pre- & post- retrofits
 - Energy-related IAQ and comfort parameters
 - Equipment use monitoring

IEQ measurements

- Indoors & outdoors
- IEQ
 - Time-resolved: T, RH, CO, CO₂, PM
 - Time-integrated: NO₂, NO_x, O₃, aldehydes, VOCs
- Equipment monitoring
 - Heating and cooling
 - Bath and kitchen exhaust fan
 - Hot water heater
 - Selected windows
 - Dryer on/off



Analysis

- Compare annual and seasonal energy use
 - Direct and weather-adjusted
- Compare pollutant concentrations
 - Adjust for outdoor contributions
 - Integrated 1-week
 - Highest hour
 - Amount of time above threshold value
 - e.g. bathroom RH; CO₂



Perception survey

Three sections

– Baseline

- Key apartment conditions
- Tenants behavior influencing retrofit impacts

– Pre-retrofit & Post-retrofit

- Assess satisfaction with retrofit via changes in indoor conditions
- Open-ended questions about retrofits for feedback



Retrofit of Summer Building

Sacramento

- Built 1967 (windows & faucets upgraded)
- Sec 8, 144 units
 - 2 BR: recent electric furnace
 - 3 & 4 BR: gas rooftop package units
- Gas water heaters & cooktops with pilots



Inspections

- 9 apts: six 3BR, three 4BR
- Tight units, small duct leakage
- Bath and kitchen exhausts not venting outside
- Natural draft water heaters



Retrofit Selection

- A priori retrofits:
 - Weatherstrip door
 - Mechanical ventilation to meet ASHRAE 62.2
 - Balanced ventilation with small ERV
 - Replace bath exhaust venting to outside
 - Replace kitchen hood venting to outside
 - HVAC filter upgrade

- Cost: \$3,300



Benefit Scale

Retrofit	Score/\$ 1K	Cost	Running cost
1. Add air-moving device (fan)	10	100	100
2. Install CO monitor	10	100	200
3. Energy efficient lighting upgrade (i.e., CFLs)	10	100	300
4. Replace pilot ignition gas stove with electronic ignition unit	3.8	800	1,100
5. Limited scale moisture and mold retrofits	2	500	1,600
6. Replace refrigerator with more energy efficient unit	1.7	600	2,200
7. Replace pilot ignition water heater with efficient electronic ignition unit	1.2	1,700	3,900 (total of \$7,250)
8. Replace heating and cooling device (with sealing of accessible ducts)	0.7	4,700	8,600

Adding vented kitchen hood increases backdrafting risk

Not ideal solutions

- Power vent WH: loud
- Add penetration and isolating zone: often impractical and expensive
- No efficient natural draft ultra low NOx WH



Discussion

- Retrofit selection protocol
 - Useful to identify beneficial measures
 - Need to consider other elements
 - Rebates & financing
 - Equipment life expectancy
 - Standards & guidelines

- Local exhausts vs backdrafting risk
 - Adding ASHRAE 62.2 requirements
 - Could lead to failure of CAZ depressurization (BPI)
 - Lack of practical, healthy and efficient solutions

Audience

- Agencies subsidizing low-income housing
- Companies performing retrofits
- Apartment building owners
- Non-profits working to improve apartments for low-income tenants
- Policy makers & energy agencies



Thank You

Questions?



Aging In Place:

Links Between Energy, Safety, Health, and Housing As We Age

A. Tamasin Sterner

www.PureEnergyCoach.com



We Believe This:

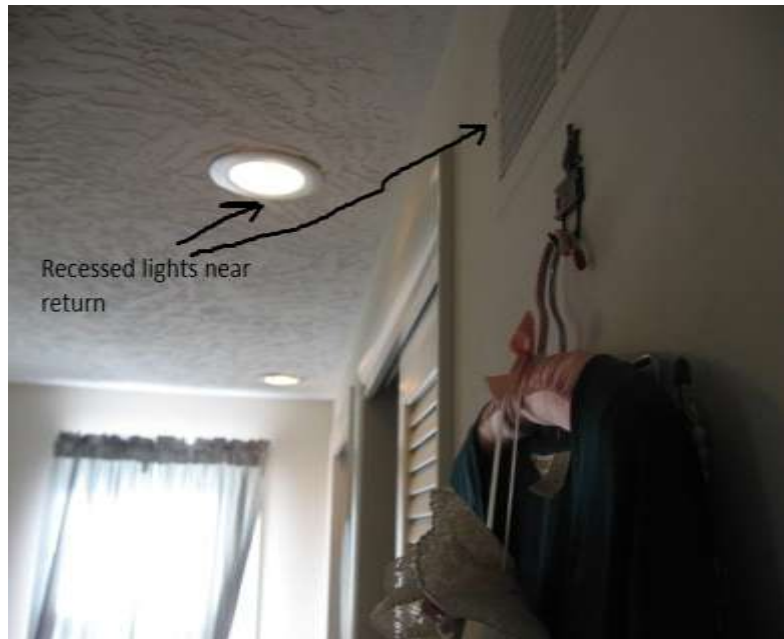
- If people could afford to stay in their house as they age, they might stay
- People might be able to afford to stay if their energy bills were low



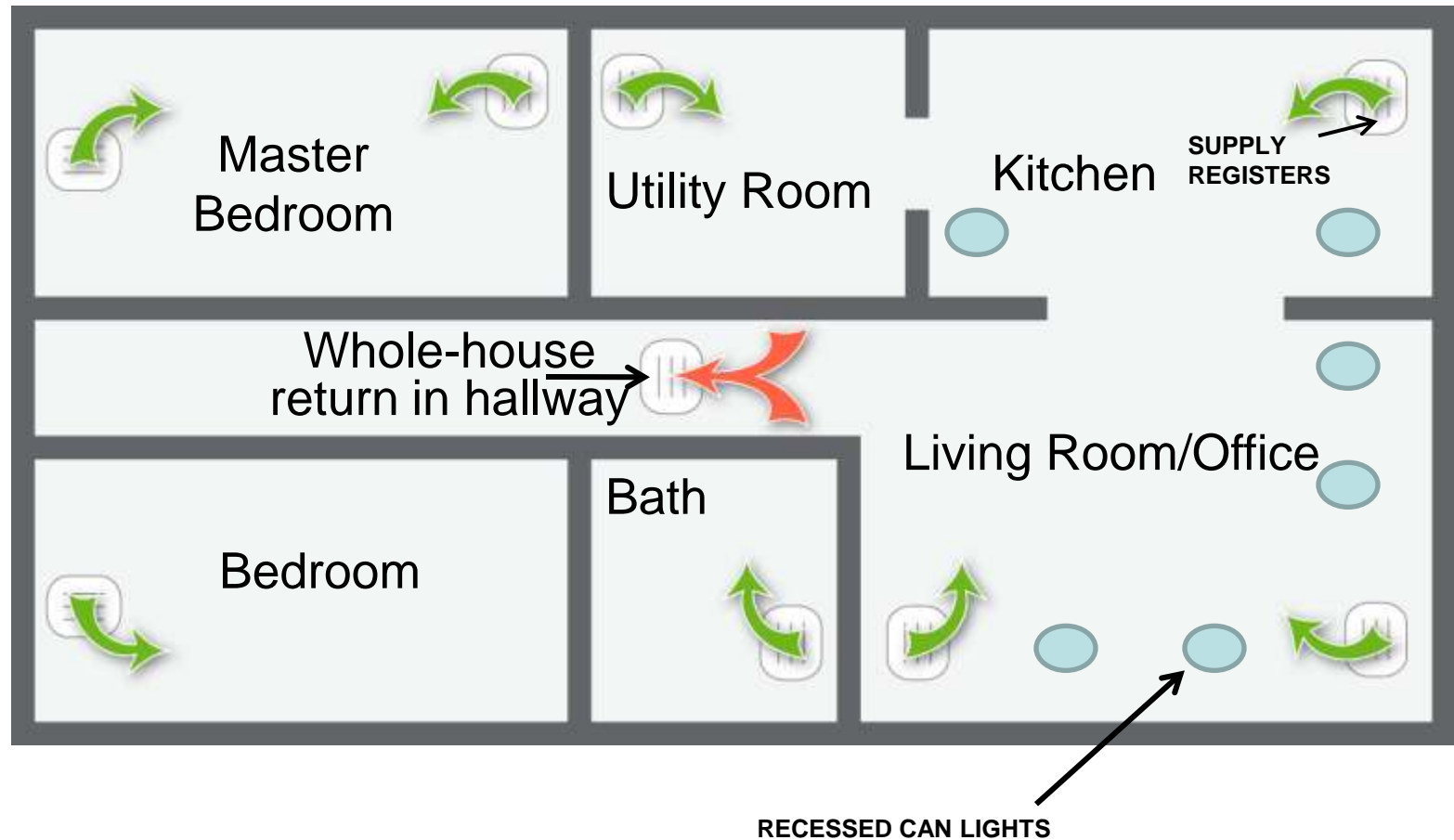
The Opportunity & The Challenge

- It is possible to reduce energy bills to very low amounts
- The best way to do this is typically to seal the air leaks in the building, especially those that are between the living space and the attic, and insulate
- If not done properly, the house and all its systems can become unbalanced
- Changing the indoor environment can cause problems
- Care must be taken to keep the air safe and healthy

Case 1: Unbalanced Air



Q: Why do I feel sick after my contractor insulated my attic, especially in the living room with the recessed can lights?



Unbalanced Room Pressures

Suck and Blow

- Some supply registers were blocked, and the return was partially closed, causing the room pressures to be unbalanced
- Recessed lights and attic hatch were not air sealed, allowing house air to leak into the attic and attic air to leak into the house
- Furnace fan stuck in the ON position, further causing house pressure unbalances
- Customer and dog are sick
- Thousands of dollars later...

Case 2: I Smelled Lysol

- Older couple “doctored” for two years
- Doctors couldn’t explain their health issues: Mostly Deep Fatigue
- I met in the chiropractor’s waiting room
- Overheard their conversation about being “doctored” for years
- Smelled Lysol (a typical cover-up for mold)
- Couldn’t keep quiet and asked if they have mold in their house

Next Steps

- Explained the affects of mold exposure on health
- Gave free consultation, referred to resources
- Moldy materials removed from the home
- Health improved “95%”

What is Home Performance?

The systematic approach to improving people's comfort, health, and safety, **and** the energy efficiency and durability of existing homes.



How Houses Work



Sometimes Things Go Backwards

- Back-Draft
- Flame Roll-Out
- Spillage



Consequences

Civil suit targets 12 for carbon monoxide deaths.

Three local men indicted for manslaughter.

Aspen Carbon Monoxide Deaths Lead To Charges

BY Robert Weller | Aspen, CO, USA | Jul 27, 2010

VIEWS: 285  6  1



Parker and Caroline Lofgren and their two children Owen and Sophie were killed by ...

Two County Staff Among Three Charged In Deaths In World Famous Resort Town

The deaths of four members of a Denver family in a home just east of Aspen during the Thanksgiving weekend two years ago has resulted in the indictments of three people, including a building inspector and building plans' inspector.

Sources of CO

- Fuel burning furnaces, boilers, and water heaters
- Fuel burning space heaters
- Fireplaces
- Gas ranges & ovens
- Vehicles
- Tobacco smoke

Characteristics of CO

- Odorless
- Colorless
- Tasteless
 - Mixes well in air
 - Does not stratify
- Follows air flow in a structure
- Poisonous

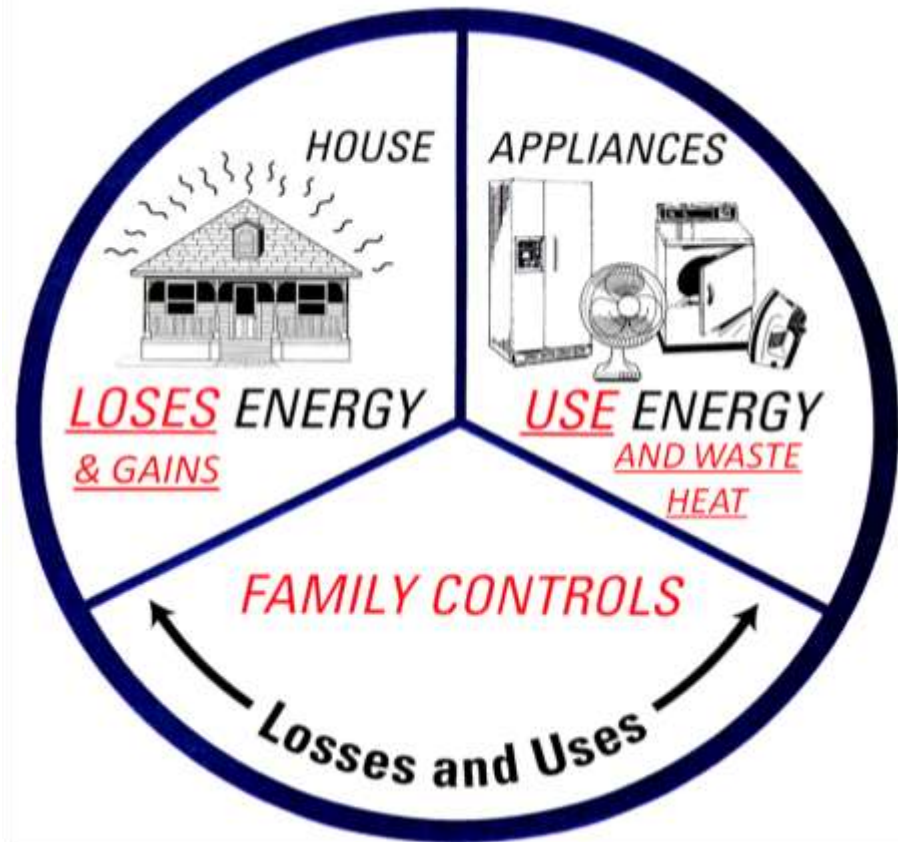


Courtesy of Bill Spohn, Trutech Tools

CO Health Effects

- 35 ppm NIOSH Permissible Exposure Limit – 8 hours
- 200 ppm NIOSH Ceiling– 15 minutes
- 200 ppm Slight headache with 2-3 hours
- 400 ppm Headache within 1-2 hours
- 800 ppm Sickness & twitching of limbs within 1-2 hours; unconsciousness in 2 hours
- 1,600 ppm Headache within 20 minutes; **death** within 2 hours
- 3,200 ppm **Death** in 30 minutes
- 6,400 ppm **Death** in 10-15 minutes
- 12,800 ppm **Death** in 1-3 minutes

Houses Don't Use Energy - People Do



The Coaching Model

with thanks to Maria Nemeth, Ph.D.

- Look
- See
- Tell the Truth
- Take Authentic Action

If Authentic Action needs to be taken to get results,
the Truth needs to be told

The Future of Housing and Aging

How would you feel if:

- You wanted to stay in your home forever,
- You could afford to stay because your bills were low, and,
- Your home was comfortable and healthy?

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