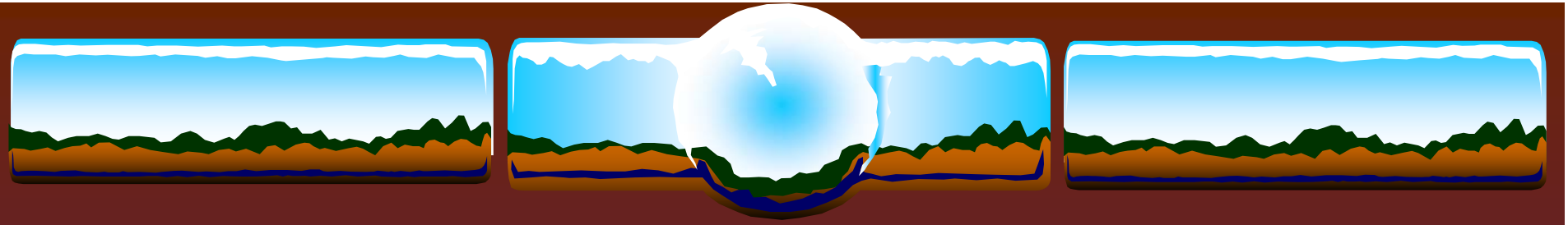


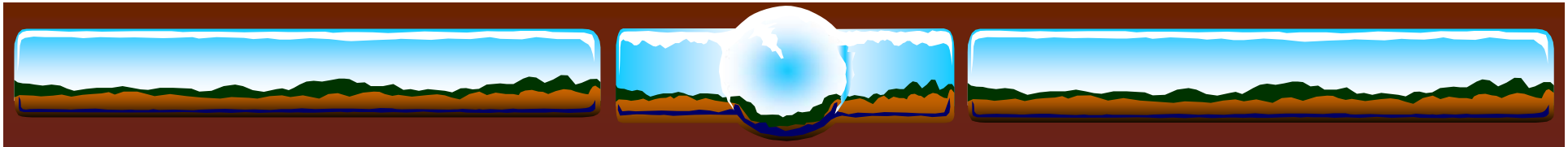
WHY WE VENTILATE: Recent Advances

Max Sherman

BA Stakeholders meeting

ASHRAE BIO

- Distinguished Lecturer
- Exceptional Service Award
- Board of Directors; TechC
- Chair of committees:
  - 62.2; Standards Committee
  - TC 4.3; TC 2.5
- Holladay Distinguished Fellow



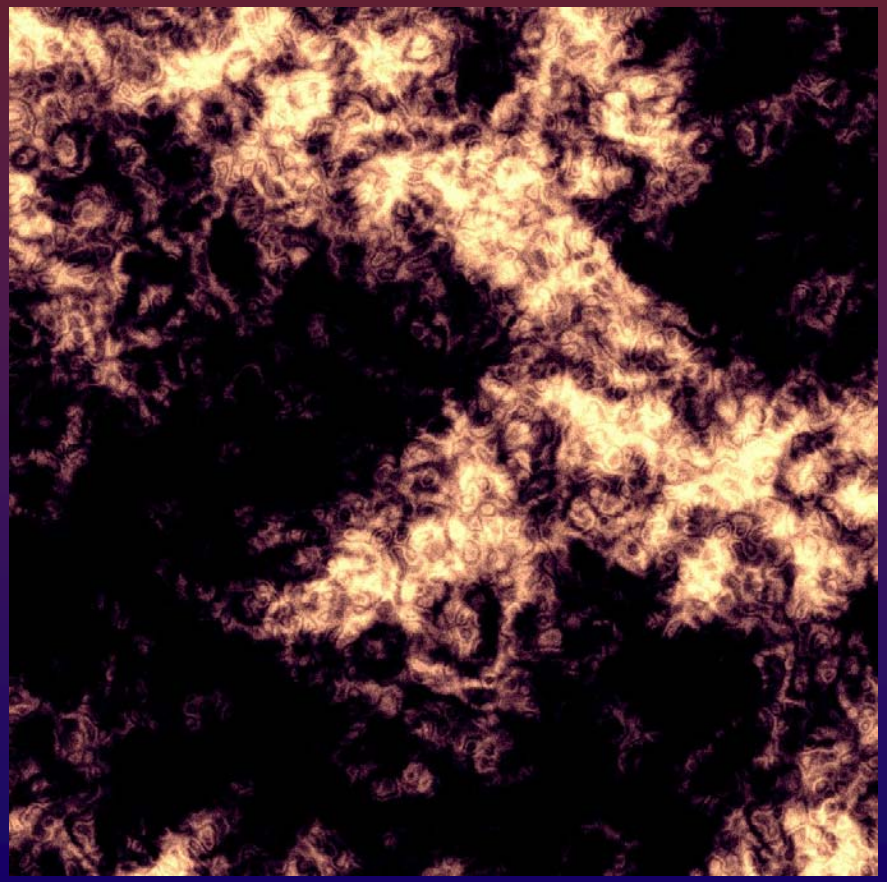
OVERVIEW QUESTIONS

- What is Ventilation? What is IAQ?
- What functions does it provide?
- How much do we need? Why?
- How should ventilations standards be made?

LBL has working on these problems

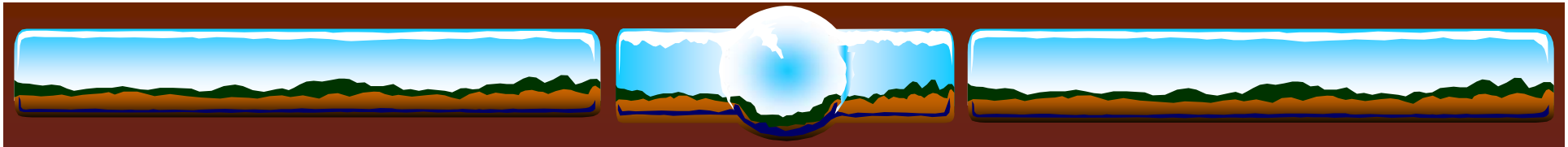
Who Are You?

- Engineers (ASHRAE Members & not);
- architects,
- contractors,
- reps,
- builders,
- vendors,
- code officials



WHAT IS VENTILATION

- Medicine: To Exchange Air In the Lungs
- Latin: *Ventilare*, "to expose to the wind"
- Today: To Bring In Outdoor Air And Replace Indoor Air Of The Occupied Space



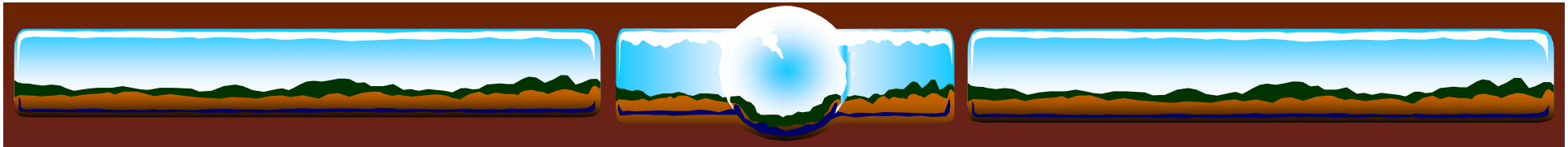
VENTILATION: Do We Like it?

Sustainable

- Improves Comfort
- Reduces Exposure to Contaminants
- Saves Energy
- Control Moisture
- Improved Durability

Not Sustainable

- Reduces Comfort
- Increase Exposure to Contaminants
- Costs Energy
- Causes Moisture Problems
- Reduces Durability

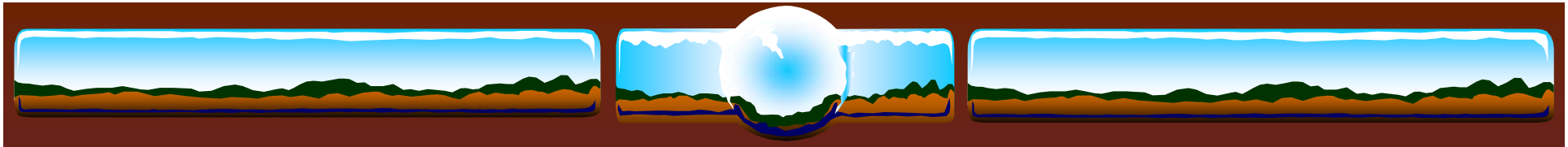


VENTILATION FOR COMFORT

- Thermal Comfort
  - Prevents overheating by venting excess heat
  - Air movement makes us feel cooler
- Odor Control
  - Not all odors are bad
  - Occupants are best “sensors” –can take actions
  - Most odors not controlled by constant ventilation

Key Odor: US!

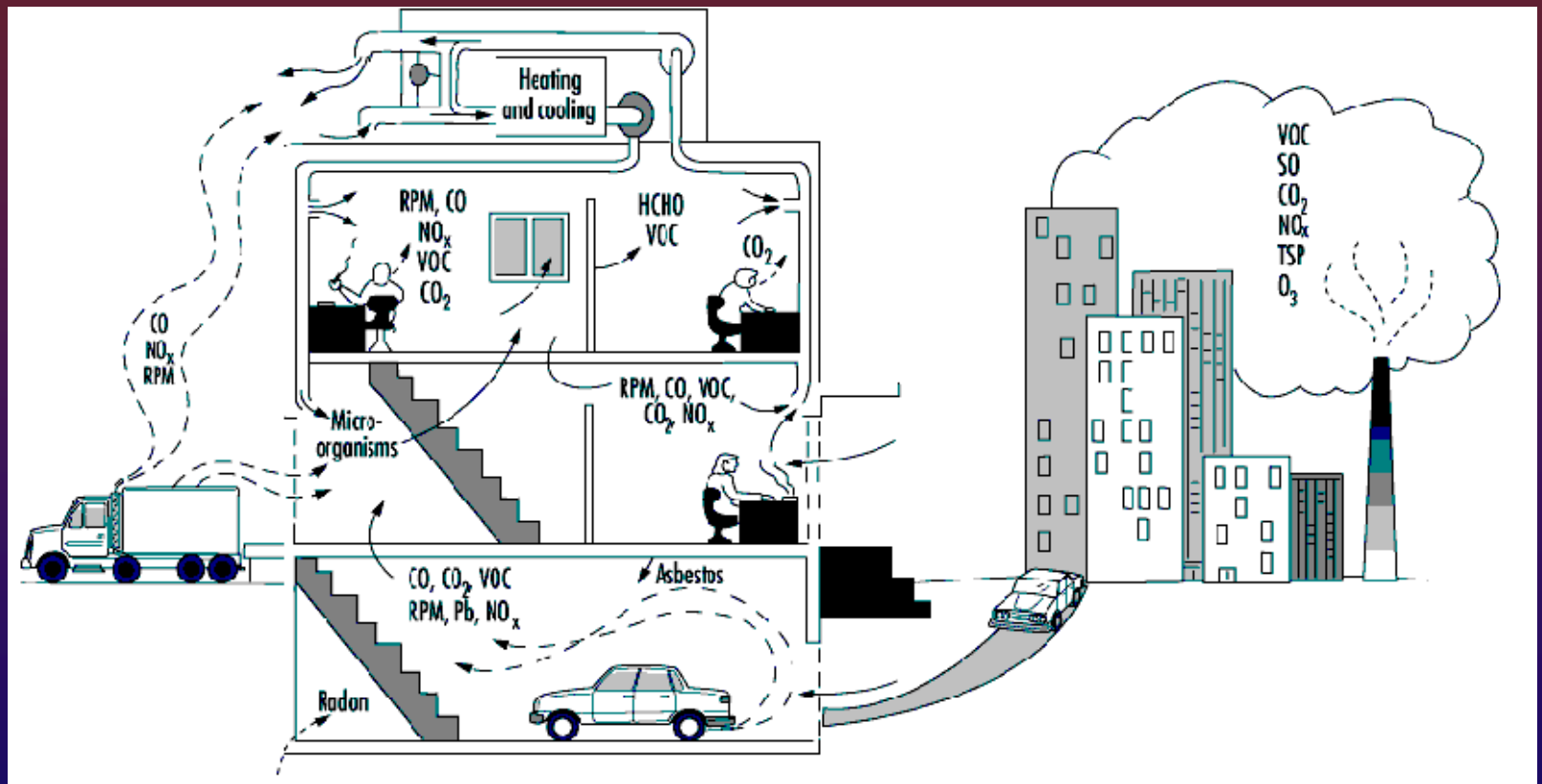
- People Emit "Human Bioeffluents"
  - CO_2 is only surrogate
- Daily Hygiene of Western World
  - 5 cfm adapted (occupants)
  - 15 cfm unadapted (visitors)
- Dominates In High-Density Spaces
- Sets Floor Otherwise



VENTILATION FOR HEALTH

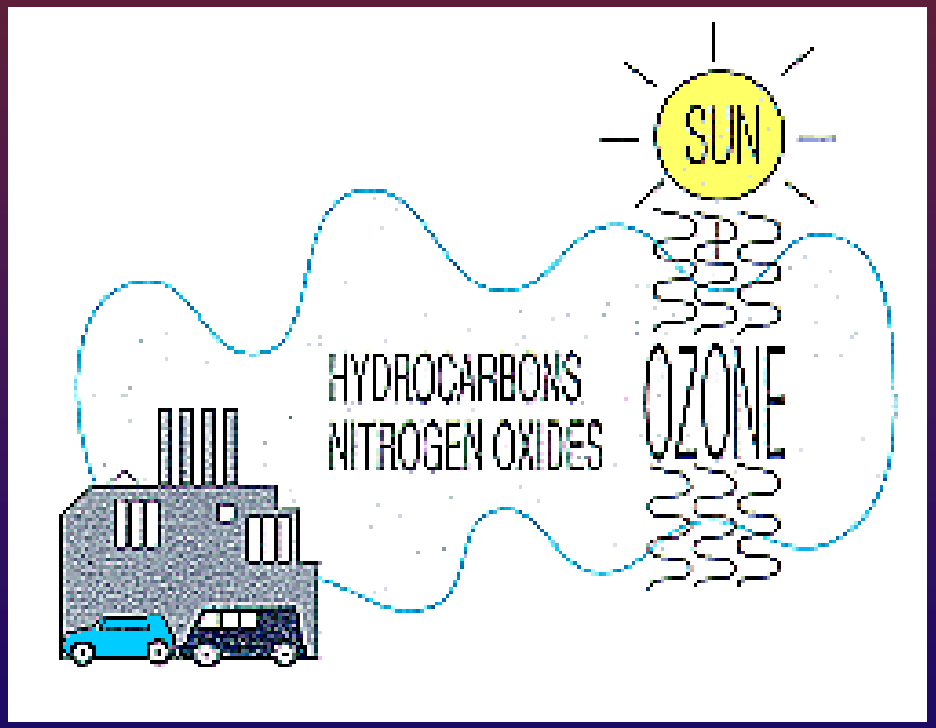
- Occupants not usually good sensors
  - So, we must design healthy buildings
- Key Questions:
  - What are the important contaminants?
  - How do we measure harm from them?
  - How do we mitigate that harm?
- Contagion not typically a justification

CONTAMINANT SOURCES



CO = carbon monoxide; CO_2= carbon dioxide; HCHO = formaldehyde; NO_x= nitrogen oxides; Pb = lead; RPM = respirable particulate matter; VOC = volatile organic compounds.

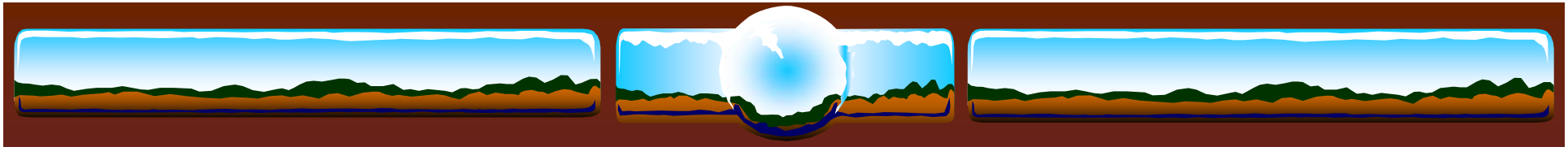
OZONE



- Usually Lower Indoors
- Highly Reactive
  - Reacts w/ almost anything
- Can Be Mitigated by
  - Envelope Performance
  - Closed Windows
  - Pressure Management
  - Activated Carbon

COMBUSTION

- Lots of Pollutants
  - NO_x, SO_x, CO_x
  - H_2O
  - Ash & Soot
  - Other Stuff
- Outdoors
- Indoors worse if not vented



NAAQS: CRITERIA POLLUTANTS

- Lead: A Lesser Airborne Contaminant Of Concern
  - Still some local issues
- SO_2: From High-Sulfur Coal In Power Plants
  - Acid Rain is a local phenomena
- CO, NO_2: Mostly From Combustion
- Ozone: Photochemically Produced From (Auto) Combustion By-Products
- Particulates: PM2.5 *(mass below 2.5μ)*

BIOLOGICAL

- Dust Mite, Pets
- Mold, Fungi
- Allergies
- Asthma

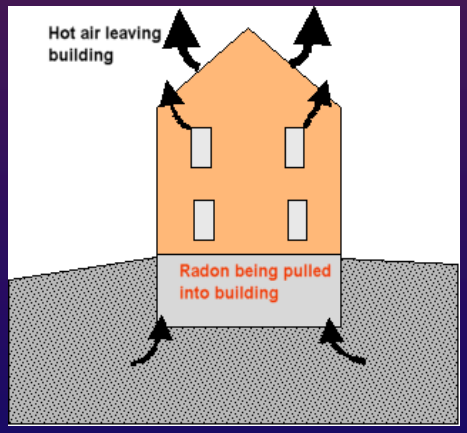
Mostly moisture control

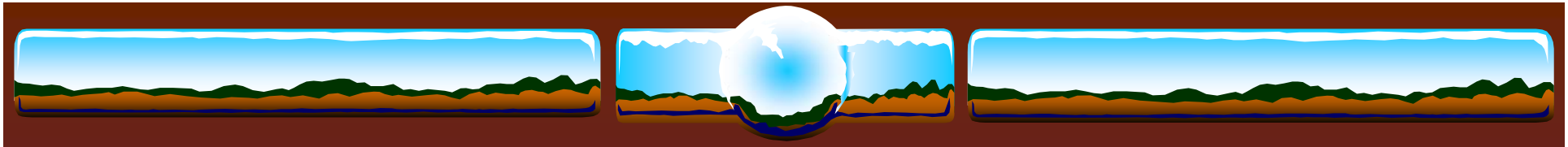
Toxic Air Contaminants

- Activities
  - Cleaning
  - Painting
  - Pesticides
  - Hobbies
  - Office
- Residues Linger
- Entrainment

BUILDING EMISSIONS

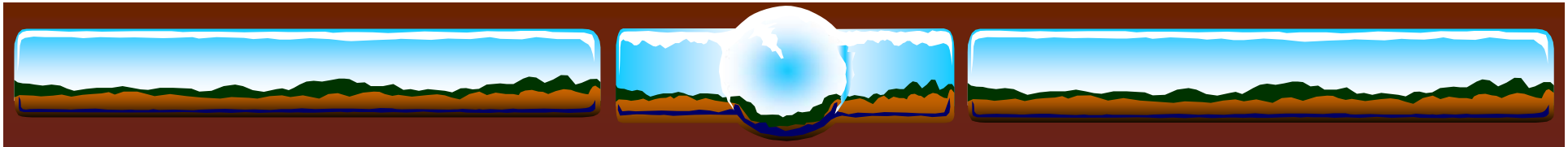
- Volatile Organic Compound (VOC)
  - Formaldehyde
- Radon
  - Soil Gas
- Particles
- Others





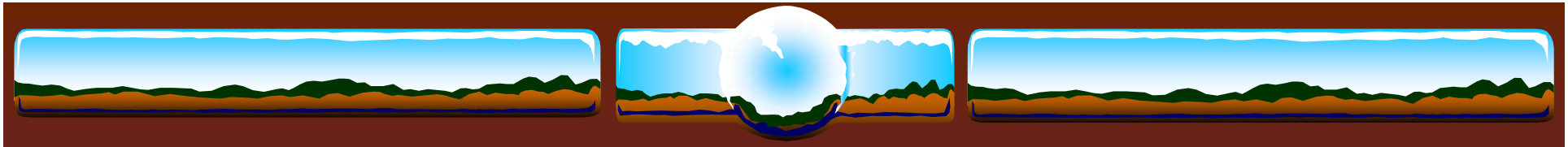
HISTORY OF STANDARDS

- These contaminants require ventilation
  - From cave-man to euro-man
- Rates and design based on expert judgments
  - From cave-man to euro-man
- Science is latecomer
  - Need to find what we are ventilating for



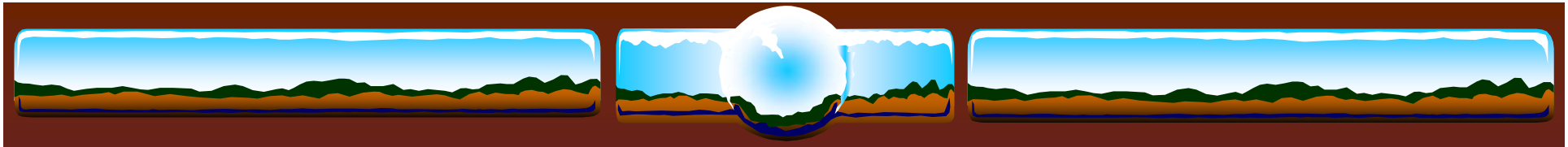
Early Codes and Standards

- 1631 King Charles & Windows
- 4 cfm/p 1836 Tredgold “Parliament Stinks”
  - Steady rise as research continues
- 30 “ 1895 ASVE Contagion-based
- 30 “ 1925 22 US State Codes
- 1927 UBC Requires 1/8 Windows



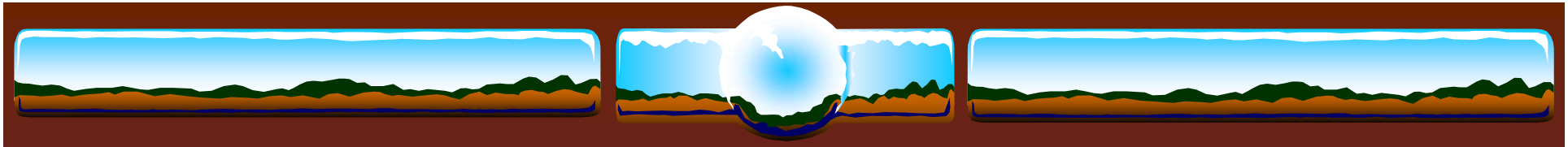
ASHRAE Standards History

- ASHRAE 62-73 Was 5 cfm/person
  - 15-20 cfm/p recommendation
- ASHRAE 62-81 Was 5 cfm/person
  - But 7.5 /l/s/p, *if smoking allowed*
- ASHRAE 62-89
  - 15 cfm/p assumed moderate smoking
  - 0.35 ACH for houses
- Separate Residential in ’97 (62.2-2003)



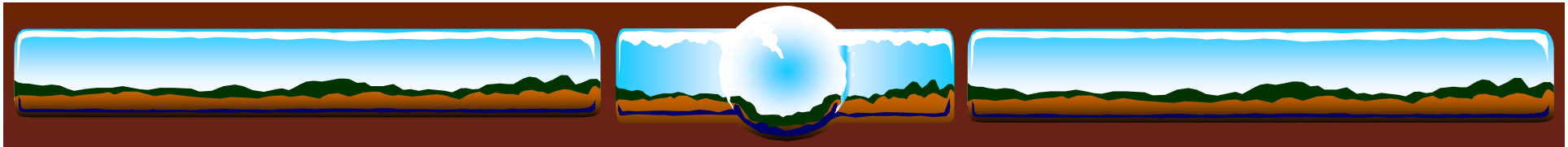
OUR APPROACH

- Hazards Analysis
  - Identify likely contaminates of concern
  - Compare measured concentrations to standards
- Harm (Risk) Analysis
  - What is the harm done from these hazards
  - What should be the focus of mitigation efforts



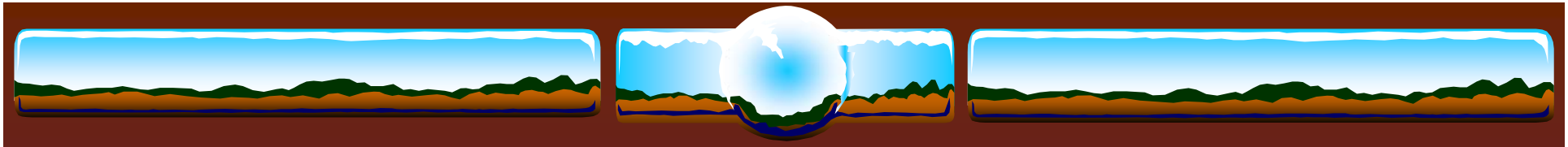
Conduct Hazard Analysis

- Study includes 77 published studies of measured concentrations indoors; focus on US homes
  - 67 relevant to long term concentrations
  - 10 relevant to short term concentrations
- 267 chemicals were included: criteria pollutants, VOCs, SVOCs, and metals
- 97 chemicals had relevant health standard or metrics for comparison



Comparing Concentrations to Health Standards

- Criteria Pollutants
  - US EPA- NAAQS (1hr, 8hr, 24hr, annual)
  - WHO (1hr, 8hr, 24hr, annual)
- HAPs/TACs
  - Cancer Health Standards
    - California EPA - Unit Risk Estimates
    - US EPA - Unit Risk Estimates
  - Non-Cancer Health Standards
    - California EPA-Reference Exposure Levels (1hr, 8hr, annual)
    - US EPA – Reference Concentrations (annual)

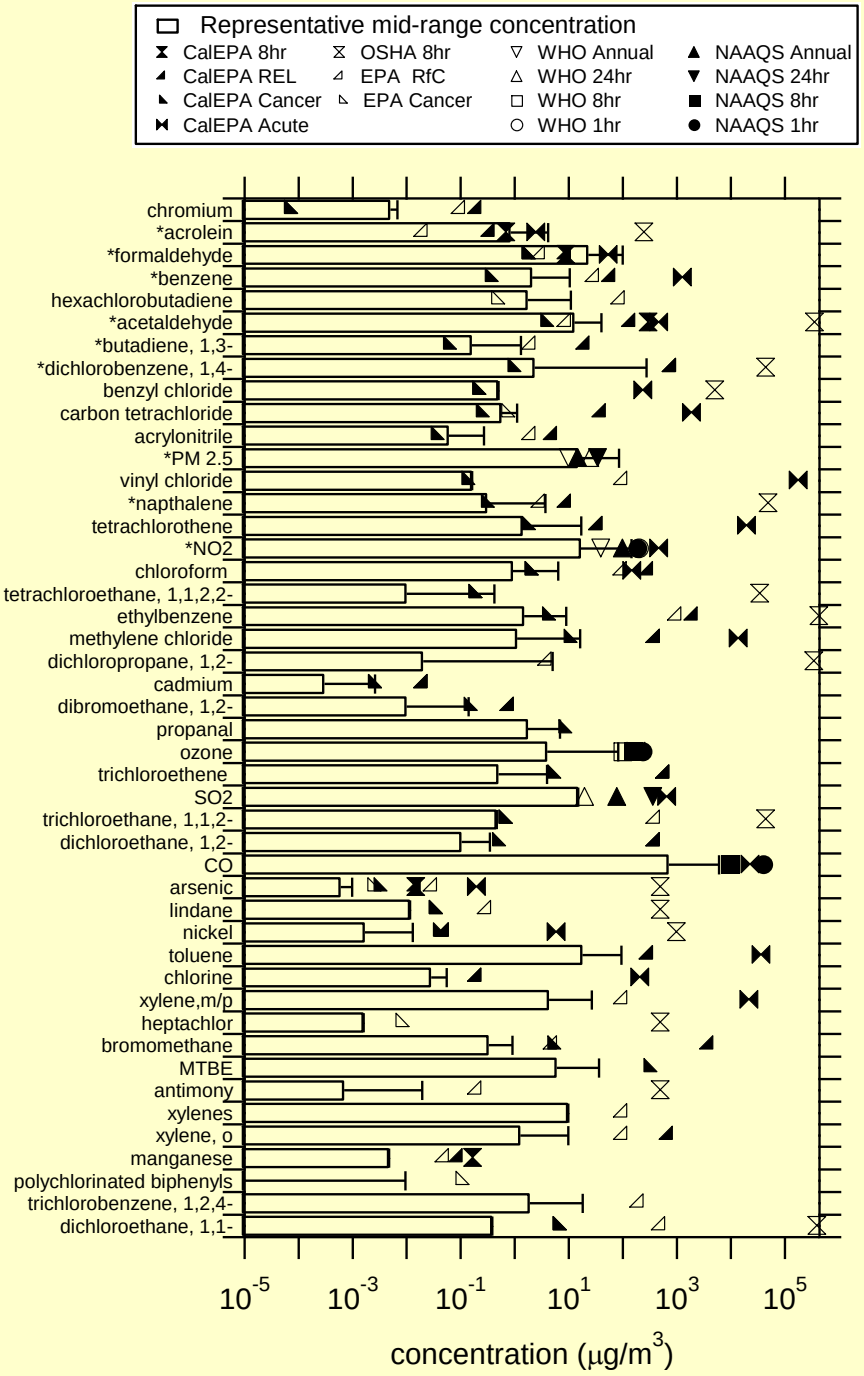


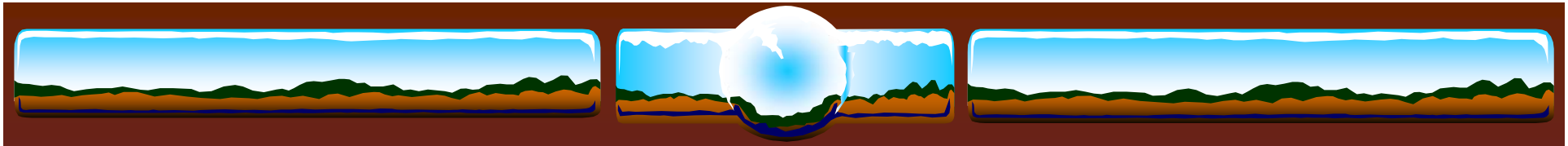
Note: ACUTE vs. CHRONIC

- Acute exposures involve strongly intermittent sources and short-term effects
- Chronic exposures caused by low level, but continual sources and have long-term effects
- Ventilation standards control
  - Acute exposures by source control or local exhaust
  - Chronic exposures by general ventilation

Identifying Chronic Health Hazards

- Non-Cancer
  - Direct comparison to published values
- Cancer
  - Cancer "REL" set to a cancer risk that correspond to a lifetime incremental risk of 1 in 10^5 assuming 70 years of continuous exposure





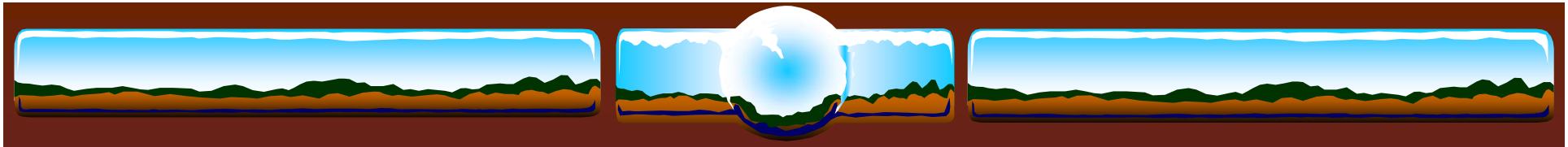
Top 10 Chronic IAQ Hazards

Priority Hazards

- acetaldehyde,
- acrolein,
- benzene,
- 1,3-butadiene,
- 1,4-dichlorobenzene,
- formaldehyde,
- naphthalene,
- NO_2,
- $PM_{2.5}$.

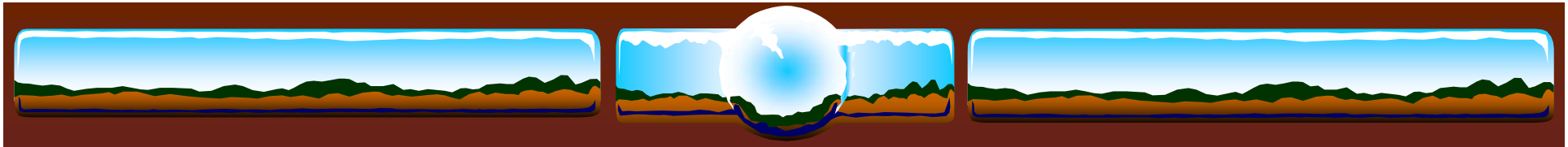
Not listed

- Carbon Tetrachloride
- Ozone
- Radon
- Tobacco Smoke



Contaminant Standards Questionable

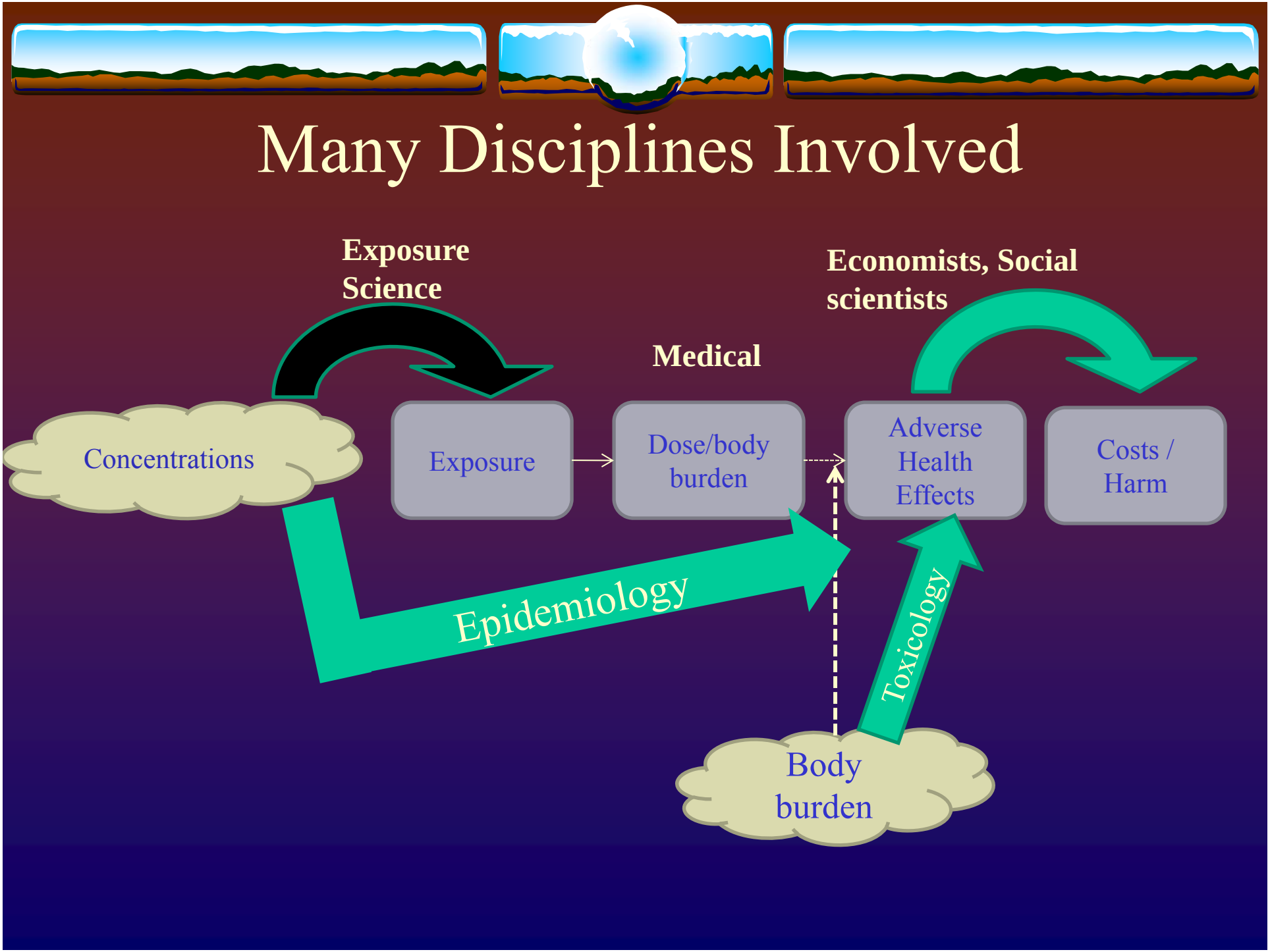
- Based on expert opinions backed by data
- But are political decisions
  - Costs & benefits; practicalities; good as can be
- Do not use same health impact criteria
  - So, can't be compared or "traded"
- Need level playing field
  - to get total cost/harm from contaminants

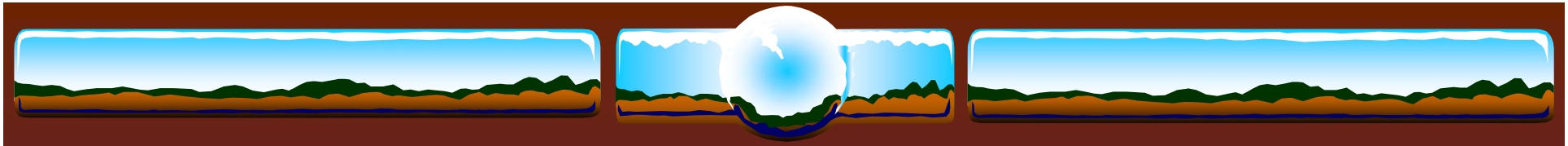


“Obvious” Approach

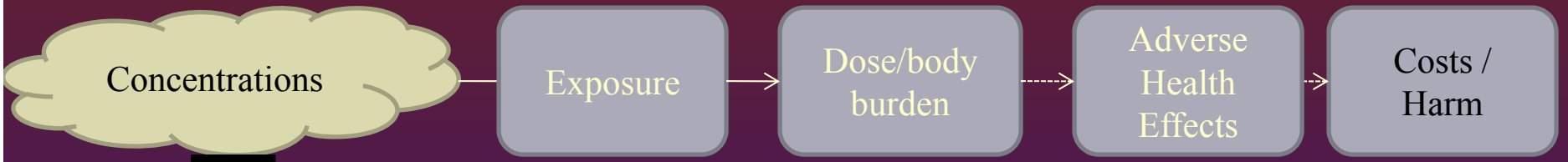
- Find out what harm (cost) a given exposure has.
  - Using a common metric
- Would allow trade-offs, and comparisons
  - Design optimization
- But not as easy to do as it is to say
  - interdisciplinary

Many Disciplines Involved

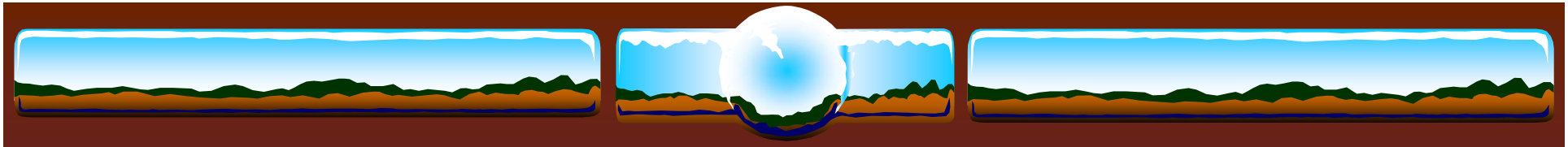




Relating Pollutant Exposure to Health



LBNL Impact Assessment Methodology

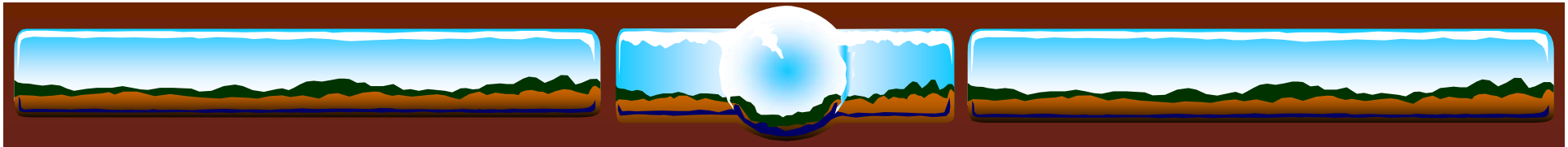


Costs of Adverse Health Effects

- Disability Adjusted Life Years (DALYs)

$$DALY = YLL + YLD$$

- YLL = Years lost to premature death
- YLD = Equivalent years lost to disability
- DALY valued at roughly $50,000 - $160,000 per 100,000/yr:
- Non-Fatal Stroke: ~9.5–13 DALYs
- Air Pollution Mortality: ~1.2-10 DALYs



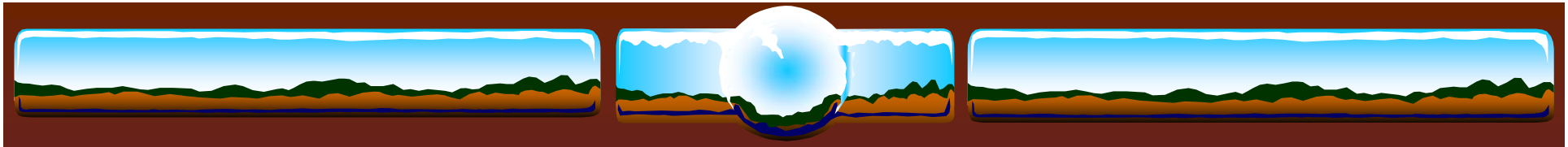
Indoor Concentrations → DALYs

- Annual DALYs lost per person=
  - Criteria Pollutants

$$\Delta concentration * \frac{\partial Disease\_Incidence}{\partial concentration} * \frac{\partial DALYs}{\partial Disease}$$

  - Single component gas phase pollutants (Huijbregts)

$$inhaled\_mass * \frac{\partial DALYs}{\partial inhaled\_mass}$$



Criteria Pollutant Approach

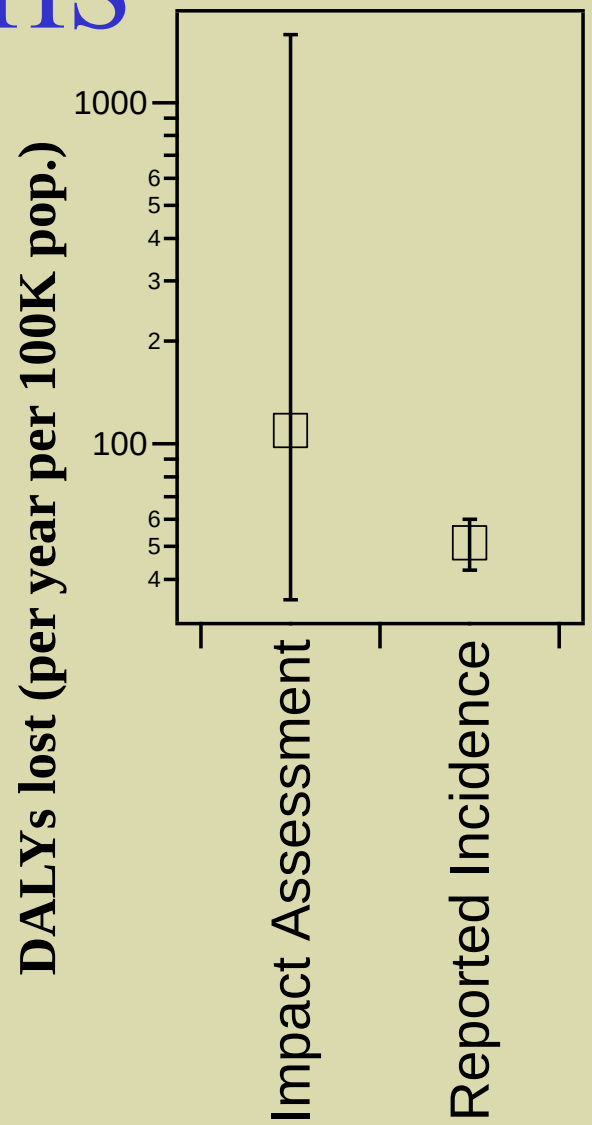
- Concentration-Response functions
  - Relate increased exposure to disease incidence
  - Derived from epidemiology studies

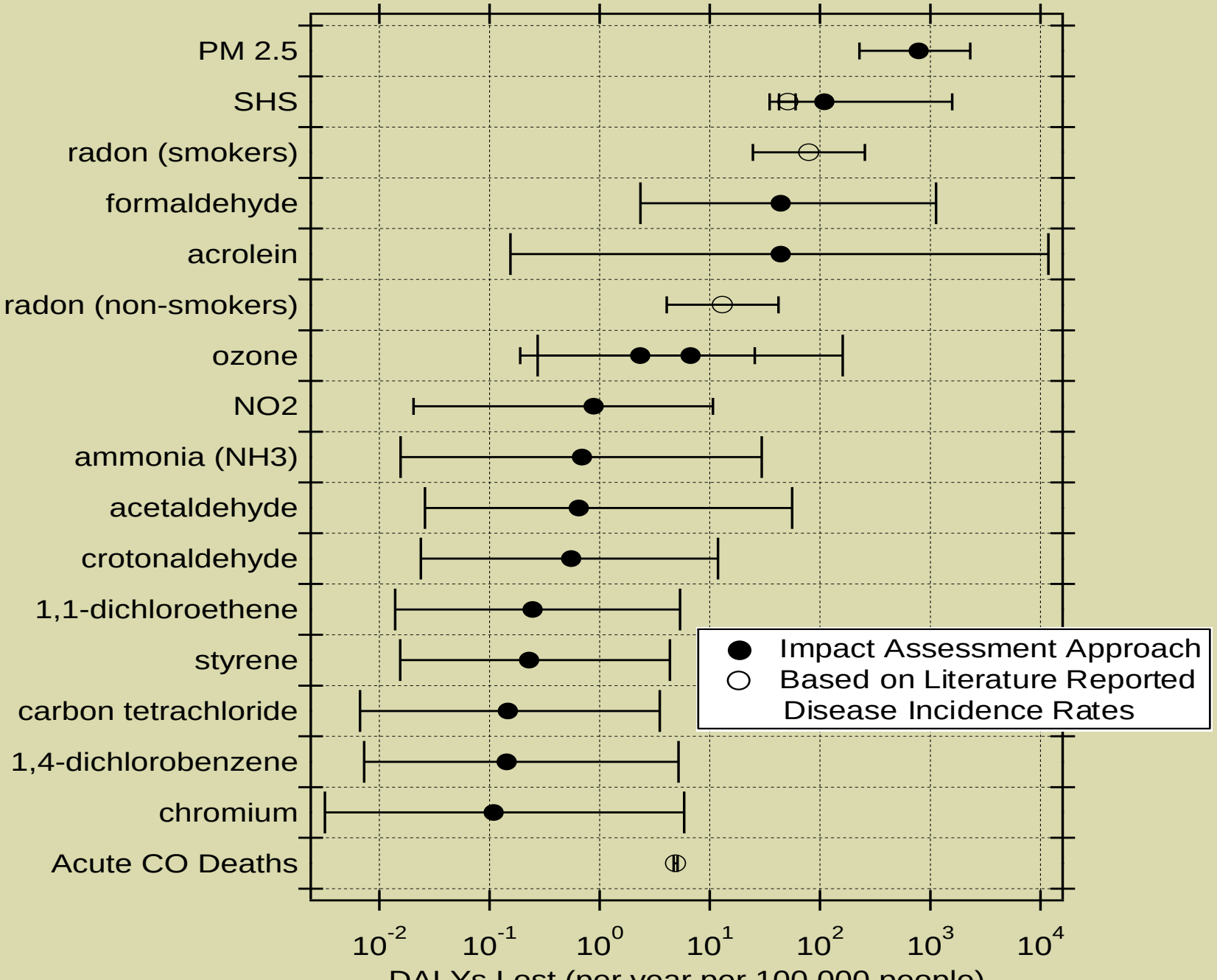
$$\frac{\partial \text{Disease incidence}}{\partial \text{concentration}} * \Delta\text{concentration} = -[y_o (\exp(-\beta \Delta C_{exposure}) - 1)]$$

- DALYs per incidence of disease (Various)
- Exposure concentrations (Logue et al. 2011)

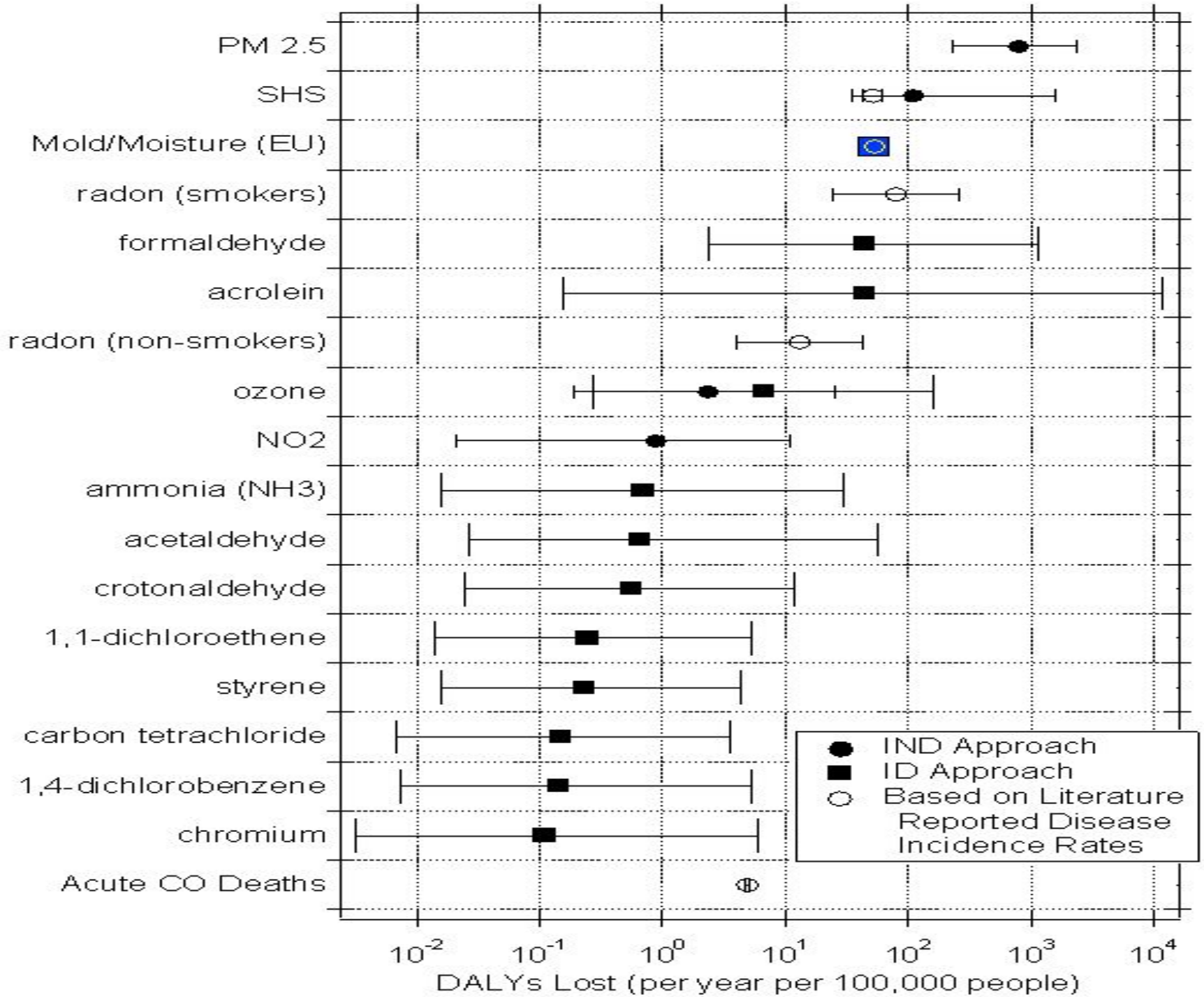
Checking Methodology: SHS

- Applied to concentrations of secondhand smoke components
- Determined damage associated with reported health impact of SHS by EPA
- Results help assess uncertainty of other indoor pollutant impacts

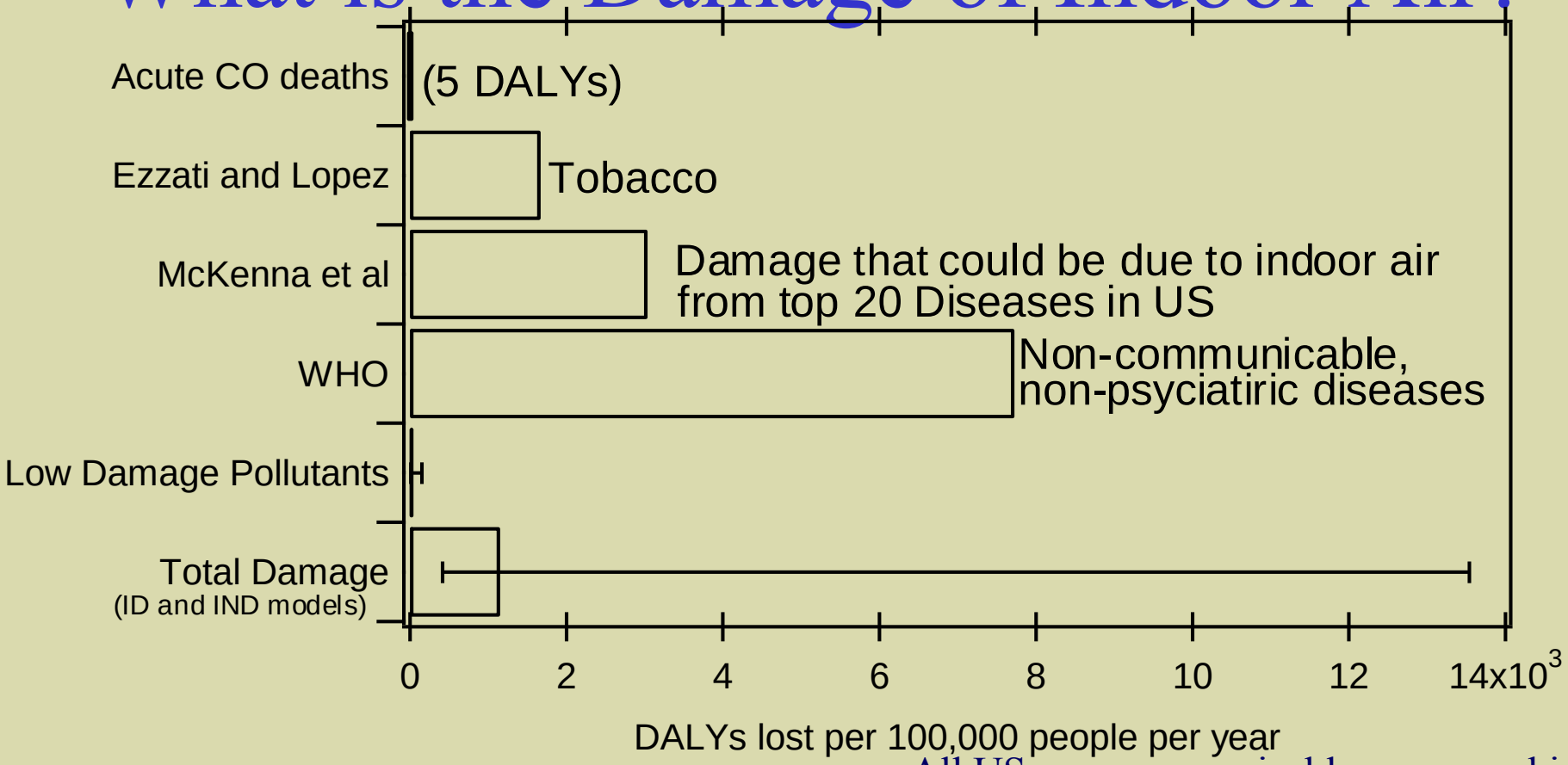




DALYs lost per year per 100K people


PM 2.5
SHS
Mold/Moisture (EU)
radon (smokers)
formaldehyde
acrolein
radon (non-smokers)
ozone
NO2
ammonia (NH3)
acetaldehyde
crotonaldehyde
1,1-dichloroethene
styrene
carbon tetrachloride
1,4-dichlorobenzene
chromium
Acute CO Deaths
IND Approach
ID Approach
Based on Literature Reported Disease Incidence Rates
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
DALYs Lost (per year per 100,000 people)

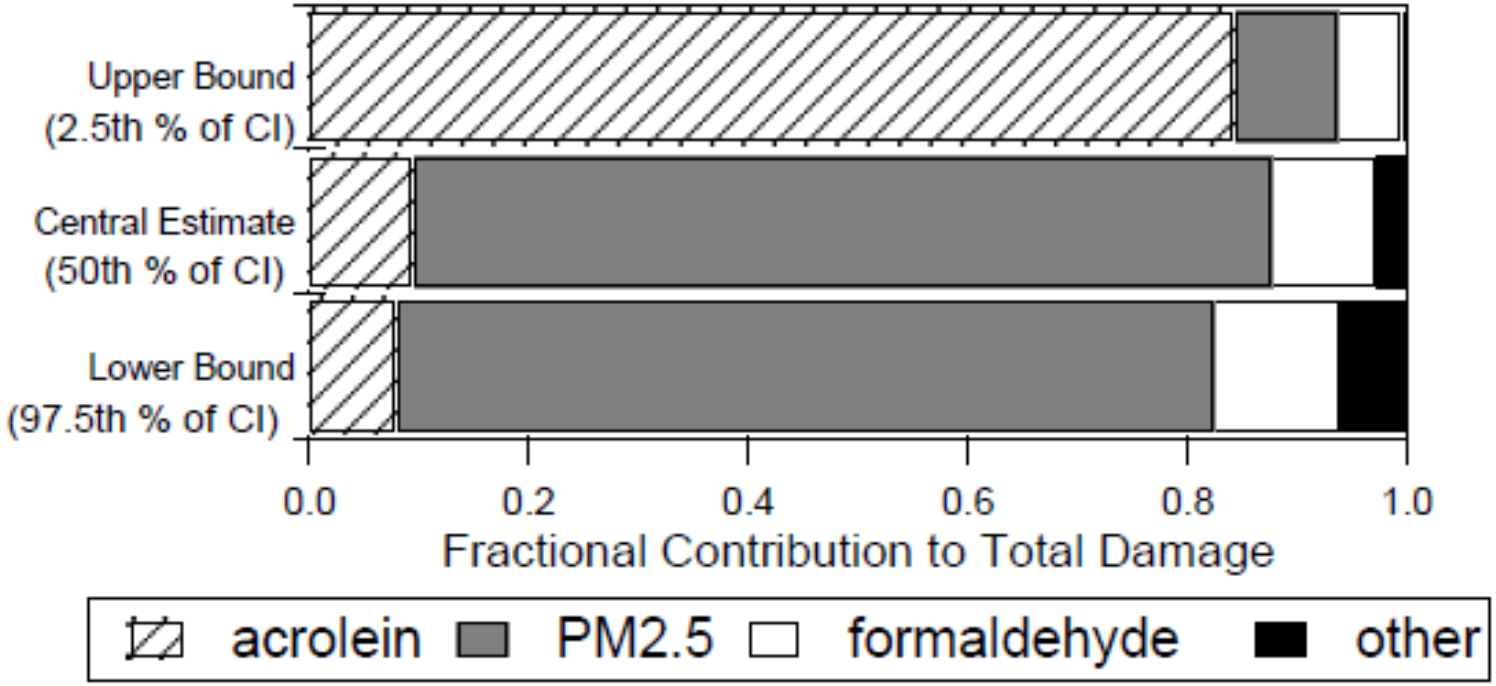
What is the Damage of Indoor Air?

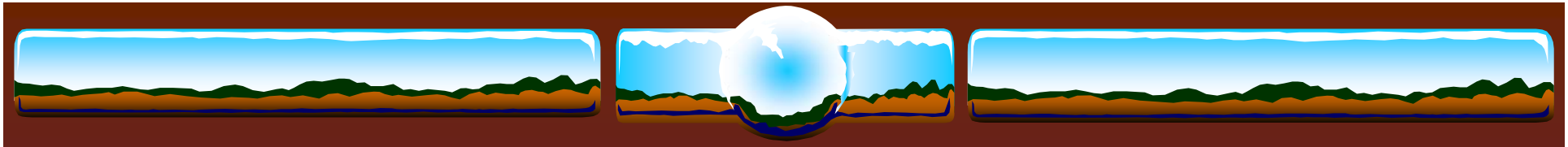


All US non-communicable, non-psychiatric

DALYs lost per year per 100K people

What Pollutants are the main risk drivers? (excludes SHS and radon)

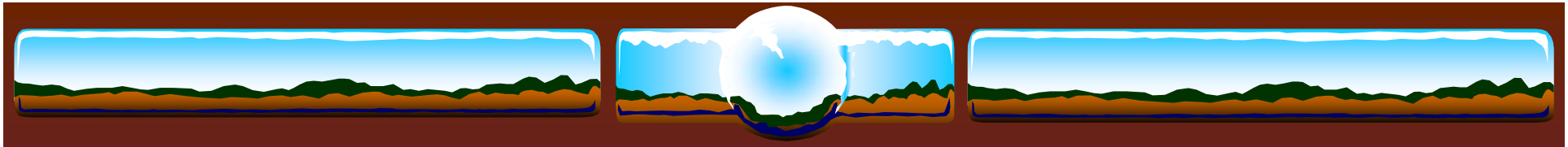




Study Results

1. PM2.5 is most significant indoor health hazard
   - Can have significant outdoor source
2. Product of combustion are 2nd most
   - Acrolein is biggest chronic contributor
   - Least studied of important compounds
3. Formaldehyde is 3rd most
   - Even though it meets WHO standards

…not counting smoking or Radon or acute



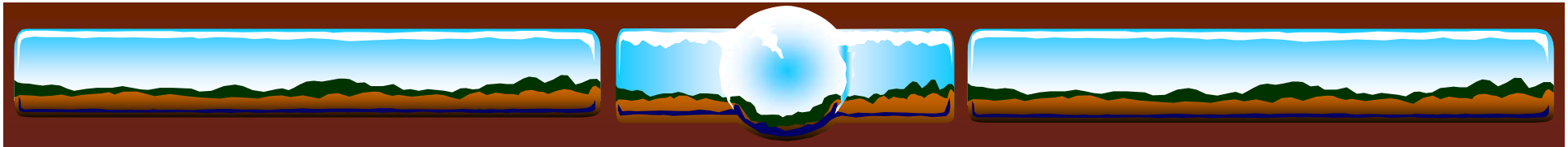
Control Approaches

1. Particle filtration (PM2.5)
   - Ventilation may not handle particles well
2. Combustion control (Acrolein et al)
   - Do not let products of combustion into space
3. Low emitting materials (HCHO mostly)
4. Then dilution ventilation (>human odor needs)
   - *We don't know what we don't know*

FOR MORE INFORMATION

- Energy Performance of Buildings Group
  - http://homes.lbl.gov
- Air Infiltration and Ventilation Center (AIVC)
  - http://www.aivc.org
- ASHRAE
  - http://www.ashrae.org


THANK YOU
Questions?



CURRENT ASHRAE STANDARDS

- 62.1-2010: Non Residential
  - Users Manual and companion guideline
- 62.2-2010: Residential
  - Users Manual and companion guideline
- Guideline 10: Indoor Environmental Quality

The Latest Tool for Good IAQ

ASHRAE's Indoor Air Quality Guide

- Practical guidance on achieving good IAQ in commercial buildings
- Joint effort of ASHRAE, AIA, BOMA, US EPA, SMACNA, USGBC
- 200 page book, 500 page CD
- Available now


THANK YOU
QUESTIONS