WHY DO WE CARE ABOUT…

IAQ METRICS

Max Sherman

MHSherman@lbl.gov

LAWRENCE BERKELEY NATIONAL LABORATORY, SENIOR SCIENTIST

UNIVERSITY OF NOTTINGHAM, PROFESSOR

MARCH, 2018

University of Nottingham

UK | CHINA | MALAYSIA

WHY DO WE CARE ABOUT…METRICS?

Metrics allow us to quantify an effect of interest	Metrics allow us to combine similar effects into a single measure of performance	Metrics allow us to optimize performance relative to other criteria	Metrics can be used in codes & standards
e.g. kWh is an *energy* metric	e.g. kWh & m^3 natural gas -> kg of CO_2	e.g. kg of CO_2 saved per $ invested	e.g. Max $CO_2/m^2/yr$

WHY DO WE CARE ABOUT…INDOOR AIR QUALITY?

IAQ is generally considered to be one of the top 5 health hazards in the developed world

but you can't get the health service to pay for it

IAQ is one of the services we expect our buildings to provide

usually through ventilation (inc. infiltration)

IAQ is a potential barrier to effecting energy efficiency in buildings

Tightening reduces infiltration

WHICH IAQ EFFECTS DO WE CARE ABOUT?

1. HEALTH: THE MOST FUNDAMENTAL IAQ CRITERION IS HARM TO PEOPLE FROM INDOOR AIR
2. ACCEPTABILITY: ODOR, IRRITANCY CAN MAKE IAQ UNACCEPTABLE EVEN IF NOT UNHEALTHY
3. MOISTURE: INDIRECT EFFECT BUT CAN PROMOTE BIOLOGICAL GROWTH OR MATERIAL DEGRADATION
4. OCCUPANTS: *THE BEST LAID PLANS OF MICE AND MEN OFTEN GO AWRY*

EACH COULD HAVE ITS OWN SUB-METRIC

WE HAVE A HEALTH METRIC: DALY

Disability Adjusted Life Years (DALYs)

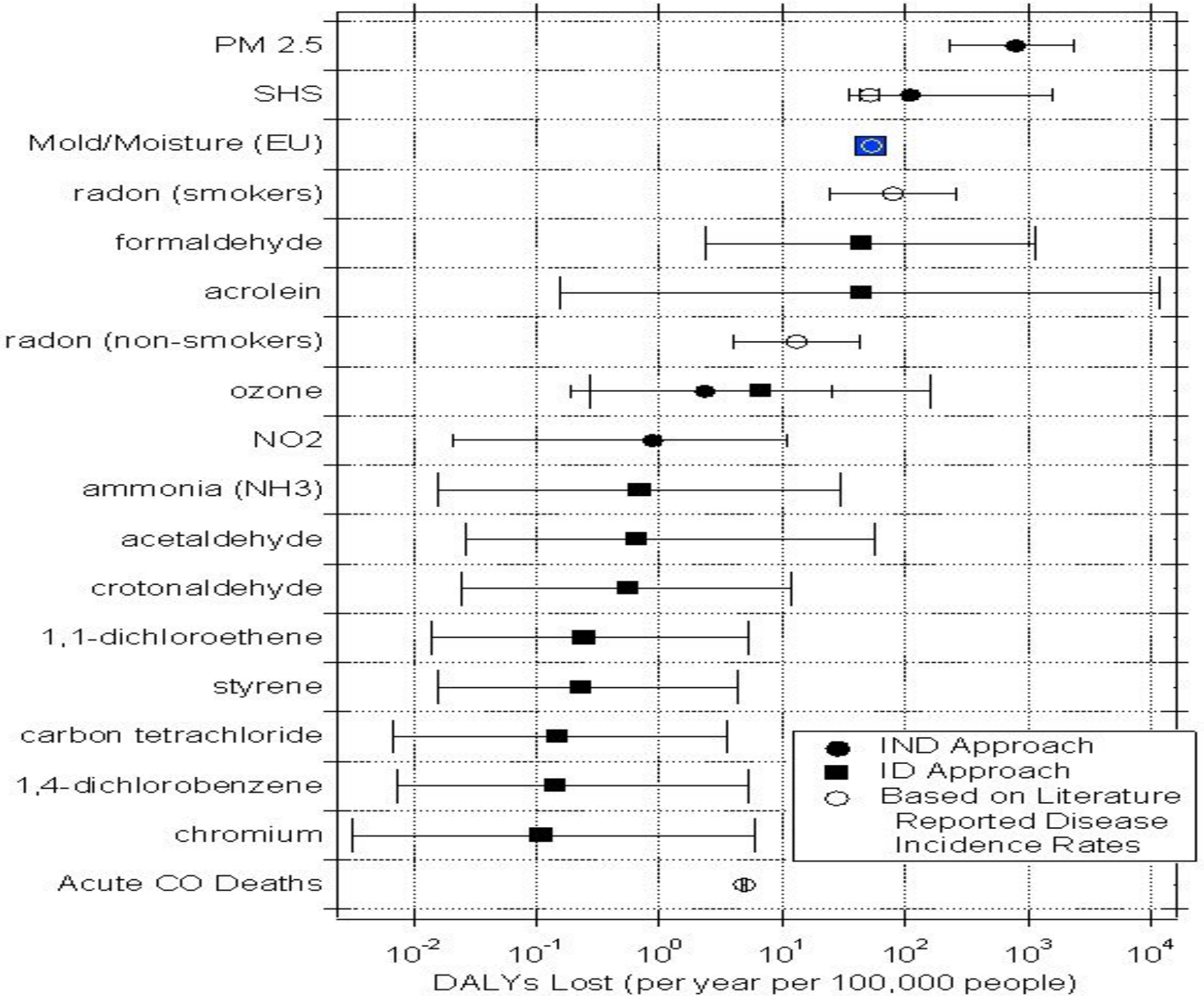
$$DALY = YLL + YLD$$

YLL = Years lost to premature death

YLD = Equivalent years lost to disability

US DALY valued at roughly $50,000 - $200,000

Non-Fatal Stroke: ~9.5–13 DALYs


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)

FULL IAQ METRICS IS THE GOAL

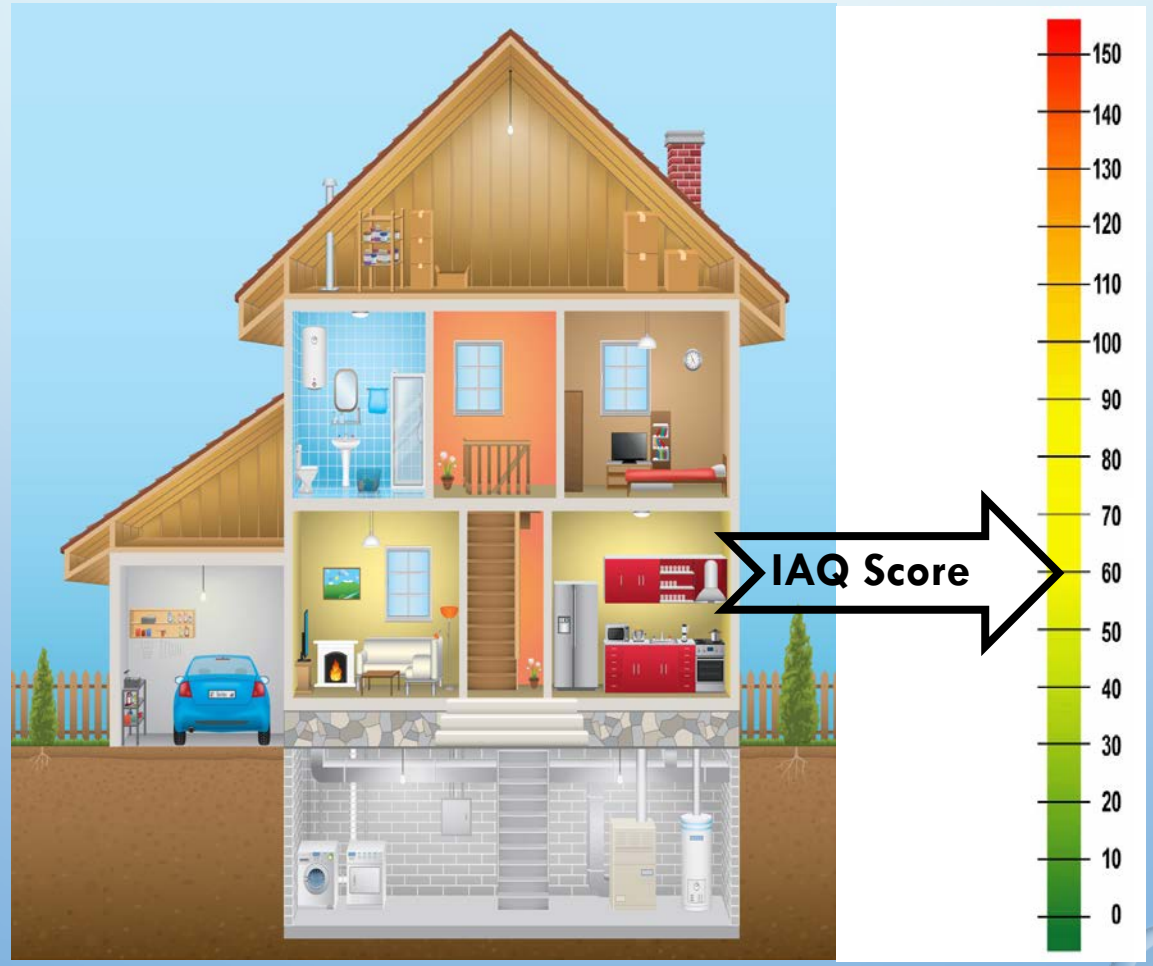
IAQ Metrics needs more research investment

- Need to know all contaminants of concern, emission rates, impacts, etc.
- Need to monetize acceptability & moisture like for DALYs. (e.g. via harm)

IAQ Score is doable now

- Substitutes expert judgement for quantitative metrics
- LBL has been developing…

IAQ SCORE DEVELOPMENT

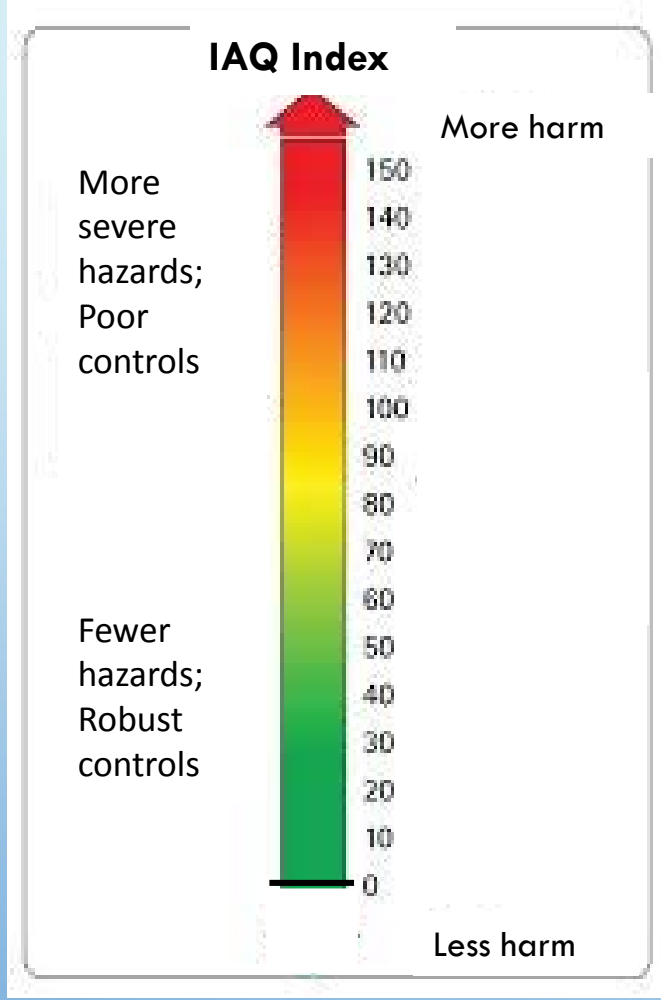


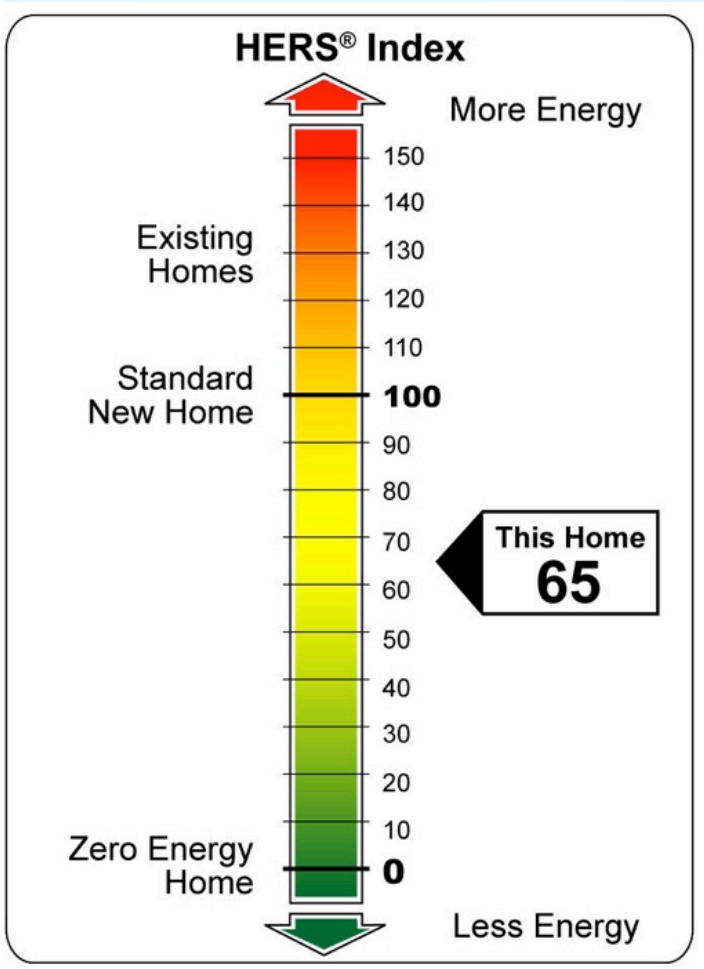
SCORE VISION IS SIMILAR TO METRICS VISION

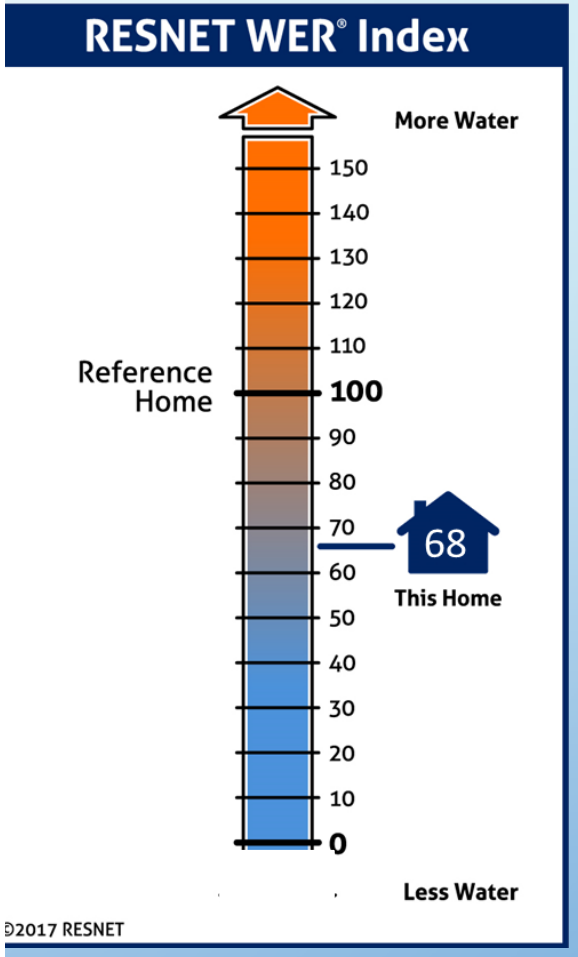
THE IAQ SCORE CAN BE USED TO ADDRESS IAQ CHALLENGES

Rate	homes and inform buyers and sellers.
Guide	new home designs and retrofits to improve IAQ
Improve	codes, standards, programs and regulations
Serve	as an interim IAQ Metric

MODELED AFTER HERS







IAQ Scoring Framework

Raters rate house as found

- Use typical occupant patterns

Identify hazards and potential harm

- Based on expert judgement

Evaluate hazards mitigation (control) impacts

- Based on expert judgement

No reference house

- Can be applied to new or existing

IMPORTANT FEATURES

No prescriptive requirements – this is a scoring tool

Measurements not required; but scores improve when device performance is verified

Many parameters have defaults; rater enters locally correct values

- Enables score when data not available
- Examples: Outdoor AQ, Radon, Fan flows....

Raters have to assess some hazards or controls

IAQ HEALTH RISKS

Contaminants identified by location and source

- Kitchen: Cooking emits $PM_{2.5}$, NO2, VOCs, etc.
- Outdoors: NO_2, PM2.5, ozone, etc.
- Building materials: formaldehyde, VOCs, SVOC
- Foundation: Moisture from ground

Contaminants

- CO, NO_2 & NO;
- PM: PM2.5, PM10, UFP
- VOCs: Formaldehyde, general VOC, SVOC, and other chemical hazards;
- Ozone; Radon;
- Mold; Allergens; Other biological hazards

Risks assessed for general population

- Hazard score considers toxicity and typical amount of exposure
- Risk for general population including susceptible groups

SPECIAL HAZARDS THAT INCREASE SCORE

- Unvented combustion appliance(s)
- Traditional fireplace
- Bad outdoor air quality, nearby sources
- Indoor hot tub or sauna
- Chemical contamination, e.g. from tobacco
- Visual or odor evidence of dampness & mold

NOT INCLUDED IN SCORE – OCCUPANT SPECIFIC

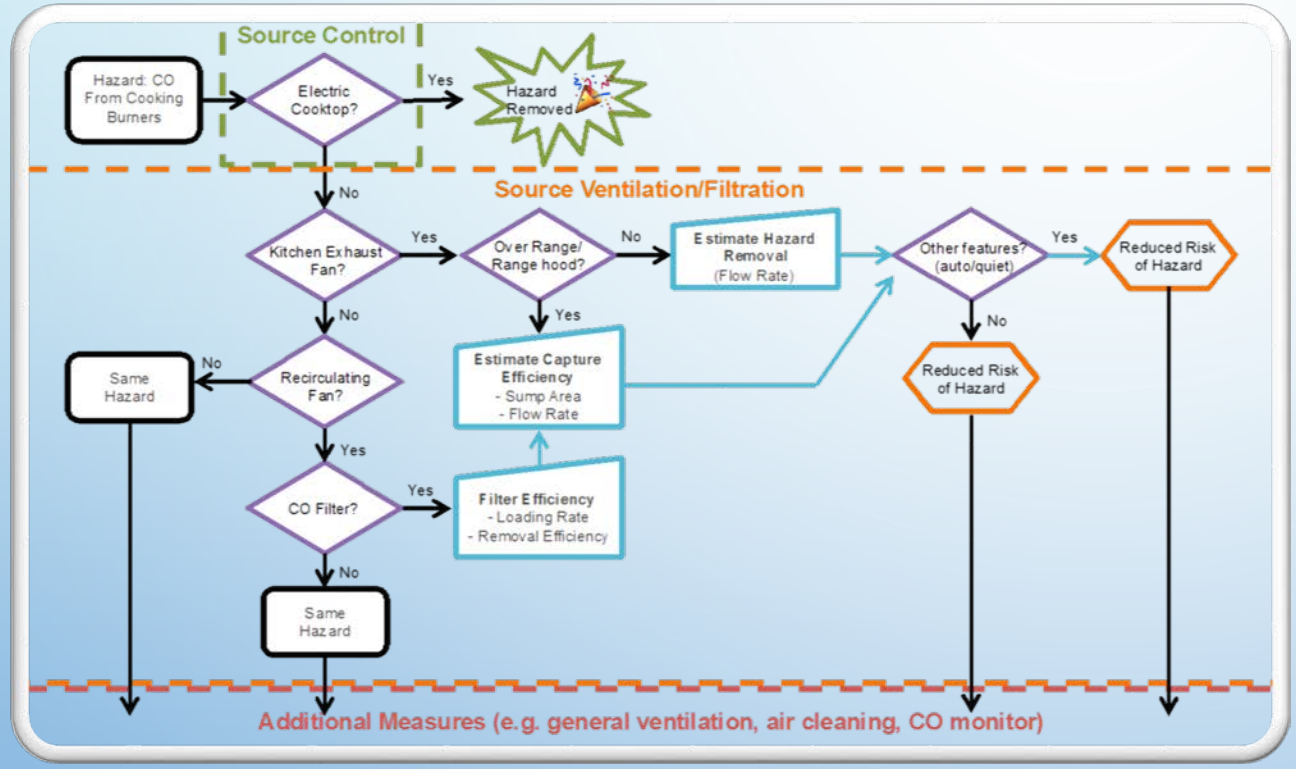
- Current smoking
- Pollutants from unusual hobbies, extreme activities
- Chemicals presently in home
- Number of current residents
- Current pets
- Clutter, dirt, grime, dirty laundry, etc.

CONTROLS ARE BUILDING ASSETS THAT MITIGATE HARM

Effectiveness of some controls will vary with home characteristics

Default values may be needed for some controls

Range hood capture efficiency	Range hood air flow rate	Bathroom fan air flow rate	Whole house ventilation



SCORING APPROACH EXAMPLE: CO FROM COOKTOP BURNER

EXAMPLE: CALCULATING A PIECE OF AN IAQ SCORE

Source of Hazard:

- Gas Range (oven under cooktop)
  - Two pilot burners

Existing Controls:

- Range hood
  - 150 cfm measured
  - 2 sones HVI-rated (or ~40 dB)
  - Unknown capture efficiency (CE)
  - Max flow of 300 cfm
- General kitchen exhaust pulling 20 cfm from kitchen

Health Hazards:
Gas Cooktop, two pilot burners

IAQ Score Type	HEALTH										
Pollutant	PM2.5	PM2.5	PM2.5	PM2.5	NO2	NO2	NO2	NO2	VOC	VOC	VOC
Source Category	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Indoor sources
Source	Gas cooktop	Gas oven under cooktop	Gas oven not under cooktop	Pilot burner(s)	Gas cooktop	Gas oven under cooktop	Gas oven not under cooktop	Pilot burner(s)	Cooking under range hood	Cooking not under hood, general food prep	Furnishings, Hobbies, Personal care prods
Contaminant Score -->	10	7	7	2	7	7	7	5	2	1	3
Hazard Quantity	1	1	0	2	1	1	0	2	1	1	1
Health Hazard	10	7	0	4	7	7	0	10	2	1	3

Source Contaminant Score ★ Quantity of Hazards = Health Hazard

IAQ Score = Sum of Reduced Hazard Scores

			IAQ Score Type	HEALTH										
			Pollutant	PM2.5	PM2.5	PM2.5	PM2.5	NO2	NO2	NO2	NO2	VOC	VOC	VOC
			Source Category	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Indoor sources
			Source	Gas cooktop	Gas oven under cooktop	Gas oven not under cooktop	Pilot burner(s)	Gas cooktop	Gas oven under cooktop	Gas oven not under cooktop	Pilot burner(s)	Cooking under range hood	Cooking not under hood, general food prep	Furnishings, Hobbies, Personal care prods
Control	Control Detailed Description	Control Scoring criteria	Contaminant Score -->	10	7	7	2	7	7	7	5	2	1	3
			Hazard Quantity	1	1	0	2	1	1	0	2	1	1	1
			Health Hazard	10	7	0	4	7	7	0	10	2	1	3
				Control Multiplier	Control Multiplier	Control Multiplier	Control Multiplier	Control Multiplier	Control Multiplier	Control Multiplier	Control Multiplier	Control Multiplier	Control Multiplier	Control Multiplier
General Kitchen Exhaust														
20 cfm	Any continuous kitchen exhaust	10%		0.1	0.1		0.1	0.1	0.1		0.1	0.1	0.1	0.1
	Measured air flow rate	+/-5% every 5 cfm above/below 20												
	Rated air flow rate	+/-3% every 5 cfm above/below 20 cfm												
	Location, better if directly above cooking device, scored separately for cooktop and oven if separate appliances	5%												
Range hood exhaust														
	Any exhaust range hood (default)	40%		0.4	0.4			0.4	0.4			0.4		
	Rated CE and flow measured	%CE												
	Rated CE	%CE*0.8												
150 cfm	Measured air flow rate	+/-5% every 50 cfm above/below 100 cfm		0.05	0.05			0.05	0.05			0.05		
	Rated air flow rate	+/-3% every 50 cfm above/below 100 cfm												
	Measured sound @ CE or flow rate	+/-10% every 1 sone above/below 3 sones												
2 Sones	Rated sound @ CE or flow rate	+/-7% every 1 sone above/below 3 sones		0.07	0.07			0.07	0.07			0.07		
300 cfm	Airflow at highest setting (to deal with emergencies)	+ 10% every 50 cfm above 200 up to 400 cfm		0.2	0.2			0.2	0.2			0.2		
	Auto operation, e.g. linked to humidistat, pollutant mst or interlocked with range	10%												
Reduced Hazard Score				1.8	1.26		3.6	1.26	1.26		9	0.36	0.9	2.7
IAQ Score (Summed)	22.14													

NEXT STEPS

For IAQ Score

- LBL hopes to have beta test this year
  - Browser based
- Create version for general use next year

For IAQ Metrics

- Needs more research on key aspects
  - Health researchers, economists, etc
- LBL efforts on hold

CONCLUSION

IAQ Metrics enable use of powerful optimization and economic tools to improve buildings

- Years away from full achievement
- Ventilation metrics help pave the way

IAQ Score gives similar functionality in the interim

- Hopefully available for use within a year

THANK YOU

QUESTIONS?

University of Nottingham
UK | CHINA | MALAYSIA