



# Efficiency vs. Toxicity

Designing for Fire

PHOTO CREDIT JAKE SCHEIDEMAN

**bnim**

**HENDERSON**  
ENGINEERS

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Wildfires are striking closer and closer to cities. We know how this will end

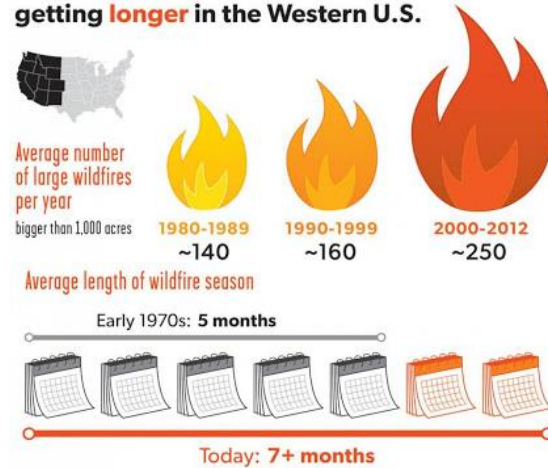
The climate crisis is a factor, but so are efforts to fight fires - which have had the opposite effect



Article/graphic from the Guardian, September 12, 2020

▲ 'As Americans in California, Washington and Oregon are discovering, wildfires do not only impact the wilderness. Towns and suburbs are not inviolate.' Photograph: Kathryn Elssesser/AFP/Getty Images

Wildfires are **increasing** and wildfire season is getting **longer** in the Western U.S.



Where we are in 2021



# Agenda

1. The Problem
2. The Research
3. The Results
4. The Next Steps



PHOTO CREDIT NEW YORK TIMES

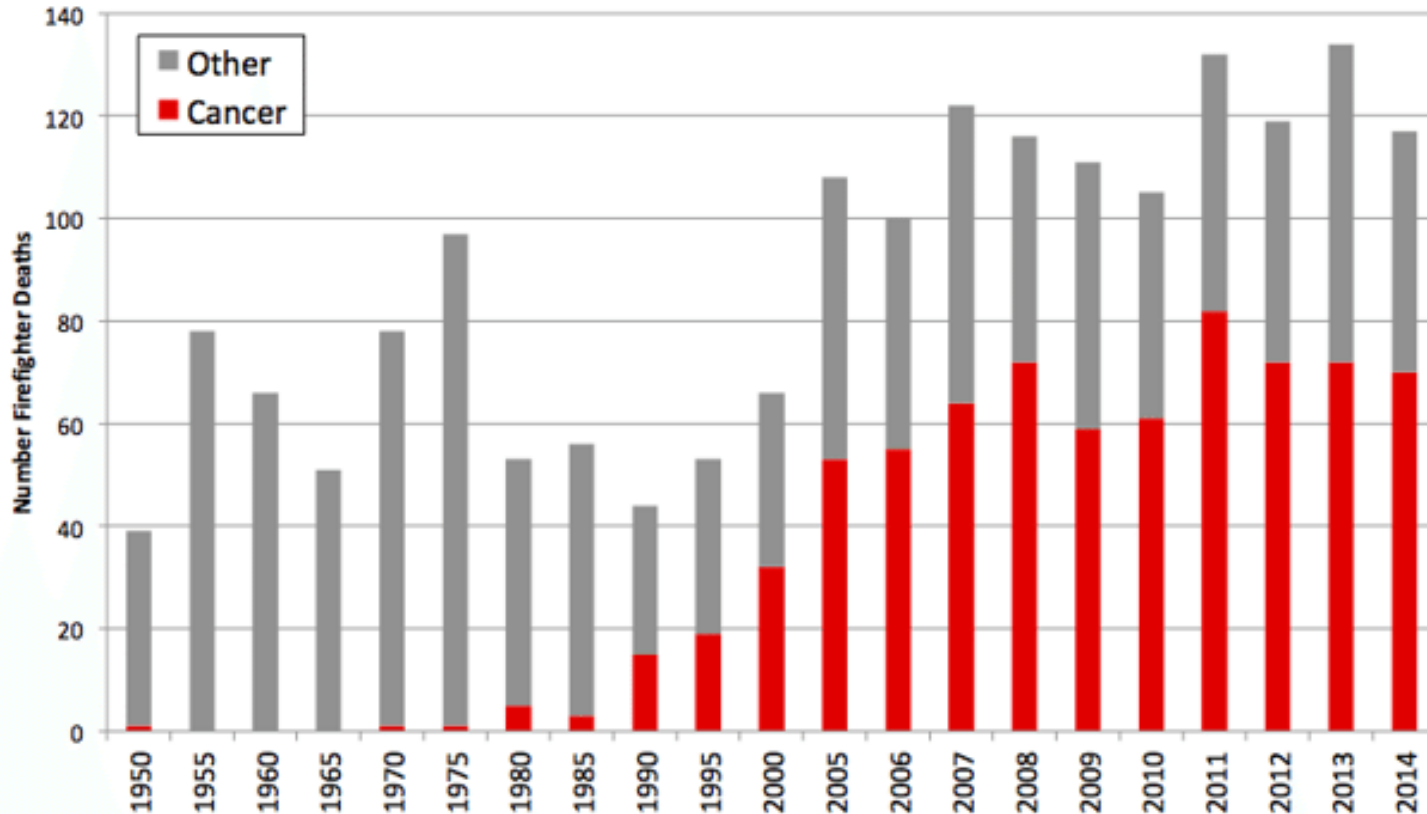
# 1. THE PROBLEM ...begins with a question

# Firefighters

- 9% Higher Risk of Cancer Diagnosis
- 14% Higher Risk of Dying From Cancer

## Types of Cancer

- 2.0 x Testicular Cancer
- 2.0 x Mesothelioma
- 1.5 x Non-Hodgkin's Lymphoma
- 1.4 x Skin Cancer
- 1.3 x Brain Cancer
- 1.2 x Prostate Cancer
- 1.2 x Colon Cancer
- 1.1 x Leukemia
- 0.6 x Esophageal Cancer



## Mortality and Incidence Rates





# Protection

## Materials Testing Standards

### ASTM Testing

American Society for Testing and Materials

- Focused on material quality and standards
- Installation standards
- VOC Testing

### NFPA Testing

National Fire Protection Association

- Fire/Smoke systems and equipment testing
- Materials fire testing
- Assemblies fire testing

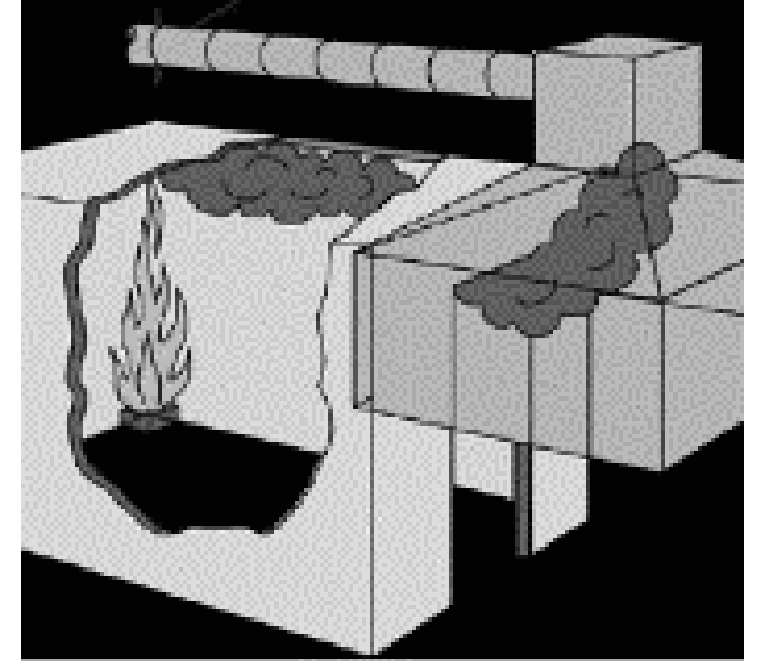
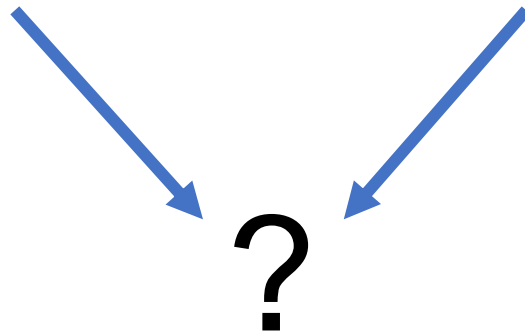


Figure 803.1.2(1)  
ROOM CORNER TEST

Material	Flame spread
Glass-fiber sound-absorbing planks	15 to 30
Mineral-fiber sound-absorbing panels	10 to 25
Shredded wood fiberboard (treated)	20 to 25
Sprayed cellulose fibers (treated)	20
Aluminum (with baked enamel finish on one side)	5 to 10
Asbestos-cement board	0
Brick or concrete block	0
Cork	175
Gypsum board (with paper surface on both sides)	10 to 25
Northern pine (treated)	20
Southern pine (untreated)	130 to 190
Plywood paneling (untreated)	75 to 275
Plywood paneling (treated)	100
Carpeting	10 to 600
Concrete	0

# Designed to Burn 1.0

- How we got started
- Facilitating cross-industry conversations
- Presented “the problem” at
  - AIA Kansas City
  - USGBC Regional Conference
  - SFPE National Conference
  - NFSA National Conference



**What are the choices we make every day that could impact this?**

# 2. THE RESEARCH



## LEED Certification

MR c4  
MR c4  
EQ c1  
EQ c2

MATERIAL INGREDIENTS REPORTING  
MATERIAL INGREDIENT OPTIMIZATION  
ENHANCED IAQ STRATEGIES  
LOW EMITTING MATERIALS



## WELL Certification

AIR 04  
AIR 25  
AIR 26  
MIND 97  
MIND 99

VOC REDUCTION  
TOXIC MATERIAL REDUCTION  
ENHANCED MATERIAL SAFETY  
MATERIAL TRANSPARENCY  
BEAUTY AND DESIGN II



## Living Building Challenge

HEALTH 9  
HEALTH 10  
MATERIALS 12  
MATERIALS 13  
MATERIALS 14

HEALTHY INTERIOR ENVIRONMENT  
HEALTHY INTERIOR PERFORMANCE  
RESPONSIBLE MATERIALS  
RED LIST  
RESPONSIBLE SOURCING



## LEED Certification



## WELL Certification



## Living Building Challenge

Rating systems currently DO address:

1. Material supply chain exposure
2. Construction activity exposure
3. Operational occupant exposure

Rating systems currently DO NOT address:

4. Occupant and first responder exposure during an emergency such as a fire.



**RED LIST CHEMICALS**

- Alkylphenols
- Asbestos
- Bisphenol A (BPA)
- Cadmium
- Chlorinated Polyethylene & Chlorosulfonated Polyethylene
- Chlorobenzenes
- Chlorofluorocarbons (CFCs) &
- Hydrochlorofluorocarbons (HCFCs)
- Chloroprene (Neoprene)
- Chromium VI
- Chlorinated Polyvinyl Chloride (CPVC)
- Formaldehyde (all types - added)

- Isocyanate based Polyurethane\*
- Halogenated Flame Retardants (HFRs)
- Lead (added)
- Mercury
- Polychlorinated Biphenyls (PCBs)
- Perfluorinated Compounds (PFCs)
- Phthalates
- Polyvinyl Chloride (PVC)
- Polyvinylidene Chloride (PVDC)
- Short Chain Chlorinated Paraffins
- Wood treatments containing Creosote, Arsenic or Pentachlorophenol

**SOLVENTS**

- Methylene Chloride (Dichloromethane)
- 1,1,1-Trichloroethane (Methyl Chloroform)
- Trichlorofluoromethane (CFC-11)
- Dichlorodifluoromethane (CFC-12)
- 1,1,2-Trichloro-1,2,2-Trifluoroethane (CFC-113)
- 1,2-Dichloro-1,1,2,2-Tetrafluoroethane (CFC-114)
- Chloropentafluoroethane (CFC-115)
- Cyclic, Branched, or Linear, completely Methylated Siloxanes (VMS)
- Tetrachloroethylene (Perchloroethylene)

- Ethylfluoride (HFC-161)
- 1,1,1,3,3,3-Hexafluoropropane (HFC-236fa)
- 1,1,2,2,3-Pentafluoropropane (HFC-245ca)
- 1,1,2,3,3-Pentafluoropropane (HFC-245ea)
- 1,1,1,2,3-Pentafluoropropane (HFC-245eb)
- 1,1,1,3,3-Pentafluoropropane (HFC-245fa)
- 1,1,1,2,3,3-Hexafluoropropane (HFC-236ea)
- 1,1,1,3,3-Pentafluorobutane (HFC-365mfc)
- Chlorofluoromethane (HCFC-31)
- 1,2-Dichloro-1,1,2-trifluoroethane (HCFC-123a)
- 1 Chloro-1-Fluoroethane (HCFC-151a)

\*inside exterior weatherproofing system

	CAN DAMAGE REPRODUCTIVE SYSTEM		CAN LOWER IQ AND LEAD TO BRAIN DAMAGE
	LINKED TO DECREASE IN SPERM COUNT		CAN CAUSE HEARING AND VISION IMPAIRMENT
	INCREASED RISK OF DIABETES		LINKED TO PARKINSON'S DISEASE
	TIED TO EARLY PUBERTY IN GIRLS		TIED WITH NEUROTOXIC EFFECTS
	RELATED TO BREAST CANCER		CAN CAUSE DECREASES IN MALE TESTOSTERONE
	CAN DISRUPT SEX HORMONE LEVELS AND SPERM COUNT		LINKED WITH A VARIETY OF CANCERS
	CAN HARM THE IMMUNE SYSTEM		CAN DISRUPT HORMONAL DEVELOPMENT IN FETUSES
	CAN CAUSE KIDNEY PROBLEMS		CAN INCREASE RISK OF BREAST CANCER
			LINKED TO OBESITY AND HEART DISEASE

# Living Building Challenge Red List

**PHTHALATES**

**EFFECTS**

- CAN DAMAGE REPRODUCTIVE SYSTEM
- LINKED TO DECREASE IN SPERM COUNT
- INCREASED RISK OF DIABETES
- TIED TO EARLY PUBERTY IN GIRLS

**HOW TO AVOID**

- AVOID PVC PLASTICS AND PLASTICS MARKED WITH RECYCLING LABEL #3
- KEEP CLEAR OF PRODUCTS THAT HAVE "ADDED FRAGRANCE" ON THE LABEL
- EAT MORE ORGANIC FRUIT AND VEG

**PERFLUORINATED CHEMICALS**

**EFFECTS**

- RELATED TO BREAST CANCER
- CAN DISRUPT SEX HORMONE LEVELS AND SPERM COUNT
- CAN HARM THE IMMUNE SYSTEM
- CAN CAUSE KIDNEY PROBLEMS

**HOW TO AVOID**

- COOK WITH CERAMICS AND GLASSWARE INSTEAD OF NON-STICK PANS
- FIND OUT IF THERE ARE PFCs IN STAIN-RESISTANT CARPETS, CLEANING PRODUCTS AND COOKWARE

**BPA (BISPHENOL A)**

**EFFECTS**

- CAN DISRUPT HORMONAL DEVELOPMENT IN FETUSES
- CAN INCREASE RISK OF BREAST CANCER
- LINKED TO OBESITY AND HEART DISEASE

**HOW TO AVOID**

- TRY TO AVOID RECEIPTS AND GO DIGITAL INSTEAD
- CUT DOWN ON PLASTIC MARKED WITH RECYCLING LABEL #7
- OPT FOR FRESH FOOD OVER CANS.



**FLAME RETARDANTS**

**EFFECTS:**

- LINKED TO THYROID HORMONES DISRUPTION
- LINKED WITH AUTISTIC SYMPTOMS
- CAN LOWER SPERM COUNT

**HOW TO AVOID:**

- USE VACUUMS CLEANERS THAT INCLUDE A HEPA FILTER
- USE FACE MASKS WHEN CLEANING CARPETS
- AVOID REUPHOLSTERING YOUR FOAM FURNITURE

**EFFECTS**

- CAN LOWER IQ AND LEAD TO BRAIN DAMAGE
- CAN CAUSE HEARING AND VISION IMPAIRMENT
- CAN DISRUPT HORMONAL DEVELOPMENT IN FETUSES AND PREMATURE BIRTH
- CAN LOWER SPERM COUNT

**HOW TO AVOID**

- AVOID OLD PAINT THAT IS CHIPPED OR CRUMBLING
- INVEST IN A GOOD WATER FILTER
- DON'T WEAR OUTDOOR SHOES INDOORS TO AVOID LEAD FOUND IN SOIL

**LEAD**

**EFFECTS**

- LINKED TO PARKINSON'S DISEASE
- TIED WITH NEUROTOXIC EFFECTS
- CAN CAUSE DECREASES IN MALE TESTOSTERONE
- LINKED WITH A VARIETY OF CANCERS

**HOW TO AVOID**

- EAT MORE ORGANIC PRODUCE
- ENSURE PRODUCE IS THOROUGHLY WASHED BEFORE CONSUMPTION
- REMOVE OUTER LEAVES OF VEG SUCH AS LETTUCE TO AVOID CONTACT WITH PESTICIDE RESIDUE

**ORGANOPHOSPHATE PESTICIDES**

**EFFECTS**

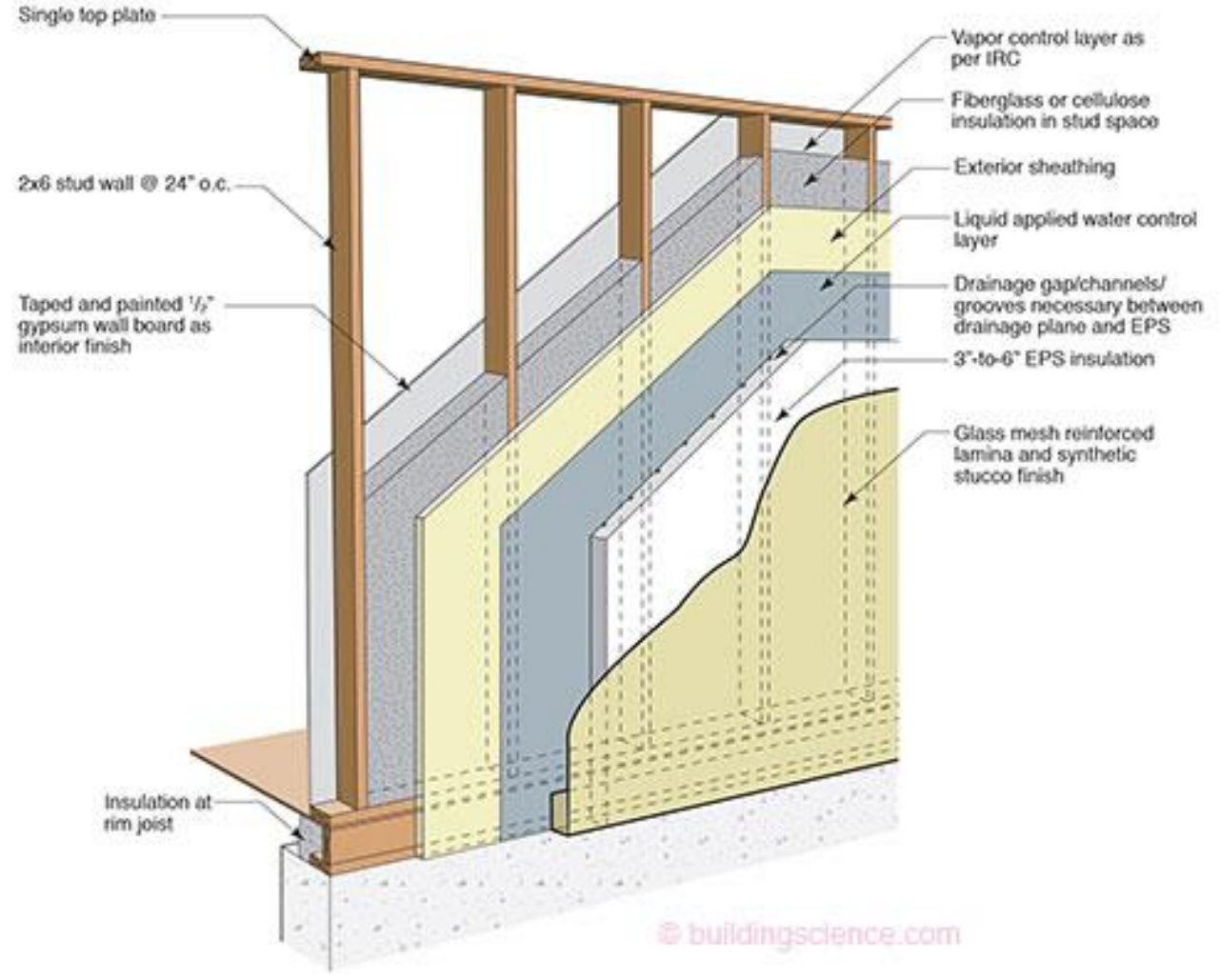
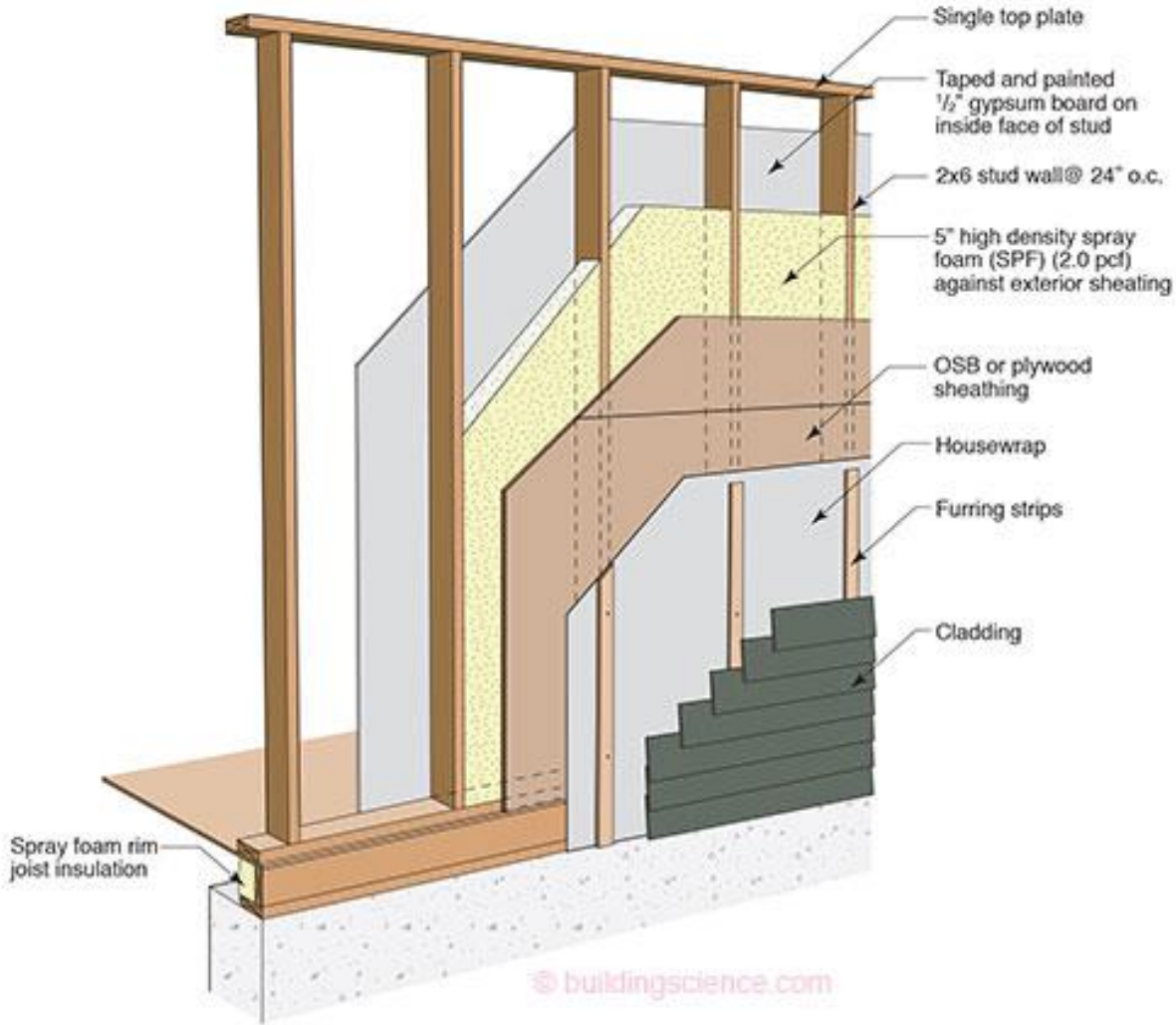
- STUDIES SUGGEST IT CAN LOWER SPERM QUALITY
- CAN DAMAGE THE IMMUNE SYSTEM
- CAN DAMAGE THE REPRODUCTIVE SYSTEM

**HOW TO AVOID**

- CUT DOWN ON ANIMAL PRODUCTS AND EAT MORE ORGANIC FRUIT AND VEG
- TRY TO AVOID CHLORINE-BASED BLEACH
- AVOID BLEACHED PAPER IN PRODUCTS LIKE DISPOSABLE DIAPERS AND TOILET PAPER

**DIOXIN**





# Fire Rated Assemblies

# Designed to Burn 2.0

- Discussions with FM, UL, USGBC, and others
- Need for applied research to test theory
- Development of testing methodology



# Designed to Burn 2.0:

Research Partnership



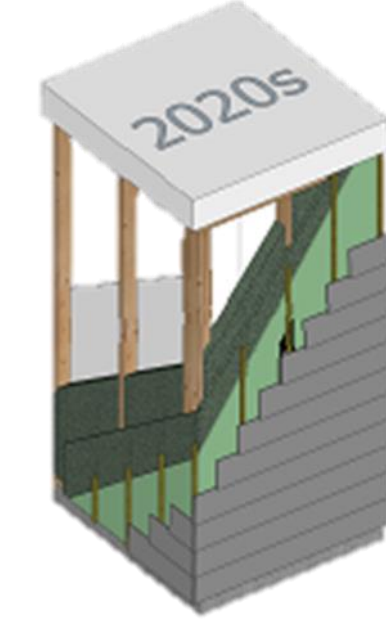
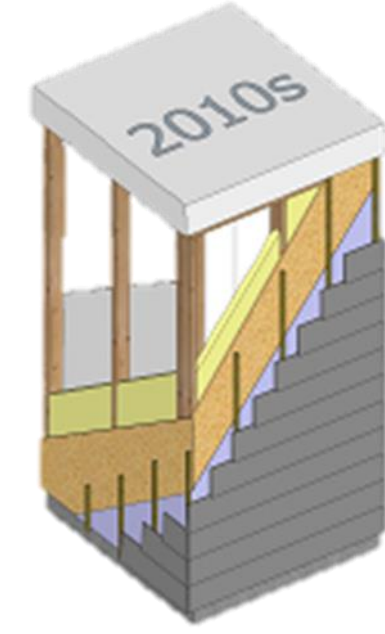
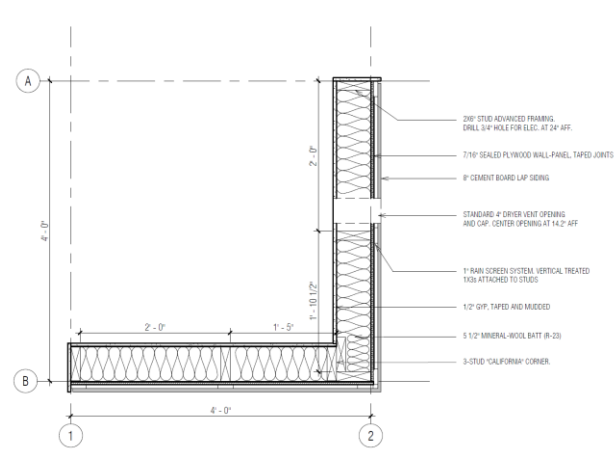
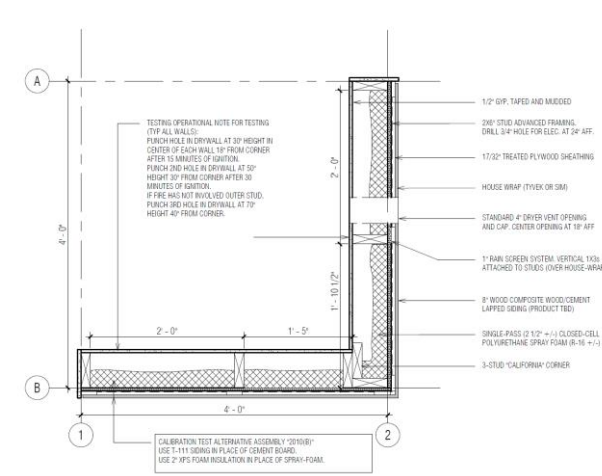
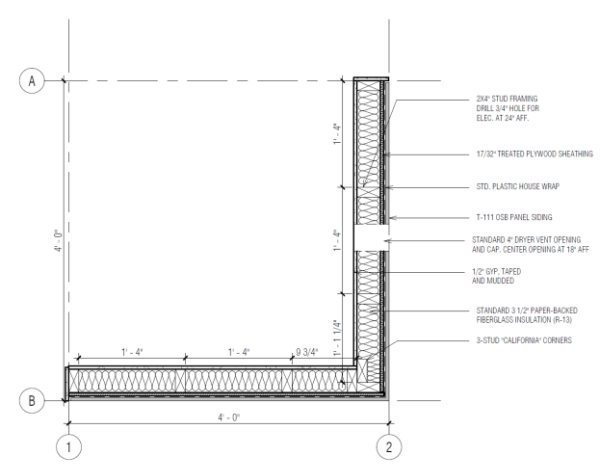
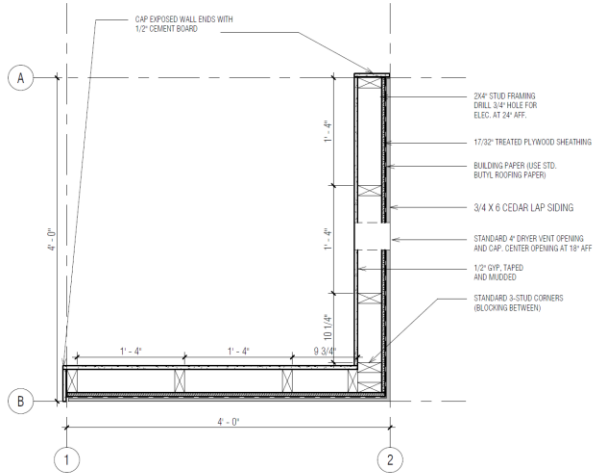
**HENDERSON**  
ENGINEERS



**Armstrong**  
*Forensic Laboratory, Inc.*

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**Turner**  
Construction Company



How has the evolution of assembly construction impacted toxic exposure?

2020

2010

2000

1950

2010  
(CALIBRATION)



# Full Scale Assemblies





SMOKE COLLECTION



EXHAUST SAMPLING



TEST EQUIPMENT



SAMPLING MEDIA

Polynuclear Aromatic Hydrocarbons (PAHs)	Acids	Metals	Phthalates (SVOCs)	Total PNOR	Volatile Organic Compounds (VOCs)
Method: NIOSH 5515 Mod	Method: NIOSH 7907	Method: NIOSH 7303	Method: OSHA 104 Mod	Method: NIOSH 0500	EPA Method: TO-15
Acenaphthene	Hydrobromic acid	Antimony	Diethyl phthalate	"Dust"	In addition to Method Analytes:
Acenaphthylene	Hydrochloric acid	Arsenic	Di-n-octyl phthalate		Acetaldehyde
Anthracene	Nitric acid	Cadmium			Acrolein
Benzo(a)pyrene		Chromium			Formaldehyde
Fluorene		Cobalt			Phenol
Naphthalene		Lead			Top (6) TICs
Phenanthrene					
Pyrene					

# Testing Method Development



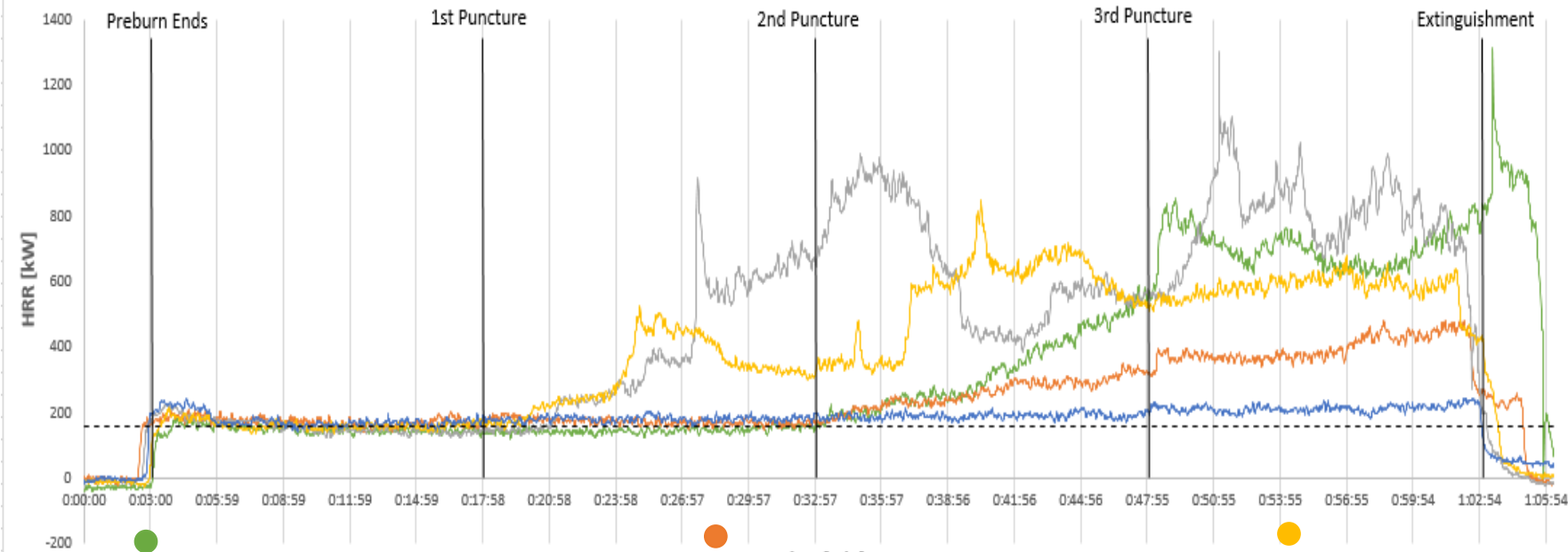
- 1. Sampling Methodology is Complex.**
  - No Standardized Testing or Sampling Procedures
  - Resource Limitations - Experience and Equipment
  - Sample Stream – Moisture and Temperature
  - Fire Size and Duration – Sample Volume
- 2. Stoichiometry – Ventilation is Complex.**
  - Unlimited Ventilation
  - Ventilation-Controlled
- 3. Scaling of Wall Assemblies.**
  - Calorimeter limitations
  - Full Scale / Quarter Scale Compartment
- 4. Limited to One Burn per Generation**
  - Academic Calendar
  - Burn Laboratory Time and Budget



# Testing Limitations

# 3. THE RESULTS

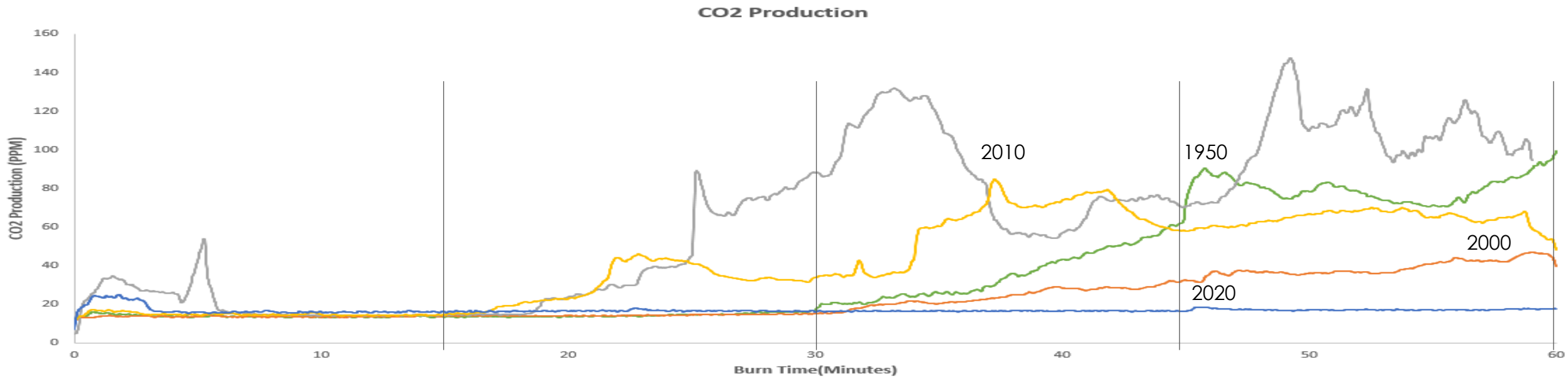
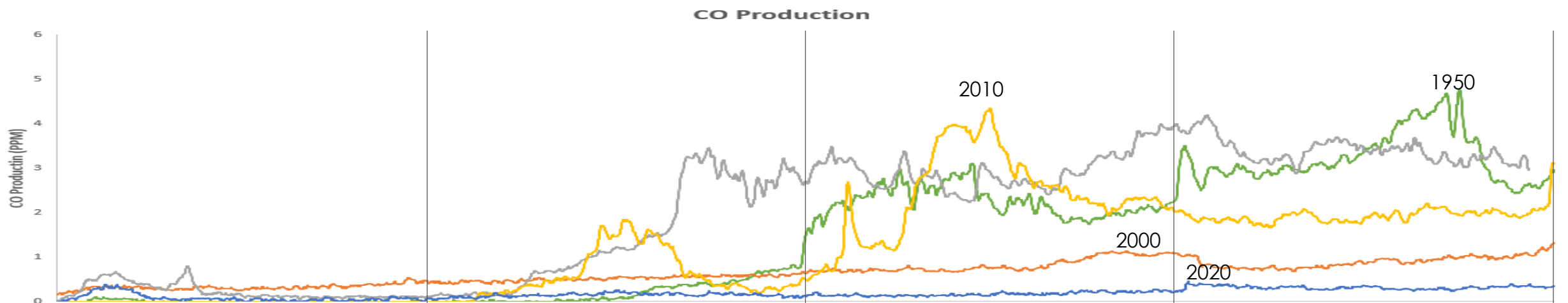
# HRR Vs Time



## Maximum Heat Release / Time

1950	853 kW / 2953 s
2000	321 kW / 3683 s
2010	688 kW / 2425 s
2020	84 kW / 3736 s

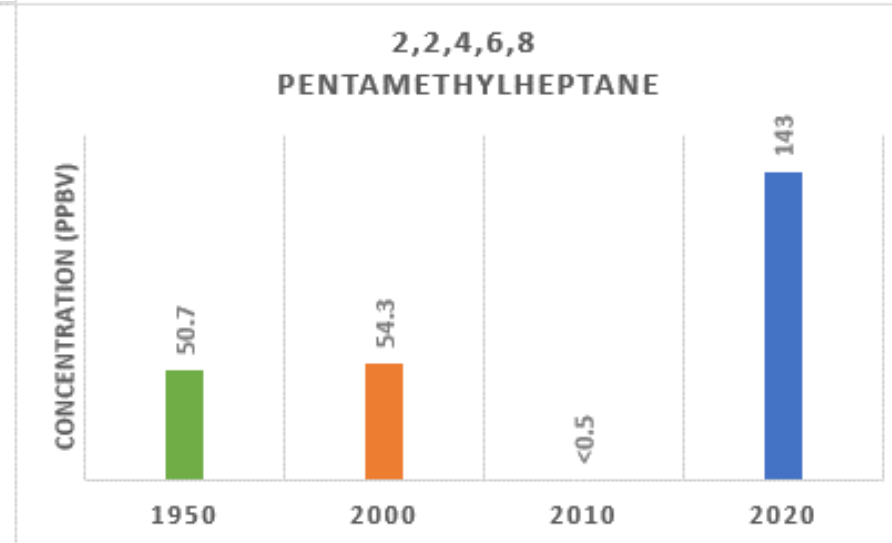
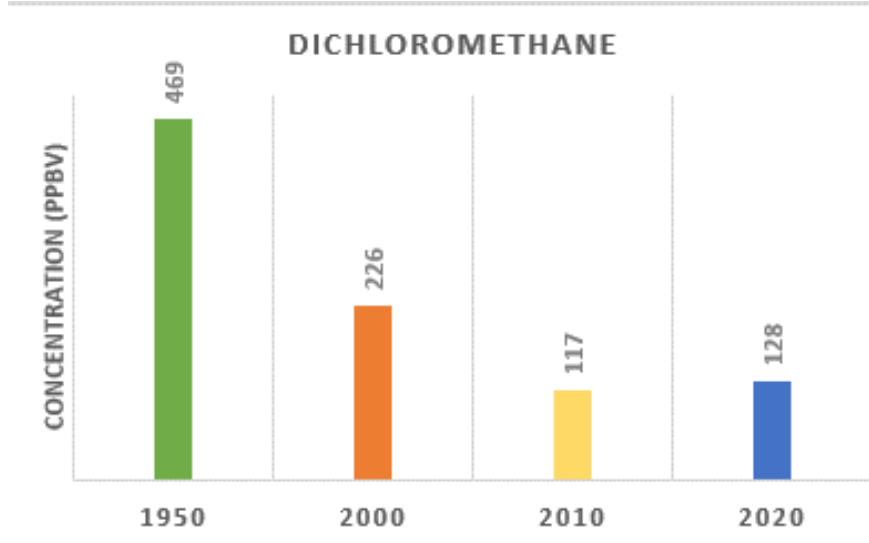
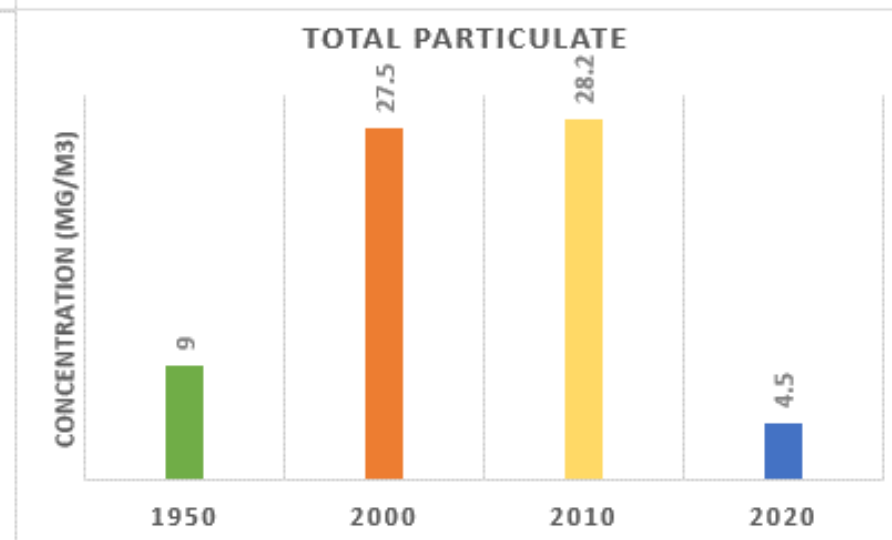
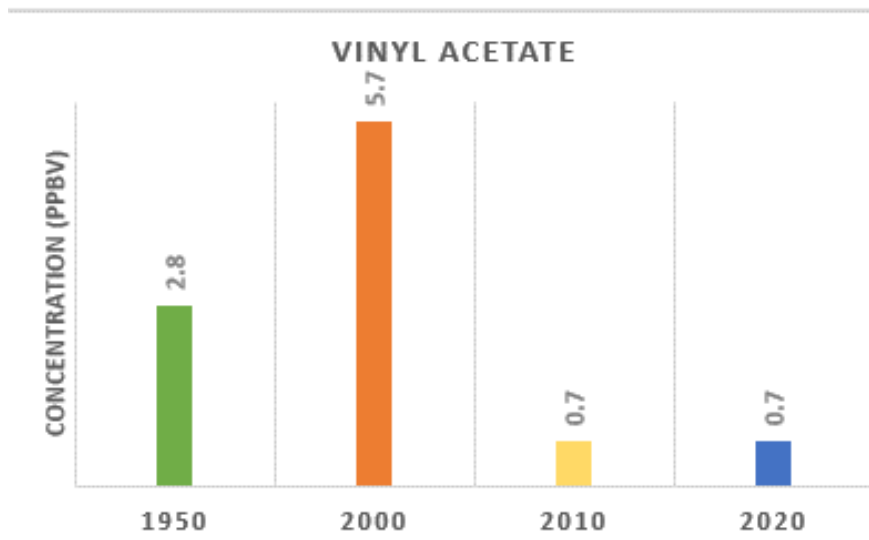




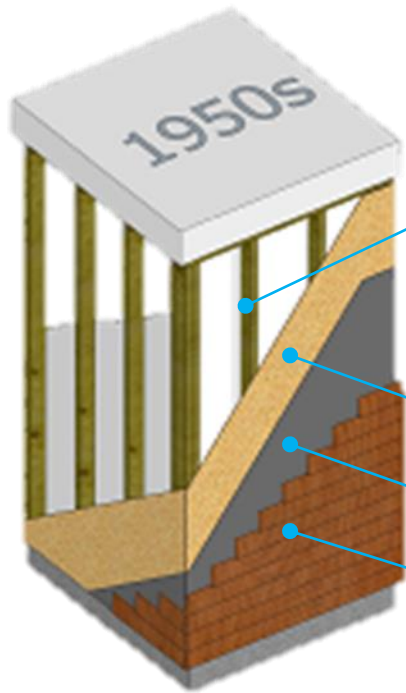
— 1950 CO2 — 2000 CO2 — 2010 SH CO2 — 2010 SP CO2 — 2020 CO2

# Products of Combustion





# Products of Combustion

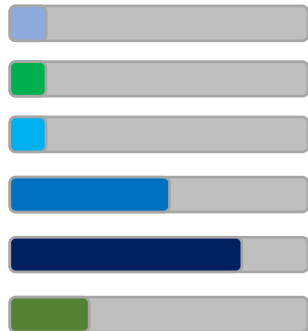


2x4 dense studs @ 16"

Plywood

Tar paper

Cedar lap



Installed cost

Energy performance

Installed toxicity

Heat Release Rate

Products of Combustion

Smoke toxicity

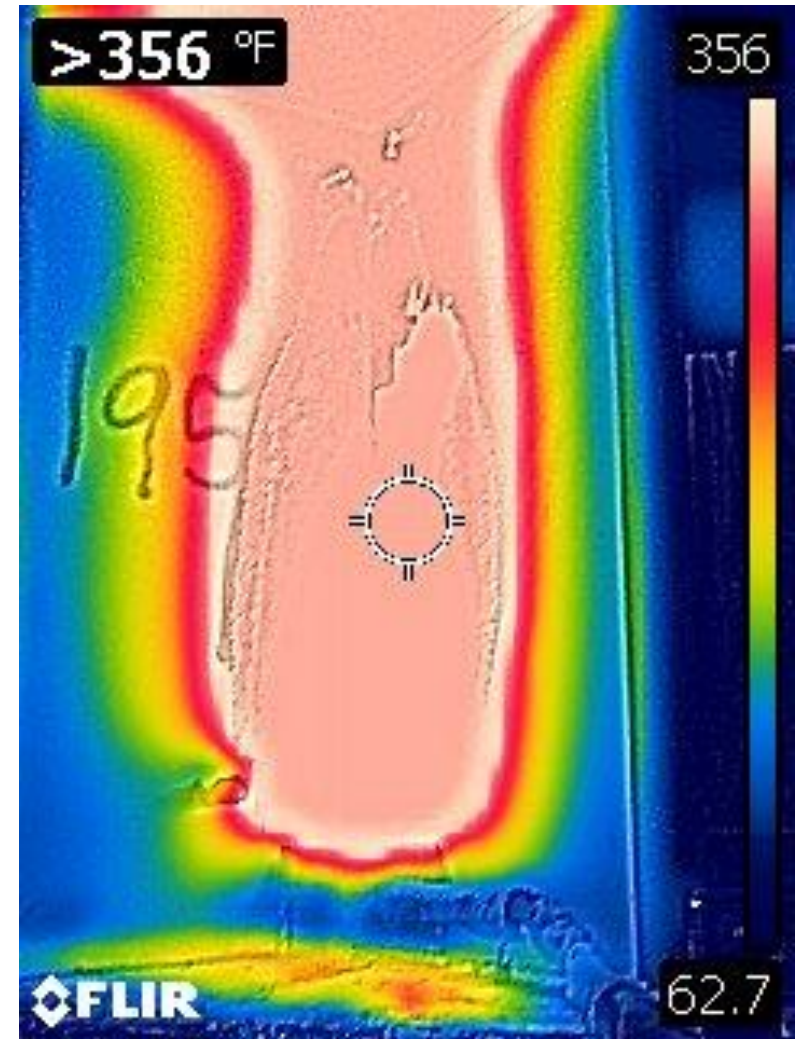
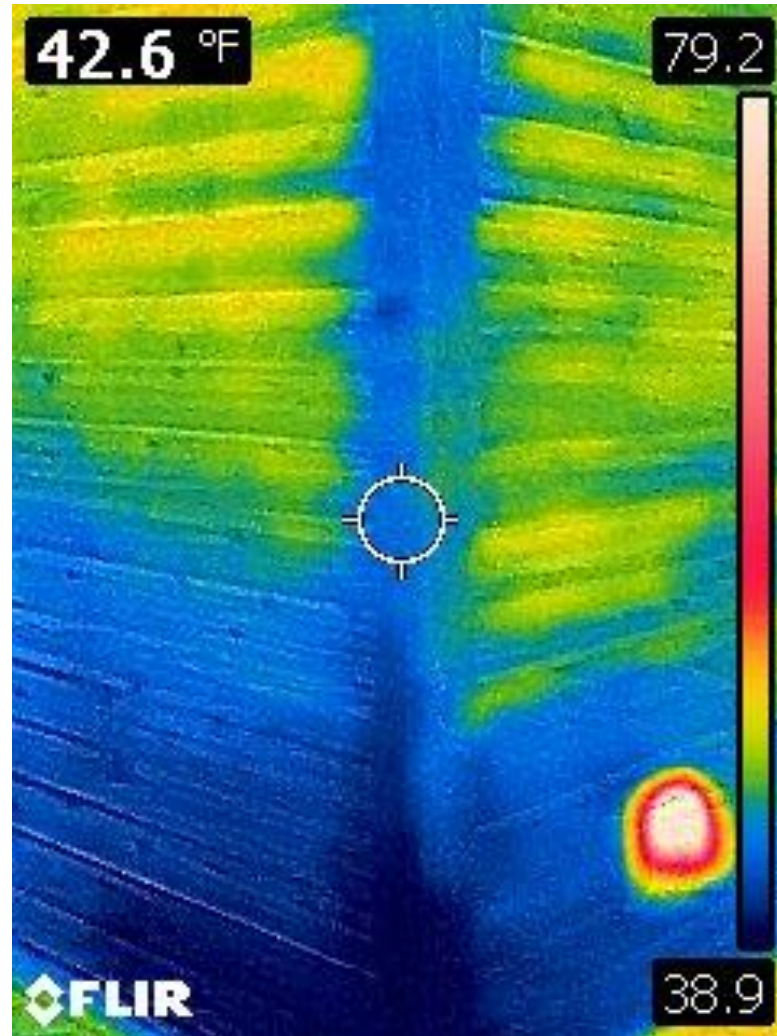
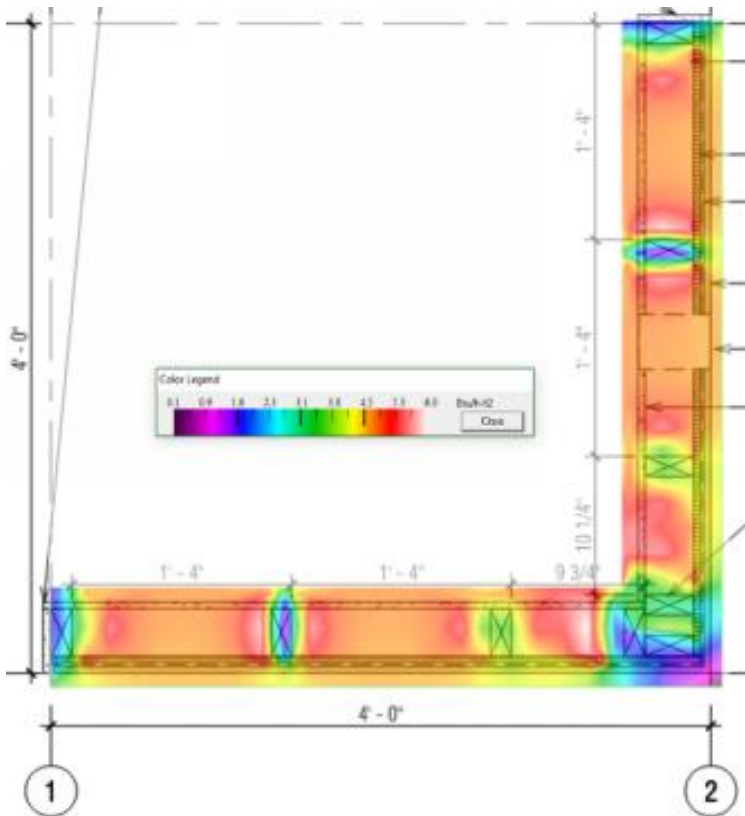




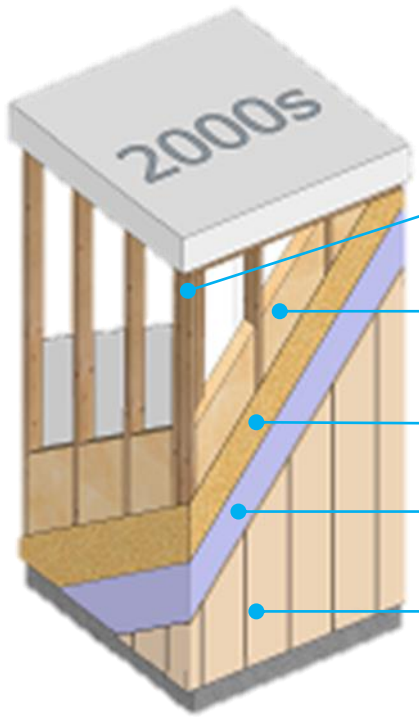
# 1950s Wall Framing

Calculated R Value = 3.78

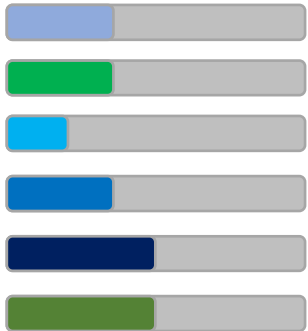
Calculated U Value = 0.26



# Assembly Performance



- 2x4 std. studs @ 16"
- Fiberglass Insulation
- Plywood
- House Wrap
- Composite siding



- Installed cost
- Energy performance
- Installed toxicity
- Heat Release Rate
- Products of Combustion
- Smoke toxicity

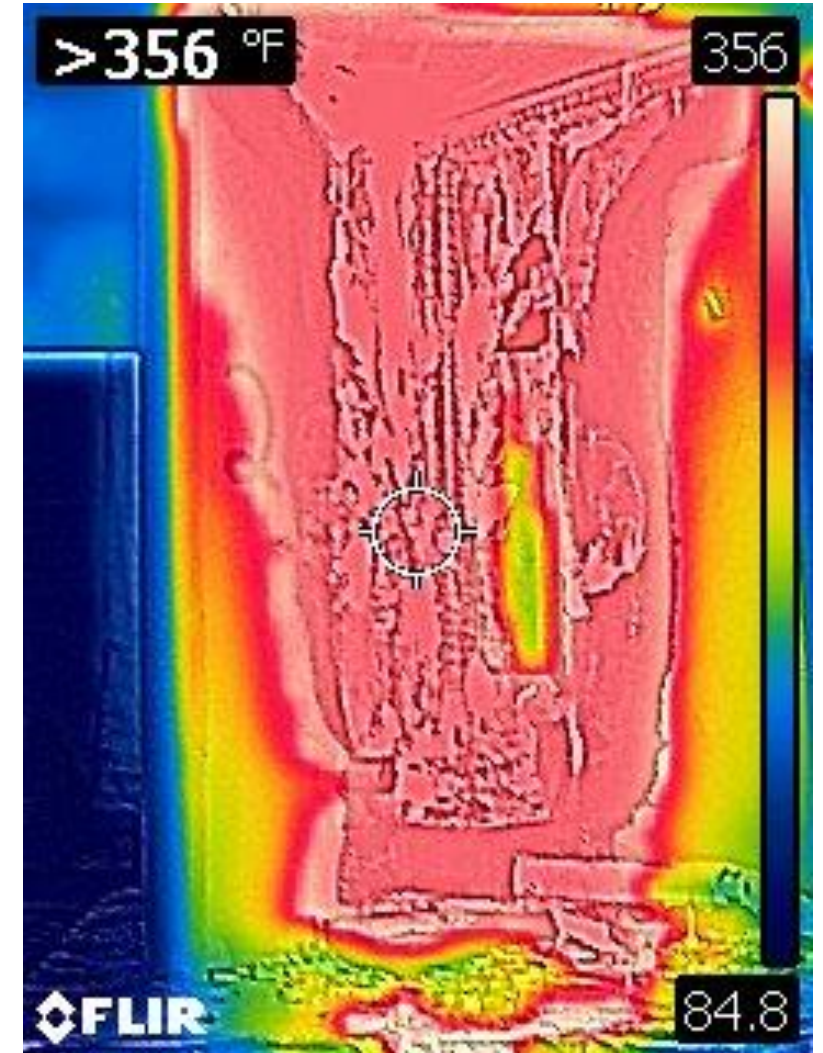
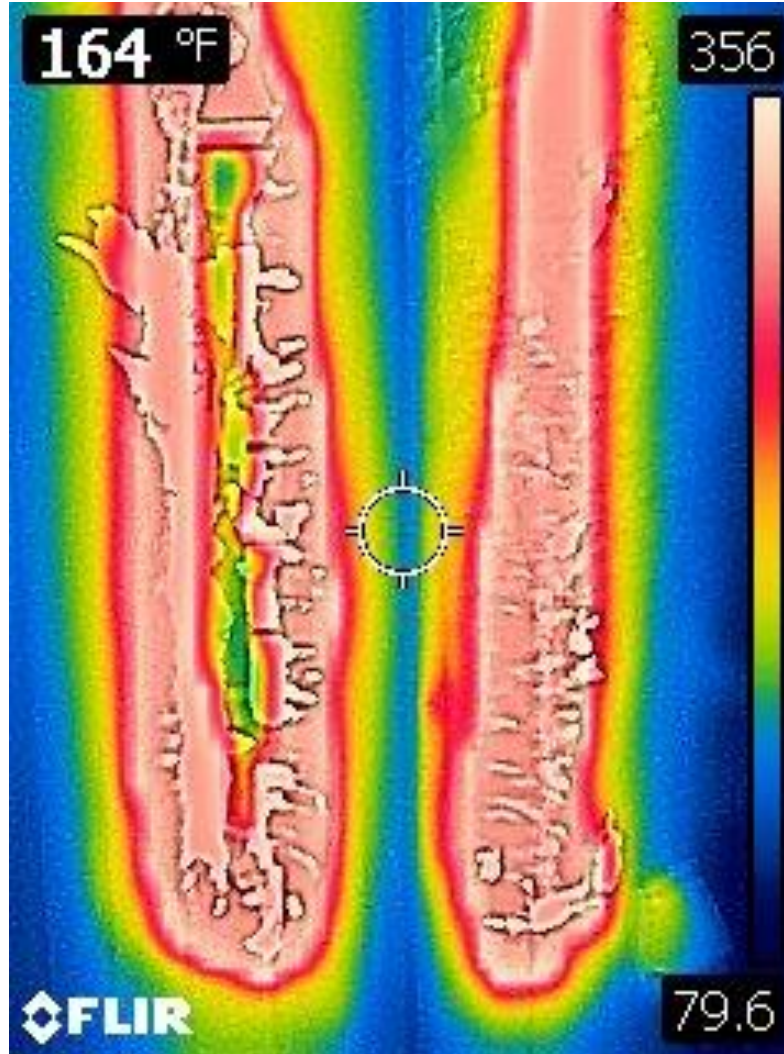
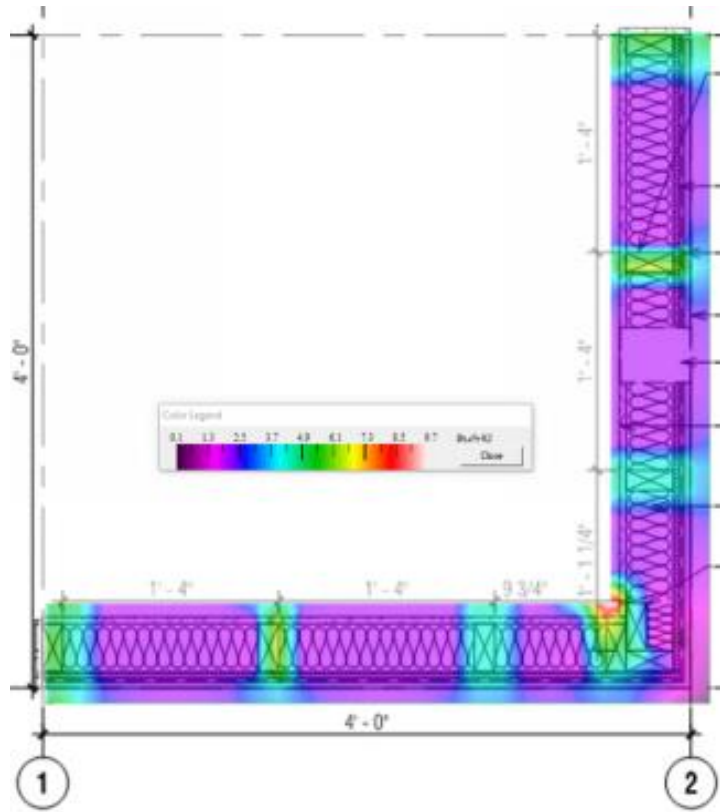




## 2000s Wall Framing

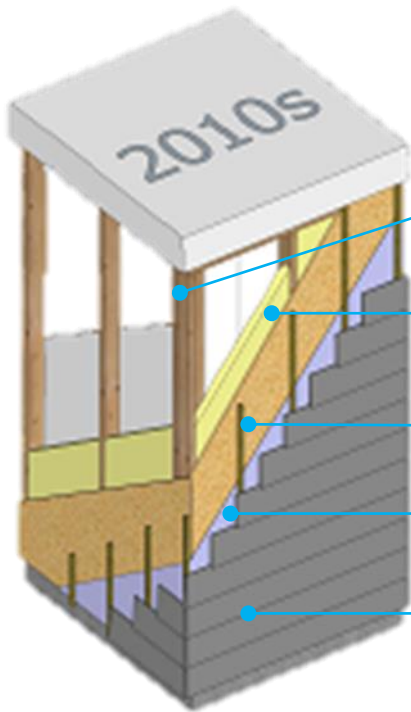
Calculated R Value = 14.97

Calculated U Value = 0.067

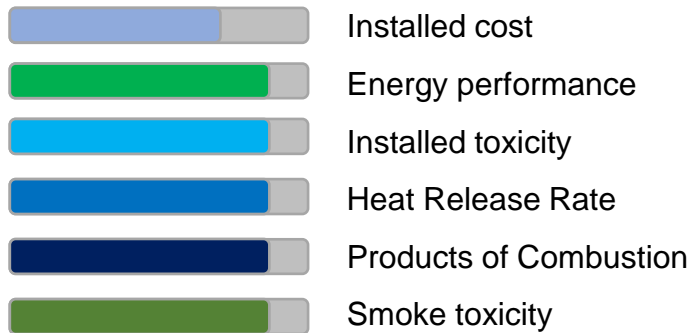


## Assembly Performance





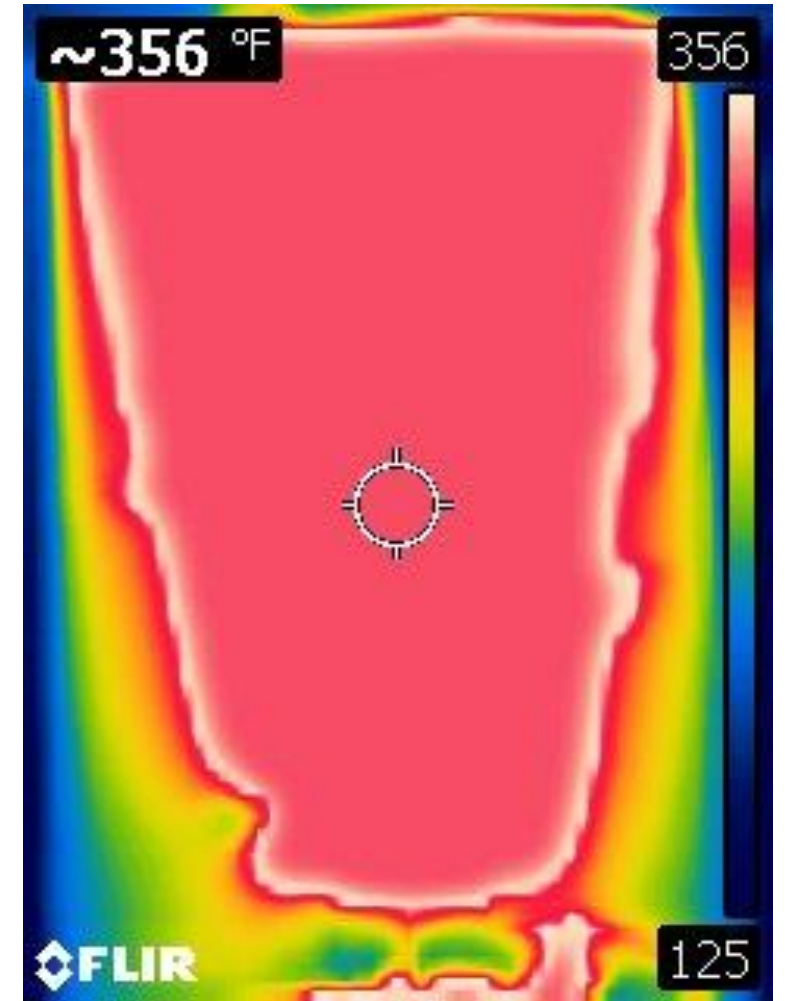
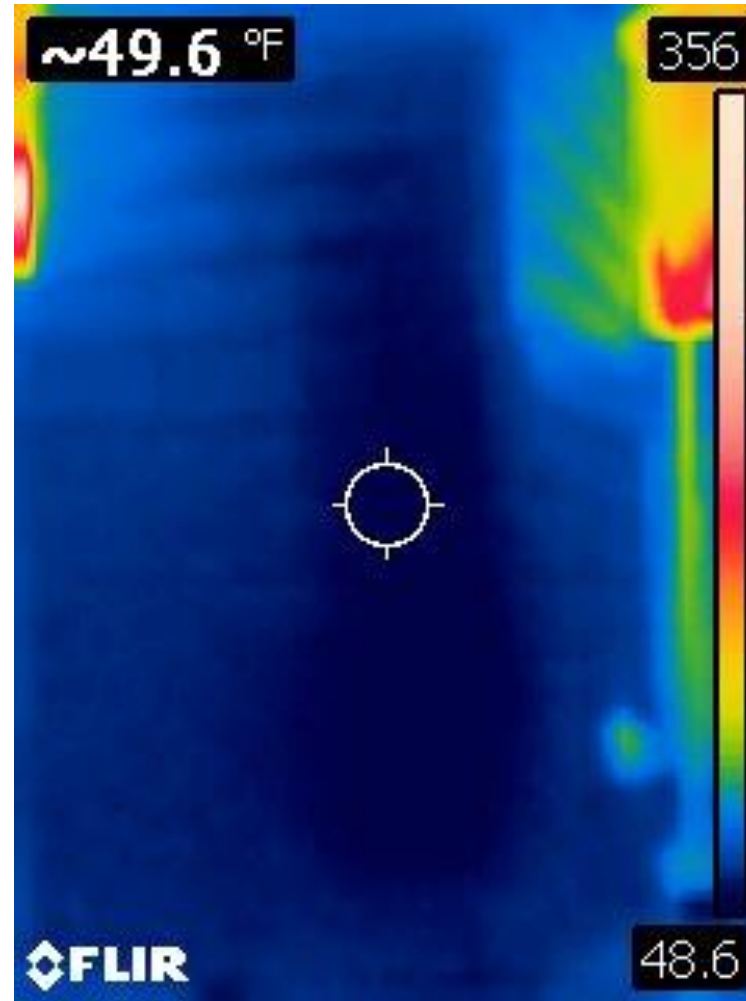
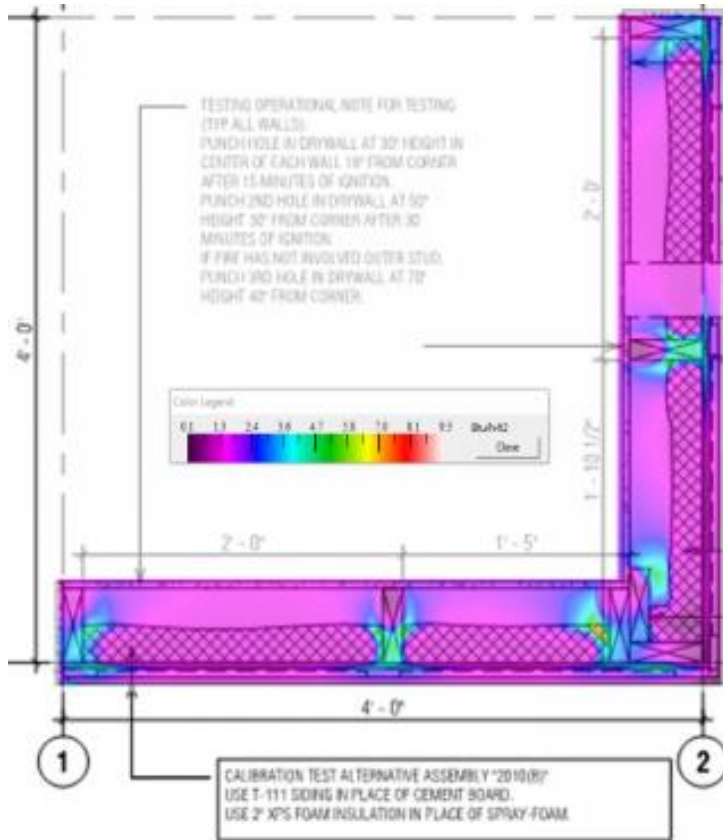
- 2x6 std. studs @ 24"
- Spray Foam Insulation
- Plywood
- House Wrap
- Cement lap siding



# 2010s Wall Framing

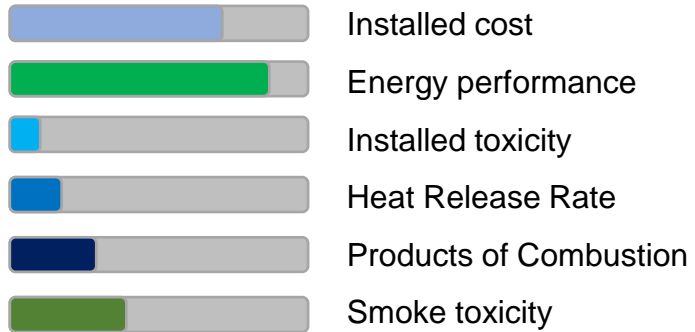
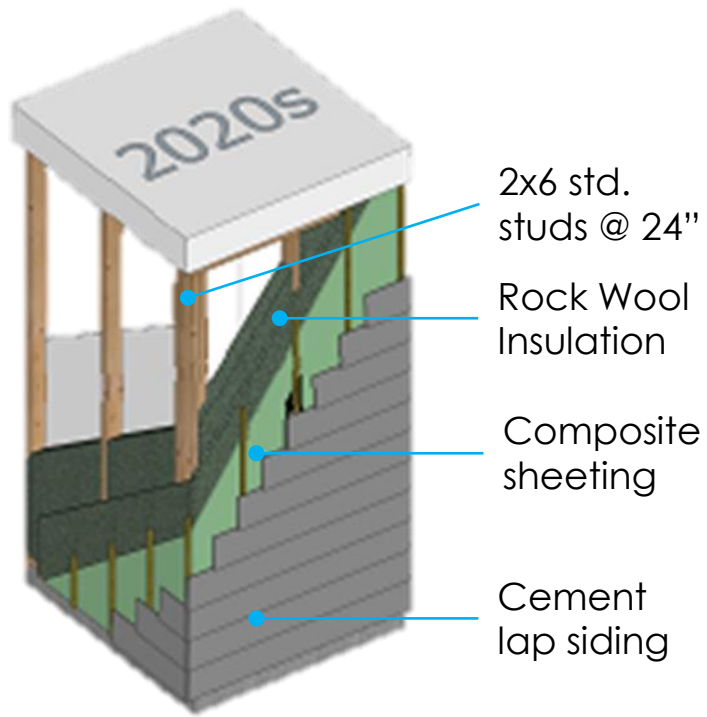
Calculated R Value = 10.05

Calculated U Value = 0.099



# Assembly Performance



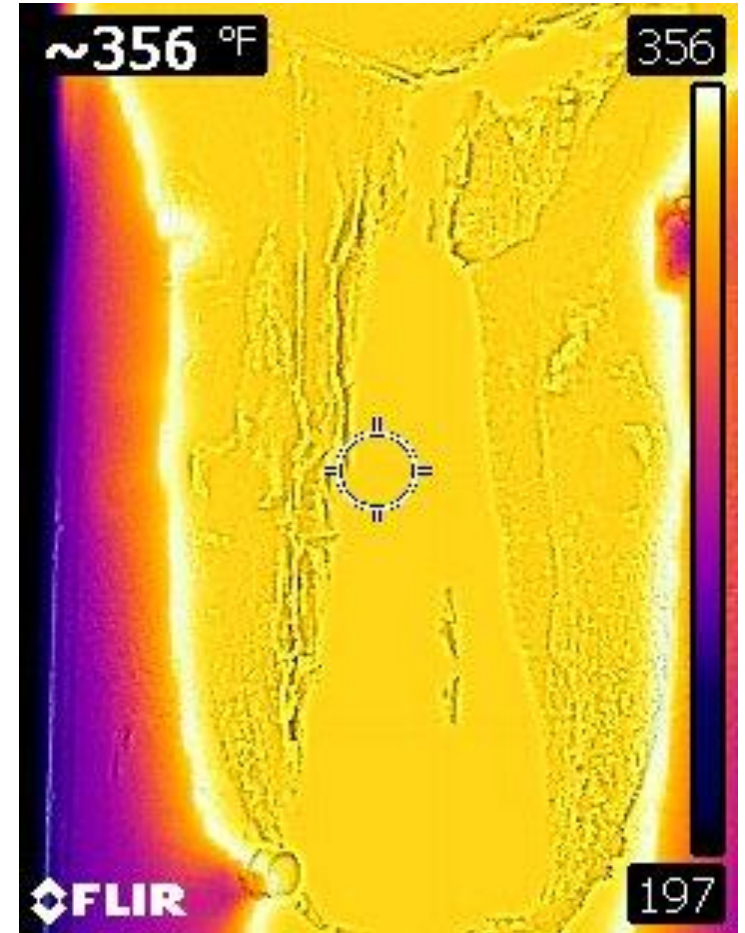
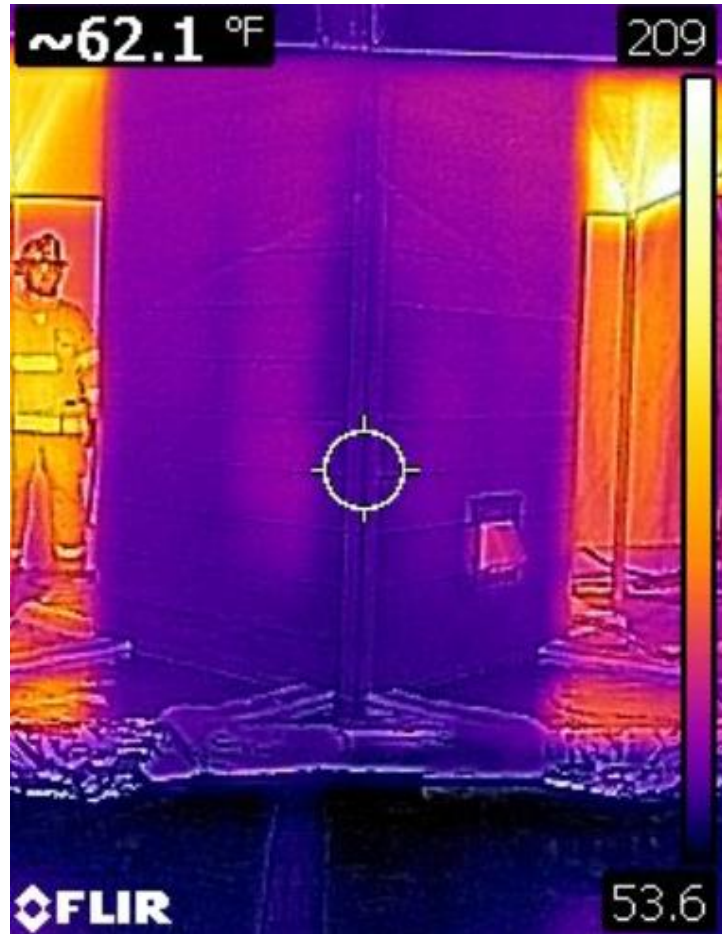
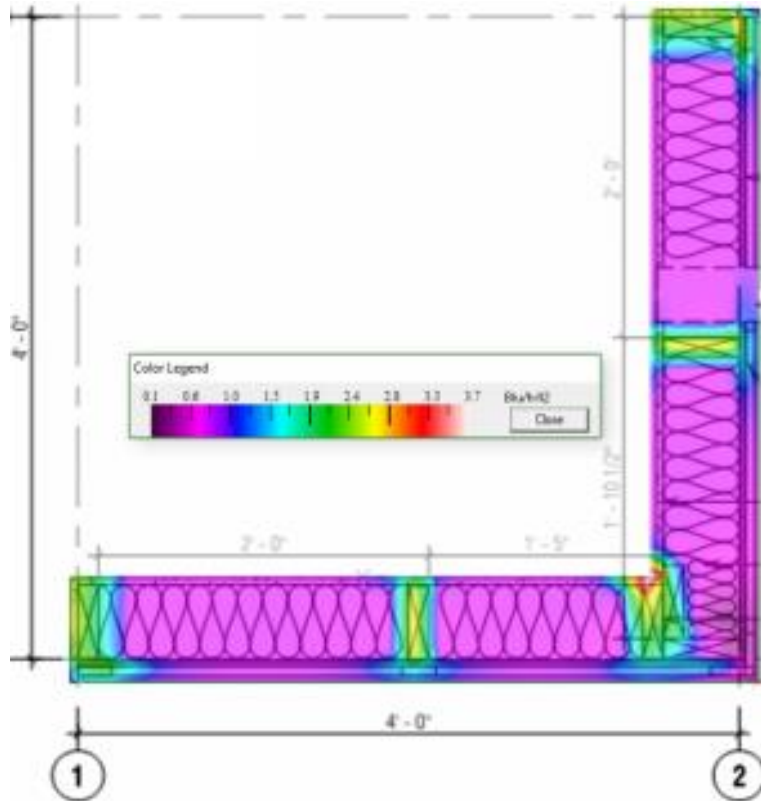




## 2020s Wall Framing

Calculated R Value = 17.38

Calculated U Value = 0.057



## Assembly Performance



INSTALLED COST



ENERGY PERFORMANCE



INSTALLED TOXICITY



HEAT RELEASE RATE

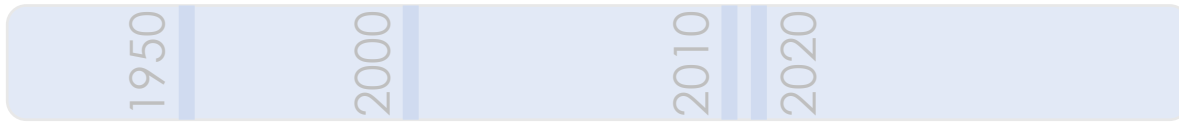


PRODUCTS OF COMBUSTION



SMOKE TOXICITY

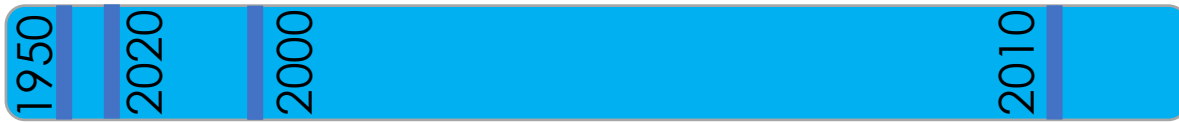
# Assembly Multi-Attribute Comparison



INSTALLED COST



ENERGY PERFORMANCE



INSTALLED TOXICITY



HEAT RELEASE RATE



PRODUCTS OF COMBUSTION

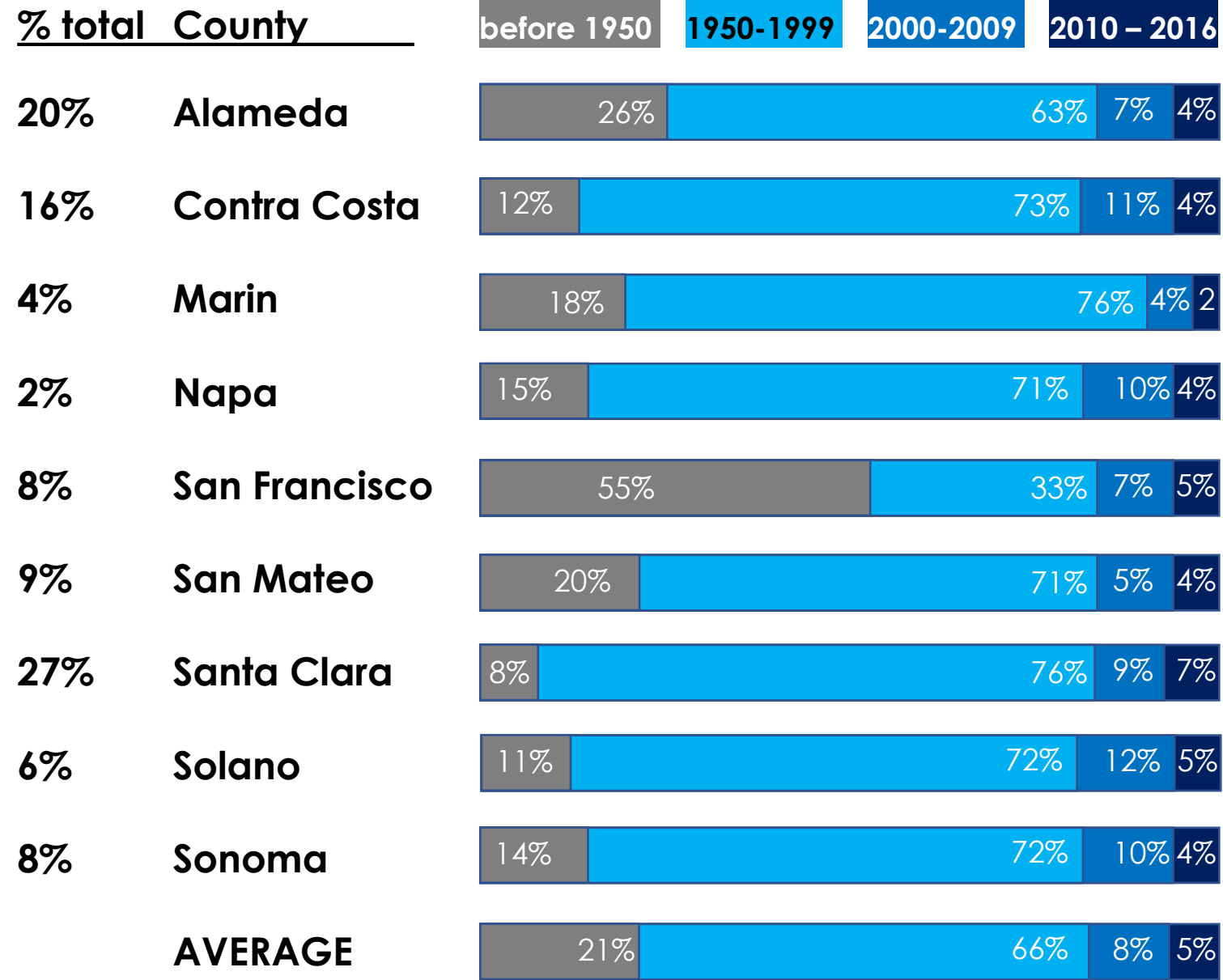


SMOKE TOXICITY

# Assembly Multi-Attribute Comparison



# Bay Area Housing





# 4. THE NEXT STEPS

## Setting a replicable standard

1. Grow the conversation
2. Refine testing methodology, working with UL/ASTM and Lab
3. Begin work with LEED, WELL, LBC to address this gap in systems
4. Start with pilot/innovation credit approach

**Where do we go from here?**

# AUDIENCE QUESTIONS



# Contact Information

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