BCxA® Building Commissioning Association

# Integrating Efficiency, IAQ, and Comfort in Building Performance

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# Course Description

Buildings have evolved from simple shelters to complex systems requiring integration of energy efficiency, indoor air quality, and sustainability goals. This session outlines the progression of building design and highlights the growing role of indoor air quality programs. It will present a practical methodology for managing design, installation, testing, and operations in today's increasingly interconnected building environment.

# Learning Objectives

- Discuss the historical evolution of building systems from simple shelters to complex, performance-driven environments.
- Analyze the interrelationship between energy efficiency, indoor air quality, occupant comfort, and sustainability goals.
- Evaluate the importance of indoor air quality programs in advancing high-performance building design and operations.
- Apply a structured methodology for managing design, installation, testing, and operations in interconnected building systems.

# Building Evolution through Ventilation to HVAC

1. Prehistoric – 1800 – Buildings proceed from caves to structures with limited ventilation and independent functionality
2. 1800-1920 – Electricity and lights and fans
3. 1880 – 1950 – Air conditioning invention and development
4. 1940 – 1980 – Multiple function  systems developed with controls and related testing
5. 1980 – 1990 – System complexity advanced along with system integration  and related automation functions
6. 1990 – 2025 – Buildings and systems design and performance advanced to respond to various programs to respond to external stimulation

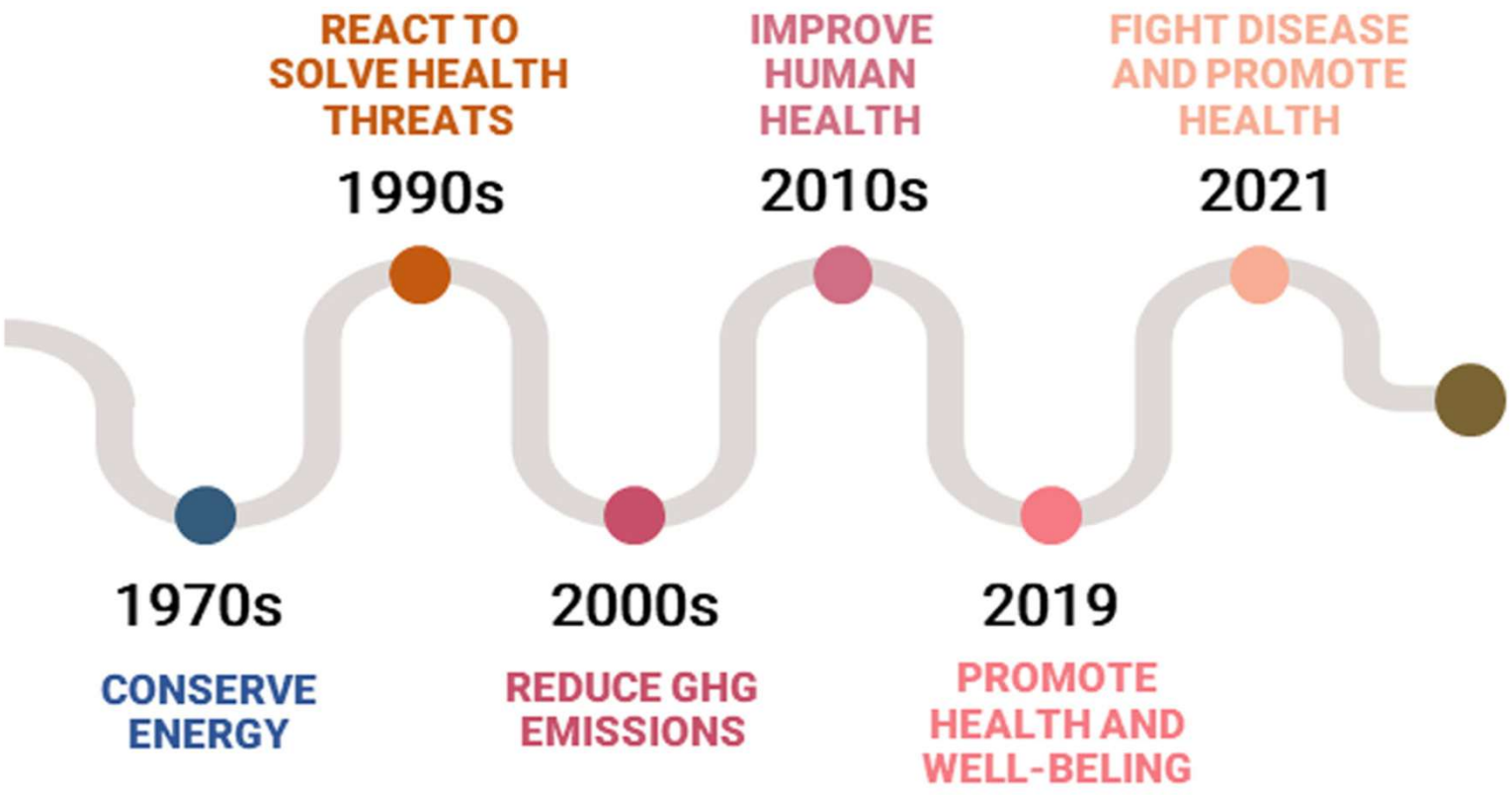
# Evolution of Programs Affecting Building Systems

| Period | Situation | Programs |
|---|---|---|
| 1980's | Energy Crisis | EPA-Energy Star, Ventilation Standards, IAQ Industry |
| 1990's | "Green" = Sustainability Movement, Recycling | LEED, TRUE Program, Green Globes |
| 2000's | Global Warming, Climate Change, Energy Usage Reduction, Atmospheric Contamination & Health Situations, Carbon Reduction | WELL Building, NET ZERO Programs, Updating Existing Programs, Research programs and equipment advances,2030 Challenge |

# Program Development

| Time Period | Situation | Program Examples |
|---|---|---|
| 1990-2010 | Energy Conservation, Sustainability | Energy Star, LEED, Green Globes Building Codes |
| 2010's | Building Performance, Net Zero, Carbon Reduction | Living Building, Passive House, Industry, and Government Programs |
| 2020's | Building Occupant Health Pandemic – Covid 19, Occupant Programs, Building Technical Performance, Computerization & Communications | ASHRAE, CDC, EPA, WELL Building, FITWELL, RESET |

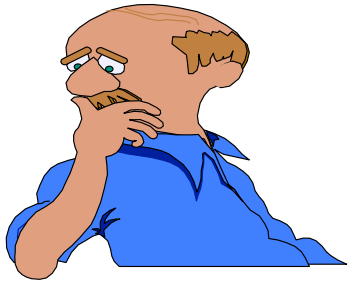
# Summary of Program Development



# National Building Codes & Green Building Certifications

| | |
|---|---|
| ICC Building Codes | Building, Mechanical, Plumbing, Electrical |
| ICC Energy Codes | Energy Code (IECC-2024) - Relates to ASHRAE Standard 90.1-2022 |
| ICC Green Codes | International Green Construction Code (IGCC-2024) - Relates to ASHRAE 189.1-2023, Standard for Design of High-Performance Green Buildings |
| Green Building Certification Programs | LEED, Green Globes, WELL, FITWEL, Living Building Challenge, Etc. |

# Building Process Optimization



- Building Performance Requirements Documented
- Design Meets Requirements
- Construction Meets Design Documents
- Systems Tested to Verify Performance
- Operators Trained
- Documentation and Records

# Current Building Design Assemblies & Systems

- Base Building
  - Site
  - Foundations
  - Structures
  - Enclosures
  - Windows
  - Roofing
  - Insulation

- Systems
  - Electrical
  - Air Conditioning and Heating
    - Ventilation-Heat & Cool
    - Pressurization
    - Controls and Monitoring
  - Plumbing
  - Fire Protection
  - Security, Building Access
  - Safety, Fire Alarm
  - Telephone
  - Communications
  - Computer & Connectivity

# Managing Difficulties in the Design, Construction and Operating a Building

Design - architects/engineers

Coordination - construction management

Construction of systems - subcontractors

Communication breakdown

# Management Difficulties

Who provides system coordination and verification, along with the needed reports?

# IECC-2024 Section C402.6.2.3
# Building Envelope Performance Verification

Continuous air barrier verified by code official, registered design professional, or approved agency with:

1. Review of construction documents and supporting data
2. Inspection of air barrier components and assemblies
3. Final commissioning report provided to the owner, identifying deficiencies found during reviews, inspections, and corrective measures taken

# IECC-2024 Section C408
# Maintenance Information & System Commissioning

- C408.1.1 Building Operations and Maintenance Information
  - Provided to Owner in Documents
    - Specifications and designs
    - Manufacturer's information – submittals
    - Programming procedures and data points
    - Installation, maintenance and operation procedures
  - Equipment labeled with title, publication # and location of operation and maintenance (Systems) manual

# IECC-2024 Section C408.2
# Mechanical & SWH Systems Completion Requirements

- Construction documents shall include system operation requirements, commissioning, and completion requirements.
- Commissioning Plan drafted by Commissioning Provider before permit.
- Prior to final inspection, the design professional or approved agency shall provide evidence of mechanical system commissioning and completion to the owner, and to the AHJ if requested.

# IECC-2024 Section C408.2
# Maintenance Information & System Commissioning

- C408.2.1 Commissioning Plan:
  - Provided by Design Professional or Approved Agency
  - Include narrative description of Cx activities and team
  - Include list of specific equipment and required tests
    - Some system sizes excluded
  - Functions to be tested includes calibrations and economizers
  - Include testing conditions
  - Include measurable criteria for performance

# IECC-2024 Section C408.2
# Maintenance Information & System Commissioning

- C408.2.2 Systems Adjusting and Balancing
  - **HVAC Systems balanced** to accepted industry standards
  - **Air Systems balancing** – each air outlet and terminal is equipped with means for balance per the Mechanical Code
  - **Hydronic Systems balancing** – individual heating and cooling coils equipped with means for balancing and measuring flow.
  - **Written test and balance report required**
    - Reviewed by Cx Provider, Included in Systems Manual, Available to Building Official

# IECC-2024 Section C408.2
# Maintenance Information & System Commissioning

- C408.2.3 Functional Performance Testing Required
  - Demonstrate installation and operation to approved plans and specifications, including all modes and sequences of operation
  - Control systems tested to document calibration and adjustment to operate according to approved plans
  - Economizers to undergo functional tests

# IECC-2024 Section C408.2
# Maintenance Information & System Commissioning

- C408.2.4 Preliminary Commissioning Report
  - Required **prior to project final** inspection and CO
  - **Test results** provided to building owner
  - Provided by Design Professional or Approved Agency
  - **Include performance test procedures** used, including measurable criteria for acceptance.
  - **Include itemization of deficiencies** not corrected
  - **Include deferred test** with climatic conditions required for final testing
  - **Include results of functional performance tests**

# IECC-2024 Section C408.2
# Maintenance Information & System Commissioning

- C408.2.5.2 Final Commissioning Report
  - **Provided to Owner** within 90 days of project CO
  - Final **test and balance** report
  - Report of **test procedures**
  - Results of **functional performance tests**
  - Disposition of deficiencies, including corrective measures

# IECC-2024 Section C408.3
# Lighting System Commissioning

- Testing and reports include:
  - Occupancy sensors
  - Time switch controls
  - Daylight responsive controls
  - Drawings and O&M manuals
  - Reports

# IECC - 2024 – Chapter 5 Existing Buildings

- C502 Additions shall conform to new construction requirements
- C503 Alterations shall comply with new construction requirements with some variations
  - New HVAC, hot water, and lighting systems in additions and alterations shall comply with new construction requirements
- C504 Repairs not normally required to comply
- C505 Change in Occupancy requires IECC compliance if energy use is increased

# Building Energy Systems and Conservation

- Factors that impact the usage and thus the cost of energy for a building
  - Owner's requirements
  - Design and location
  - Occupancy and usage
  - Usage schedules
  - Types of mechanical equipment and controls
  - Types of lighting and controls
  - Building a central control system – usually computerized
  - Equipment and processes that use power
  - Electrical power systems and supply source
  - Effectiveness of installation verification process
  - Maintenance processes and effectiveness
  - Green building systems if used = LEED, WELL Building, Fitwell, and others

# Energy Cost Factors for Building

- Local building codes for enclosures and systems
- Types of building systems
- Local energy supplies
- Energy and related cost
- Local weather conditions
- Requirements of energy-using processes in building
- Occupant requirements and preferences

# Opportunities for Energy Use Reduction

- Equipment types, set up, scheduling
- Energy supply availability, contract options, and incentives
- Type of energy utilized
- Building Interior conditions

# AIR: What is it and why is it important to buildings

Air is a fundamental necessity for human survival.

Air consists mostly of Oxygen and Nitrogen and often small portions of other materials that can cause problems for humans and materials.

The human body requires a basically continuous supply of clean air to breathe.

# AIR: What is it and why is it important to buildings

American adults spend about 90% of their time in buildings, and air is important to their comfort and health.

Monitor systems that sense and report air conditions in multiple areas.

These systems need to be designed into the building systems along with verification of their operation before occupancy.

# Providing Interior Building Conditions for Performance
# What is “Good Air Quality”?

INDOOR CARBON DIOXIDE - ASHRAE position paper on Feb 12, 2025

- 1,000 PPM of CO2 inside a building – not cited as an absolute level for all spaces
- Can be used for monitoring and building ventilation

The USEPA NAAQS for the United States

- Potential Limits for Carbon Monoxide, Lead, Nitrogen Dioxide, Ozone, Particulate Matter, Sulfur Dioxide

# Providing Interior Building Conditions for Occupant Performance

- ASHRAE Standard 62.1-2022, Ventilation and Acceptable Indoor Air Quality
- Chapters 62.1 the impact the building performance include:
  - Outdoor Air Quality
  - Systems and Equipment
  - Procedures
  - Construction and Start Up
  - Operations and Maintenance

# Contents in AIR Determine the Quality

| Parameter | Source | Health Risk |
|---|---|---|
| Thermal Comfort | High temperatures & levels of water vapor in the air | Feeling of discomfort |
| Carbon Dioxide | Human exhalation | Impaired cognitive abilities, drowsiness, nausea |
| Particulate matter | Construction, carpeting, wildfires, and cooking | Eye, nose, throat, and lung irritation, coughing, sneezing, runny nose, and shortness of breath |
| Ozone | Outdoor Emissions and some office equipment | Respiratory effects, including shortness of breath and difficulty breathing; aggravating existing lung conditions |
| Volatile organic compounds (VOCs) | Building materials, furnishings, cleaning agents, occupants | Eye, nose, and throat irritation, headaches and nausea, loss of coordination, fatigue, dizziness allergic skin reactions; severe long-term risks |

# Typical Causes of Air Quality Problems

| Category | Examples | Air Pollutants |
|---|---|---|
| Building Components | Paints, caulking | VOCs, Particulates |
| Mechanical Systems | Chemicals, Operation | VOCs, particulates |
| Furnishings | Carpets & textiles, deteriorated furniture | VOCs, particulates |
| Office equipment | Printers, copiers | Ozone, VOCs |
| Supplies | Solvents, toner, ammonia | VOCs |
| Cleaning, Housekeeping | Air fresheners, cleaning wipes, trash, airborne dust | VOCs, particulates |
| Maintenance | Paints, caulk, adhesives | VOCs |
| Pest control | Pesticides | VOCs, particulates |
| Occupants | Deodorants, cosmetics, clothing, and work activities | VOCs, particulates, mold, biological |
| Food, snacks | Food service areas, snacks | VOCs, particulates, mold |

# Air Quality Solutions

- Building and system designs
- Material selection
- Construction and maintenance/cleaning
- Control and monitoring systems
- Verification and testing
- Adjustment of building systems
- Increased outside air ventilation
- Filtration increases
- Change from problem materials

# Air Condition Contaminant Testing

## Test Sets Path 1 - Particulate Matter and Inorganic Gases

| Ambient Condition Levels | Contaminant Method - | Target or Allowable |
|---|---|---|
| Temperature | Electronic Temp. Sensor | 73 +/- 3 Deg. -target |
| Humidity | Electronic RH Sensor | 30-60 % - target |
| Carbon Dioxide | Electronic CO2 Sensor | <900 ppm - target |
| Carbon Monoxide | Electronic CO Sensor | <9 ppm |
| Ozone | Electronic O3 Sensor | <.070 ppm |
| Total Particulates- PM 2.5 | Particle Counter | < 12 PM µg/m3 |
| Total Particulates- PM 10 | Particle Counter | < 50 PM µg/m3 |

# Air Condition Contaminant Testing

Test Sets Path 2 – Volatile Organic Compounds

| Ambient Condition/ Contaminant | Method - | Target or Allowable Levels |
|---|---|---|
| **Total Volatile Organic Compounds** | Multisorbent Sampler | < 500 µg/m$^3$ |
| **Formaldéhyde** | Aldéhyde DNPH Sampler | < 20 µg/m$^3$ |
| **Acétaldéhyde** | Aldéhyde DNPH Sampler | < 140 µg/m$^3$ |
| **Benzène** | Multisorbent Sampler | < 3 µg/m$^3$ |
| **Hexane (n-)** | Multisorbent Sampler | < 7,000 µg/m$^3$ |
| **Naphtalène** | Multisorbent Sampler | < 9 µg/m$^3$ |
| **Phénol** | Multisorbent Sampler | < 200 µg/m$^3$ |
| **Styrène** | Multisorbent Sampler | < 900 µg/m$^3$ |
| **Tétrachloroéthylène** | Multisorbent Sampler | < 35 µg/m$^3$ |
| **Toluène** | Multisorbent Sampler | < 300 µg/m$^3$ |
| **Vinyl Acétate** | Multisorbent Sampler | < 200 µg/m$^3$ |
| **Dichlorobenzene (1,4-)** | Multisorbent Sampler | < 800 µg/m$^3$ |
| **Xylenes-total** | Multisorbent Sampler | < 700 µg/m |

# Building Air Quality Importance

THE IMPACT OF BUILDINGS ON
COGNITIVE FUNCTION

Buildings as a powerful tool for
HEALTH AND PRODUCTIVITY

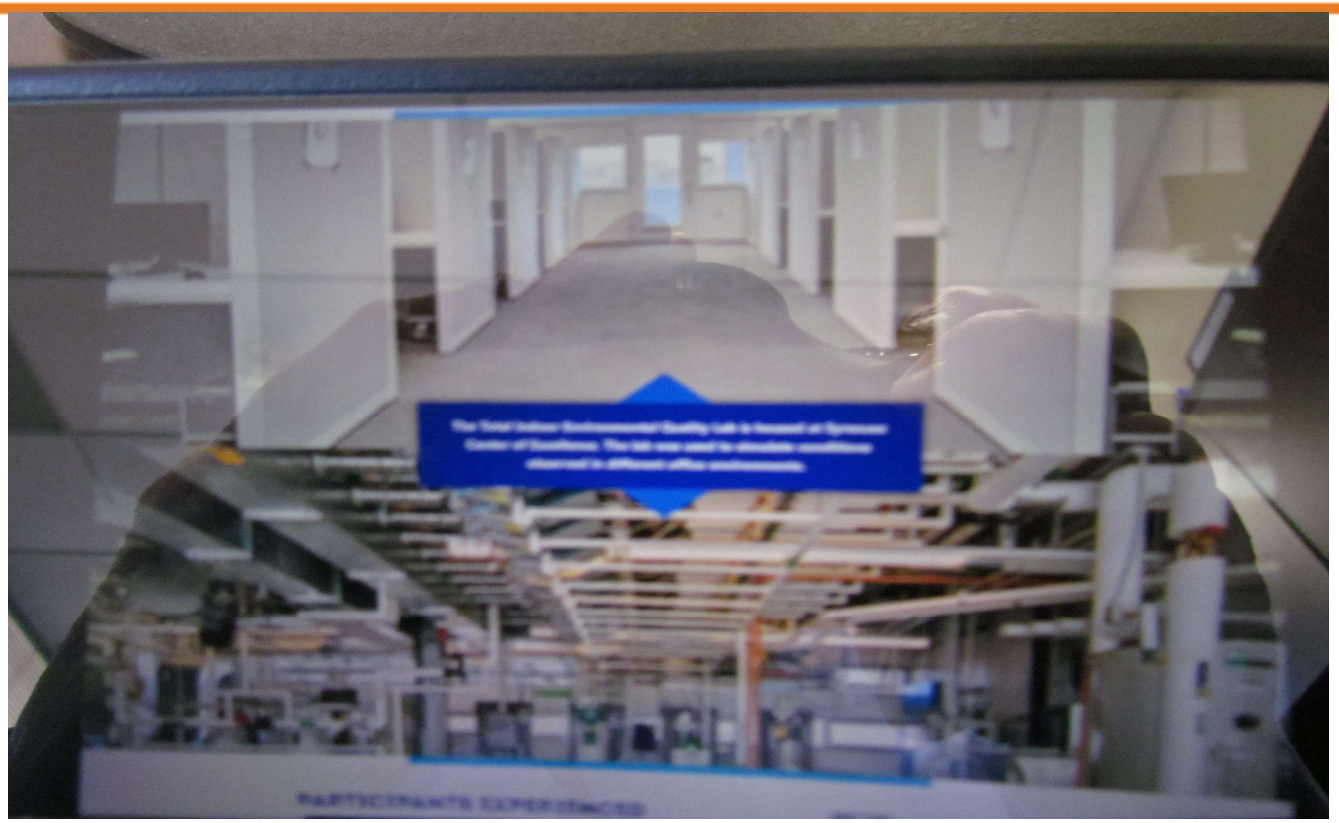
# Air Quality as a Factor in Productivity and Efficiency

## AIR QUALITY AND COGNITIVE FUNCTION BY DOUBLING VENTILATION

Following the release of The COGfx Study, which showed dramatic impacts of ventilation on cognitive function, the research team sought to evaluate the economic and environmental costs against the health and productivity benefits of enhanced ventilation in office buildings. Studying three ventilation strategies and four different heating, ventilating and air conditioning (HVAC) systems across seven U.S. cities, the team found that the indoor environment previously associated with a doubling of cognitive function test scores can be achieved at an energy cost between $14 and $40 per person per year and result in as much as a $6,500 equivalent in improved productivity per person per year. When energy-efficient technologies are utilized, the study found the energy costs to be between $1 and $18 per person per year, with a minimized environmental impact equivalent to approximately 0.03 cars on the road per building per year.

**CARRIER - HTTPS://THECOGFXSTUDY.COM/**

# HARVARD UNIVERSITY COGFX STUDY

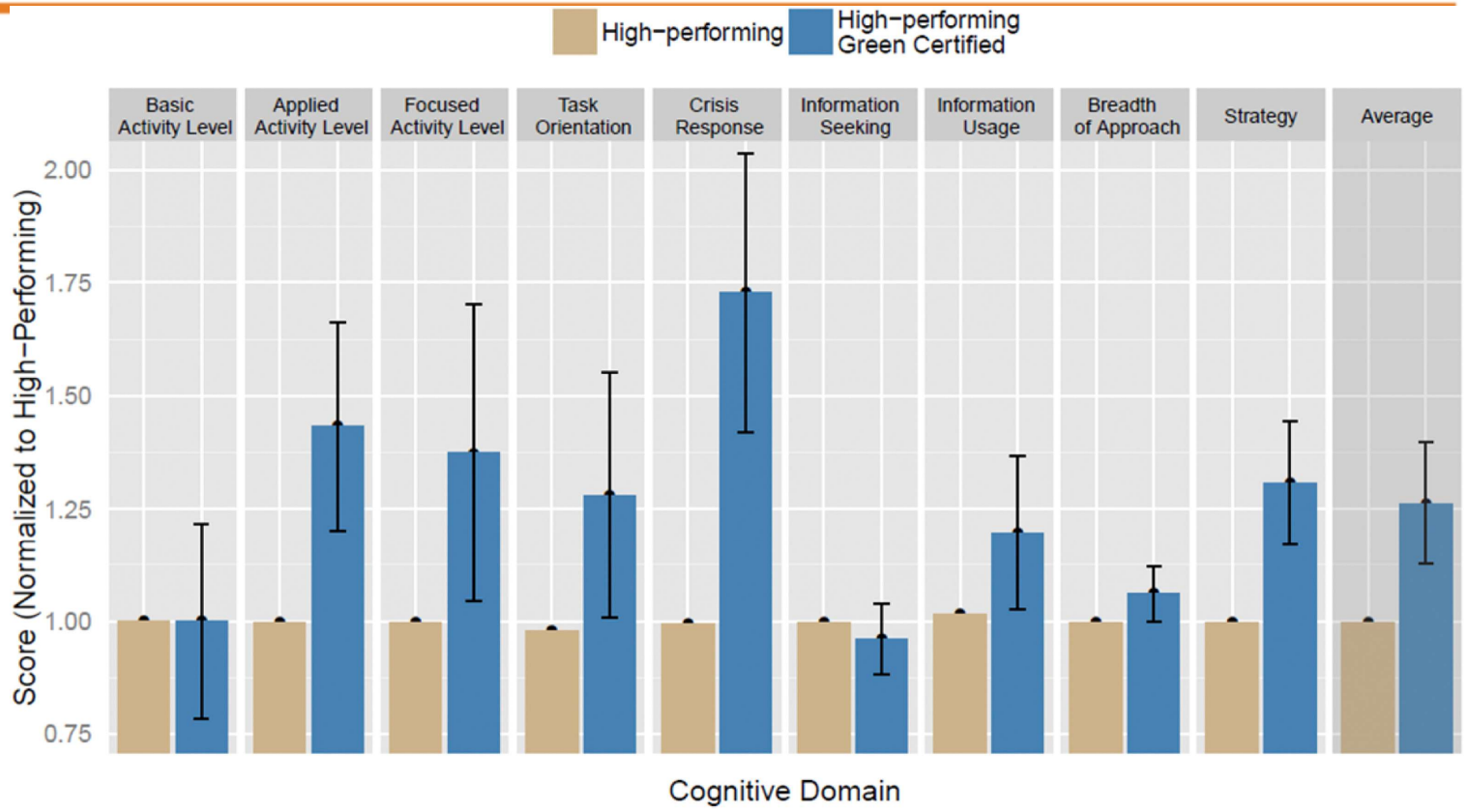


https://healthybuildings.hsph.harvard.edu/research/indoor-air-quality/cogfx/

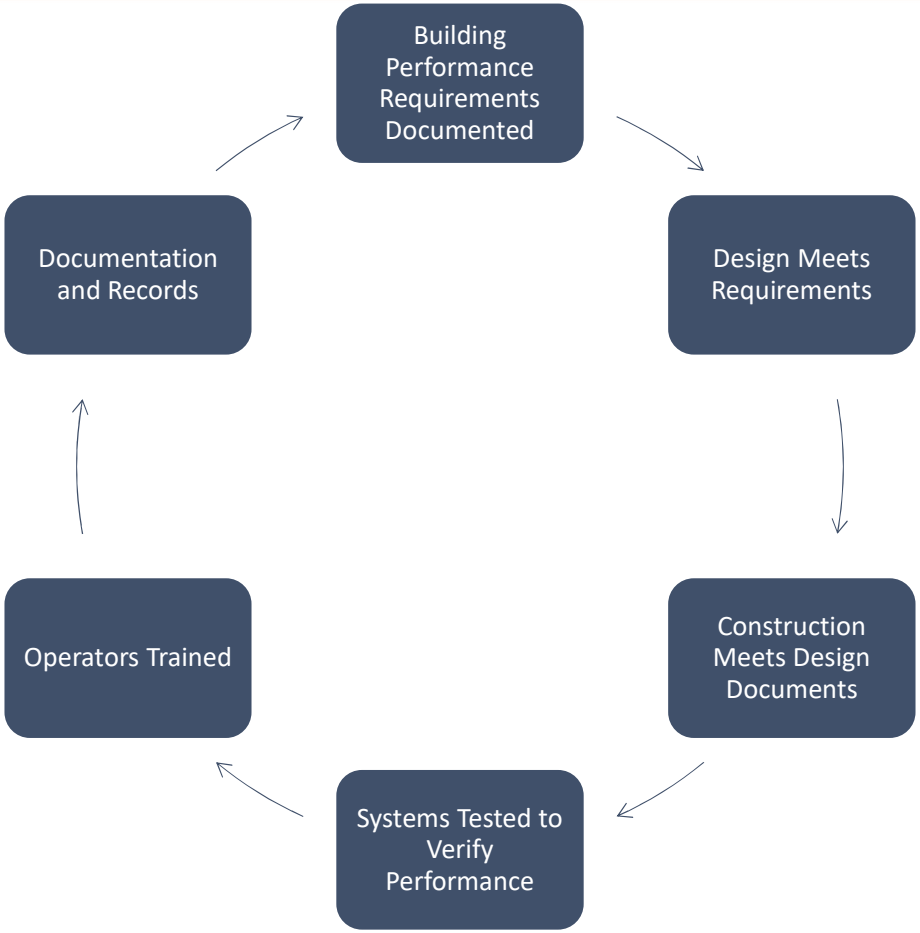
## HARVARD UNIVERSITY COGFX STUDY

- 24 professionals for six days over two weeks
- Multiple tests for building types
- Domain occupant evaluations
- Results Green Buildings 61% Higher
- Enhanced Green Buildings 101% Higher

# HARVARD UNIVERSITY COGFX STUDY



# Verification - Who's Job is It Anyway?



# Commissioning Provider

## Commissioning Definition

A quality-focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements.

(ASHRAE Std. 202-2024)

# Questions – Comments

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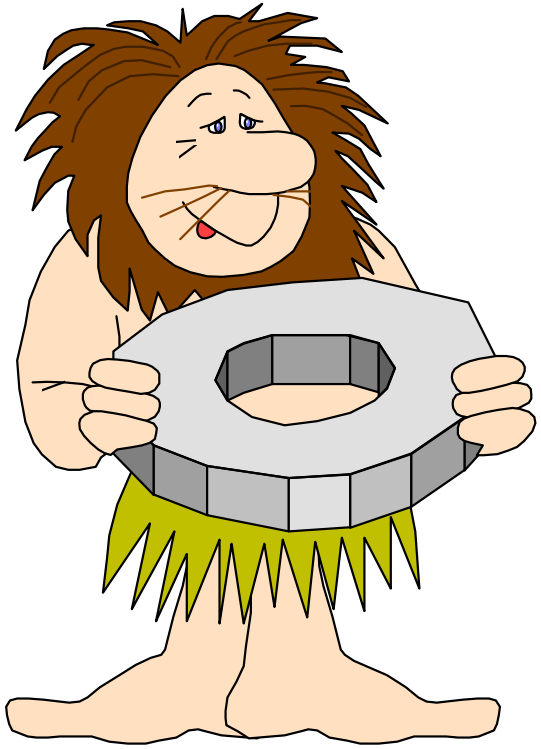

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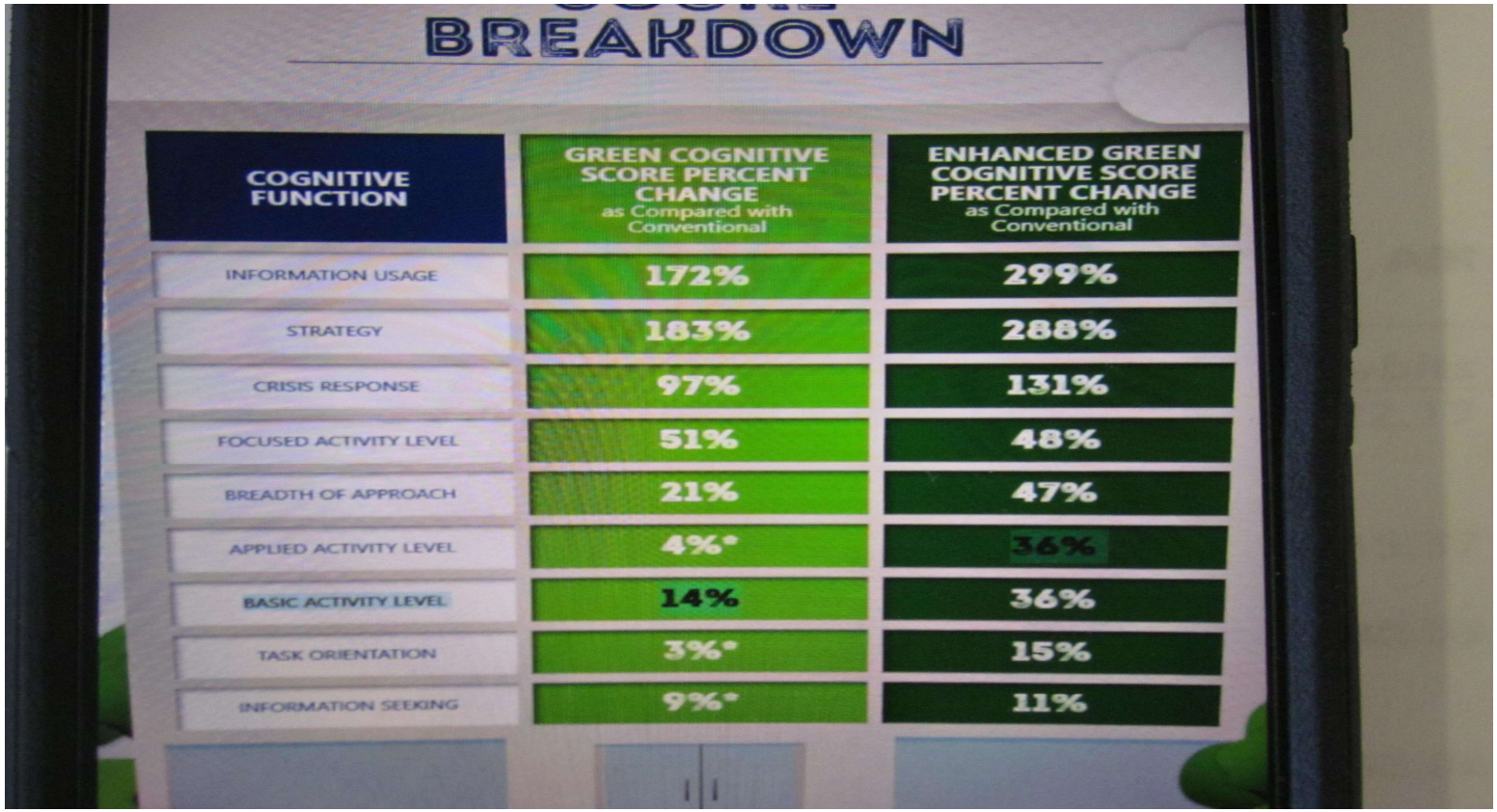

BREAKDOWN

| COGNITIVE FUNCTION | GREEN COGNITIVE SCORE PERCENT CHANGE as Compared with Conventional | ENHANCED GREEN COGNITIVE SCORE PERCENT CHANGE as Compared with Conventional |
|---|---|---|
| INFORMATION USAGE | 172% | 299% |
| STRATEGY | 183% | 288% |
| CRISIS RESPONSE | 97% | 131% |
| FOCUSED ACTIVITY LEVEL | 51% | 48% |
| BREADTH OF APPROACH | 21% | 47% |
| APPLIED ACTIVITY LEVEL | 4%* | 36% |
| BASIC ACTIVITY LEVEL | 14% | 36% |
| TASK ORIENTATION | 3%* | 15% |
| INFORMATION SEEKING | 9%* | 11% |