U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# Compressed Natural Gas (CNG) Vehicle Maintenance Facility Modification Handbook

Clean Cities

U.S. Department of Energy

December 7, 2017

# Webinar Agenda

## CNG Vehicle Maintenance Facility Modifications

| Topic | Speaker |
|---|---|
| Welcome Remarks | Dennis Smith,<br>U.S. Department of Energy |
| Basic Properties of CNG and Indoor Release Modeling Research | Myra Blaylock,<br>Sandia National Lab |
| CNG Vehicle Maintenance Facility Modifications Handbook Overview | Bob Coale and Jarrod Kohout,<br>Gladstein, Neandross & Associates |
| Best Practices for Working with Local Codes Officials | John Gonzales and Kay Kelly,<br>National Renewable Energy Lab |
| Audience Q&A Session | All |

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# Compressed Natural Gas (CNG) Vehicle Maintenance Facility Modification Handbook


Dennis Smith

Technology Integration Program

Vehicle Technologies Office

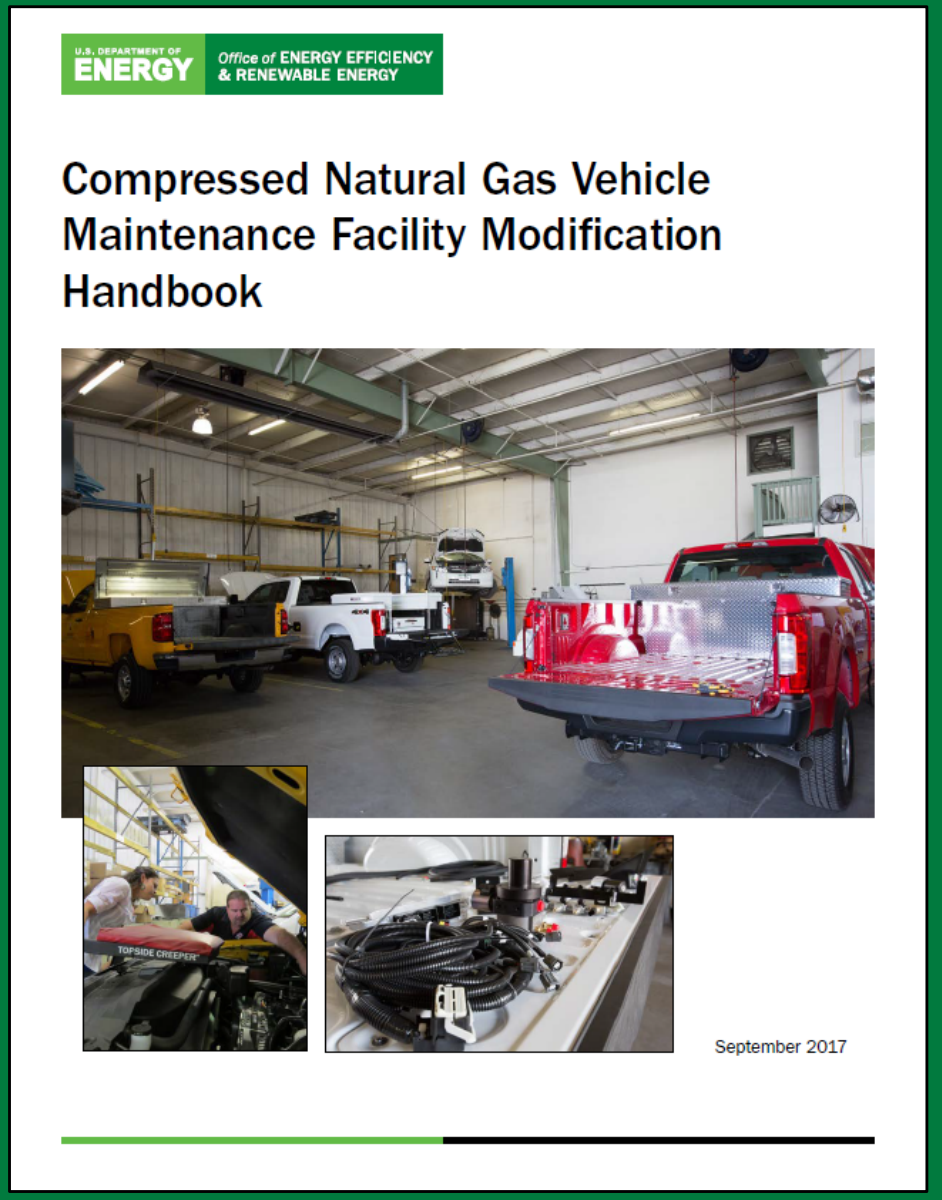

December 7, 2017

Clean Cities

U.S. Department of Energy

# CNG Maintenance Facility Modification Handbook

- Released September 2017
- Involved extensive collaboration with fleets and industry
- Responds to recurring questions received by Technical Assistance requesting help in locating, deciphering and complying with CNG facility codes



# Additional Training Resources

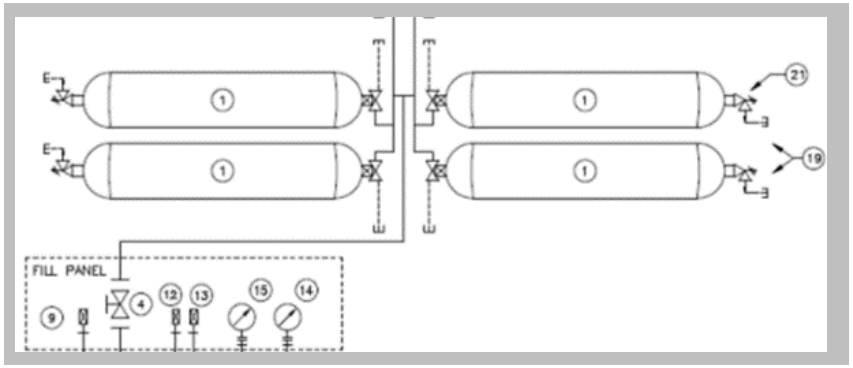
- **Alternative Fuel Vehicle Workplace Safety Programs (2016 DOE Funding Opportunity)**
  - **Gas Technology Institute (GTI)** will create training and guidance materials for garage facility upgrades and building modifications for facilities that service natural gas, propane, and hydrogen vehicles.
  - **Marathon Technical Services USA, Inc.** will develop a unified reference guide of design requirements, and provide in-person training and tours that showcase best practices for garage/maintenance facilities that service natural gas, propane, and hydrogen vehicles.

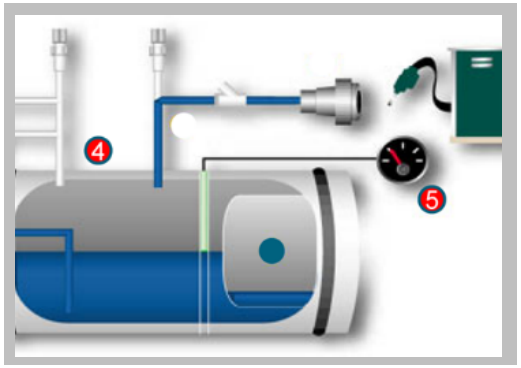
# Basic Properties of CNG and Indoor Release Modeling Research

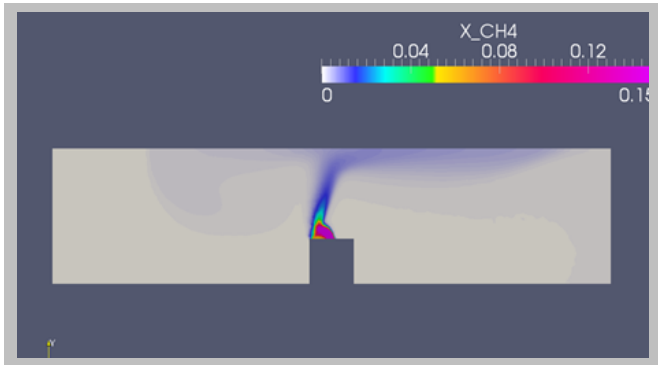
## Sandia National Lab

*Exceptional service in the national interest*

Sandia National Laboratories






# Natural Gas Vehicles Facility Analysis

## Project sponsored by DOE Clean Cities:

## Technical & Analytical Assistance

Myra Blaylock, PhD

Sandia National Laboratories

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National Nuclear Security Administration

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SAND NO. 2017-13311 PE

# SNL Project Motivation

- Improve **codes and standards** for gaseous fuel vehicle **maintenance facility** design and operation to reflect technology advancements

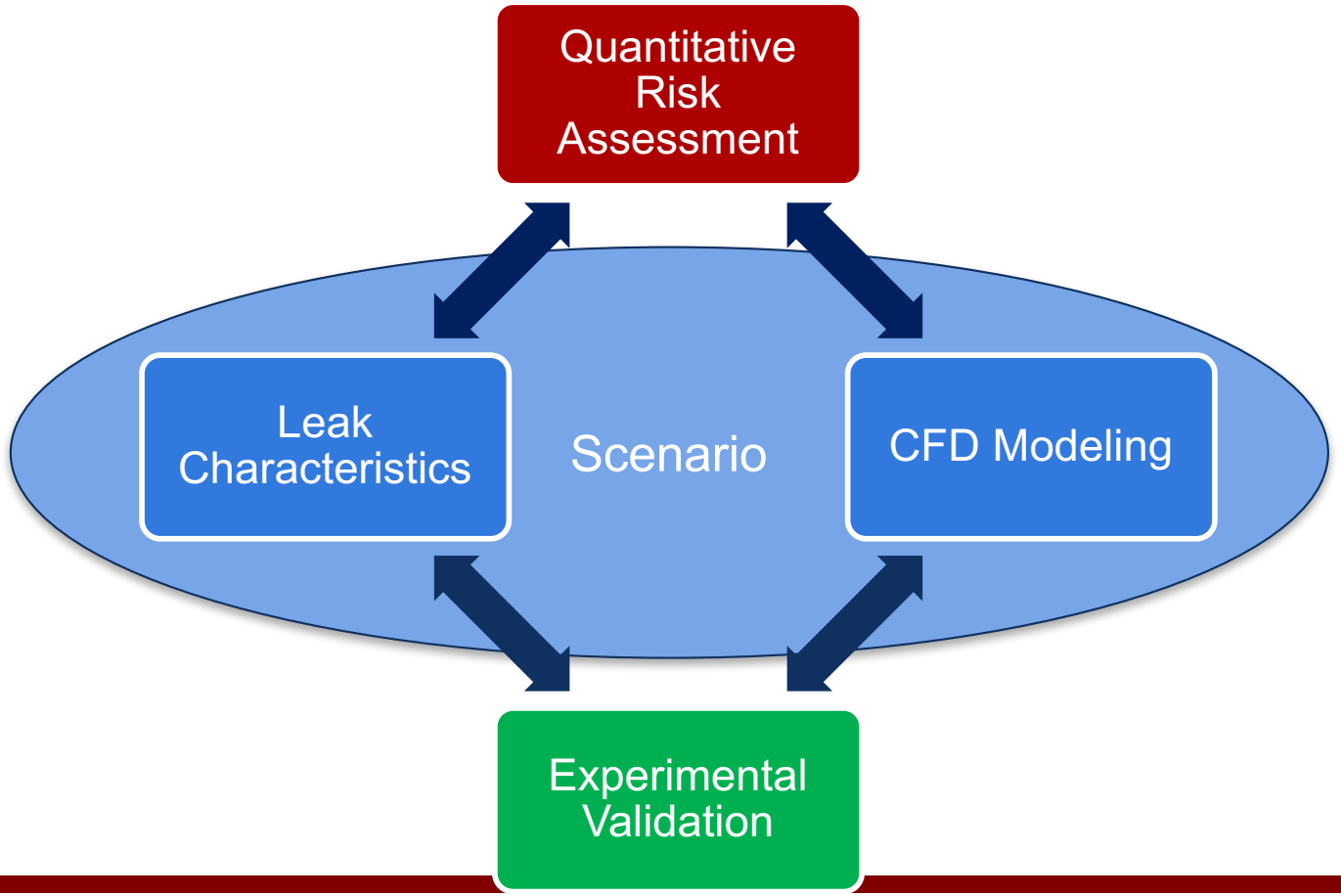





Image: http://www.energyburrito.com/tag/natural-gas-vehicles/

# CNG Properties

- Density: lighter than air
  - 0.56 kg/m$^3$ compared to 1.225 kg/m$^3$
- Flammability Range:
  - 5% to 15% by volume
- Typical Tank Size
  - Light Duty: ~350 L at 250 bar (3600 psi)
  - Heavy Duty: ~700 L at 250 bar (3600 psi)
- Typical leak
  - Most likely is a crack in a pipe or hose: ~3 L of fuel
  - Worst case is failed valve to full tank

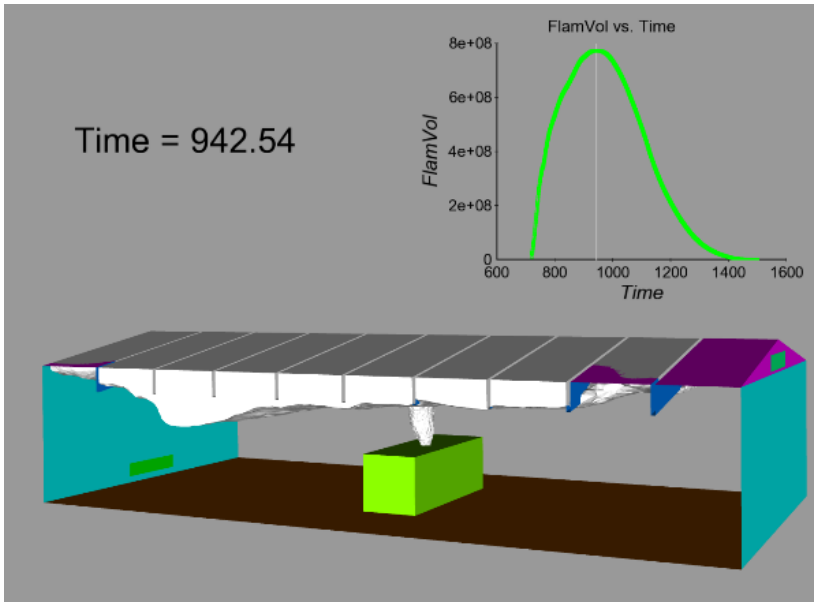



Image: http://www.energyburrito.com/tag/natural-gas-vehicles/

# Addressing Code Issues with Risk Assessment and Modeling

- HAZOP study identified which scenarios are most critical to alleviate and understand better through simulations

- NFPA 30A restricts sources of ignition from areas within 18” of ceiling
  - Based on legacy releases of gasoline



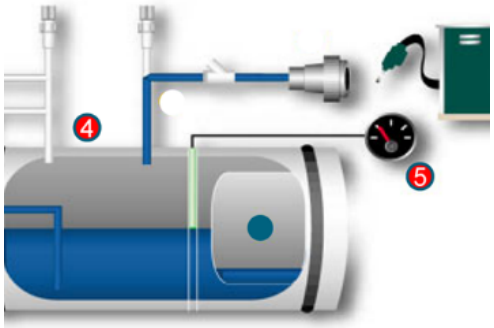

*Modeling demonstrates that simple ceiling stand-off distance does not capture hazardous areas*

# Network Flow Modeling: Upstream of Leak

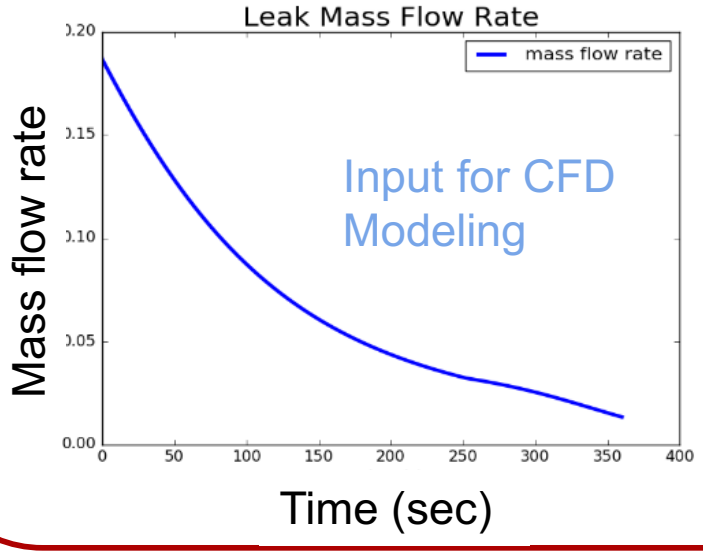
Sandia National Laboratories

Fast transient system analysis

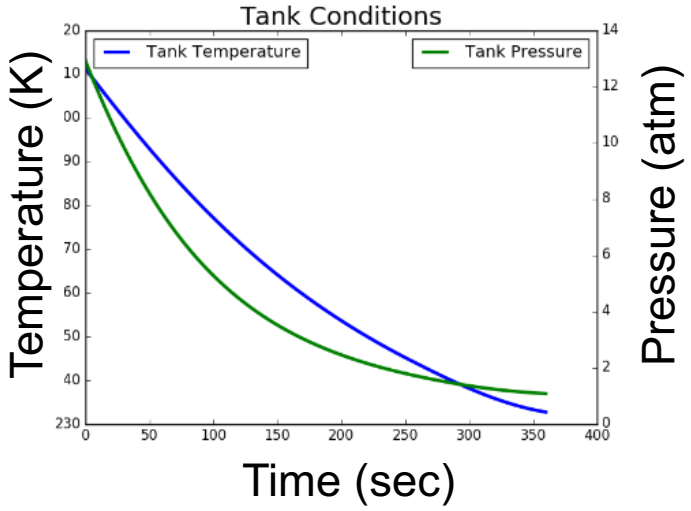
- Models venting/leaks of complex CNG/LNG tank and tubing systems




Generates leak input boundary conditions for CFD modeling




Calculates time required for tank to empty



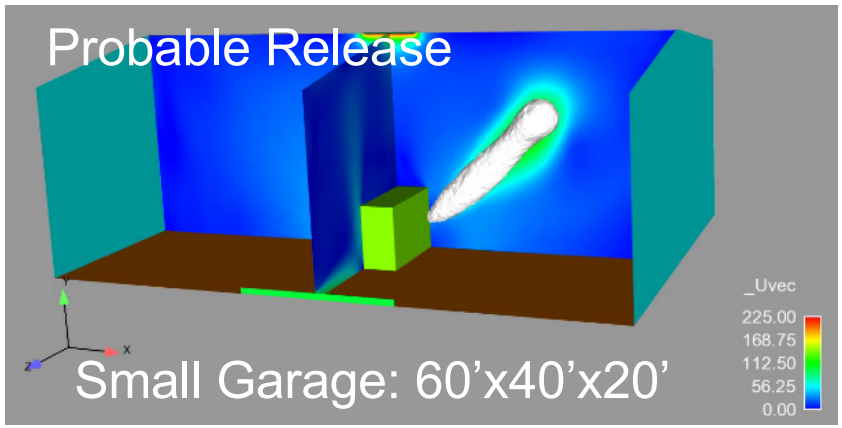

*Fast and accurate modeling of leaking tanks and piping provides high quality CFD boundary conditions*

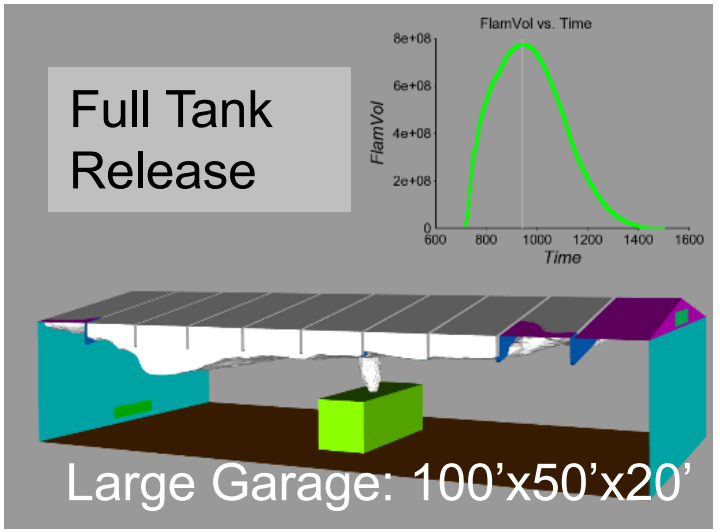
# 3D Computational Fluid Dynamics Modeling

Sandia National Laboratories

Risk Assessment identified several scenarios to model:

- Two sizes of garages
- Leak location and amount
- Presence of ceiling beams: **no significate difference found**
- Ventilation: **reduces but doesn't eliminate flammable concentrations**

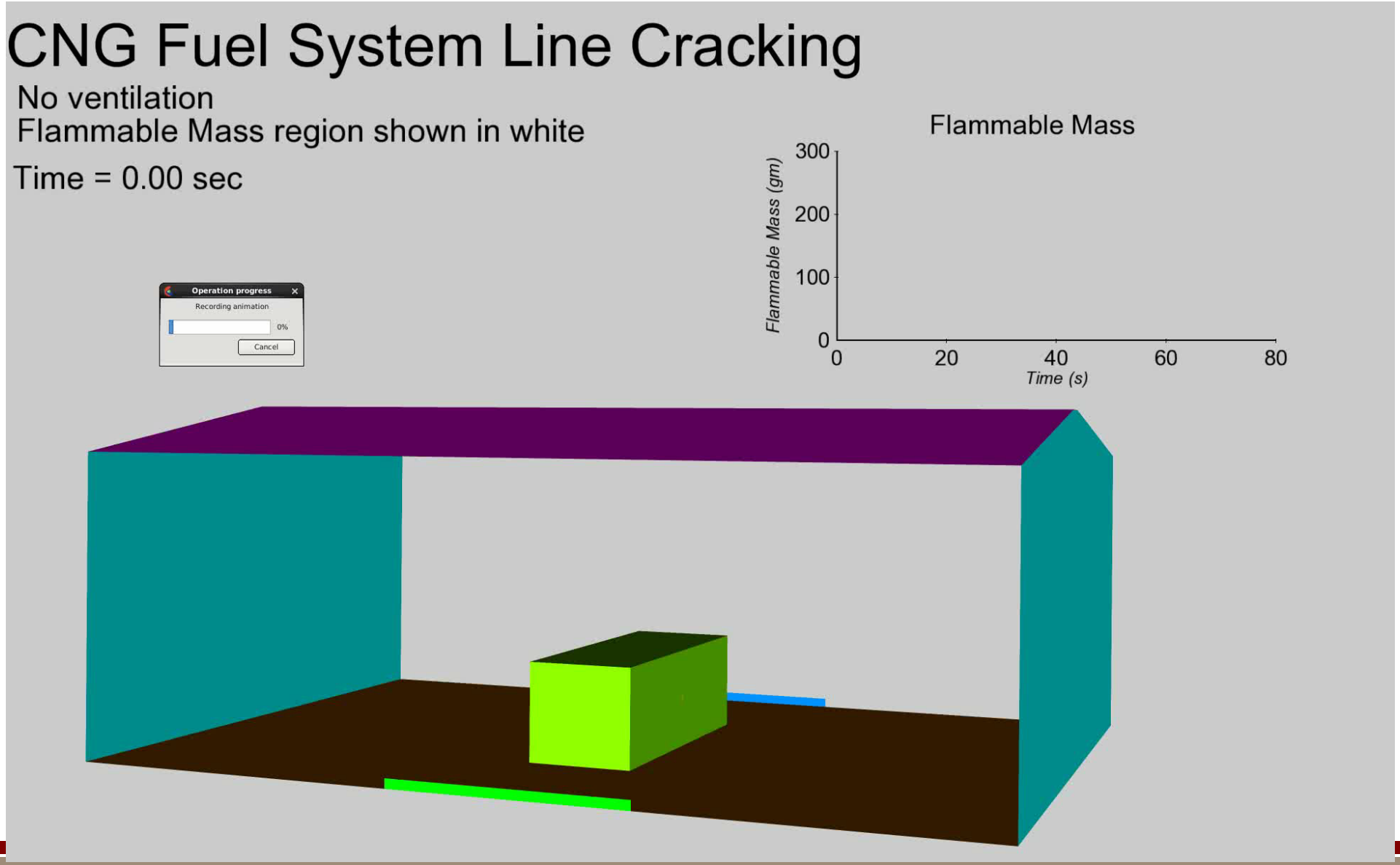



Results indicate that flammable concentrations can occur in regions not protected by NFPA 30A (lower than 18" from the ceiling).
Results can be used to assess sensor placement.

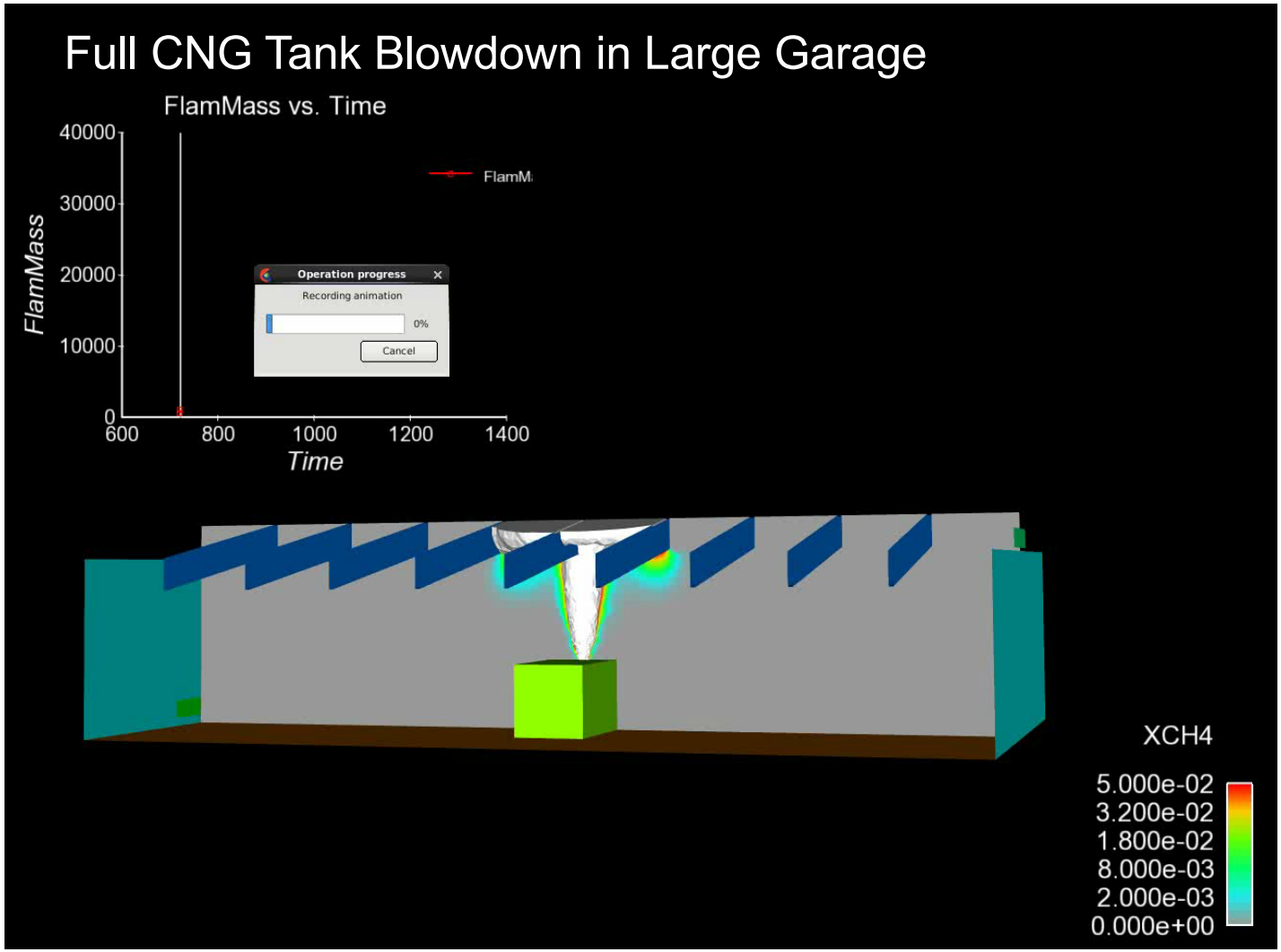
# Where is the flammable gas in a likely scenario?

Sandia National Laboratories



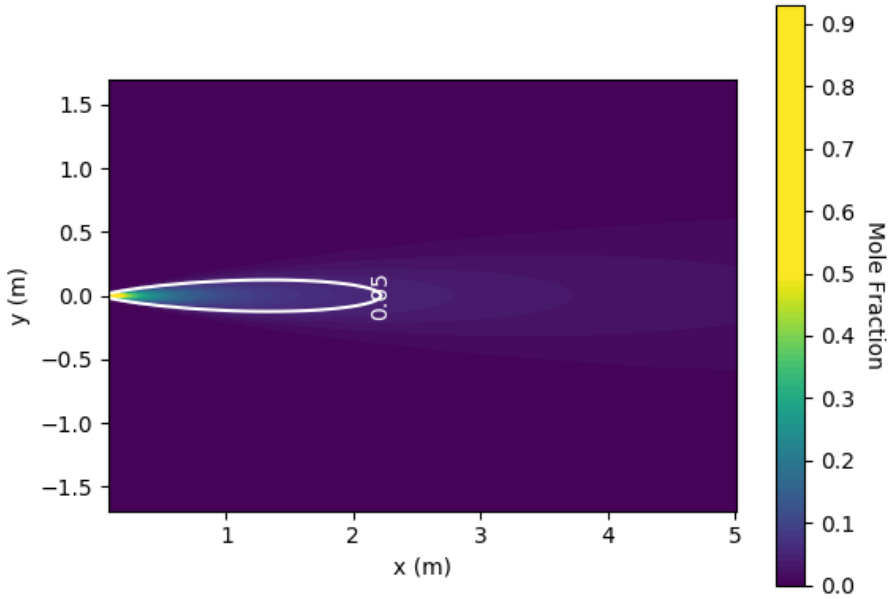
# Can we have beams?
# What does ventilation do?

Answers: Yes. Helps, to an extent



# Plume Modeling

- Analytical solution to get size of plume
- IFC: Depressurize tanks to 250 psi before entering garage



Thank you!

Questions?

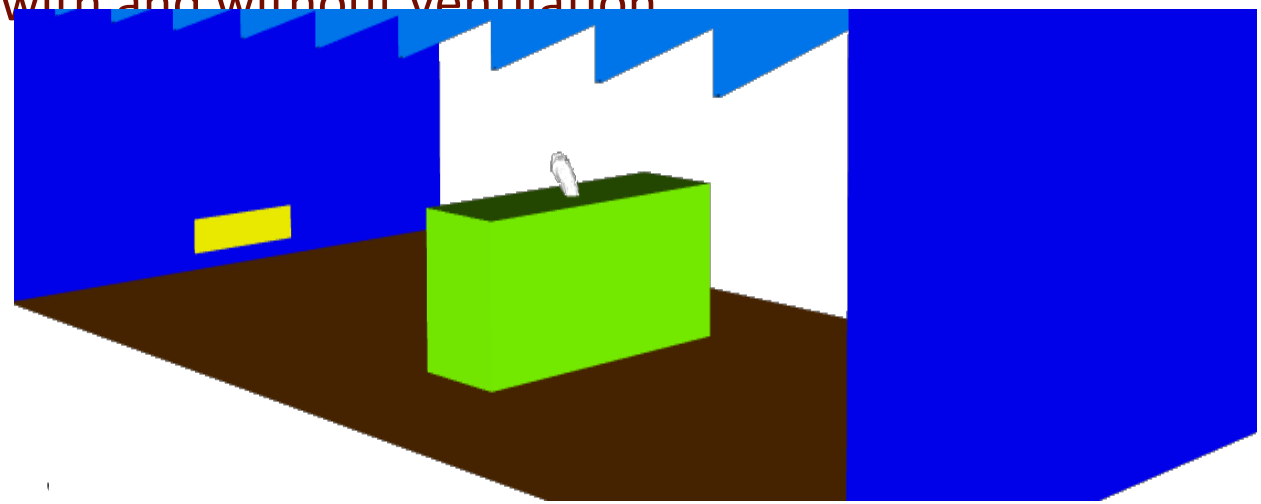
altfuels.sandia.gov

Myra.Blaylock@sandia.gov

# Natural Gas Vehicle Maintenance Garage

Sandia National Laboratories

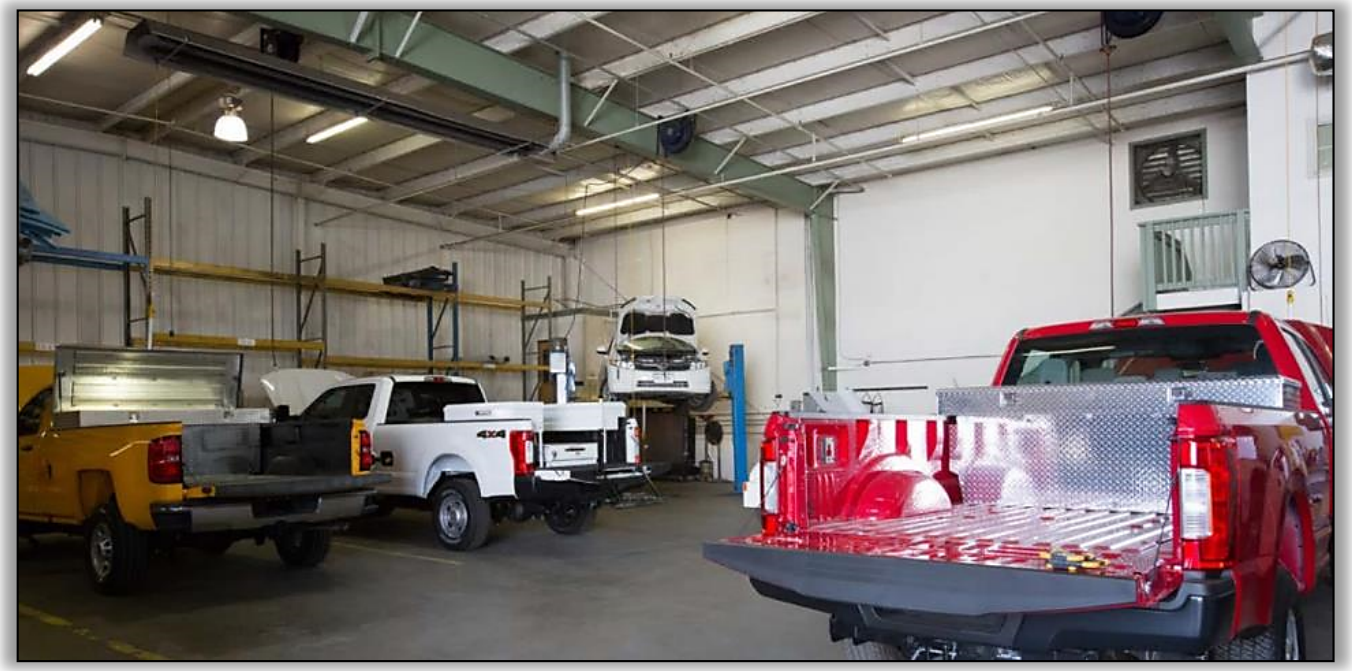
- Dimensions: 100’ x 50’ m x 20’ ; 1:6 roof pitch (60 x 40 x 20)
- Layouts w/ and w/o horizontal support beams investigated:
  - 9 beams (6” x 42”) spaced 10’ & parallel to the roof pitch
- Two vents were used for air circulation
  - Inlet near the floor — outlet along roof of opposite side-wall
  - Vent area for both vents was 2’ x 10’
  - Ventilation rate set to 5 air changes/hour (~2 m/s w/ current vent sizing)
  - Simulations were run with and without ventilation
- NGV modeled as a cuboid
  (8’ x 8’ x 24’)

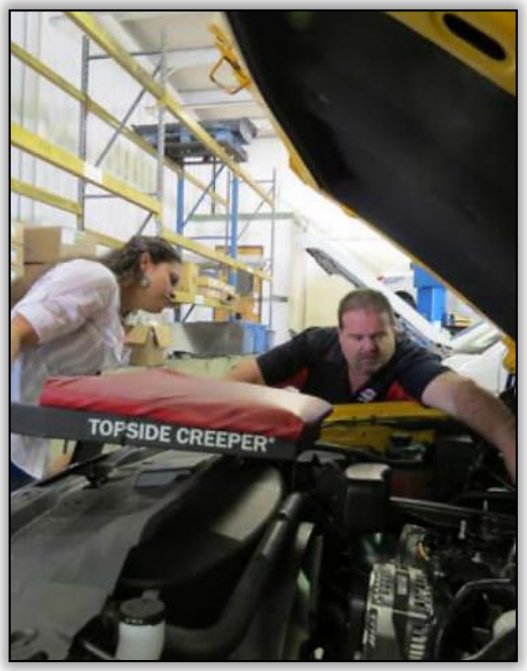


# CNG Vehicle Maintenance Facility Modifications Handbook Overview

Gladstein, Neandross & Associates

# Compressed Natural Gas Vehicle Maintenance Facility Modification Handbook






Bob Coale, P.E.
Jarrod Kohout

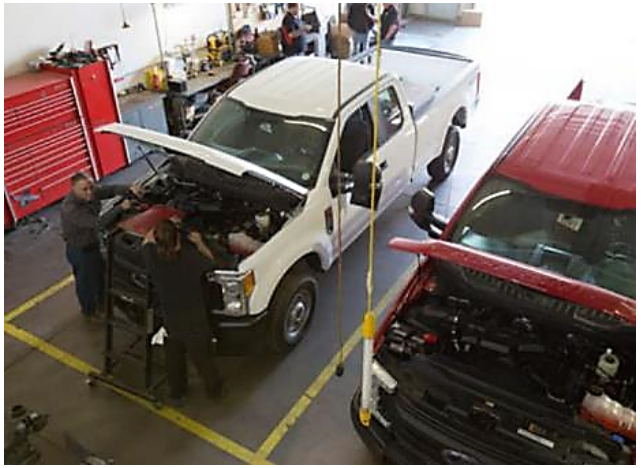
**December 7, 2017**

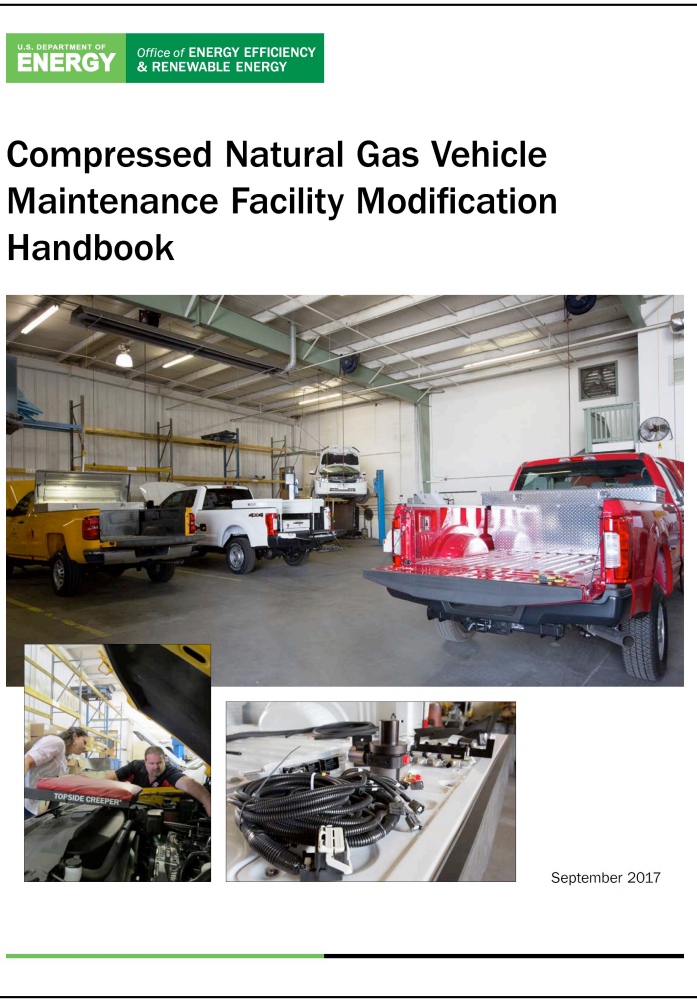
GLADSTEIN, NEANDROSS & ASSOCIATES

CLEAN TRANSPORTATION & ENERGY CONSULTANTS
Santa Monica, CA • New York, NY • Irvine, CA
310.314.1934 • www.gladstein.org

# CNG Facility Modification Handbook

- Handbook provides a review of all aspects of indoor compressed natural gas vehicle maintenance facility protection.
  - Initial facility assessment
  - Code compliance and requirements
  - Specific design criteria






https://www.nrel.gov/docs/fy17osti/67371.pdf

# Facility Modification Handbook Background

- Handbook developed to ensure the safety of personnel and facilities as required by law and guidelines of the following:
  - National Fire Protection Association (NFPA)
  - International Mechanical Code (IMC)
  - International Fire Code (IFC)
- All fuels have an explosion or fire potential under specific conditions
  - Methods of ensuring safety in CNG maintenance facilities differ from those necessary to protect against hazards presented by liquid fuels
  - Facilities that maintain liquid-fueled vehicles are protected by ventilation and detection systems designed to capture vapors at/near floor level
  - Facilities that maintain CNG-fueled vehicles are protected by ventilation and detection systems designed to capture vapors at/near ceiling level

# Role of Authority Having Jurisdiction (AHJ)

- Responsible for approving facility modification designs
- The AHJ can be determined by consulting local building/fire department
- Usually the fire marshal's office
- Often inexperienced with CNG and requirements for both fueling and maintenance
- Very early involvement essential to mitigate project delays
- Will provide guidance on regulations in effect

# Maintenance Facility Classification

- NFPA defines facility modification requirements based on functional use of the facility

- **Major Repair Garage**
  - *Activities including engine overhauls, painting, body and fender work, and repairs that require the emptying of the motor vehicle fuel tank. This includes maintenance work on the vehicle fuel system during which gas could be discharged into the area*

- **Minor Repair Garage**
  - *Activities including lubrication, inspection, and minor automotive maintenance work, such as engine tune-ups, replacement of parts, fluid changes (e.g., oil, antifreeze, transmission fluid, brake fluid, air conditioning refrigerants, etc.), brake system repairs, tire rotation, and similar routine maintenance work. Maintenance, repair, or service to the vehicle fuel system is not permitted in a minor maintenance and repair garage.*

# Distinction of Classification

- Fleet and garage managers must determine the nature of the maintenance to be performed
- The entire facility will be classified by the nature of the work performed therein
  - *If ANY work classified as major is to be performed, the facility MUST be classified as a major repair garage, regardless of how infrequent or how small the activity*
- Distinctions are critical because they define the types of protection needed within the facility and the nature of the maintenance work that may be performed
- The protection needed for a minor repair garage is generally less extensive and less costly than that required for a major repair garage

# CNG Maintenance Facility Design: Five Primary Elements

## I. Paths of Migration

- Flow paths by which the released gas travels throughout the structure must be controlled to prevent gas from entering unprotected areas

## II. Ventilation

- Sufficient air flow must be provided to reduce the concentration of the released gas and evacuate the gas from the structure

## III. Space Heating

- Heating apparatuses must adhere to specific guidelines so that open flames or hot surfaces do not provide an ignition source

## IV. Electrical Wiring and Equipment

- Must be designed or installed in a manner that does not provide sources of ignition due to sparking

## V. Methane Detection and Control Systems and Alarms

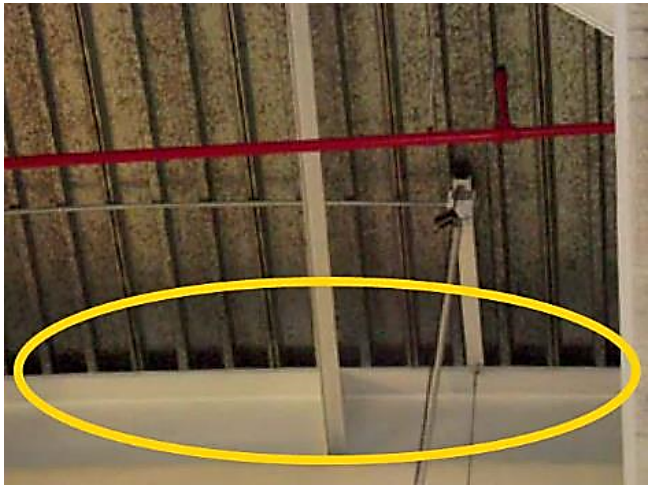
- Detection and alerts must provide defense against dangerous concentrations of natural gas by alerting personnel and disabling potential ignition sources

# I. Paths of Migration

- Natural gas is lighter than air and initially accumulates near the ceiling before dispersing throughout the structure
- Unsealed conduits or pipes passing through walls or ceilings

# Paths of Migration

- Structural elements passing through walls
- Gaps between walls and ceilings
- Facility characteristics



# II. Ventilation

- Ventilation is the primary means of preventing explosive concentrations of natural gas by
  - Quickly diluting concentrations of released natural gas to below the combustible level,
  - Directing released natural gas to alarm and detection systems, and
  - Directing released natural gas to evacuation points
- Ventilation rates and controls are mandated by codes
  - IFC
  - NFPA 30A

# Ventilation Rates and Controls

- Requirements for ventilation rates and controls differ between IFC and NFPA codes
- IFC requires 5 air changes per hour (ACH) based total volume of the structure
  - Continuous ventilation
  - Controlled by occupancy
  - Controlled by gas detection and alarm systems
- NFPA 30A requires 4 air changes per hour based on the volume of air 18 inches below the ceiling
  - Operational parameters not specifically addressed

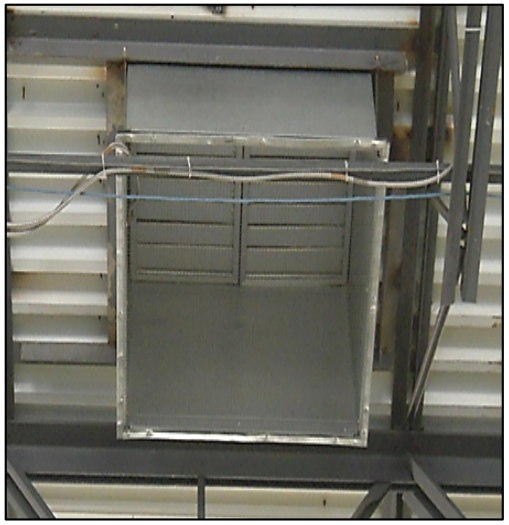
***Involve the local governing body (AHJ) early in the process to determine which of the codes (or hybrid) is applicable for the specific location***

# Ventilation Design

- Five variables affect the design and construction of ventilation systems
  1. **Applicable code(s):** Local governing body's decision regarding which (IFC or NFPA) code applies
  2. **Construction constraints:** Design and construction elements of the existing facility and ability to accommodate modifications
  3. **Weather:** Climate in which the facility is located (i.e. warm weather vs. cold weather)
  4. **Operation considerations:** Ease of operation
  5. **Cost:** Budget available to perform the modifications
- These factors influence the following design elements:
  - Locations of exhaust fans
  - Makeup air volumes and sources
  - Direct evacuation or ducting
  - Continuous vs. intermittent operation

# Ventilation Strategies – Direct and Ducting

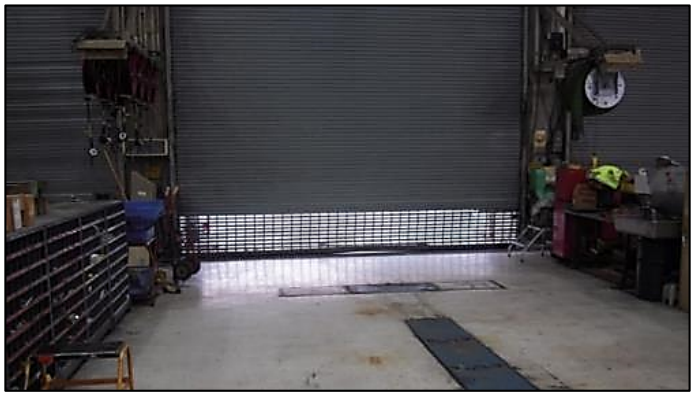
- Roof mounted fans
- Direct fan intake with louvers
- Interior intake ducting used to evacuate air from specific locations
- Exterior ducting and ground-mounted fans



# Ventilation – Sources of Makeup Air

- In-wall louvers

- Overhead door security mesh



- Powered sidewall fans

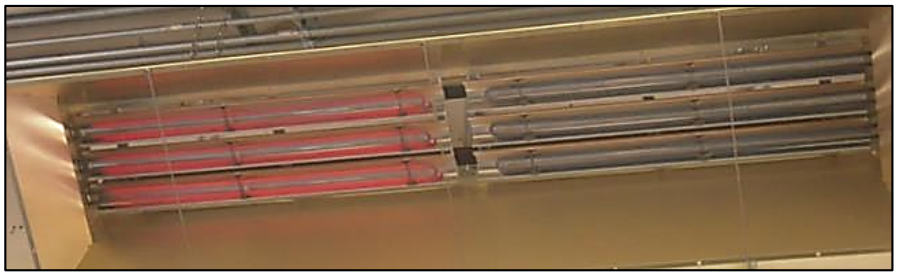
# Ventilation – System Control Strategies

- Continuous operation
  - Consider cost of tempering air, electrical and maintenance costs
- Based on input from gas detection and control system
- Based on building occupancy through lighting system

- Not necessary to ventilate all ceiling pockets if no ignition source

# III. Space Heating

- Codes mandate space heating requirements
  - No open flames
  - Surfaces less than 75O °F
  - Combustion and exhaust air must be contained
- Space heating that must be removed or replaced
  - Gas-fired infrared
  - Electric infrared
  - Gas-fired fan
  - Propane floor mounted




# IV. Electrical Wiring and Equipment

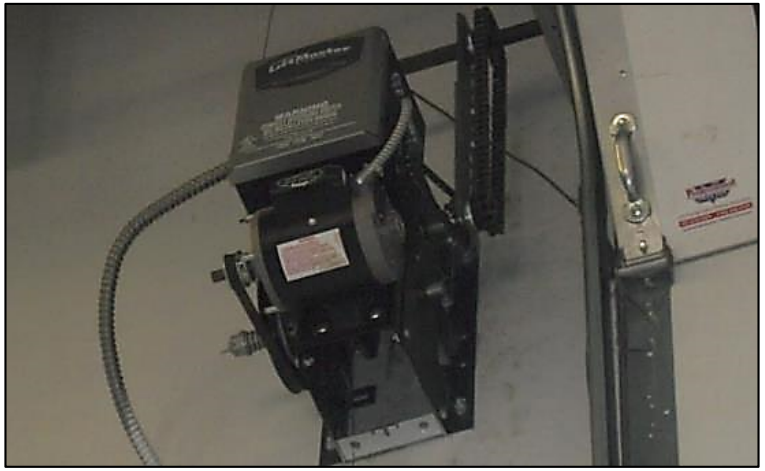
- Potential problem areas include
  - Conduits and wiring
  - Lights
  - Motors
  - Low voltage applications
- Class I, Division 2 designation may be required except for following scenarios:
  - The facility is classified as a minor repair garage.
  - The facility is classified as a major repair garage with a 4 ACH ventilation system.

***Involve the local governing body (AHJ) early in the process to determine which of the codes (or hybrid) is applicable for the specific location***

# Electrical Wiring and Equipment

- Overhead light fixtures and fans must be relocated to outside of the hazardous zone

- Overhead cranes and electric door motors must be relocated or shunt tripped



# Electrical Wiring and Equipment

- Low voltage wiring and devices may not require relocation <u>if approved by AHJ</u>

- Conduits may not require relocation when seal-offs are provided <u>if approved by AHJ</u>

# V. Methane Detection and Control Systems and Alarms

- Codes do not categorically require that a gas detection system be employed but…
  - May be difficult to get approval from AHJ
  - Insurance underwriters may object
  - For cost involved, offers sound protection for personnel and property
- Provides early warning to occupants that a methane gas release has occurred
- Initiates actions to eliminate potential ignition sources
- Initiates actions that provide conditions to promote quick dilution of the concentrated gas to levels below the LFL

# Methane Detection and Control Systems and Alarms

- Initiates actions that provide conditions to promote quick dilution of the concentrated gas to levels below the LFL

- Concentration Levels for Action Specified
  - 25% LFL suggested by NFPA 30A
  - Consider two levels – 20% and 40%
    - Offers protection against nuisance alarms and call-outs
    - Provides two levels for action
    - Requires AHJ approval – but widely accepted

# Methane Detection and Control Systems and Alarms

- Types of detectors
  - Catalytic bead
  - Infrared
    - Point type (recommended)
    - Open path
  - Periodic calibration required
  - Hand-held portable detectors


- Types of alarm activation
  - Audible and visual alarms
  - Ventilation system
  - Deactivate heating systems
  - Shunt-trip selected circuits
  - Personnel notification

# Facility Modification Costs

- Factors that influence project costs
  - Number of bays that need to be modified
  - Age of the overall facility
  - Associated attached or nearby structures
  - Sophistication of the modification and the extent to which new systems are required
  - Inclusion of “non-modification” upgrades
- Typical cost: $40,000-80,000 per bay
- Ensure management is aware and has budgets in place
- Can control budget with operational protocols
- Need not modify entire garage

# Typical Facility Modification Project Timeline

| CNG Vehicle Maintenance Facility Modification Schedule | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activity** | **Weeks** | | | | | | | | | | | | | | | | | | | | | | | |
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| **Initial Assessment** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Preliminary Design / AHJ Approval** | | | | | | | | | | | | | | | | | | | | | | | | |
| **RFP Preparation** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Contractor Selection** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Detailed Facility Design** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Final Permitting** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Equipment Procurement** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Modification Work** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Construction** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Startup / Acceptance Testing** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Training** | | | | | | | | | | | | | | | | | | | | | | | | |

# CNG Maintenance Facility Modification Resources

***Compressed Natural Gas Vehicle Maintenance Facility Modification Handbook***

https://www.nrel.gov/docs/fy17osti/67371.pdf

- Handbook provides valuable guidance to fleet managers which includes the following
  - Details on the specific requirements necessary to perform maintenance and repairs on CNG vehicles
  - **Preliminary Maintenance Facility Assessment** tool that aids in determining if modifications are necessary based on a fleet's individual needs
  - **Critical Decision Path of CNG Vehicle Maintenance Facility Modification** that helps determine what facility modifications will be required
  - **Maintenance Facility Assessment** that helps identify the requirements for facilities at which major repairs take place
    - Overall Facility Assessment
    - Ventilation Assessment
    - Space Heating Assessment
    - Electrical Wiring, Lighting, and Appliance Assessment
    - Project Related Assessment

# Best Practices for Working with Local Codes Officials

## National Renewable Energy Lab

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

# Best Practices for Working with Local Codes Officials on CNG Maintenance Facility Modification Projects

John Gonzales and Kay Kelly

December 7, 2017

# Understanding Building Code Roles and Responsibilities

**Codes & Standards Agencies**

## Develop Codes

- International Building Code
- International Electric Code
- International Mechanical Code
- NFPA 52 – Vehicular Gaseous Fuel Systems Code
- NFPA 88A – Standard for Parking Structures
- National Electric Code
- National Fire Code
- National Mechanical Code

**Local Governing Bodies**

Decide which codes (and versions of codes) are applicable in their jurisdiction

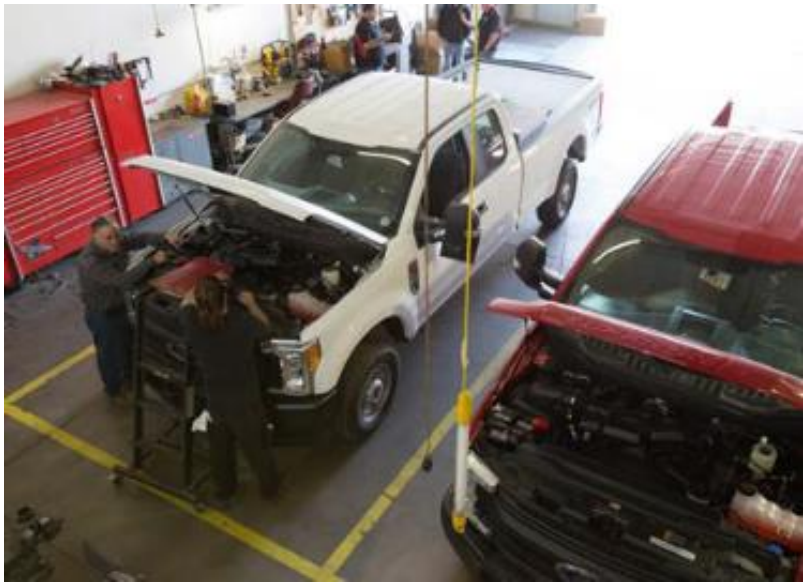
**AHJs**

Ensure the applicable codes are met

# Best Practices for Working with AHJs

- Establish an open dialog

- Engage early and often
  - Prevents costly and time-consuming re-work
  - Helps the permitting process to go smoothly and avoids delays
  - Allows for immediate purchase of long-lead equipment items



# Local Assistance through Clean Cities Coalitions

*Clean Cities Coalitions are public-private partnerships that share information and resources, inform public policy, educate the public, and collaborate on transportation projects.*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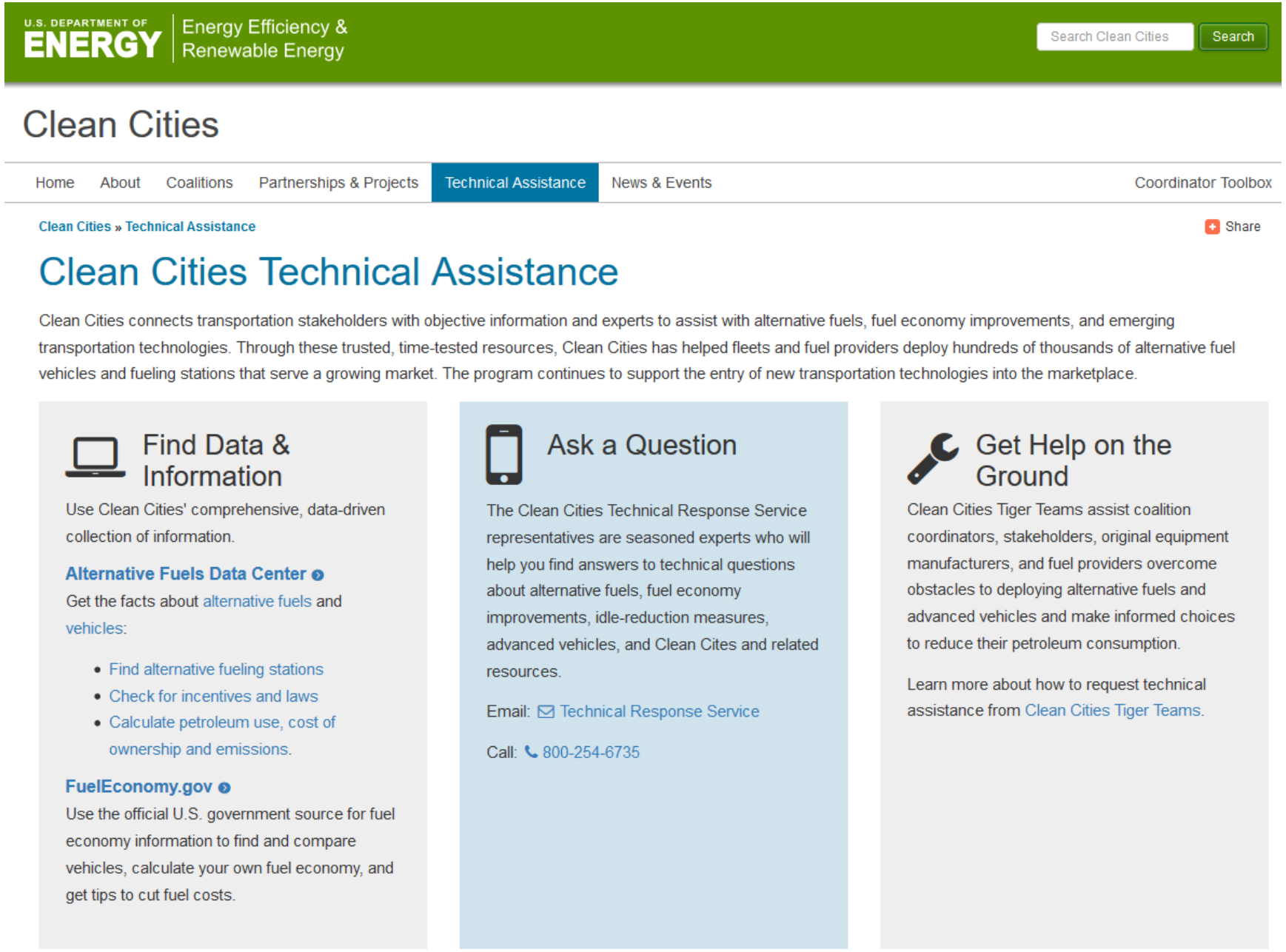
Coalitions can assist in locating qualified facility assessors, design engineers, and construction firms with CNG experience

# Assistance through DOE Vehicle Technologies Office



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# Please type your questions into the question panel.

Note: Webinar slides and recording will be posted to https://cleancities.energy.gov/webinars/ within one month.

Thank you for participating in today's webinar!