

# CPSC Staff Technical Research to Address the Carbon Monoxide Hazard for Portable Generators

PGMA Technology Summit  
March 17, 2016

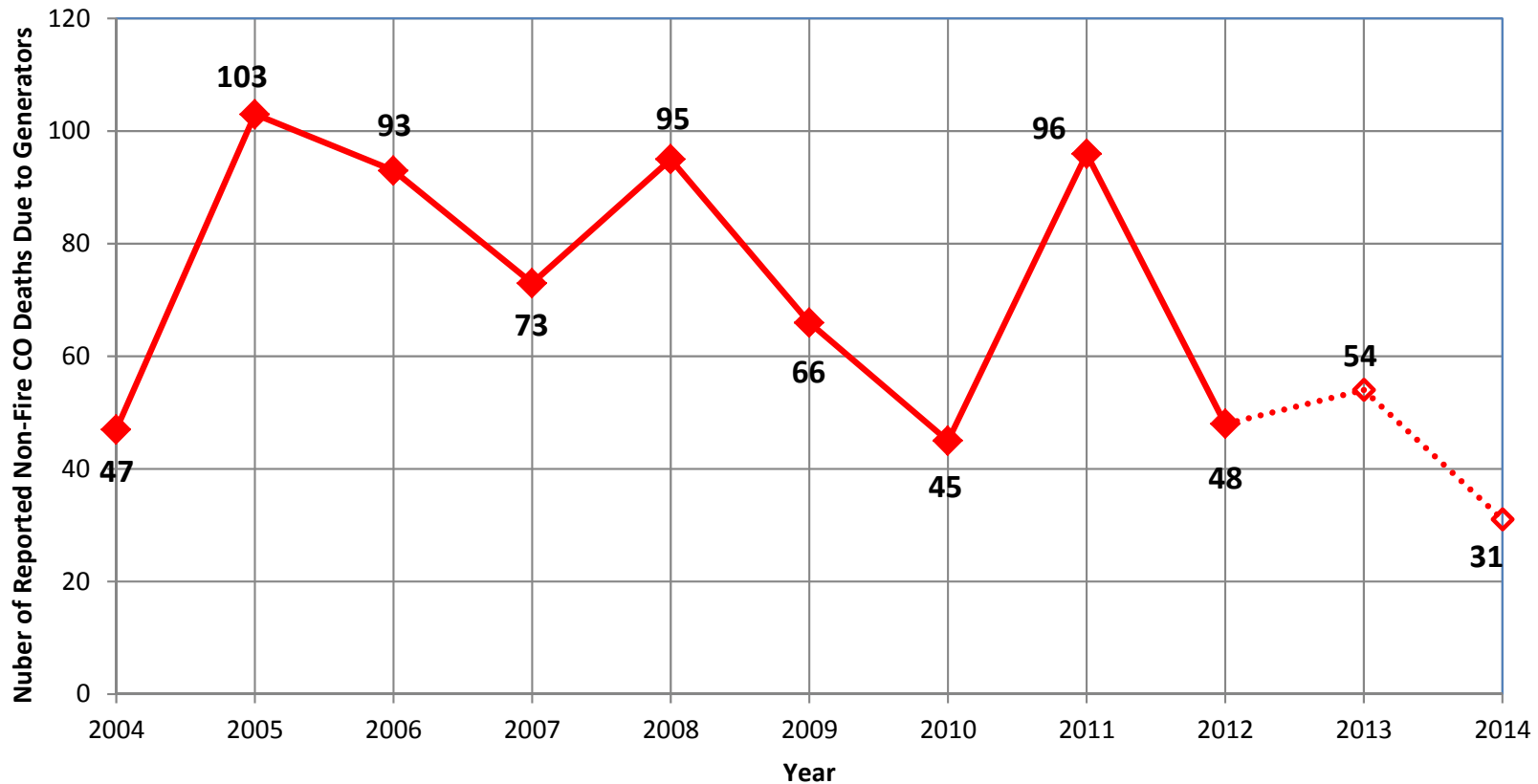


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**U.S. Consumer Product Safety Commission**

# Why CPSC Is Concerned About Generators

## Number of Reported CO Deaths Associated with Portable Generators



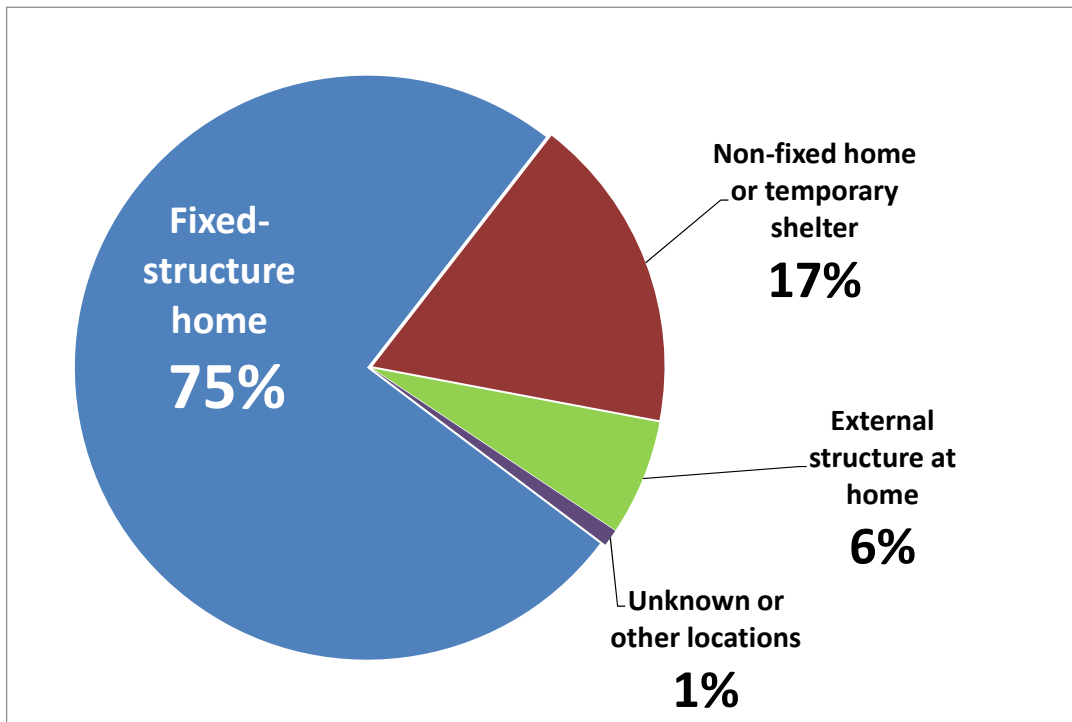
...◆... Reporting for years 2013 and 2014 is considered incomplete and is likely to change in future reports.

—◆— Reporting for years 2004-2012 is considered largely complete but may change to a relatively small extent in future reports.

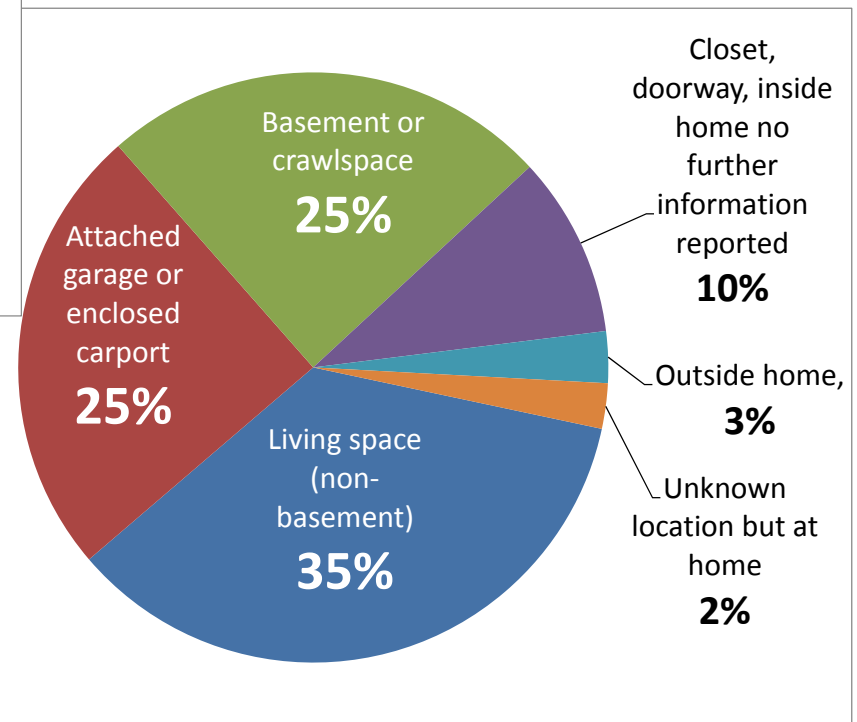
*Source:* Hnatov, M. V. *Incidents, Deaths, and In-Depth Investigations Associated with Non-Fire Carbon Monoxide from Engine-Driven Generators and Other Engine-Driven Tools, 2004-2014.* U.S. Consumer Product Safety Commission, June 2015.

# Some of our hazard analysis...

## Location where incident occurred



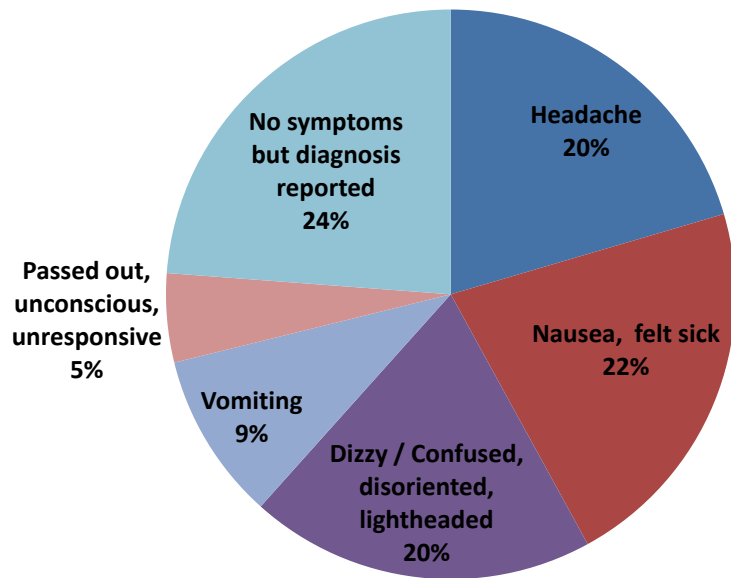
## Specific location of generator in incidents that occurred in fixed-structure home location



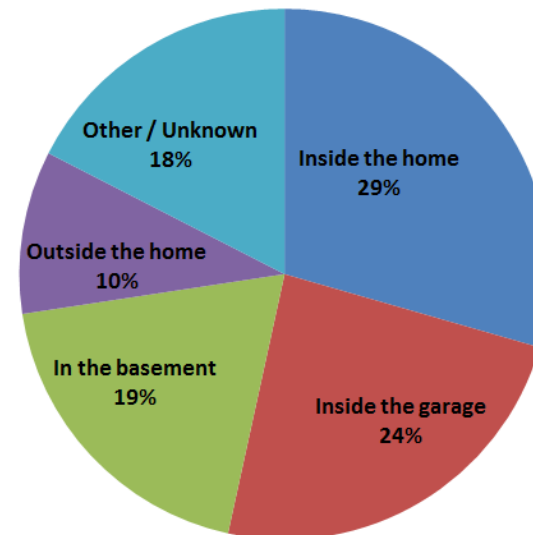
# CO Injury Estimates

8,703 estimated generator-related CO injuries seen in ERs in 2004 through 2012<sup>1</sup>

Most Common Symptoms Reported in NEISS CO Cases Associated with Generators, 2004-2014<sup>2</sup>



Location of Generator Reported in NEISS CO Cases Associated with Generators, 2004-2014<sup>2</sup>



Sources:

1. Hanway, Stephen, *Injuries Associated with Generators Seen in Emergency Departments with Narratives Indicative of CO Poisoning 2004-2012 for Injury Cost Modeling*, U.S. Consumer Product Safety Commission, Bethesda, MD, March 2016
2. Hnatov, Matthew, *Summary of NEISS Records Associated with Carbon Monoxide Exposure Cases Related to Engine-Driven Generators in 2004 through 2014*, U.S. Consumer Product Safety Commission, Bethesda, MD, March 2016

# Small Engine CO Emission Rates Compared to Cars

5kW generator



=

280 – 625 cars



Typical engine powering a 5 kW generator emits a weighted average CO rate of nominally 1500 g/hr<sup>(1)</sup>

Idling mid-size late 1990's-vintage cars emit 2.4 – 5.4 g/hr<sup>(2)</sup> of CO

## Sources:

1. <http://www3.epa.gov/otaq/certdata.htm#smallsi>

2. Frey, H., et al., *On-Road Measurement of Vehicle Tailpipe Emissions Using a Portable Instrument*, Journal of the Air & Waste Management Association, Vol.53, August 2003.

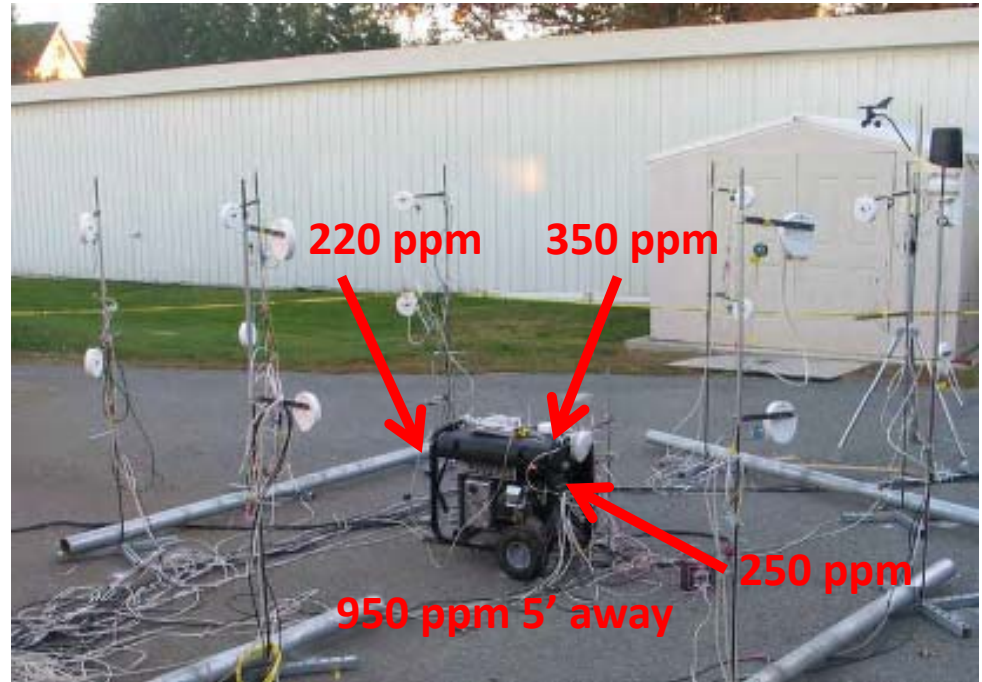
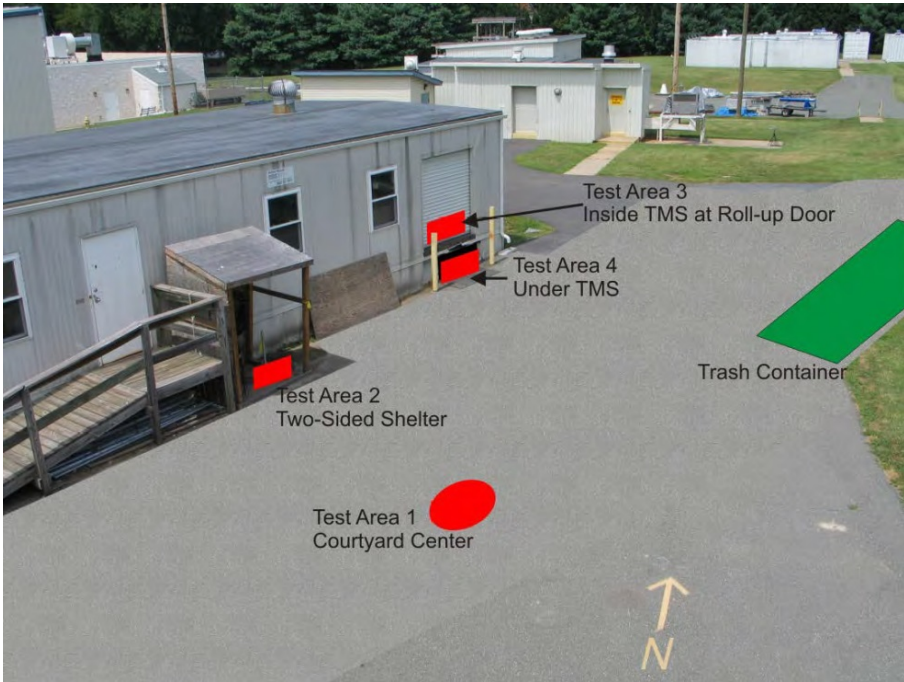
# **Overview of CPSC Efforts to Address the CO Hazard**

- **STP for UL 2201 since inception – 2002 to present**
- **Public Forum - 2004**
- **Staff Report “Review of Portable Generator Safety” – 2006**
- **Advanced Notice of Proposed Rulemaking - 2006**
- **Mandatory Label – 2007**
- **Shutoff concepts - 2006 to present**
- **CO emission rate reduction – 2006 to present**
- **CO Task Group for UL 2201 – 2014 to present**
- **Canvass committee for ANSI/PGMA G300 - 2015**

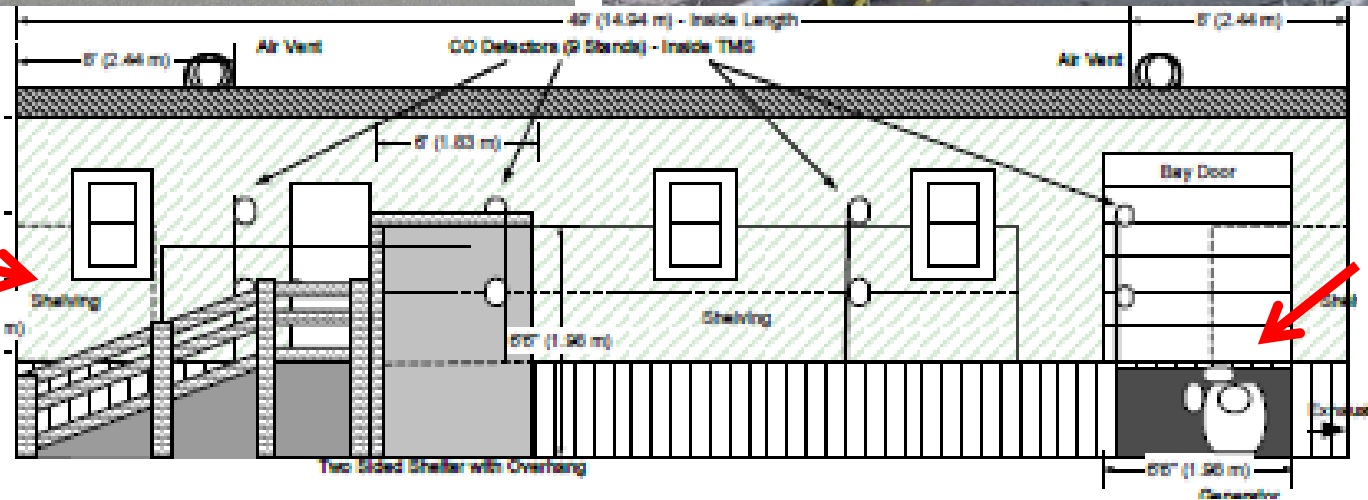
# Shutoff Concepts Investigated by CPSC Staff

- Staff focusing on designing out the risk of CO poisoning from portable generators through any number of technologies.
- CO sensing system mounted on generator
- Remotely located CO sensing system that communicates with generator; relies on user to place sensing unit in proper location
- GPS system mounted on generator; relies on poor signal strength to infer generator is located indoors
- Algorithm programmed into engine control unit (ECU) on prototype; relies on electronic fuel injection (EFI) system sensors to infer indoor operation

# Generator-Mounted CO Sensing System



1000 ppm measured in this end of building before CO sensors mounted on generator shut it off

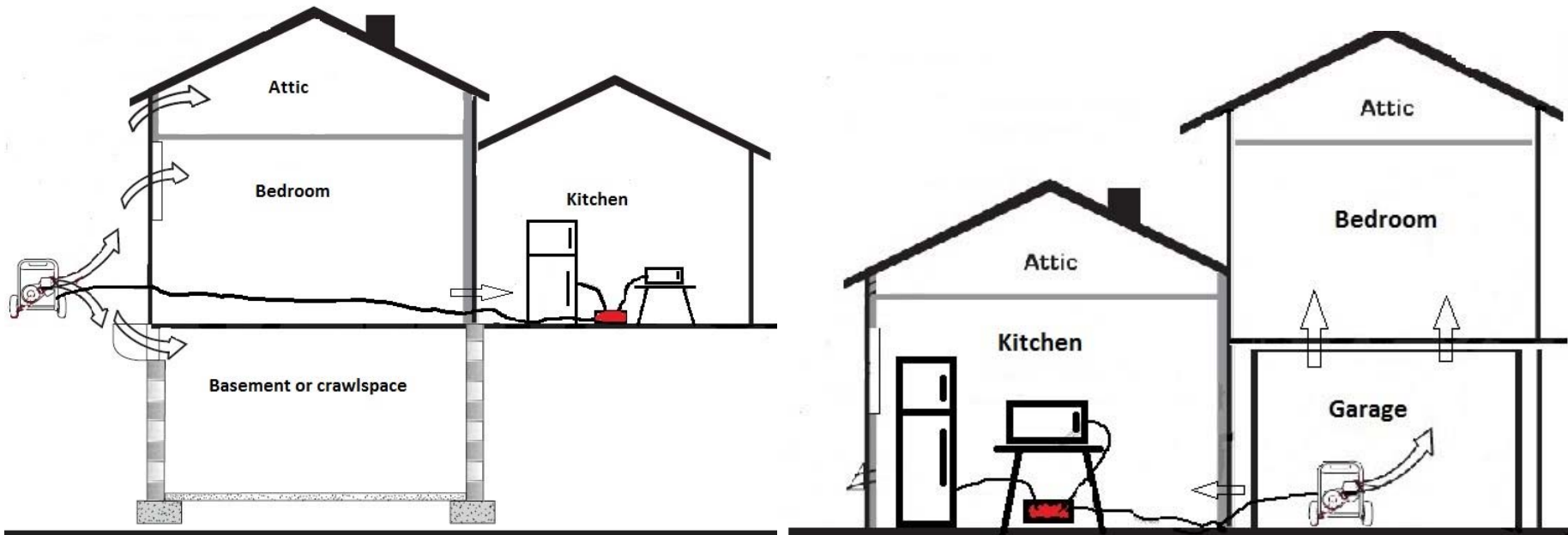


Generator operated inside - bay door closed

Source: Brown, Christopher, *Engine-Driven Tools, Phase 2 Test Report: Portable Generator Equipped with a Safety Shutoff Device*, U.S. Consumer Product Safety Commission, Bethesda, MD, July 2008.



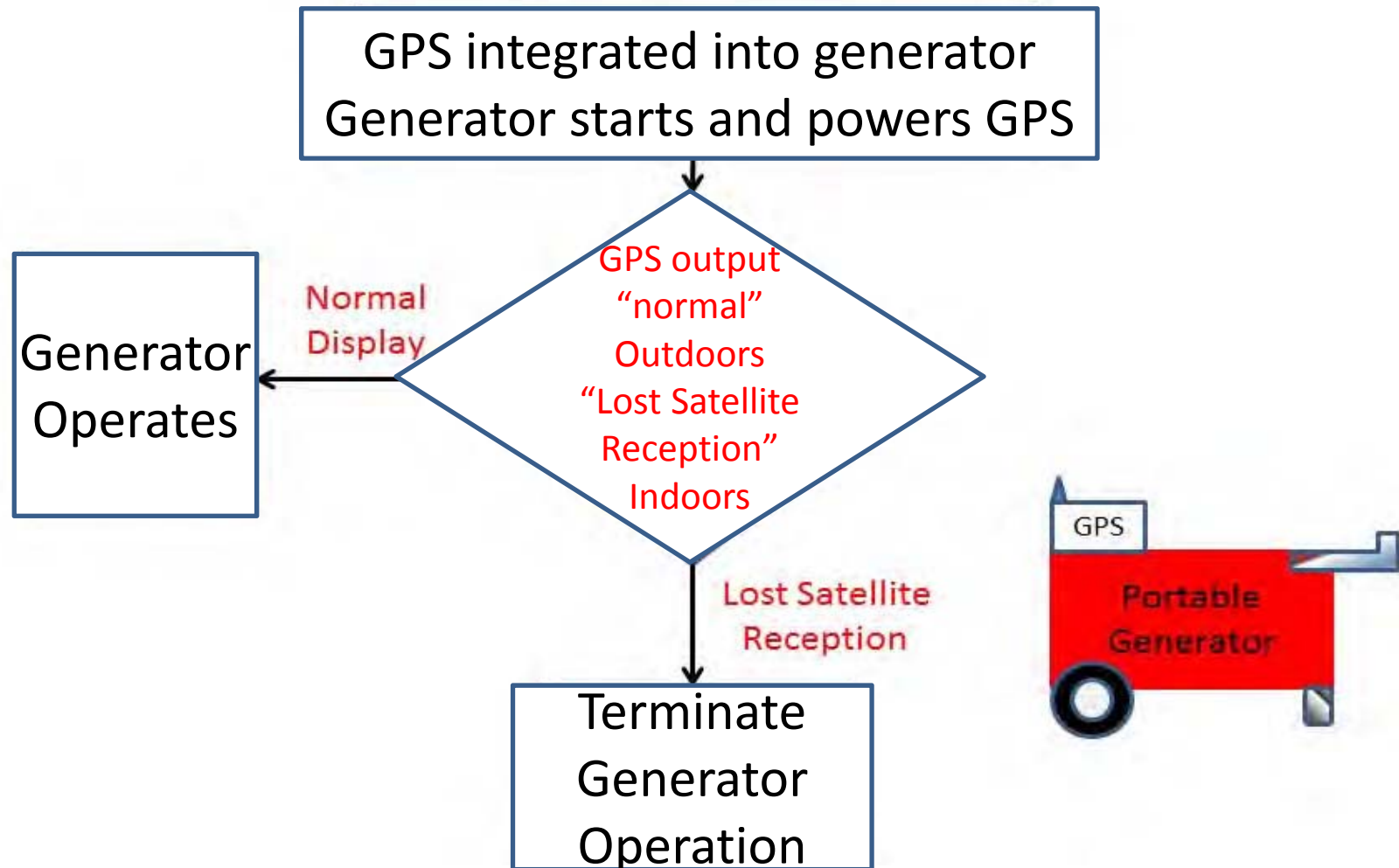
# Remotely Located CO Sensors for Generator Shutoff System: Pitfalls of Relying on User to Find Best Location for CO Sensor



- Generator outdoors
- CO infiltrates rooms without sensor
- Danger in those rooms

- Generator in garage
- CO infiltrates rooms without sensor
- Danger in those rooms
- Consumer entering garage will walk into potentially lethal environment

# Generator-Mounted Global Positioning System to Infer Generator Is Located Indoors



Source: Lim, Han, *Investigating the Utility of Global Positioning System (GPS) Technology to Mitigate the Carbon Monoxide (CO) Hazard Associated with Portable Generators – Proof of Concept Demonstration*, U.S. Consumer Product Safety Commission, Bethesda, MD, June 2013.

# Generator-Mounted Global Positioning System to Infer Generator Is Located Indoors

Home	Indoor Detection	Front Yard (Outdoor) Detection	Back Yard (Outdoor) Detection
Single -family detached home with 2-car garage	YES	YES	YES
Townhouse with 1-car garage	YES	YES	YES
Single-family detached home with 4-car garage	YES	<b>NO</b>	YES
Single-family detached home with 1-car garage	YES	YES	YES
Single-family, one level detached home with detached garage (2-car garage)	YES	YES	YES
Single-family detached home with 1-car garage	YES	YES	<b>NO</b>
Single-family, detached one-level home, no garage	YES	<b>NO</b>	<b>NO</b>

# Algorithm Programmed into Prototype Generator's Engine Control Unit (ECU) (University of Alabama)

- UA developed algorithm to sense when generator is operating in an enclosed space and automatically shut it off
  - No additional sensors beyond those already integral to the existing engine management system
  - First algorithm: testing by CPSC staff and NIST found unacceptable
    - occasionally shut the generator off when operated outdoors
    - under certain circumstances would not shut off when operated indoors
  - Second algorithm: limited testing performed by UA
    - shut off when operated indoors (7 tests)
    - did not shut off when operated outdoors (5 tests)

*Source: Haskew, Timothy, PhD., Paul Puzinauskas, Advanced Algorithm Development and Implementation of Enclosed Operation Detection and Shutoff for Portable Gasoline-Powered Generators, University of Alabama, October 2013.*

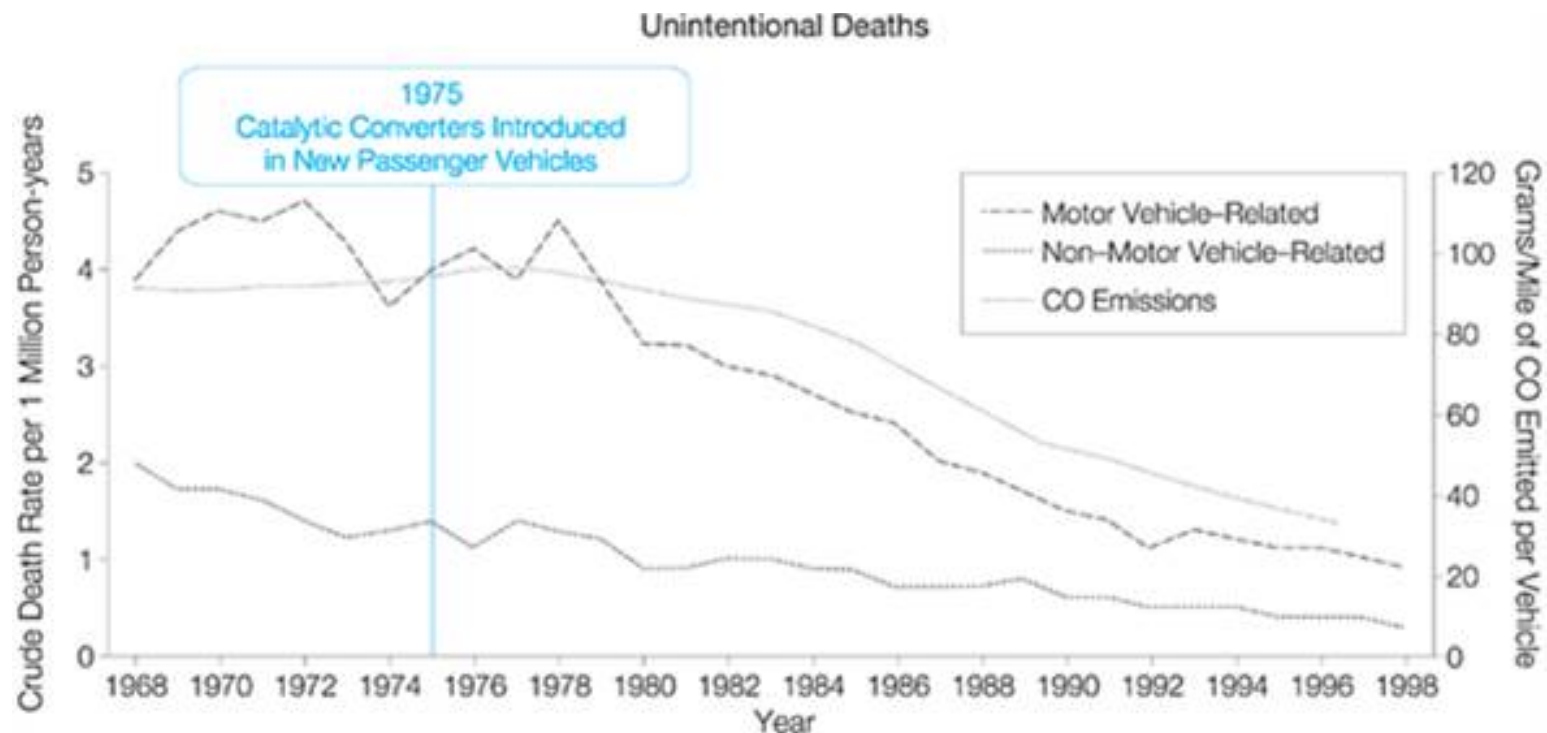
## Safety-Critical Requirements for Systems Intending to Prevent CO Deaths and Injuries When Generator is Used Indoors

If intent with shutoff strategy is to prevent CO injuries and deaths when generator is operated indoors, then:

- shutoff must occur before exhaust creates unsafe CO exposure
- In addition, consideration needs to be given to requirements for:
  - a supervisory circuit that prevents the generator from starting if shutoff system:
    - is bypassed due to consumer tampering, or
    - fails in some way (contaminated sensor, discharged battery, etc.)
  - durability so that the system will work throughout the generator's operational life without the need for calibration or service

# CO Emission Rate Reduction Strategy to Reduce CO Deaths and Injuries

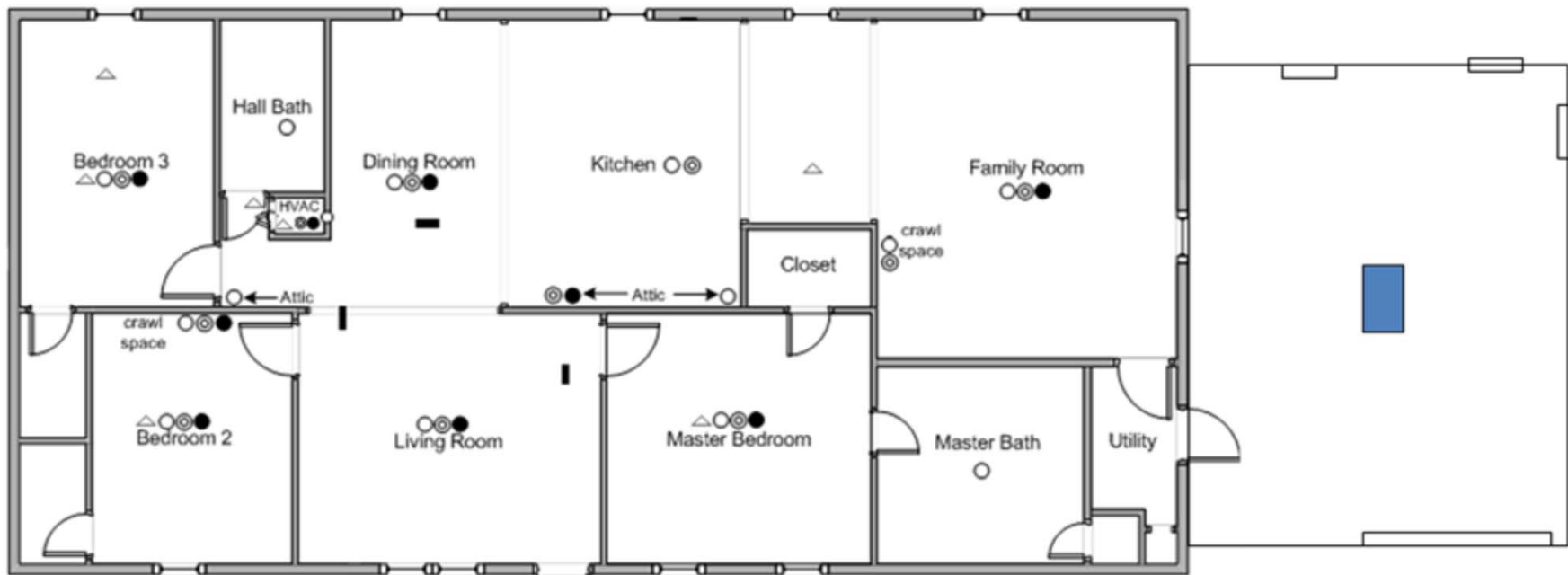
- 5.0 g/kW-hr CO emission standard specifically for small SI engines powering marine generators. Limit for all other small SI engines is 610 g/kW-hr.
- 4.4 g/kW-hr CO emission standard for large SI engines powering equipment designed for use in enclosed spaces.



Source: Mott, J.A., et al., *National Vehicle Emissions Policies and Practices and Declining US Carbon Monoxide-Related Mortality*, Journal of the American Medical Association, 288 (8): 988-995, August 2002.

# Hazard Characterization of Common Incident Scenario: Generator operation in SFH attached garage

National Institute of Standards and Technology (NIST)

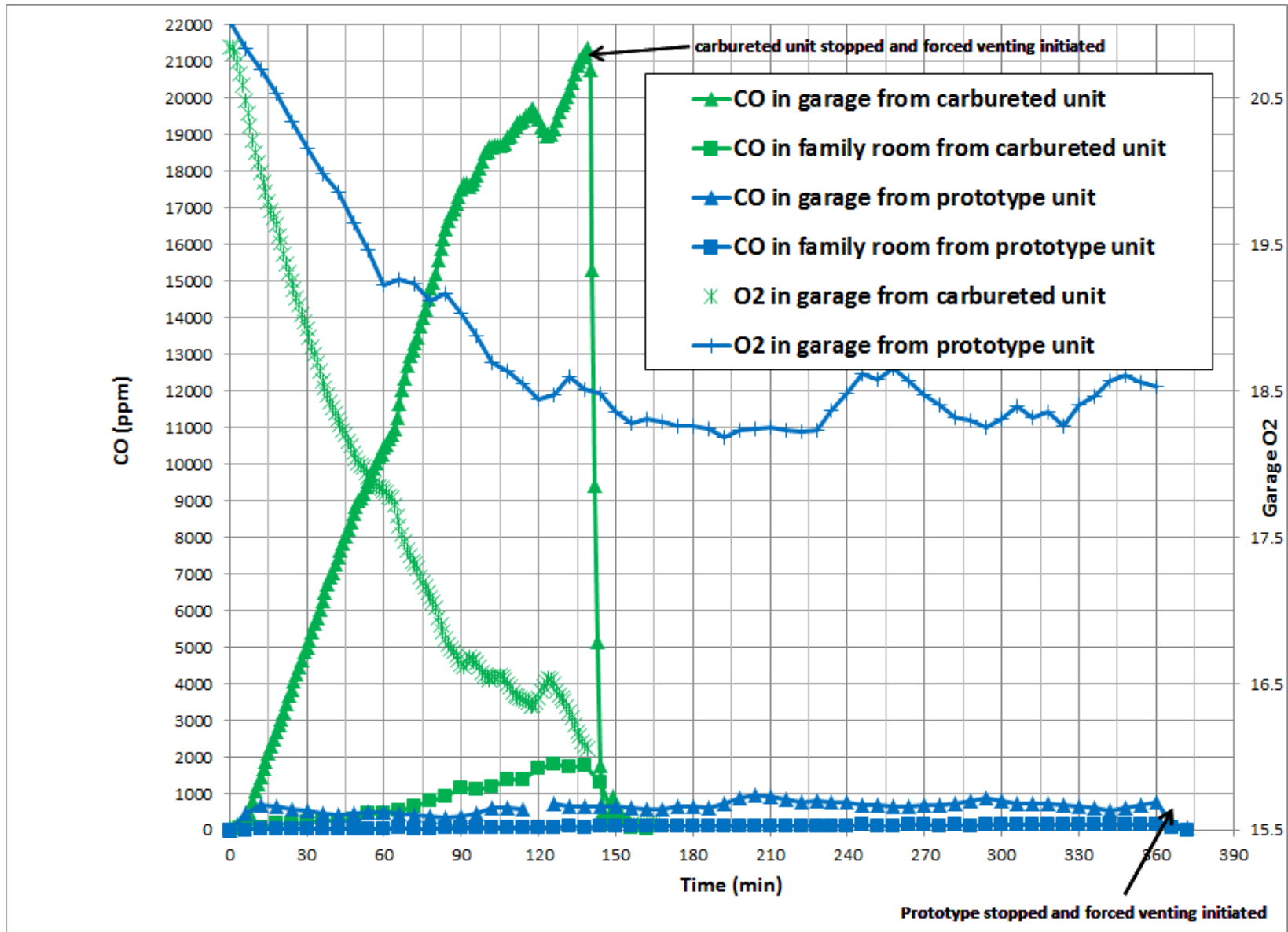


Source: S. J. Emmerich, A. K. Persily, and L. Wang, *Modeling and Measuring the Effects of Portable Gasoline Powered Generator Exhaust on Indoor Carbon Monoxide Level* (NIST Technical Note 1781), Feb 2013.

# Garage and Family Room CO Concentration Profiles from Unmodified, Carbureted 5 kW Unit and Prototype 5 kW Unit

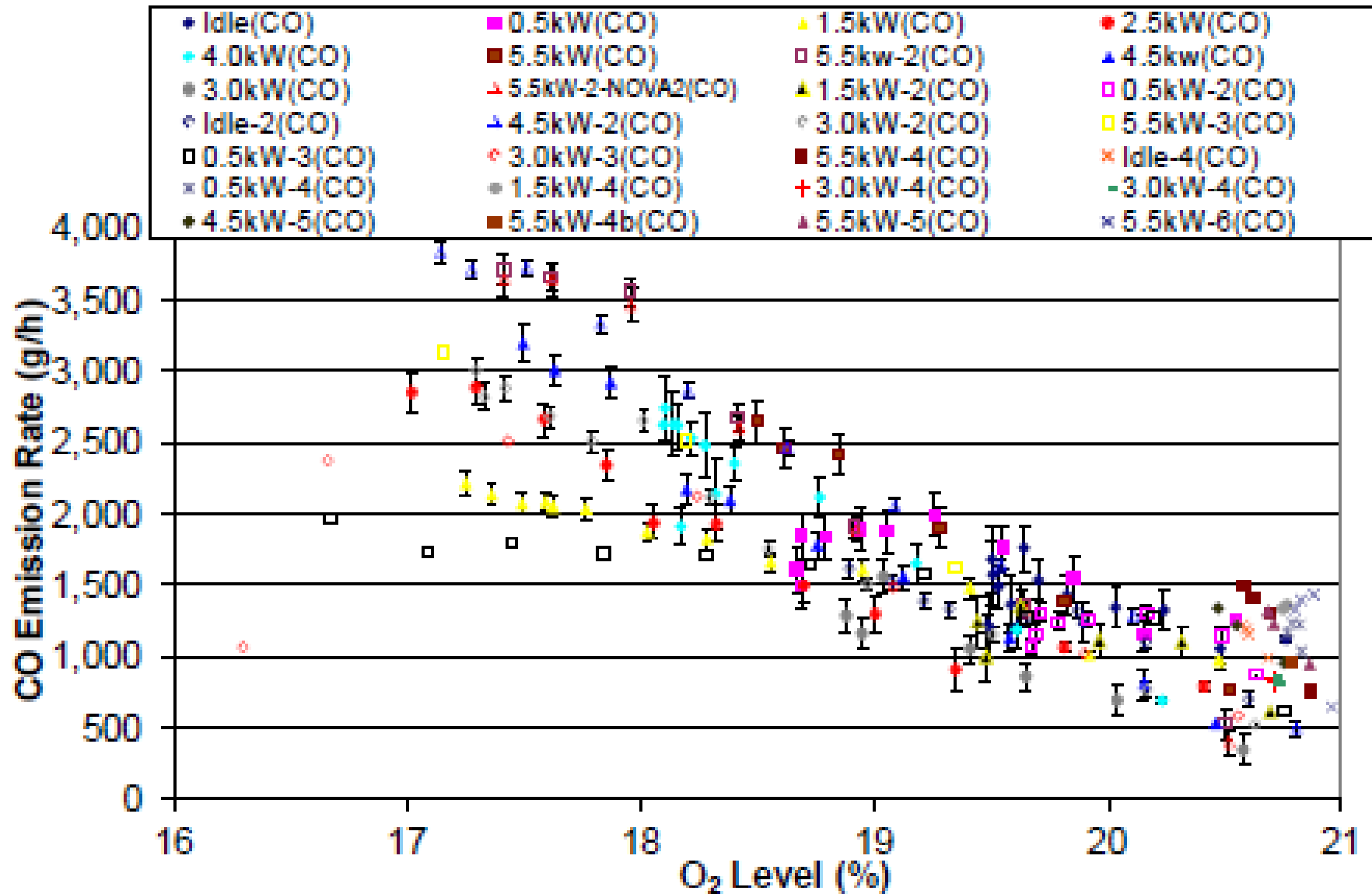
6-load hourly load profile applied to generator

Garage Bay Door Fully Closed, Garage/Utility Room Door Fully Closed, and HVAC Fan On





# NIST's Determination of Generators' CO Emission Rates at Reduced O<sub>2</sub>



# UL CO Task Group

- **Staff committed to actively engaging in all voluntary standards efforts to address CO poisoning from portable generators**
- **CO emission reduction strategy**
  - Performance requirement that sets a limit on the generator's CO emission rate
  - Test method for CO emission rate when the O<sub>2</sub> in the intake air is below ambient (20.9%)
    - Subgroup for test method is developing alternative options to NIST's test method
- **Shutoff strategy**
  - If intent with shutoff strategy is to prevent CO injuries and deaths when generator is operated indoors, then
    - Shutoff must occur before exhaust creates unsafe CO exposure
    - In addition, consideration needs to be given to requirements for:
      - Supervisory circuit that prevents the generator from starting if shutoff system:
        - is bypassed due to consumer tampering, or
        - fails in some way (contaminated sensor, discharged battery, etc.)
      - Durability so that the system will work throughout the generator's operational life without the need for calibration or service
    - To also address CO deaths and injuries when generator operated outdoors and exhaust infiltrates indoors, limit on CO emission rate in ambient oxygen needed as well