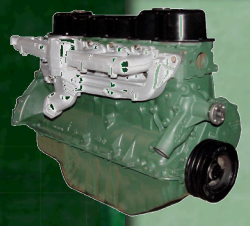
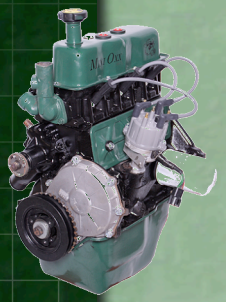
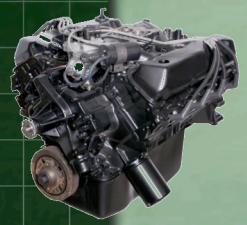






HEC

Hydrogen Engine Center, Inc.

www.hydrogenenginecenter.com

AMMONIA – FUELED ENGINES
A PROGRESS REPORT

Ted Hollinger

&

Don Vanderbrook

October 16, 2007

Oxx Power

HEC - INTRODUCTION

- Based in Algona, IA
  - Controls group in Quebec
- Founded 2003
- Publicly traded since Sept. 2005
- Primary products are alternative fuel engines, power generators, and controls

TRENDS

- Total vehicle emissions remain constant even with marked improvement in emissions control
- Why?
- Auto and truck registrations projected to increase to 3.5 billion in 2050 from 800 million in 1996 (source: US DOE)
- Other sources will follow suit such as off road mobile applications, but at a lesser rate.

SOLUTIONS

- Carbonless off road mobile fuel alternatives
  - Fuel Cells
    - Barriers
      - Cost
      - Acceptance
      - Service Infrastructure
  - IC Engines
    - Enablers
      - Cost
      - Acceptance
      - Service Infrastructure

KEYS TO SUCCESSFUL ICE OPERATION

- Oil Control
  - Cylinder Finish
  - Piston Rings
  - Piston Ring Placement
  - Valve guides
- Engine Control
- Control robustness
  - A/F Ratio
  - Ignition timing
    - Exhaust Temp
- Valve Timing
- Optimize mean effective pressure

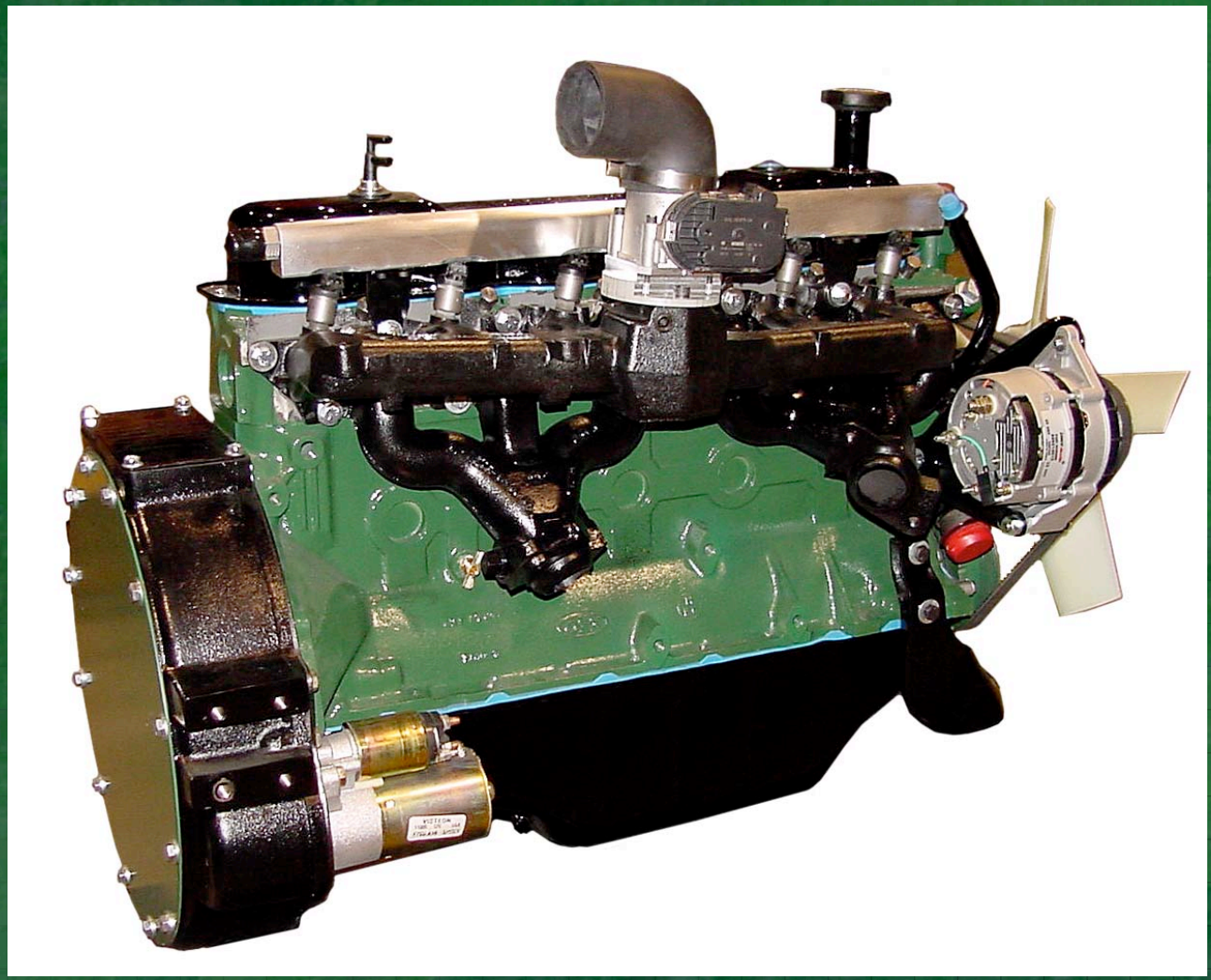
GENERAL – H2 OXX POWER™ ENGINES

- ~ 80 ft^3/min of H2 will produce 120 kW @ 35% efficiency (η) at a stoichiometric (balanced) air fuel ratio
- When properly tuned, base exhaust byproducts are water and nitrogen with very low trace emissions elements

HEC ENGINE PLATFORM

- 4.9L In line 6 cylinder engine
- 60 + kW peak w/H2 fuel
- Oxx Boxx™ full authority engine controller
- Turbocharged or naturally aspirated
  - Variants
    - 3 cylinder 2.4L
    - 2 cylinder 1.6L
    - 1 cylinder .8L
  - 87% parts commonality

HEC OXX POWER™ 4.9L H2 ENGINE

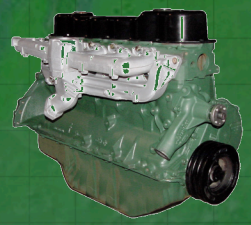


OXX POWER ENGINE FAMILY

Development of a 12L and 23L Engine

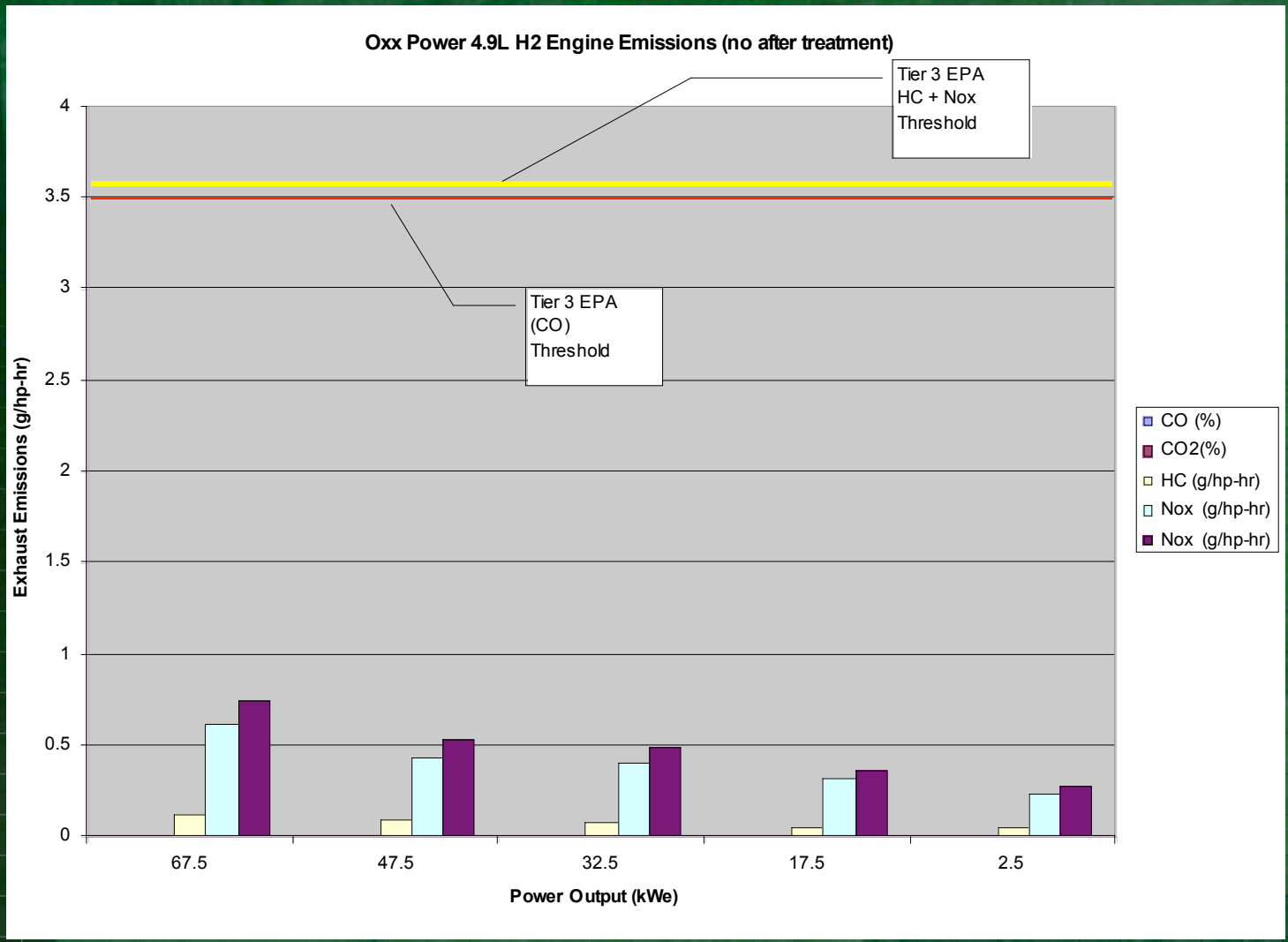
1 cyl .8L

3 cyl 2.4L



6 cyl 4.9L

EMISSIONS PERFORMANCE



THE HYDROGEN PARADIGM

- Current DISABLERS to widespread hydrogen use as a fuel:
  - Lack of infrastructure
  - High storage pressures
  - Low energy storage density
  - High cost of onsite manufacture

THE HYDROGEN ENABLER

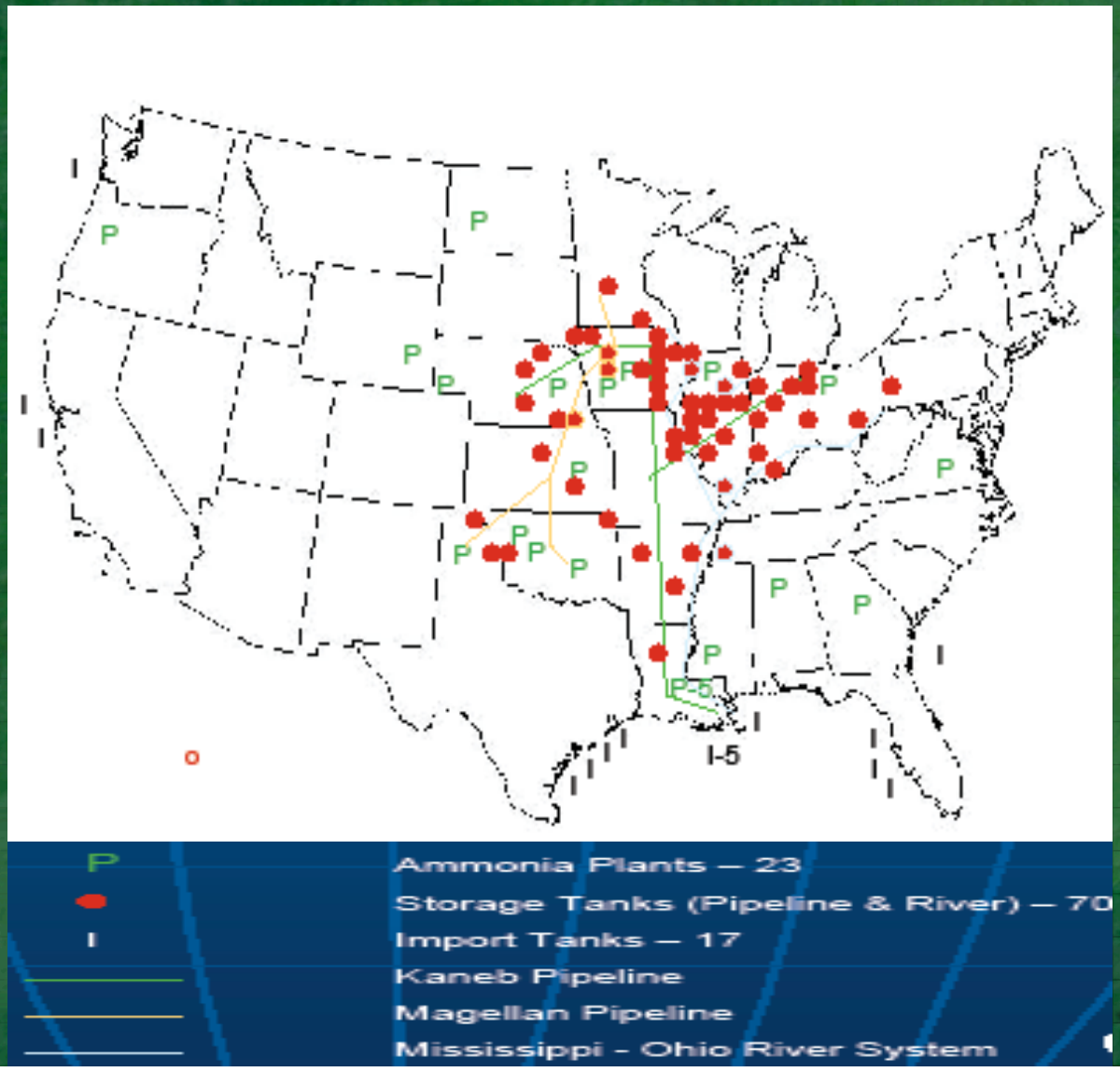
- Anhydrous Ammonia
  - 17.65% H2 by weight density vs.14% for Liquid H2
  - Established infrastructure
  - Carbonless
  - Second most produced chemical

ANHYDROUS AMMONIA – BUSINESS CAS

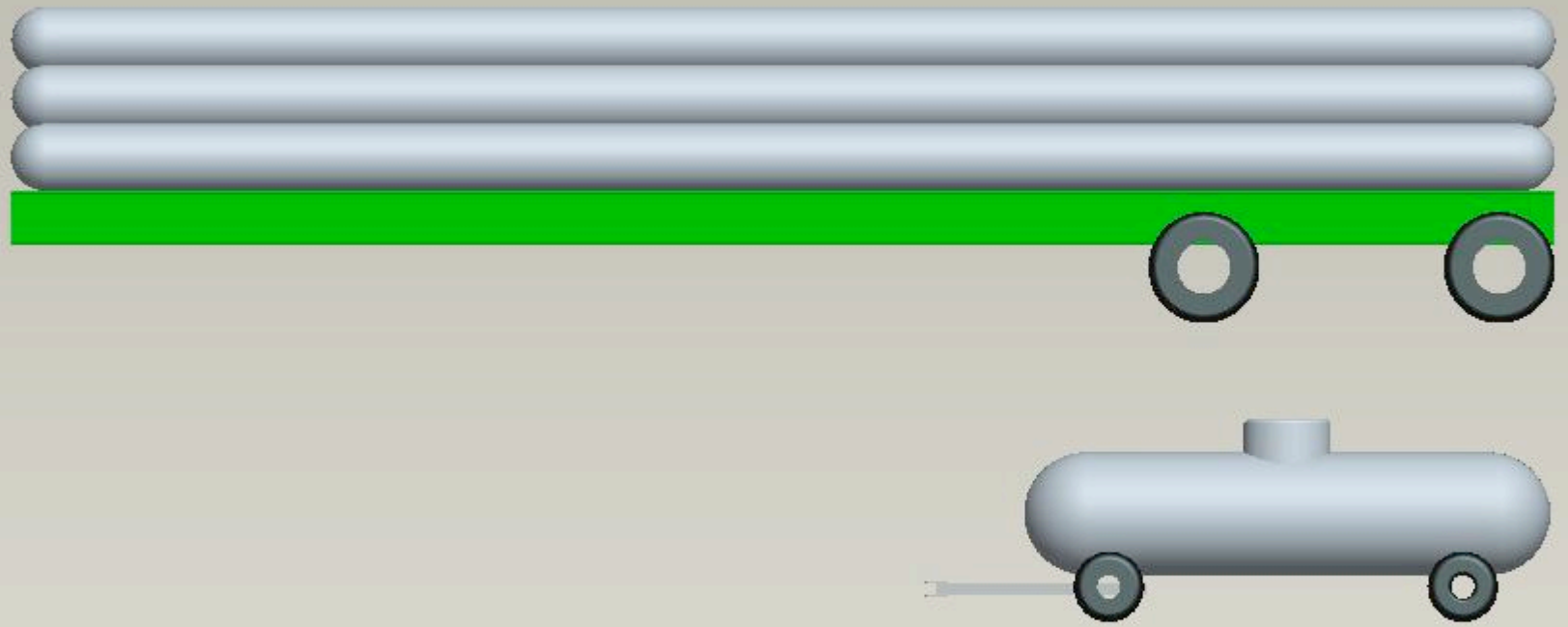
- Infrastructure
  - 44 Distribution Terminals
  - Total Storage
  - 3100 miles of pipeline
  - 23 plants

ANHYDROUS AMMONIA BUSINESS CASE

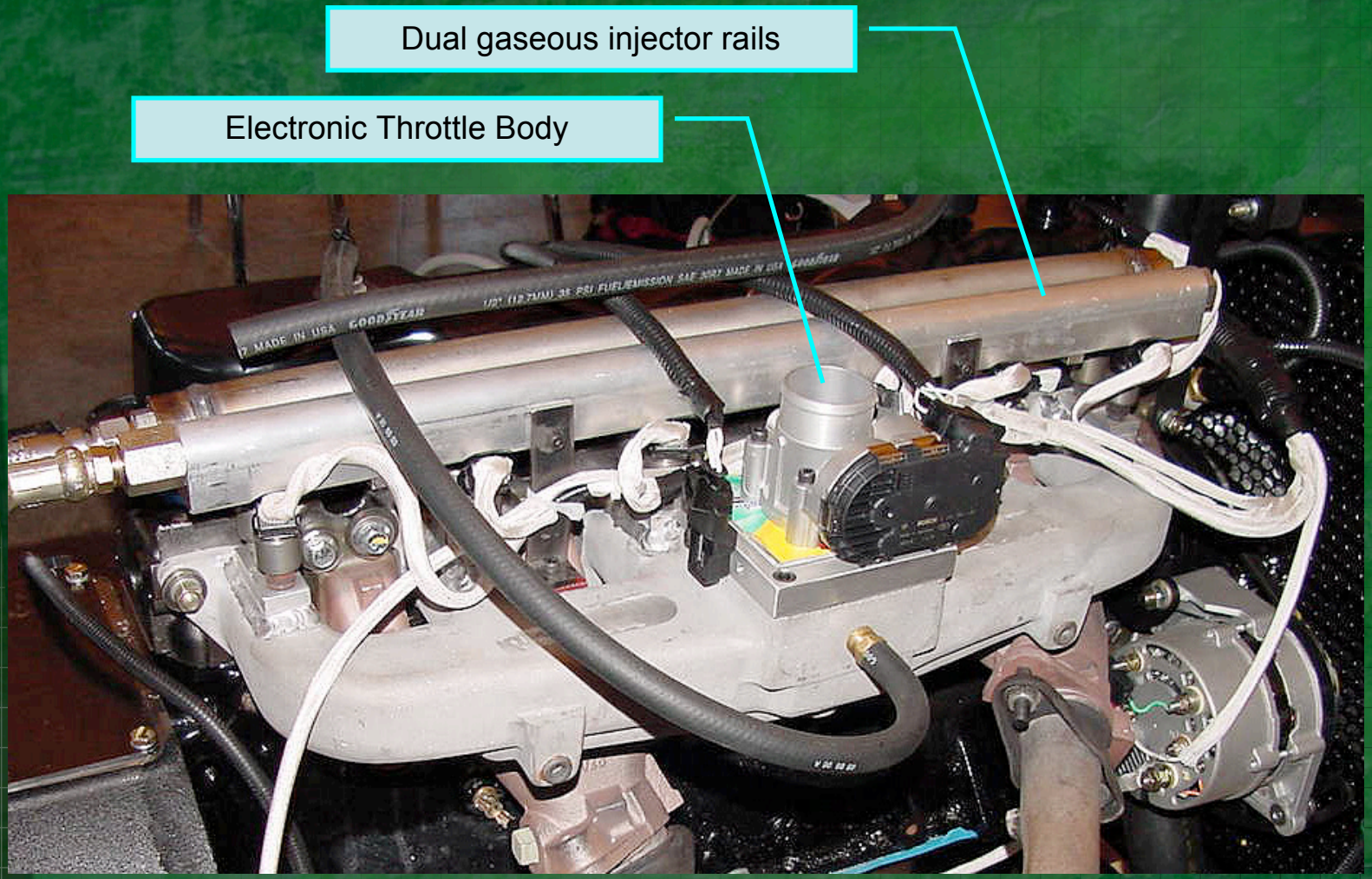
- Production Infrastructure



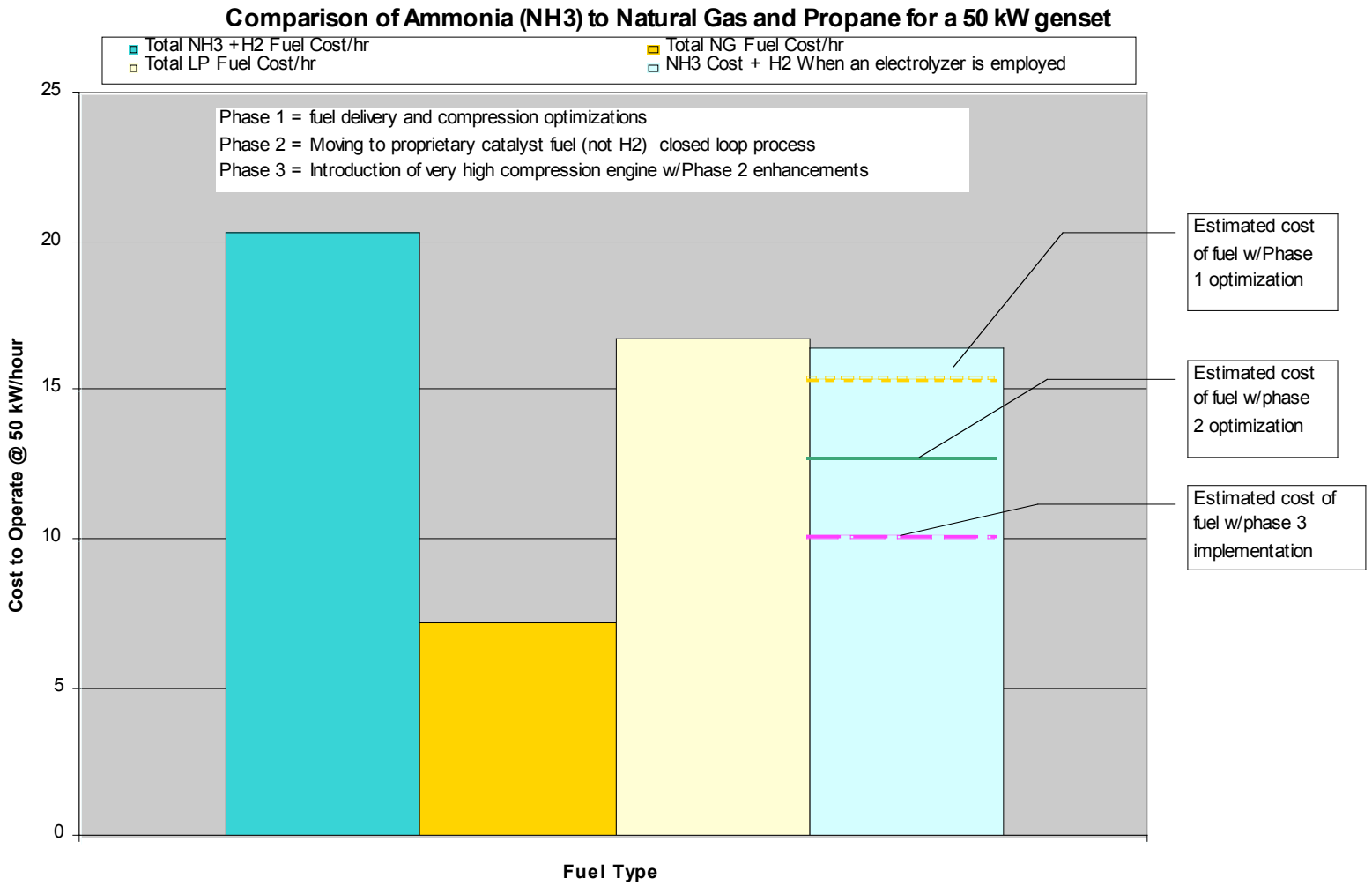
Hydrogen to Ammonia Storage Comparison for
327 kg (722 LB) H2 @ 3600 psi vs. NH3 @ 1000 gallons



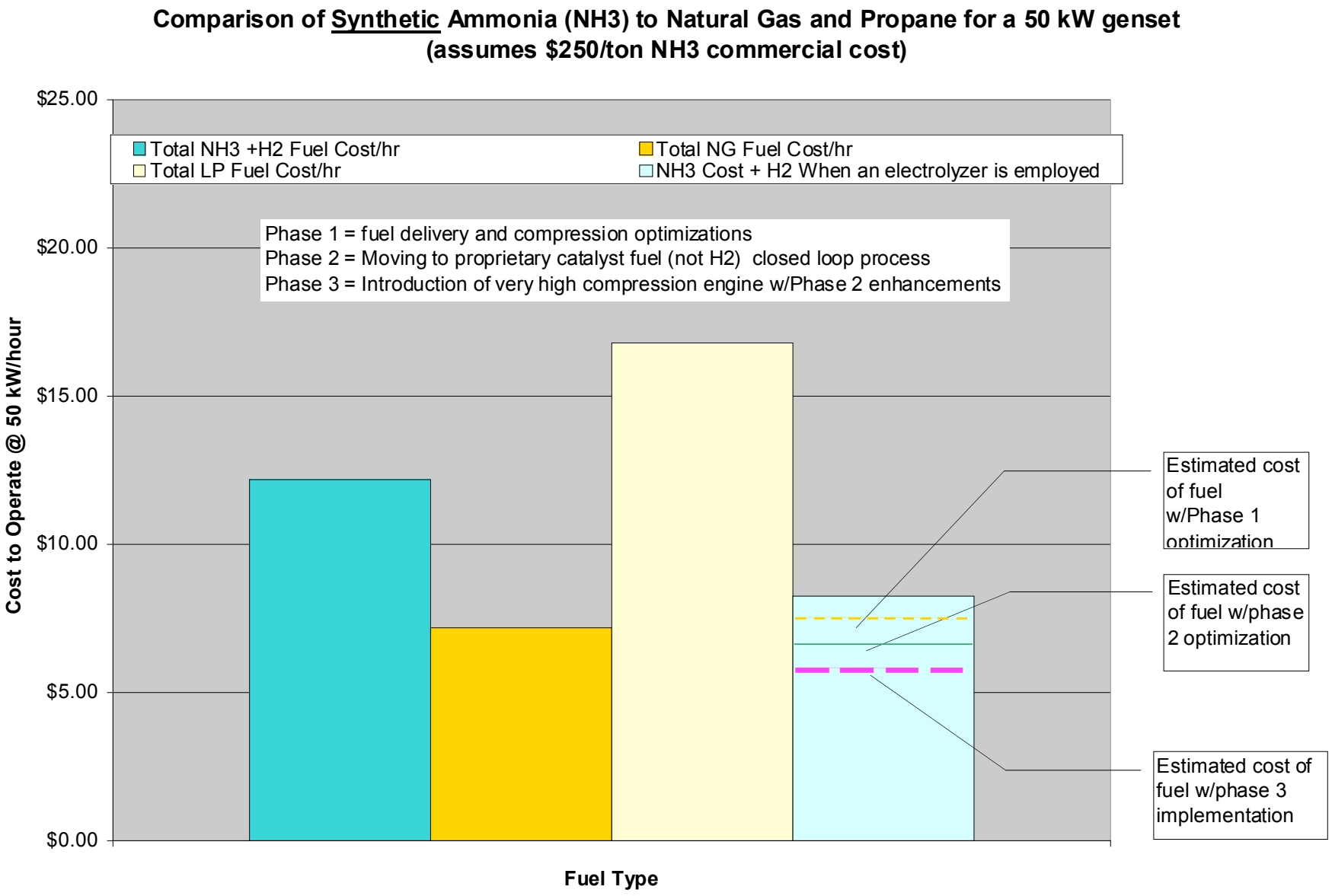
HEC NH3 OXX POWER ™ ENGINE



Ammonia Fuel Cost Comparison



AMMONIA FUEL COST COMPARISON



NH3 PROGRAM STATUS

- Ammonia Engine
  - Operating in field with 300 combined test hours
    - NH3 & LP
    - NH3 & H2 also tested at HEC
      - Unit in field operation since September 20, 2007
  - Next phase
    - 13.5:1 Test commencing
    - Integrate into generator set
    - Add additional irrigation units
  - Economics
    - Can put generation costs on par with LP currently
    - Working to put running costs on par or lower than NG and diesel
    - Low infrastructure costs

NH3 SHORT TERM OBJECTIVES

- NH3 Field Trials
  - Testing 2007
    - Establish Test Sites
      - 3 in 2007
        - » 1 Power Unit Test in progress
        - » Add additional Irrigation Power Units
        - » 1 Engine Specific (off road mobile or other)
        - » 1 DG
      - Proof of concept testing and endurance
      - Continue to refine control algorithm and fuel management system

FIELD TRIAL INSTALLATION

- Irrigation and Livestock watering application
- Location: Visalia, California
- Specifications – Pump System
  - Flow Rate: Up to 2000 gallons per minute
    - Running ~ 550 gallons per minute
  - Speed 1800 – 2200 RPM
  - Power Requirements: 35 HP
- Start up date: September 20, 2007

FIELD INSTALLATION

HEC NH3 0XX POWER™ UNIT

DRIVE SHAFT

WELL PUMP

APPLICATIONS

- Fork Lift
  - Same fuel storage as LP
- Arial Lifts
- Farm Machinery
  - Tractors
    - Diesel and SI
  - Implements
- Loaders
- Marine
- Stationary
  - Power Generation – Combine with renewables
  - Irrigation
  - Oil extraction

VISIBILITY: PRESIDENTIAL CANDIDATES

- OBJECTIVE
  - Establish awareness of HEC's solution to foreign oil dependency
    - Focus on NH3
      - Promote established infrastructure
      - Promote cost - benefit basis
      - Promote a carbonless fuel alternative that is ready to deploy

VISIBILITY

HYDROGEN PROJECTS

- United Nations Industrial Development Organization (2 x 250 hp H2 marine engines)
- Grasim Industries: 1 x 50 kW continuous power genset – project has entered next phase
- NRCAN: 1 x 4 + 1 - 250 kW system for Ramea Island
- XCEL ENERGY/NREL/DOE: 1 50kW grid connectable system coupled to wind power
- ITM Power: 1 cylinder (.8L) Oxx Power Engine coupled to ITM's H2 electrolyzer for either grid independent or dependent application
- TGP WEST: Irrigation project using Oxx Power Unit running on anhydrous ammonia
- Numerous other projects such as airport fleet retrofit with H2 Oxx Power engines, etc.

CARBONLESS FUELS: THE FUTURE

- Continue to establish hydrogen applications where they make sense
  - Wind and Solar to Hydrogen
  - Off road mobile projects
    - Proof of concept
    - Early adopter
  - Work with NH3 as the hydrogen enabler now
    - Establish durability
    - Optimize performance and emissions
    - Emissions certification
    - Market acceptance

SUMMARY

- IC engines can run reliably and cost effectively @ near zero emissions
- Ammonia can be a hydrogen enabler
- Hydrogen and NH3 can be run successfully in SI engines
- Ammonia properties similar to LP
- HEC system can be implemented on other engines

Thank You!

Hydrogen Engine Center, Inc.
2502 E Poplar St
Algona, IA 50511
www.hydrogenenginecenter.com
Phone: 515-295-3178
Fax: 515-395-1877