Development and Demonstration of a Fuel-Efficient HD Engine
(Dept of Energy Supertruck Program)

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Navistar

Technical Session: High-Efficiency Engine Technologies Part 1

DOE DEER CONFERENCE

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Dearborn, Michigan

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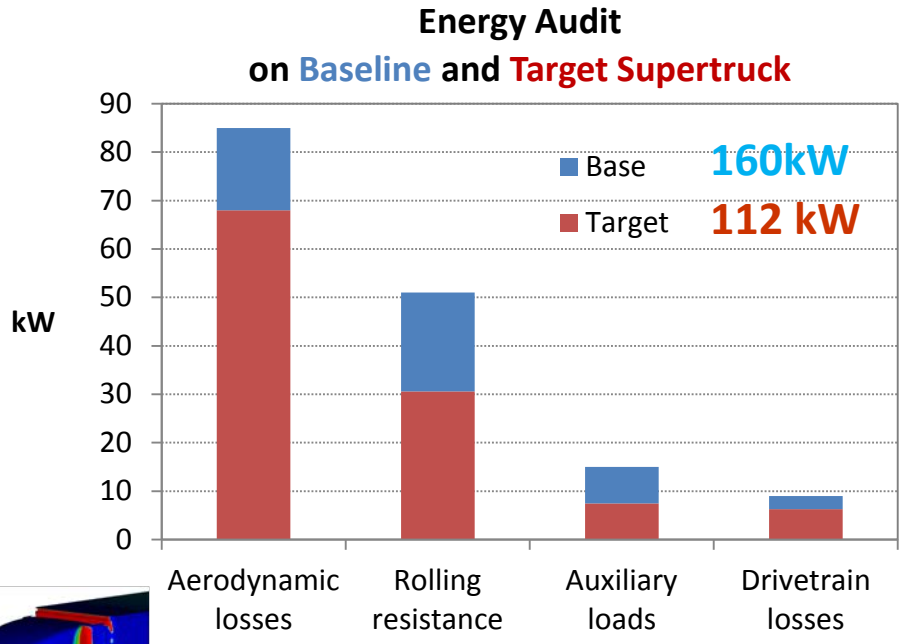
Industrial Partners: Bosch, ARGONNE, Federal Mogul, WERC

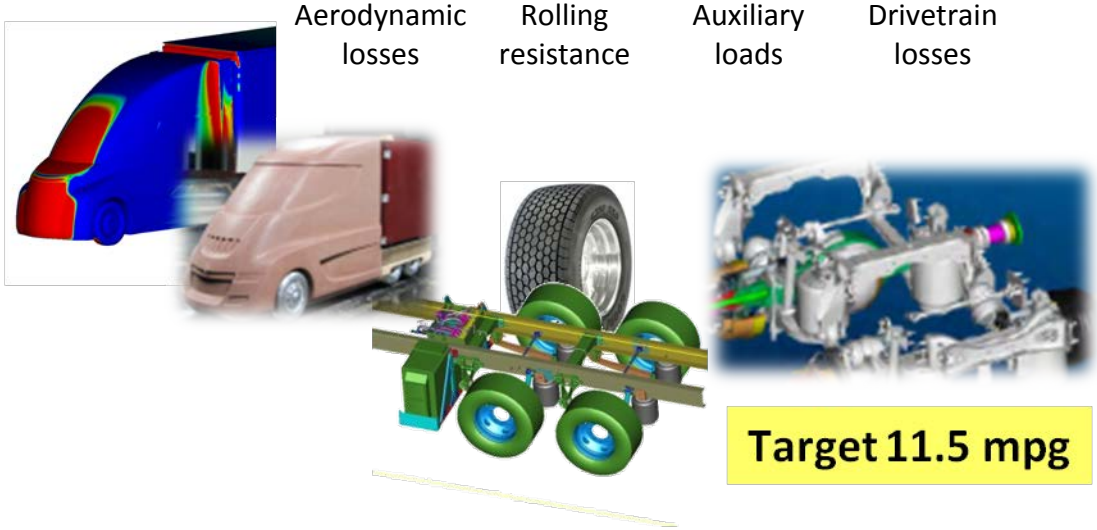
Project Goals:
Approach for Fuel Economy

Demonstrate 50% improvement in overall freight efficiency of a tractor-trailer

- **30%** through **tractor/trailer** technologies
- **20%** through **engine** technologies

Baseline
2010 ProStar with MAXXFORCE 13L





Target 11.5 mpg

Engine Technologies

BTE > 50%

20%

4. WHR

3. Friction Accessories

2. Air System

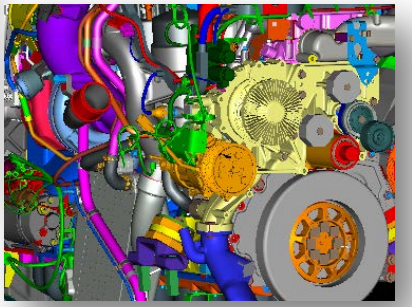
1. Combustion

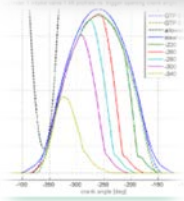
Base efficiency

Leverage Technologies

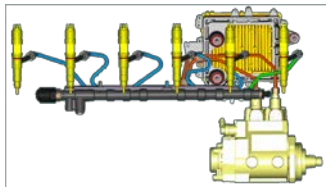
- Electrical Turbocompounding Rankine Cycle
- Low Friction components Lube system Cooling system
- VVA Turbo optimization
- Increased PCP Optimum timing Higher Injection Pressure Aftertreatment

turbocompounding

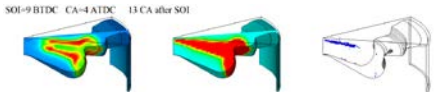




VVA + turbo match



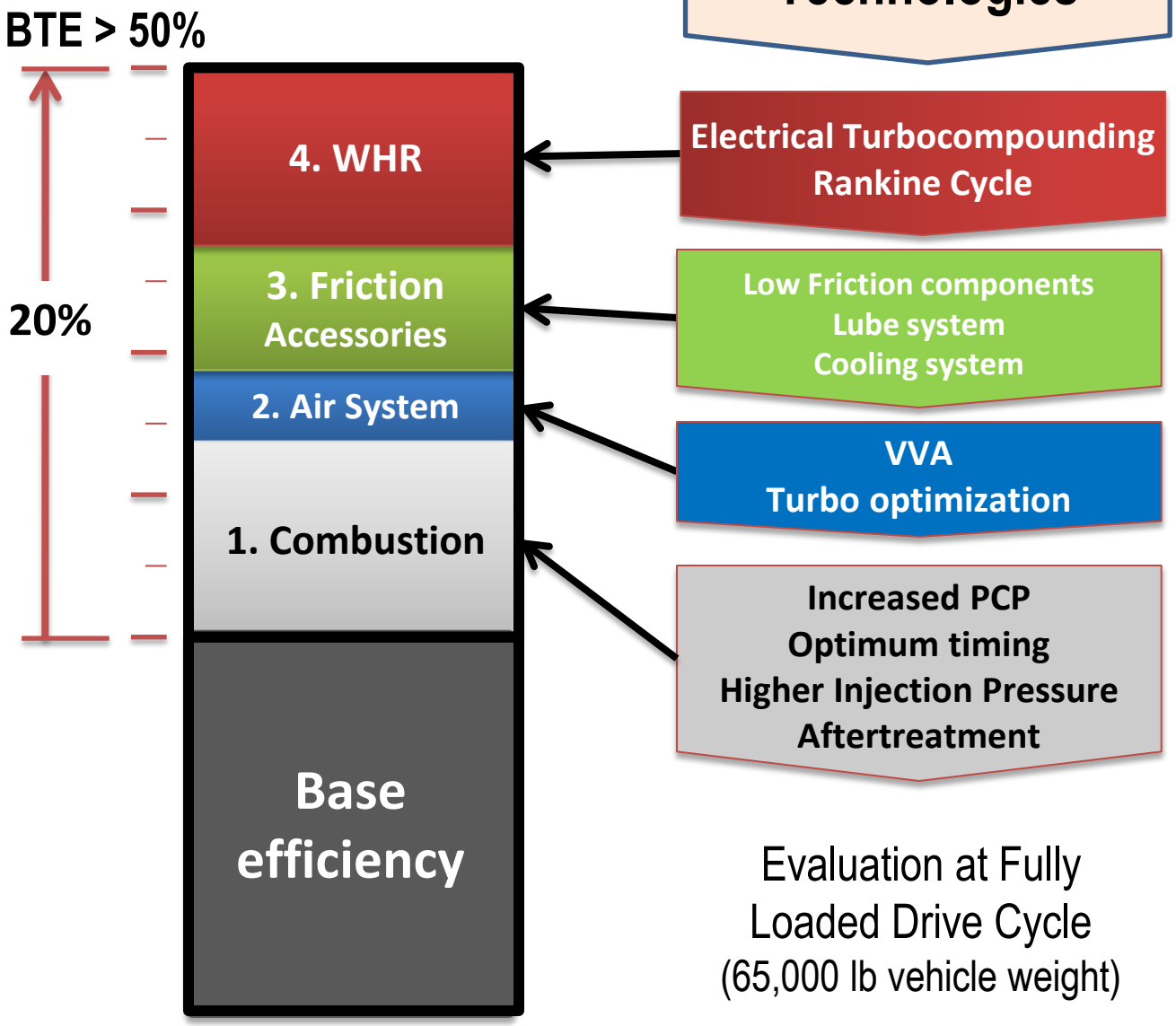
2900bar capability



Comb match

Evaluation at Fully Loaded Drive Cycle (65,000 lb vehicle weight)

Optimization criteria



Leverage Technologies

- Electrical Turbocompounding
  Rankine Cycle
- Low Friction components
  Lube system
  Cooling system
- VVA
  Turbo optimization
- Increased PCP
  Optimum timing
  Higher Injection Pressure
  Aftertreatment

Evaluation at Fully
Loaded Drive Cycle
(65,000 lb vehicle weight)

Optimize Integration Criteria

Efficiency gain
Weight
(Ton-mile/gallon)
Cost
(payback)

Engine Targets

BTE > 50%

20%

4. WHR

3. Friction Accessories

2. Air System

1. Combustion

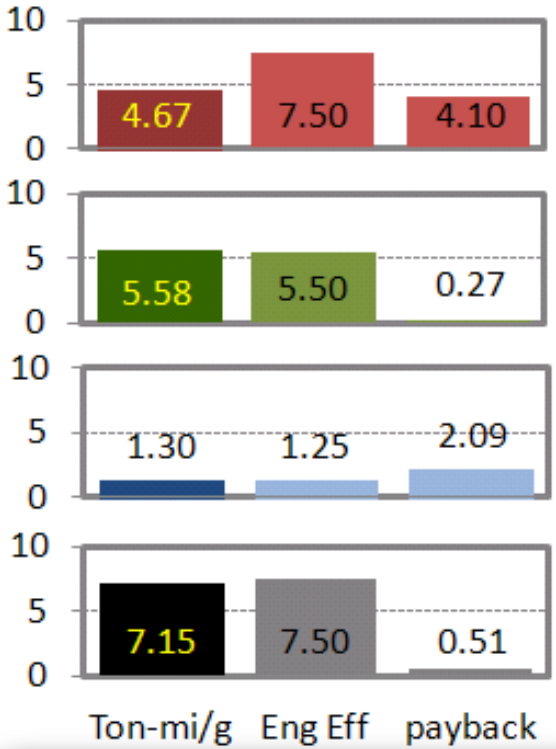
Base efficiency

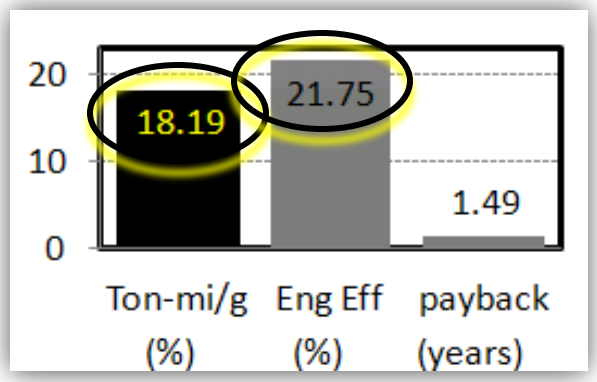
Leverage Technologies

- Electrical Turbocompounding Rankine Cycle
- Low Friction components Lube system Cooling system
- VVA Turbo optimization
- Increased PCP Optimum timing Higher Injection Pressure Aftertreatment

Evaluation at Fully Loaded Drive Cycle (65,000 lb vehicle weight)

Target :
20% Efficiency gain
20% Ton-mi/gal



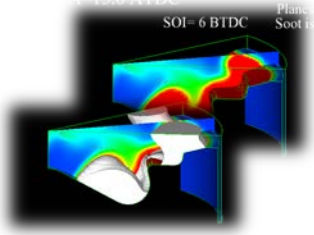


Development Facilities

Navistar

Combustion Development
Air / cooling system
Emissions
Turbocompounding
EGR-Rankine Cycle

BOSCH

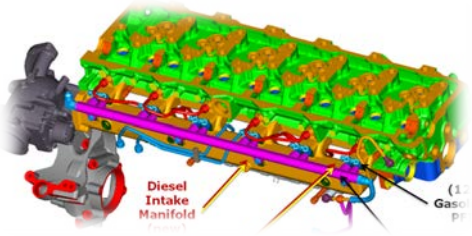


High-injection pressure capability
High Compression ratio
CFD-Engine correlations

Federal Mogul

Friction Benchmark
Power cylinder components

Argonne National Labs WERC



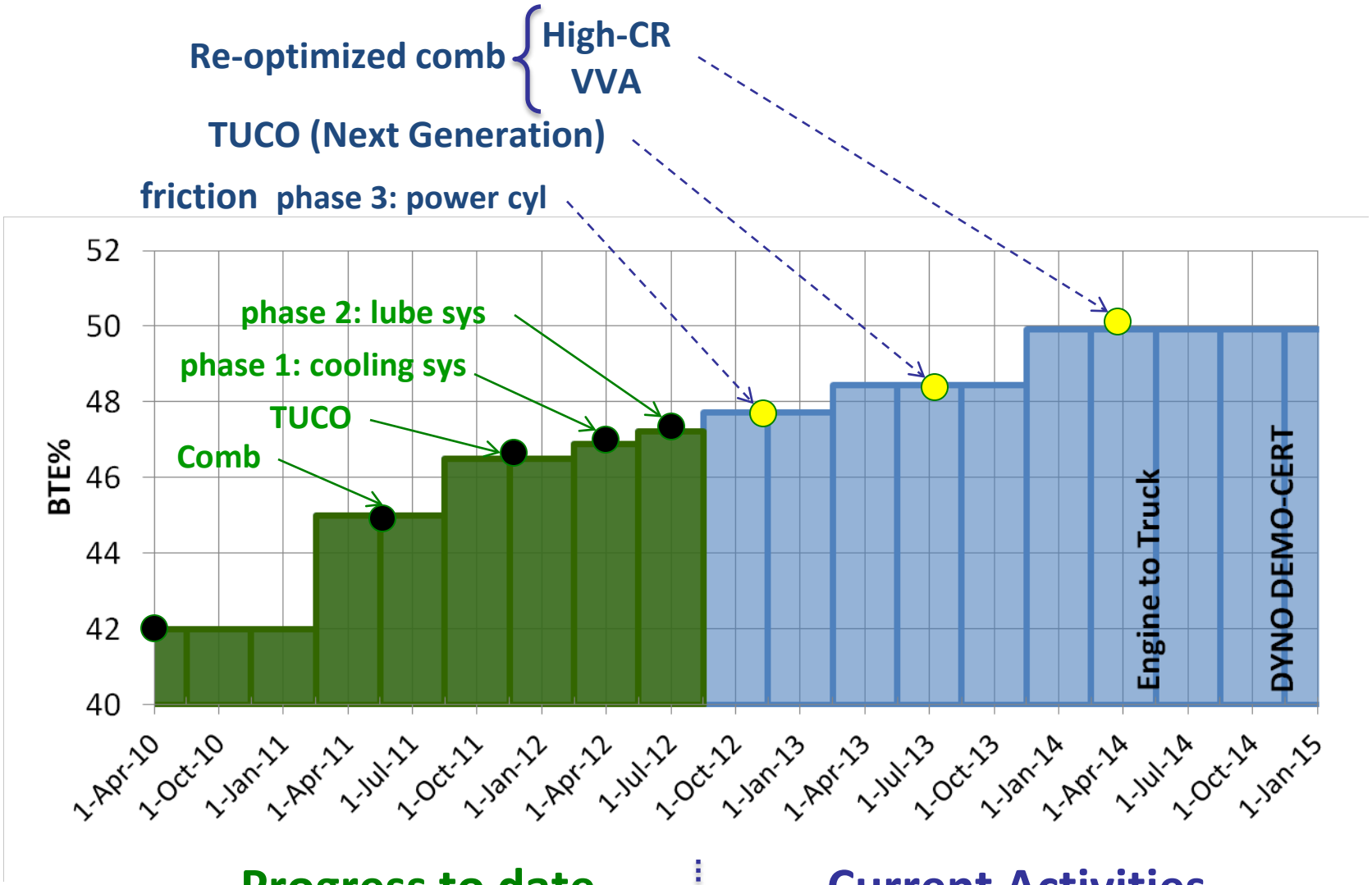
Fuel Reactivity
Cylinder head redesign
PFI system installation
Simulations

Ref DEER 2012 Navistar – Dr. Yu Zhang

Efficiency Roadmap

Technology Introduction

✓ **Preparing engine for vehicle to run at ~50% BTE**



Progress to date

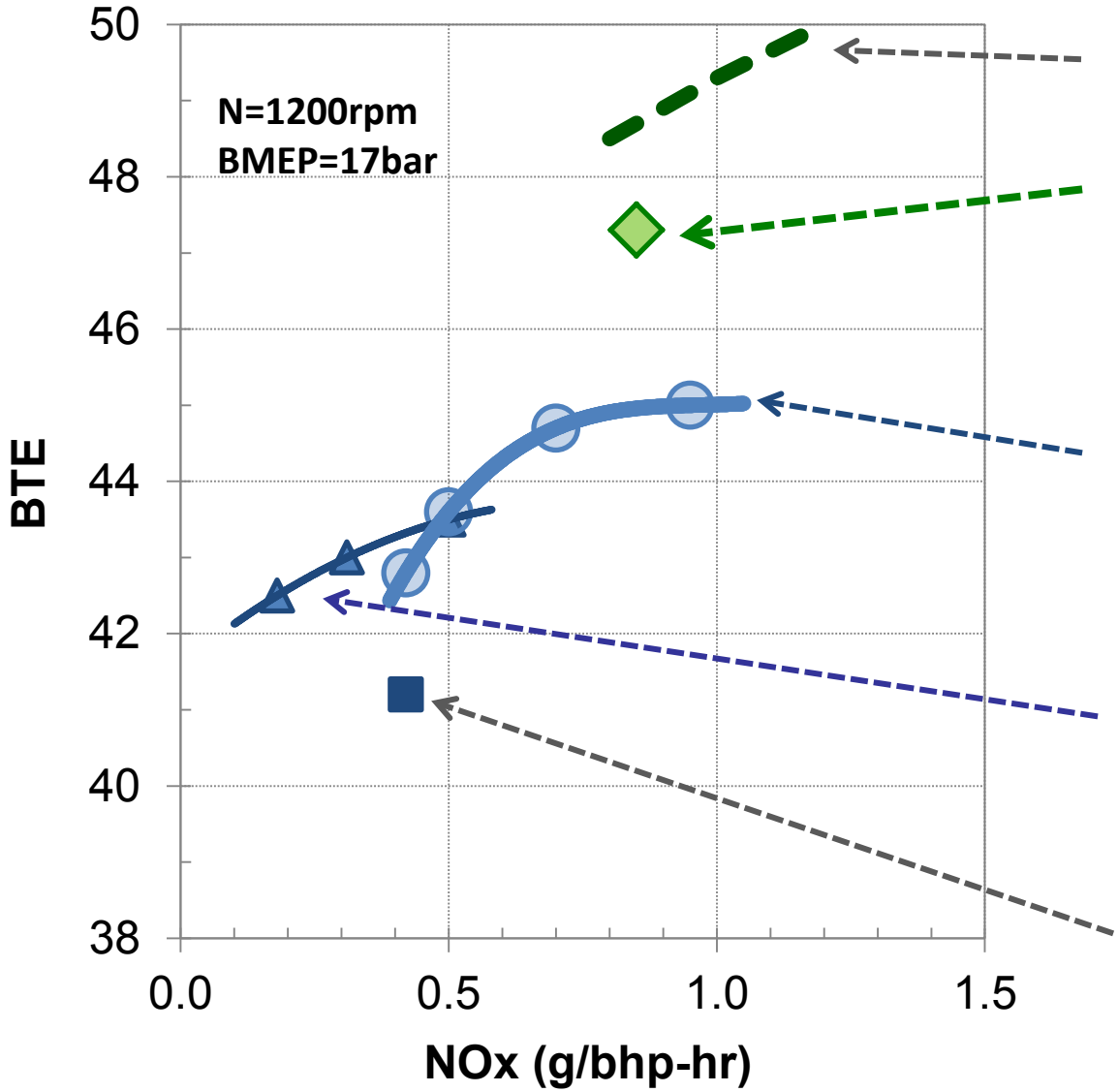
47.3% BTE

Current Activities

ORC system will be used only on dyno

Combustion

Optimization of hardware and emissions



Projected development on Supertruck during 2013

Current Demo Oct 2012
Supertruck Program
Friction reduction + TUCO

Supertruck Oct 2011
Higher CR
Advanced Fuel System
NOx ~1gNOx

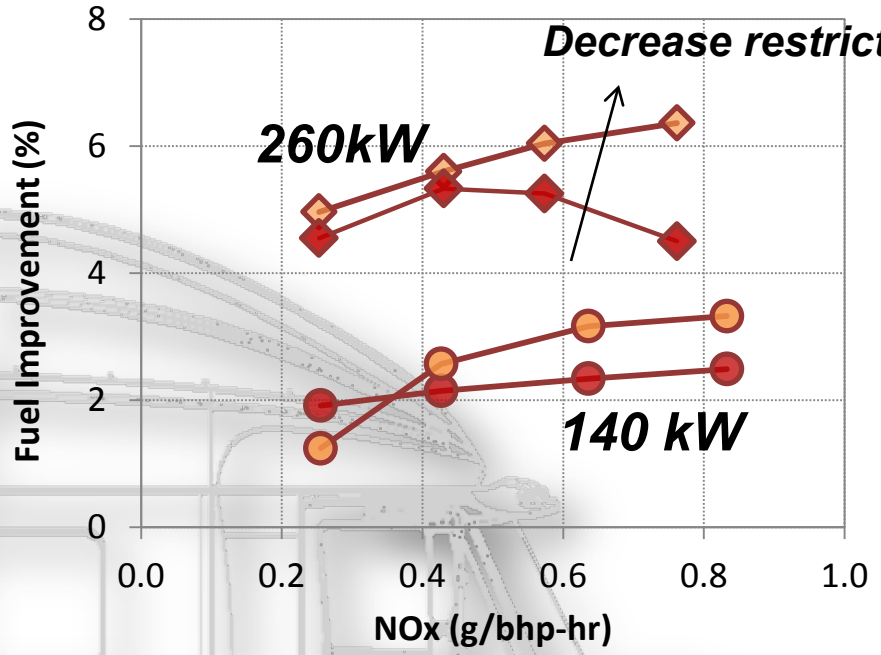
In Cylinder Solution
Combustion match
Two stage boost
Two stage cooling
High Injection Pressure
NOx ~ 0.2-0.5gNOx

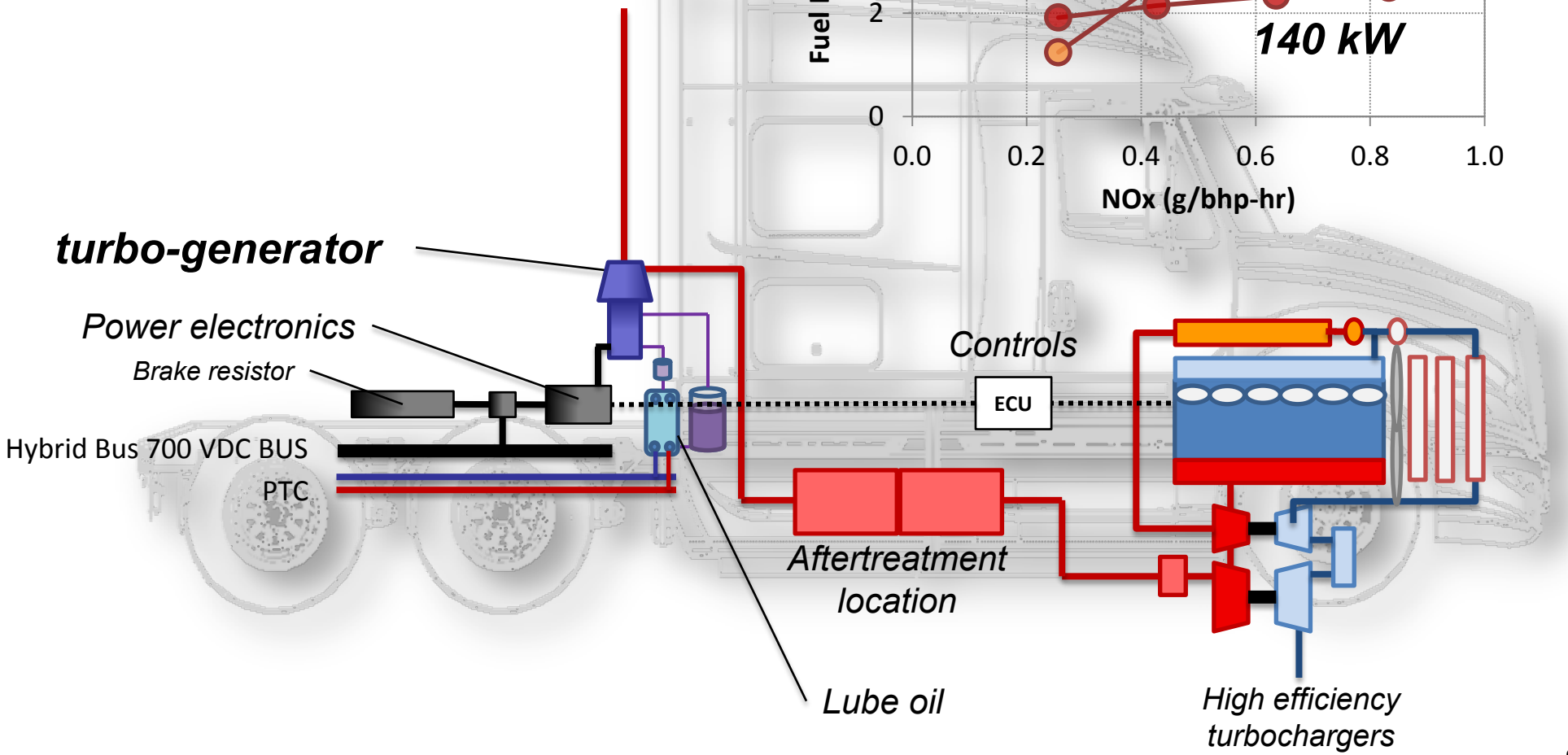
Baseline

Electrical Turbocompounding
System optimization

Advantages
- ✓ *Highest efficiency opportunity*
- ✓ *Synergistic with **Supertruck** hybridization*

Challenges:
- ❖ *Must reduce engine back pressure*
- ❖ *Must keep temps and flows up*

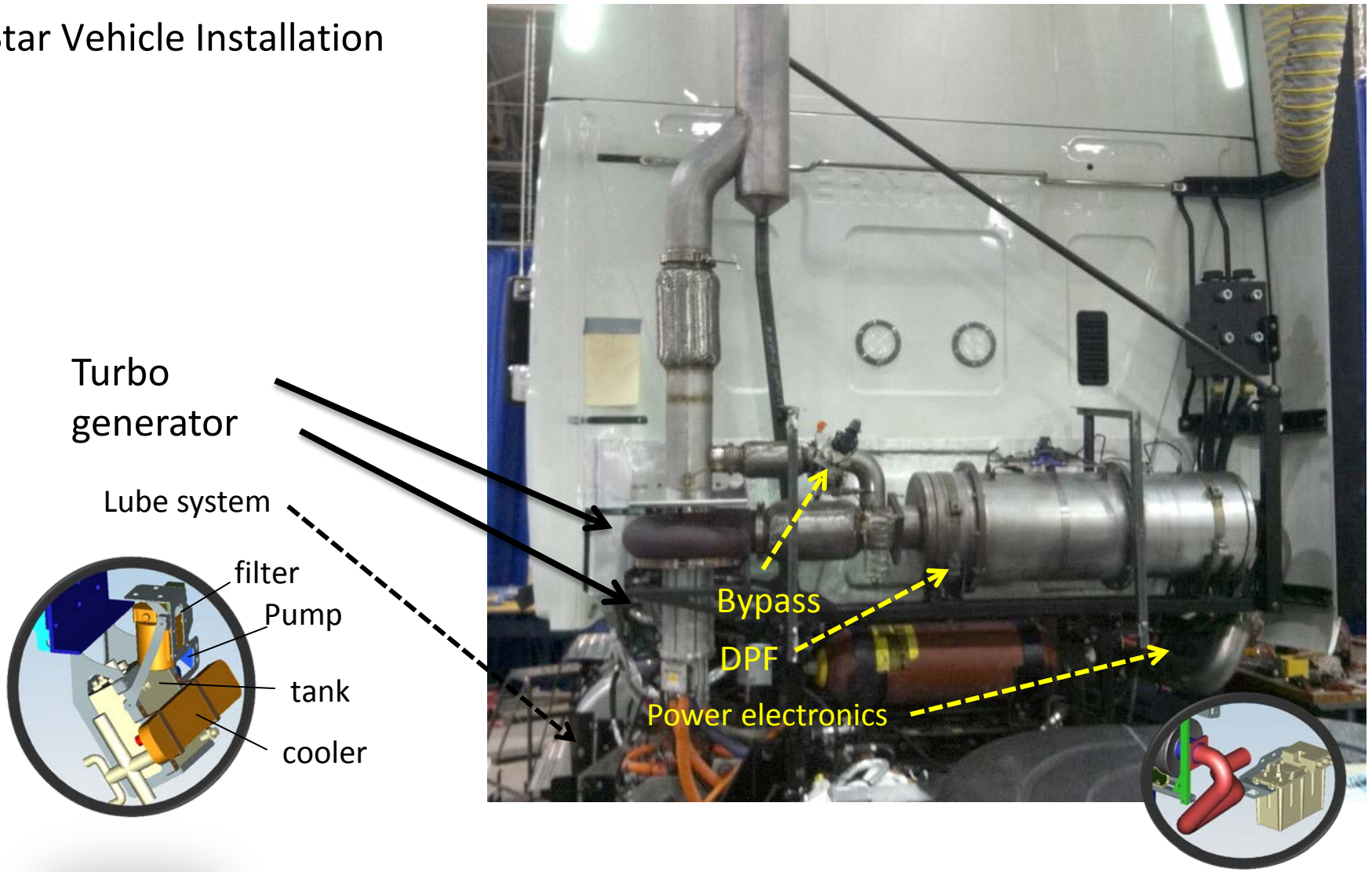




Turbocompounding

Installation on base engine

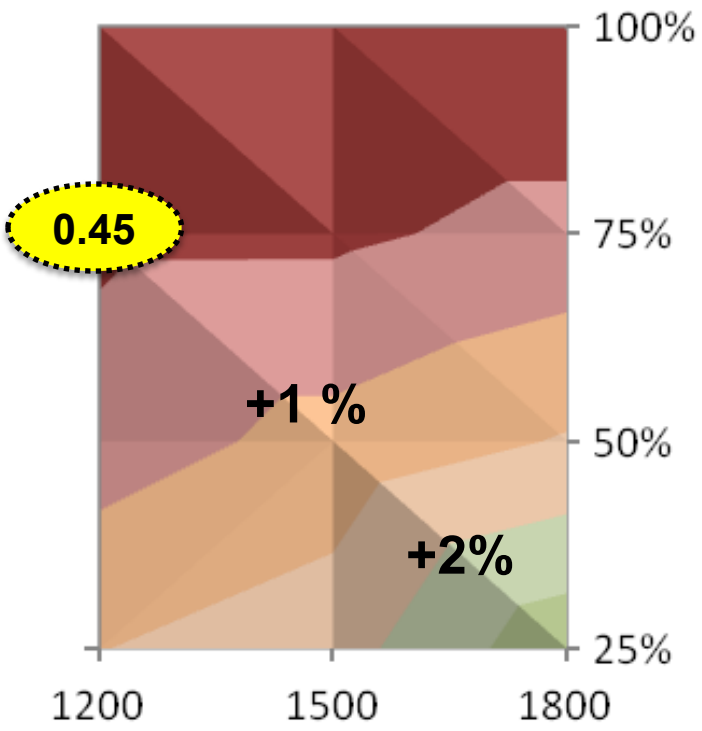
ProStar Vehicle Installation

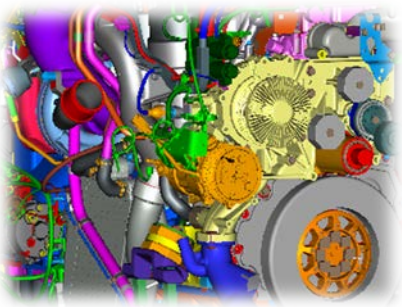


Improved Base Engine

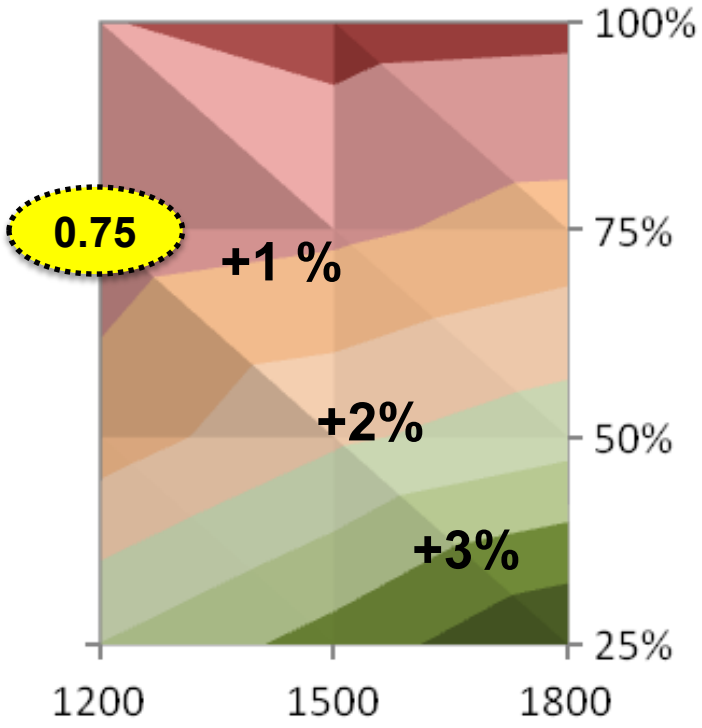
BTE gains across the engine map

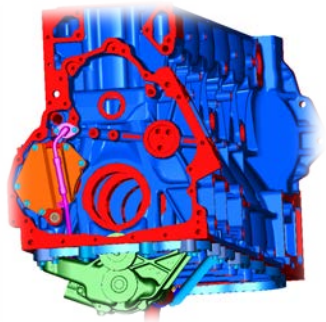
Phase I
✓ Cooling system



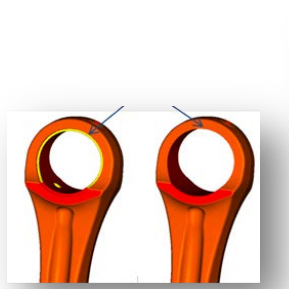


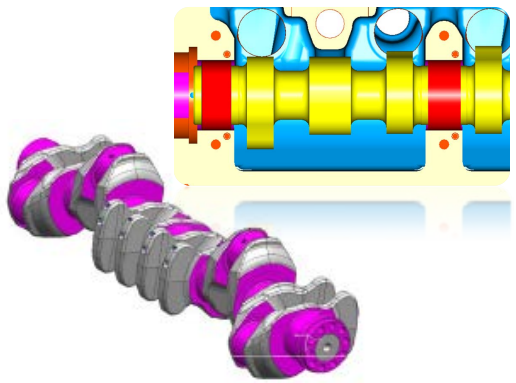
Phase 2
✓ Cooling
✓Lube oil





Phase 3
✓ Power cyl comp

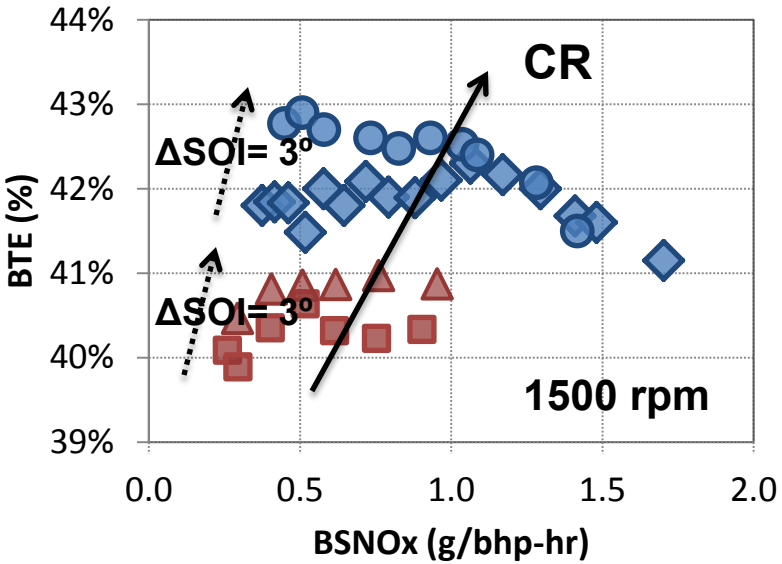


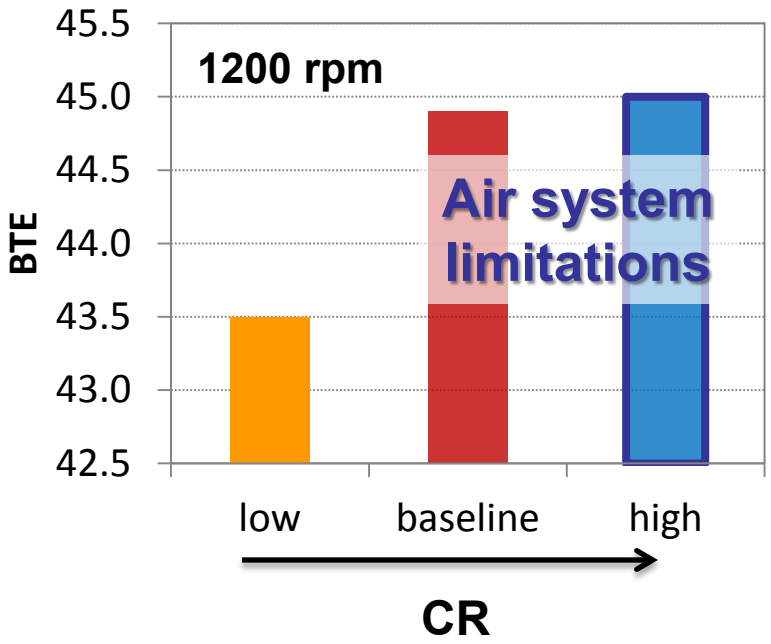


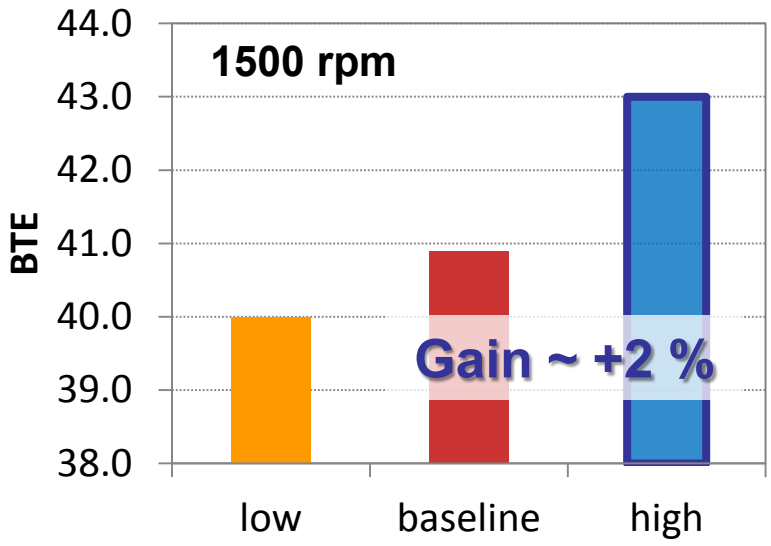
Re-matching the combustion

With turbocompounding

- ✓ *Potential gains with **higher compression ratio***
- ✓ *Re-examine other boundaries:*
  - ❖ *Air System*
  - ❖ *Peak cylinder pressures*
  - ❖ *Optimum EGR rates*
  - ❖ *…*





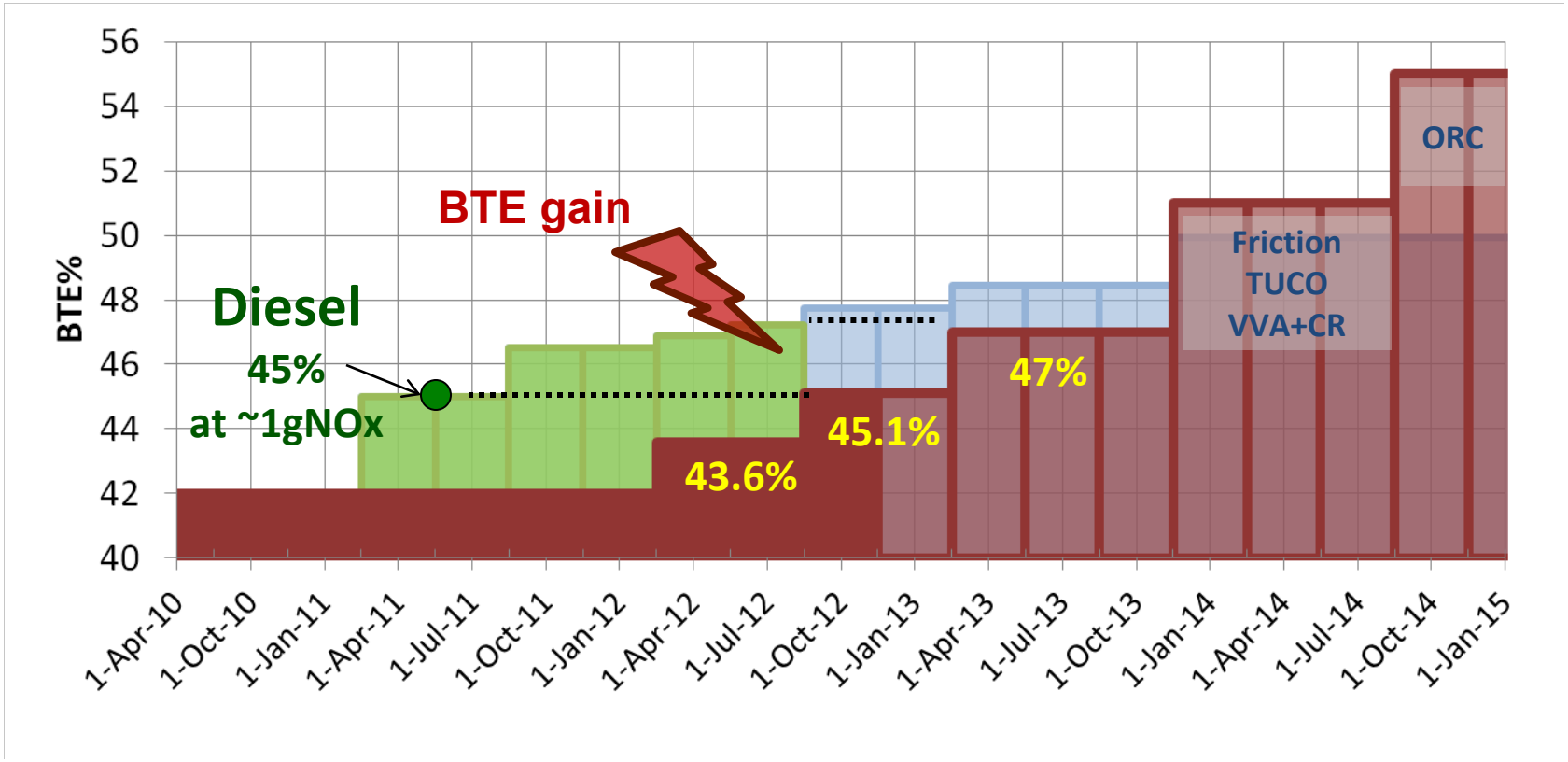


CR gains are substantial at higher engine speeds

Advanced BTE Concept
Impact of Fuel Reactivity

- ✓ *Significant improvement on BTE with fuel reactivity*
- ✓ *At better controlled engine out emissions*

Ref DEER 2012
Navistar – Dr. Yu Zhang



Progress to Date

Gasoline/Diesel
43.6%
NOx ~ 0.1gNOx

Alcohol Fuels
45.1%
NOx ~ 0.1gNOx

Current Target

Increased reactivity
BTE > 47%
at NOx < 0.1gNOx

Technologies

from the Diesel platform

Summary

NAVISTAR ENGINE GROUP

Project is assessing and developing engine and vehicle technologies to:

- ✓ Improve freight efficiency for class 8 truck and trailer
- ✓ Attain peak engine efficiencies of 50% BTE

The work to date includes:

- ✓ Combustion optimization demonstrated efficiency improvement to **45% BTE**
- ✓ Turbocompounding improvement increased BTE to **46.5%**
- ✓ First phases of Base Engine Technologies increased BTE further to **47.2%**

In addition:

- ✓ Engine has been prepared to examine the impact of **Fuel Reactivity**
- ✓ Current fuel studied increased the engine efficiency above **45%** while keeping engine NOx and PM levels significantly lower than the Diesel counterpart.

Acknowledgements

Engine Project Partners

CFD
- WERC

Fuels
- ARGONNE NATIONAL LABS

Enabling Technologies
- BOSCH
- FEDERAL MOGUL

Thank You

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