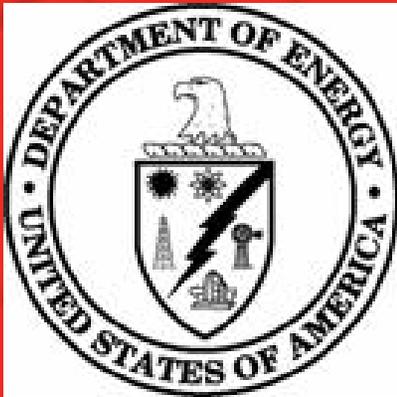


High Efficiency Engine Technologies

Chris Nelson
Cummins Inc.
August 5th, 2009





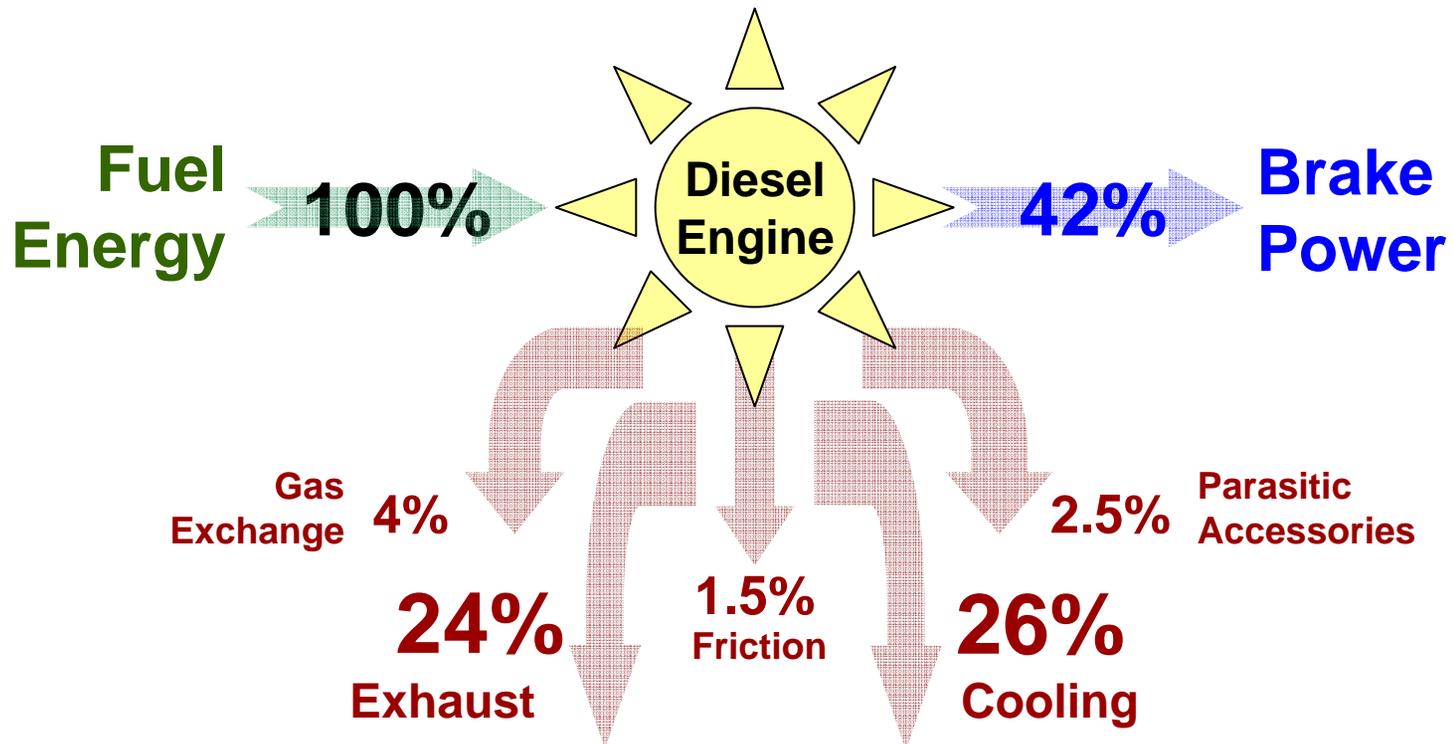
The present situation

- World demand is outpacing the development of new energy resources
 - All indicators suggest that this will continue
- Emissions legislation (NO_x, PM) has constrained our efficiency improvements
 - But this mission must remain paramount
- Energy Efficiency – has become even more critical



Current Status

Modern, heavy duty diesel engine (2007)



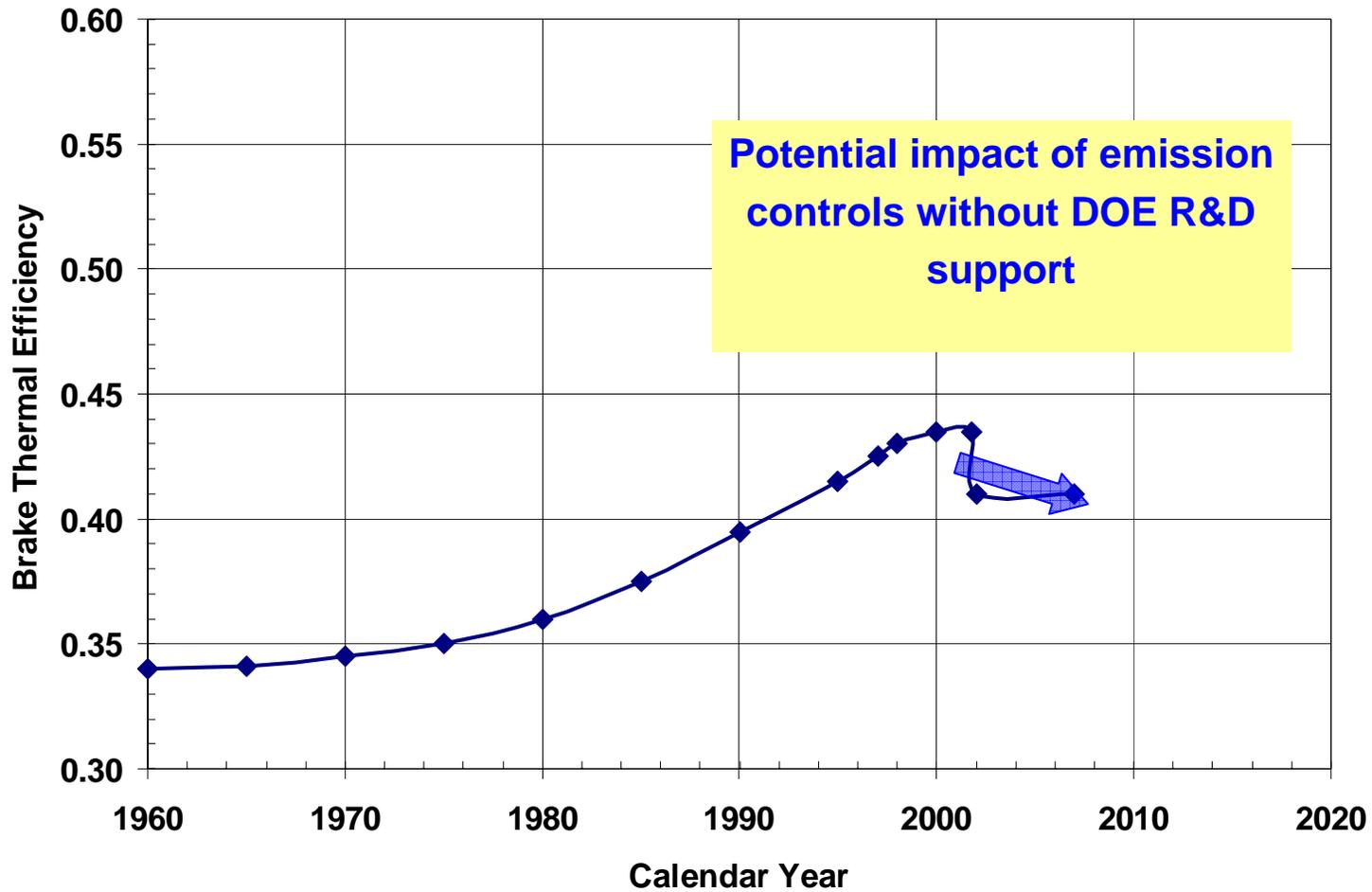


Diesel Engine Developments -

- Rudolf Diesel's first running engine was 27% efficient in 1897
- Today, after 112 years, we're at 42% after –
 - Turbocharging
 - 4-valve heads
 - High Pressure Fuel Injection
 - Electronic Controls
 - Sophisticated combustion technology
 - Near zero emissions

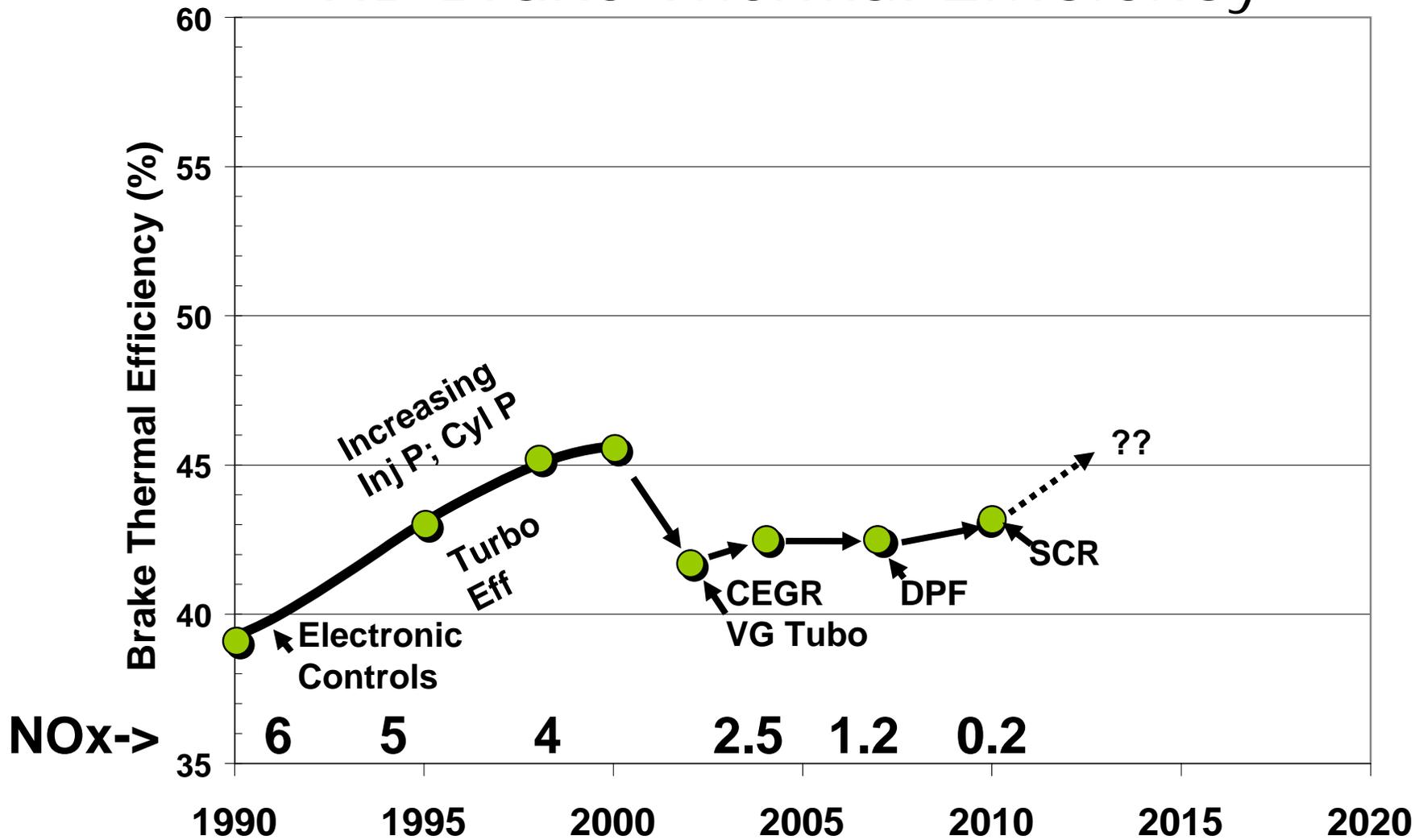


Emission Reductions Challenge on Efficiency





Historical Peak HD Brake Thermal Efficiency





Better use of what we have

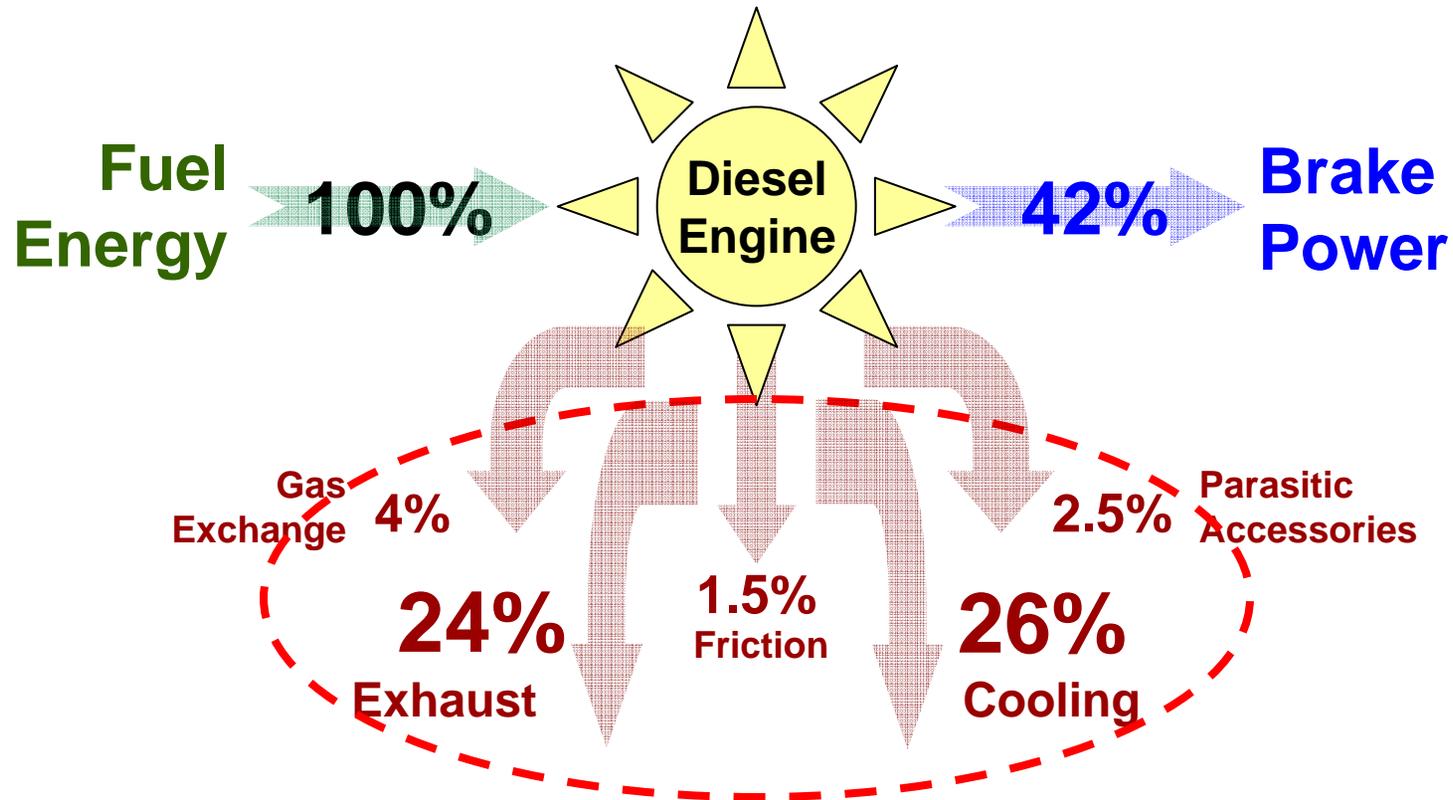
The energy 'wasted' in our combustion process is a huge untapped resource

- It's energy that's already been 'bought and paid for'
 - pulled out of the ground, processed, delivered
 - Unlocked from its chemical storage
- Recovery/conversion of this energy into useful power is a huge opportunity



Where's the energy?

Modern, heavy duty diesel engine (2007)



Heat, its capture and use

- The majority of this ‘huge, untapped resource’ is heat
 - Lower grade heat than in-cylinder, but still valuable
 - Many others have gone before in its pursuit -



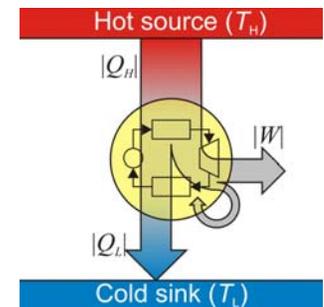
Lars Ericsson



William Rankine



Robert Stirling

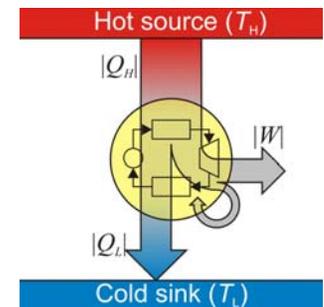


And dozens others



Heat, its capture and use

- Their ideas may be old but the technology surrounding them has progressed
- Newer materials, techniques, etc. allow improvements on their ideas and effective incorporation
- Application leads to efficiency increases
 - And establishes new starting points for further improvements



Heat, its capture and use

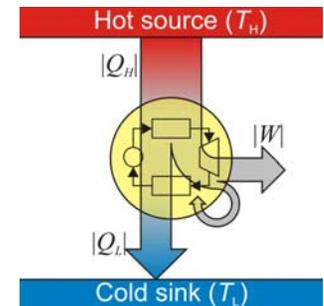
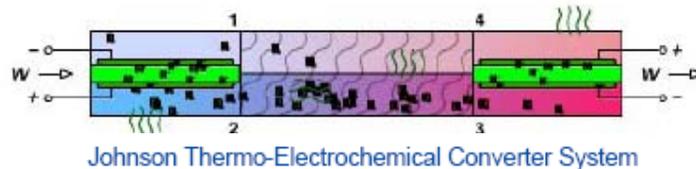
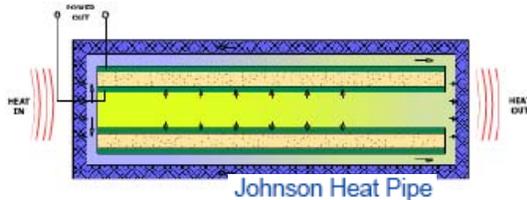
New ideas and technologies are now among us -

- Thermoelectrics



Hi-Z HZ20

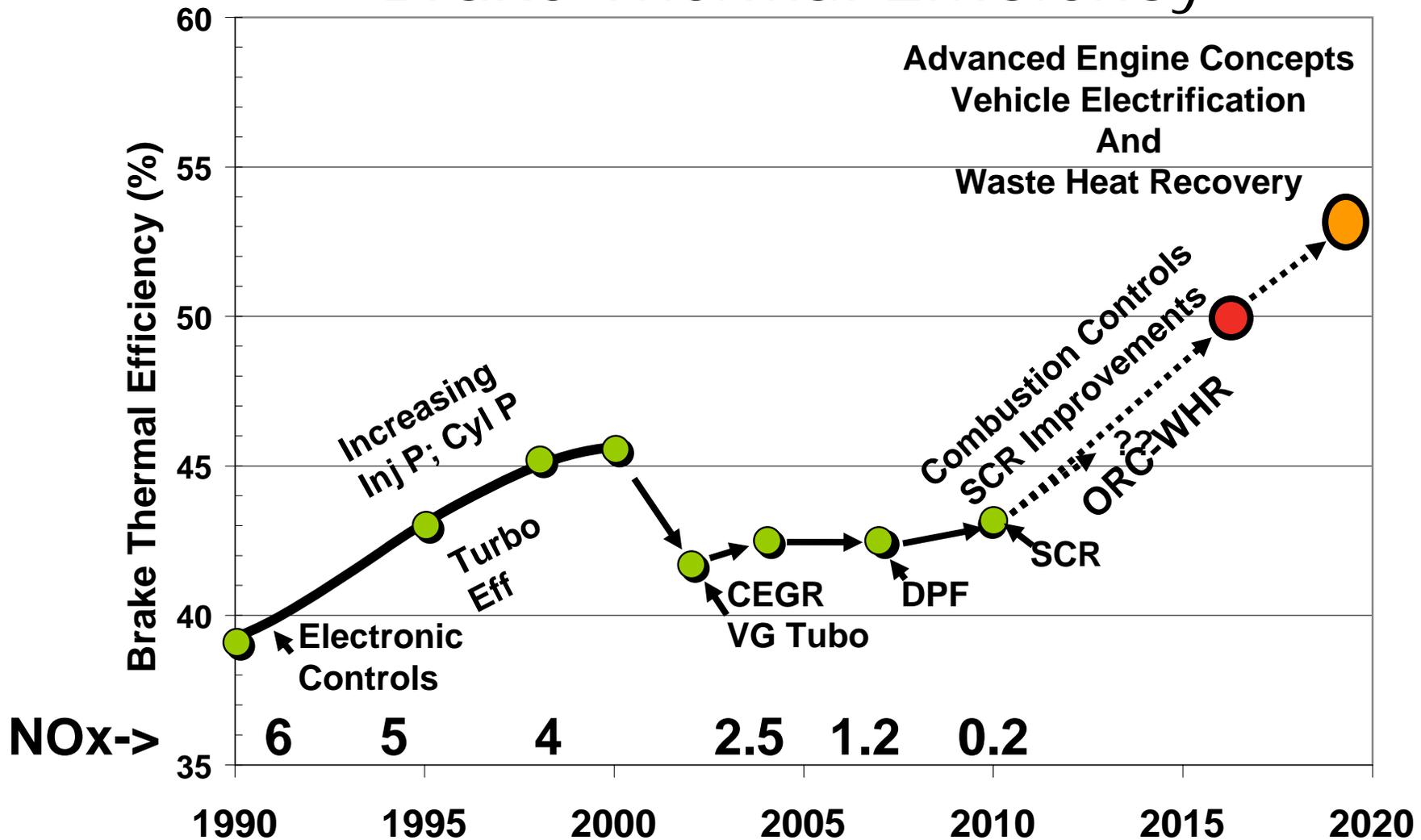
- Thermo-Electro-Chemical conversion



All with the same goal –
 – energy recovery and useful conversion



Historical and Projected Peak HD Brake Thermal Efficiency





Base Diesel Engine Efficiency must continue to improve

- It's the most efficient energy conversion system
 - Fuel systems must continue to improve
 - Lifted Flame, Stoichiometric, and Mixed-mode Combustion. Increases in cylinder pressure, and closed loop controls
 - Air Handling systems must continue to improve
 - Turbo/compressor improvements
 - Variable Valve Trains
 - Aftertreatment must become more effective
 - Etc. – Today's Session

But we must more effectively use the all energy coming to the engine system, WHR is the key