Heavy Vehicle Auxiliary Load Electrification for the Essential Power System Program: Benefits, Tradeoffs, and Remaining Challenges

presented by

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at the

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Cobo Center
Detroit, Michigan, USA

25 Years of Research Excellence 1977-2002

Introduction

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  - Task Leader,
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- Michael P. O'Keefe, speaker & primary contact
  - Heavy Vehicle Power & Propulsion Systems Team, CTTS

- National Renewable Energy Laboratory
  - U.S. Department of Energy's national lab (Golden, CO)
  - Only national lab *dedicated*
    to renewable energy &
    energy efficiency R&D

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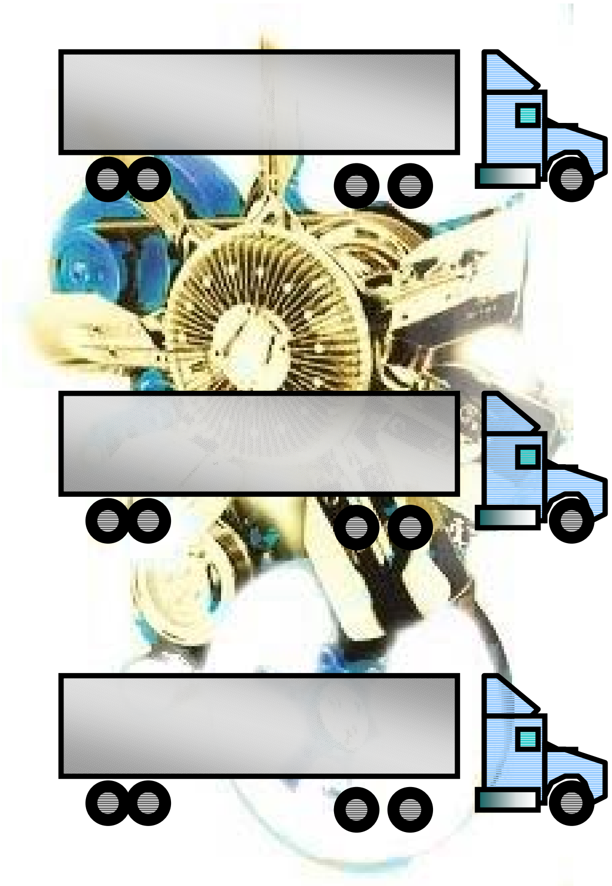
Presentation Overview

- **Essential Power System** (EPS) =

  intelligent management of
  auxiliary power

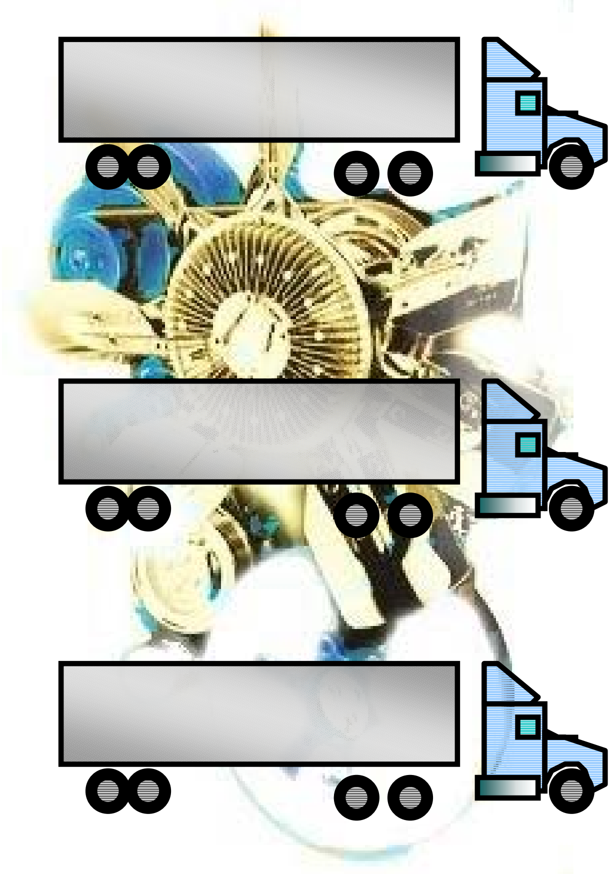
- **Energy savings** potential **significant**

- **Systems approach** is key



Outline

- **Background** on EPS Concept
- **Scope** of Analysis
- Auxiliary and Vehicle **Duty Cycles**
- EPS **Energy Tradeoff**
- Simulated **EPS Benefits** from ADVISOR
- **Conclusions**



Background on the Essential Power Systems Concept

- **Background**
- Scope
- Duty Cycles
- Energy Tradeoff
- EPS Benefits
- Conclusions

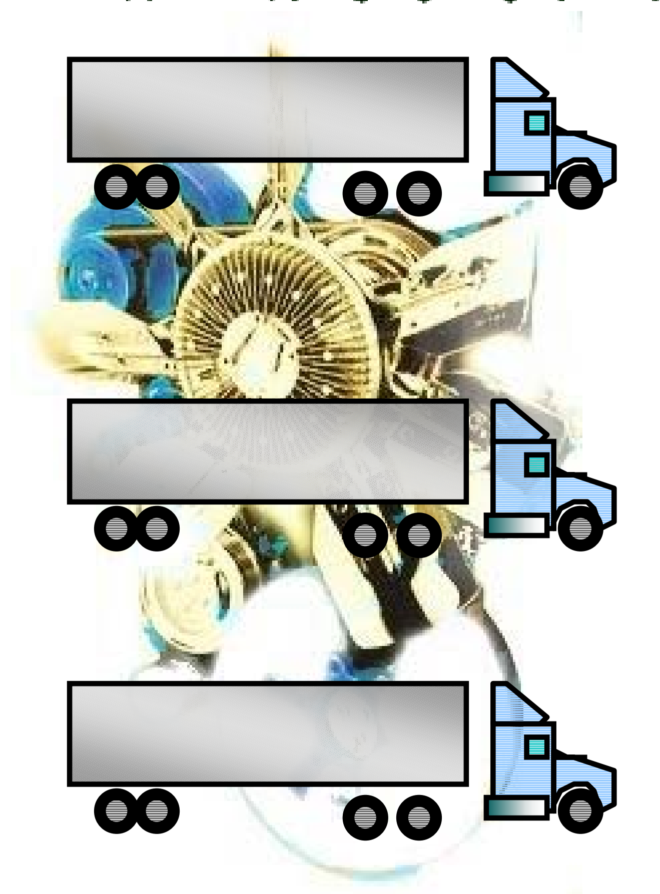
The Essential Power System Concept

- Essential ~ *only supply that power **essential** to meeting your needs **when** you need it*

- **Efficient** satisfaction of **non-propulsion** power needs
  - vehicle both in-use and idling
  - optimization/sys. analysis

- Mechanical to electrical auxiliary **transformation**

- **Alternative power** strategies provide electricity
  - integrated generation
  - waste energy recovery
  - energy storage
  - auxiliary power units (generator, fuel cell)
  - shore power
  - hybridization



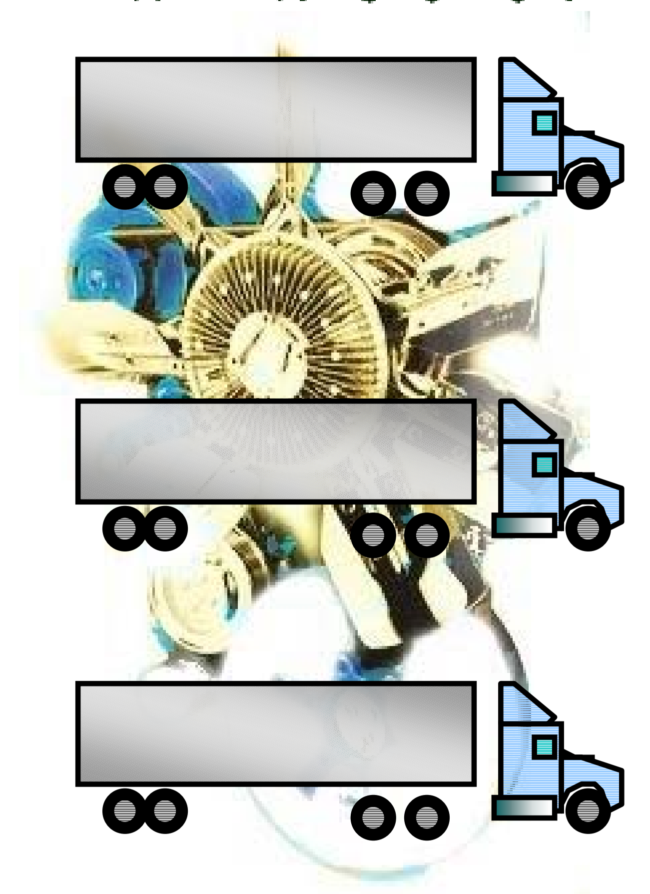
The Essential Power System Concept

OBJECTIVE:

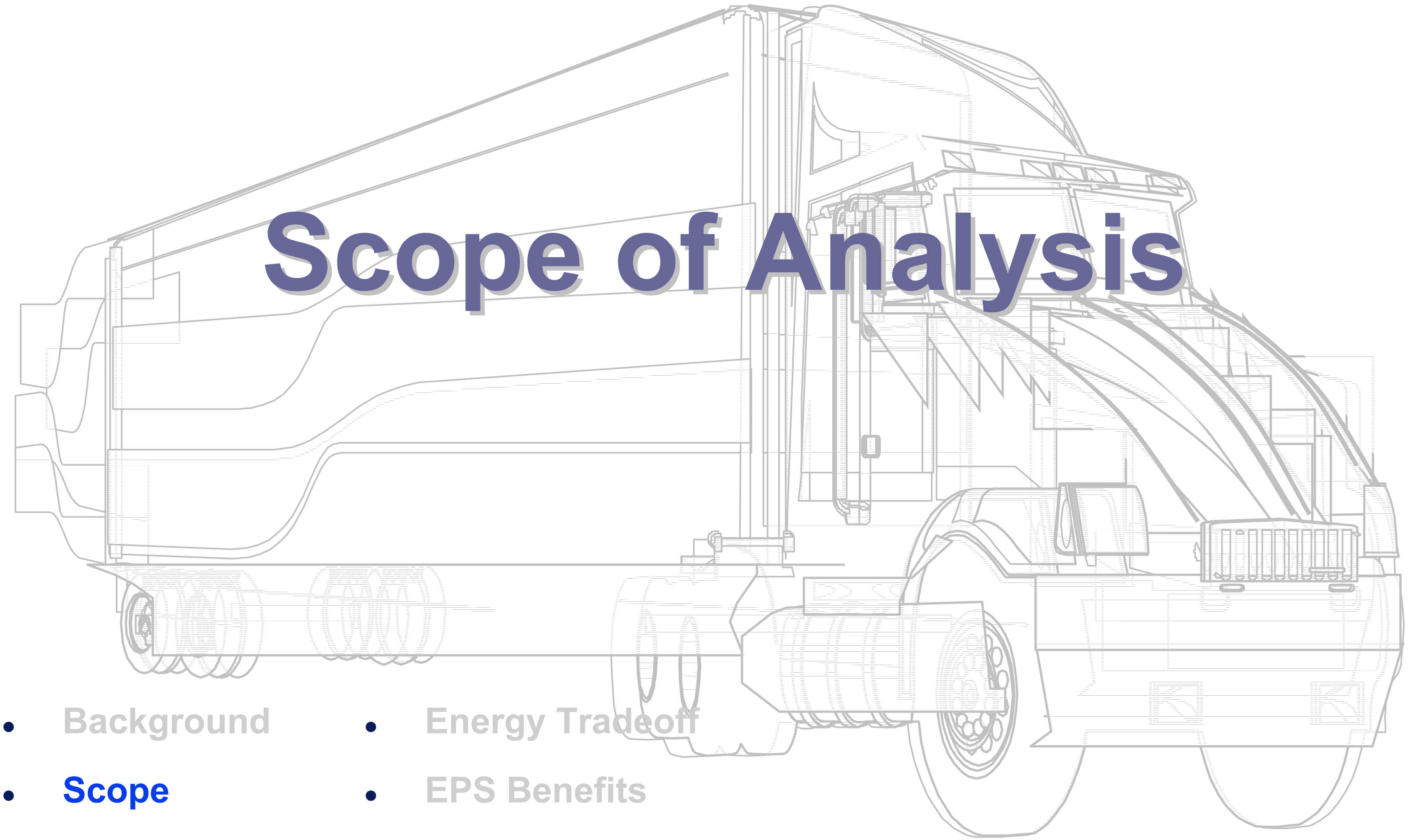
Energy Savings

using

Commercially Viable Solutions



Scope of Analysis



- Background
- Scope
- Duty Cycles
- Energy Tradeoff
- EPS Benefits
- Conclusions

Scope of Auxiliary Loads Addressed

- Platform: Class 8 non-refrigerated tractor-trailer
  - future studies will examine Classes 3-8

- Aux. Components analyzed
  - engine cooling fan
  - engine oil pump
  - engine coolant pump
  - power steering pump
  - alternator
  - air compressor
  - air conditioning compressor

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Scope of Auxiliary Load Analysis

- **System tradeoffs** of auxiliary load electrification identified
- **Potential benefit** of removing belt-driven mechanical loads quantified in ADVISOR simulation
  - moving vehicle only
  - no extended idling
- **Break-even analysis** to estimate the impact of electrical auxiliaries with APU conducted
  - fuel economy impact of electric loads not directly quantified
  - electrical device duty cycle & performance not available




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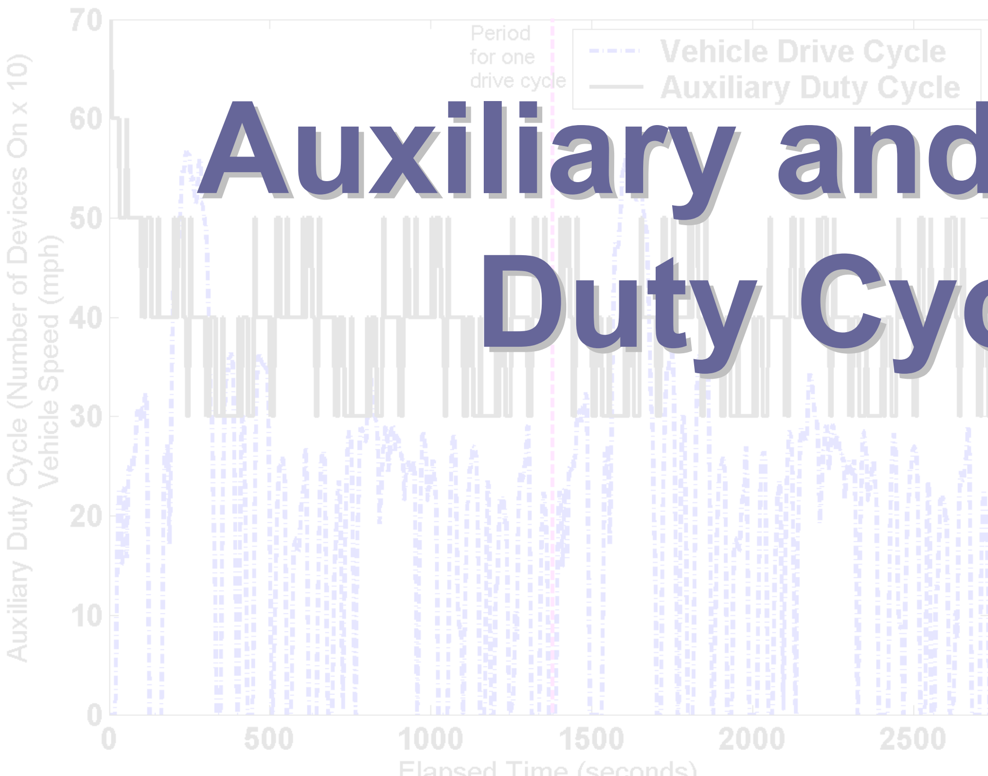
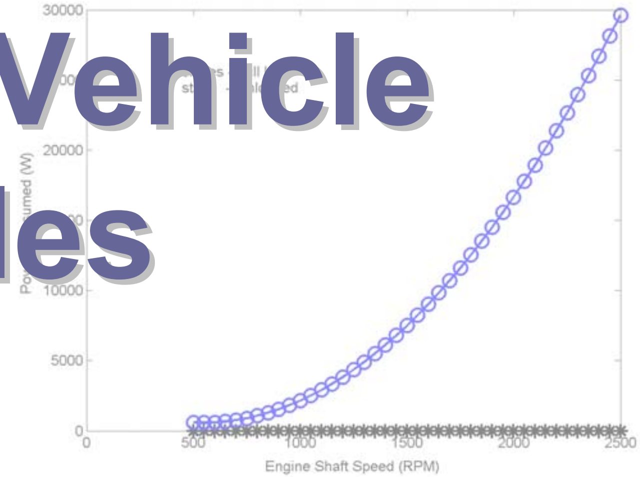
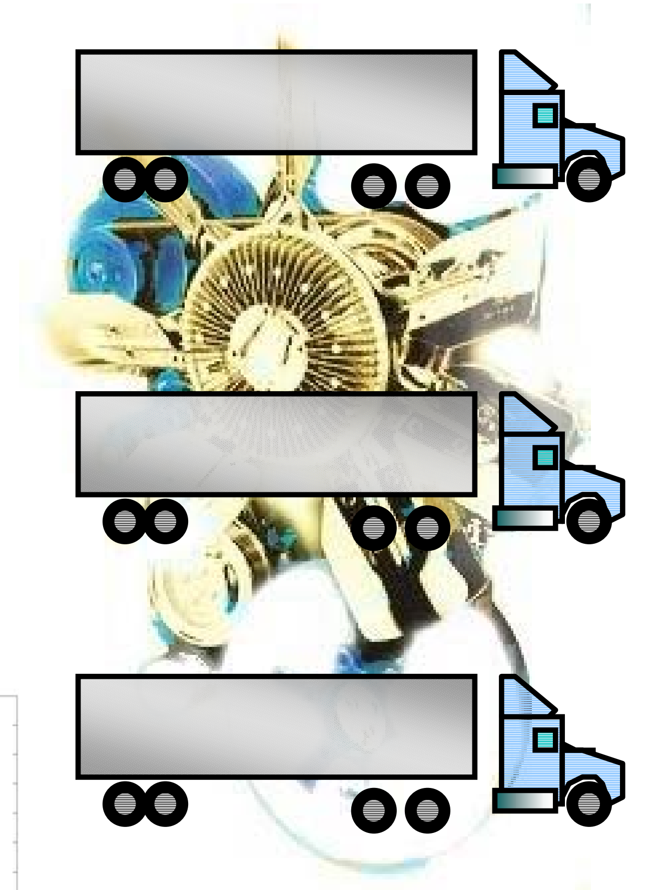
Auxiliary and Vehicle Duty Cycles



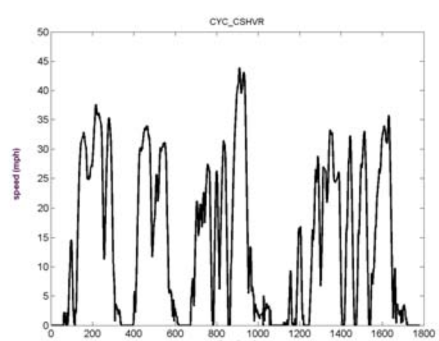


- Background
- Scope
- **Duty Cycles**
- Energy Tradeoff
- Modeling EPS Benefits
- Conclusions

Analyzing Mechanical Auxiliary Loads



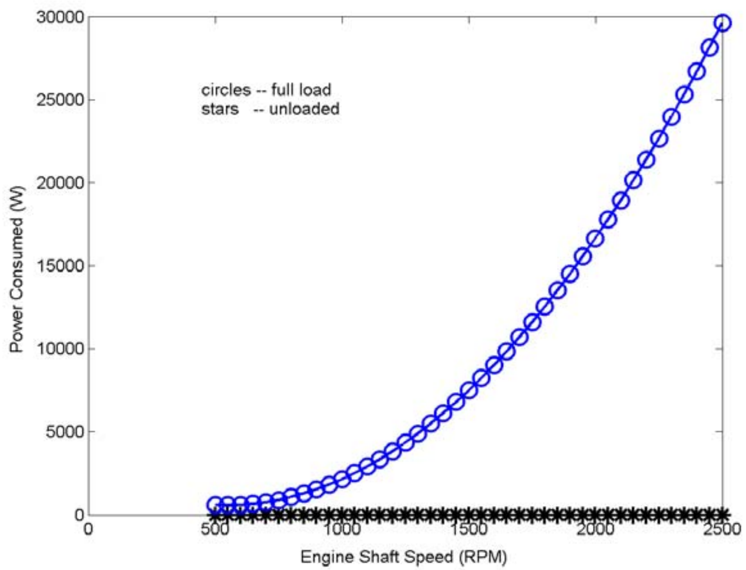
- **Objective:** determine baseline fuel consumption with conventional mechanical loads
- Required information:
  - representative **vehicle drive cycles**
  - representative **auxiliary duty cycle**
  - mech. auxiliary **energy usage by speed**
- Drive cycles used:
  - CSHVR **(urban driving)**
  - Constant 65 mph **(highway driving)**



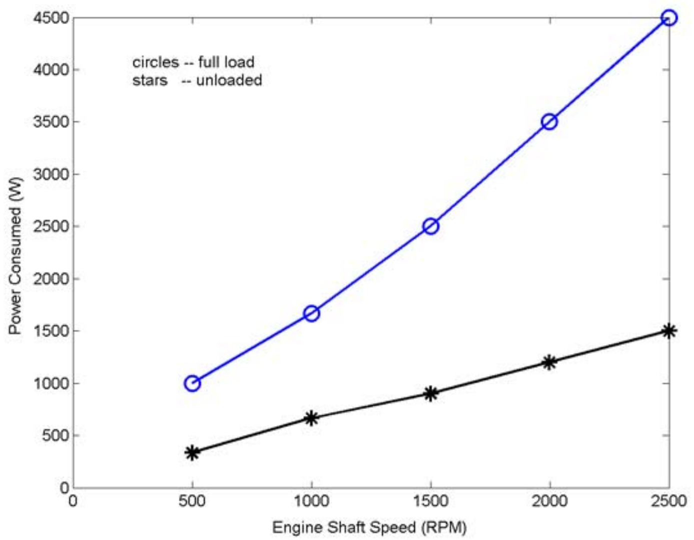
Analyzing Mechanical Auxiliary Loads

- **Auxiliary Duty Cycles** from SAE J1343
  - gives typical usage patterns for heavy vehicle accessories
- **Energy usage by speed** taken from various literature sources

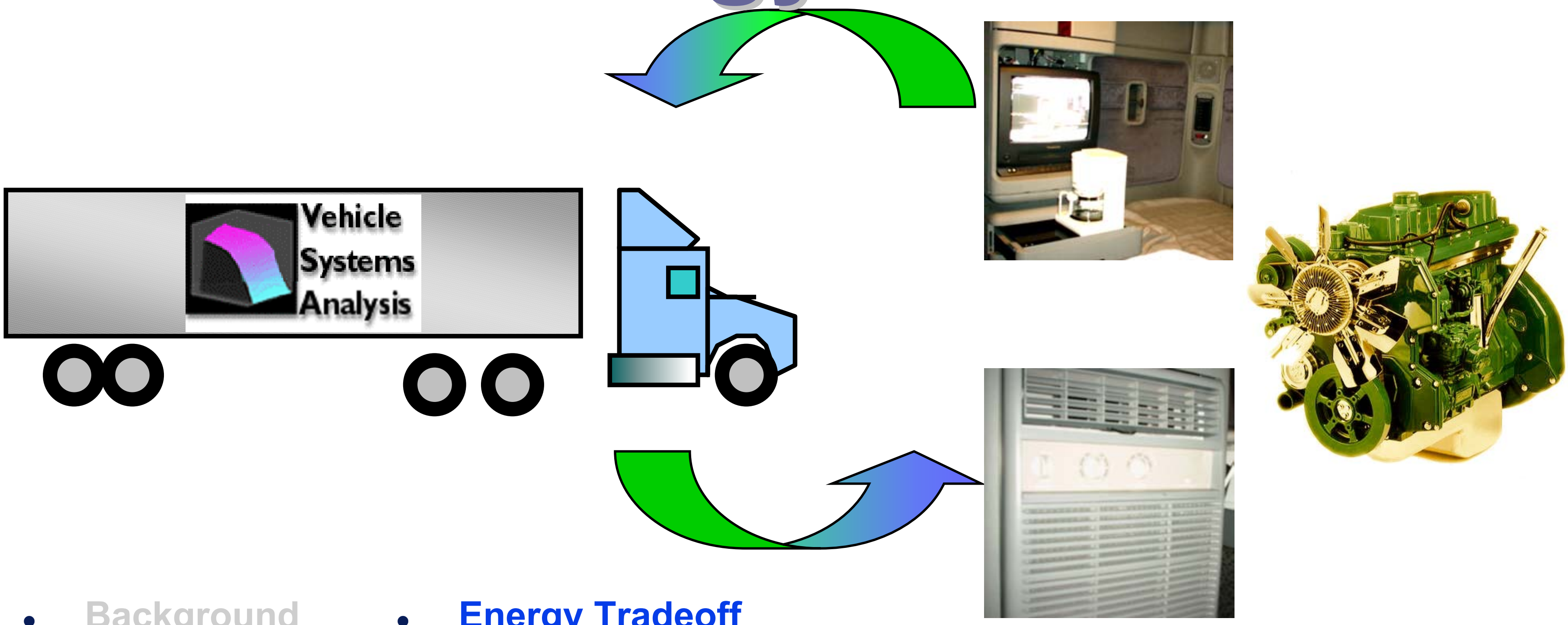
engine fan



air brake compressor

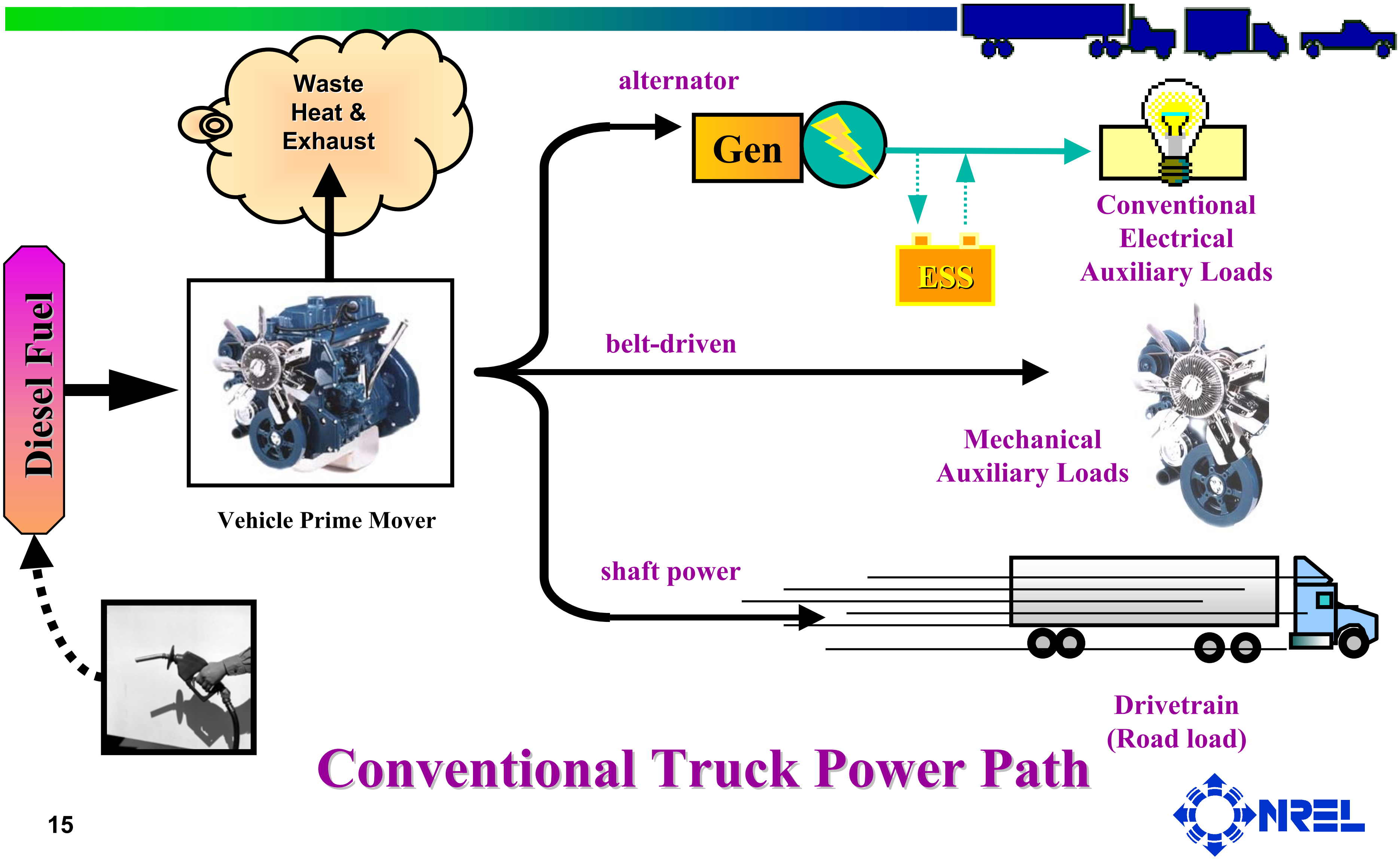


EPS Energy Tradeoff

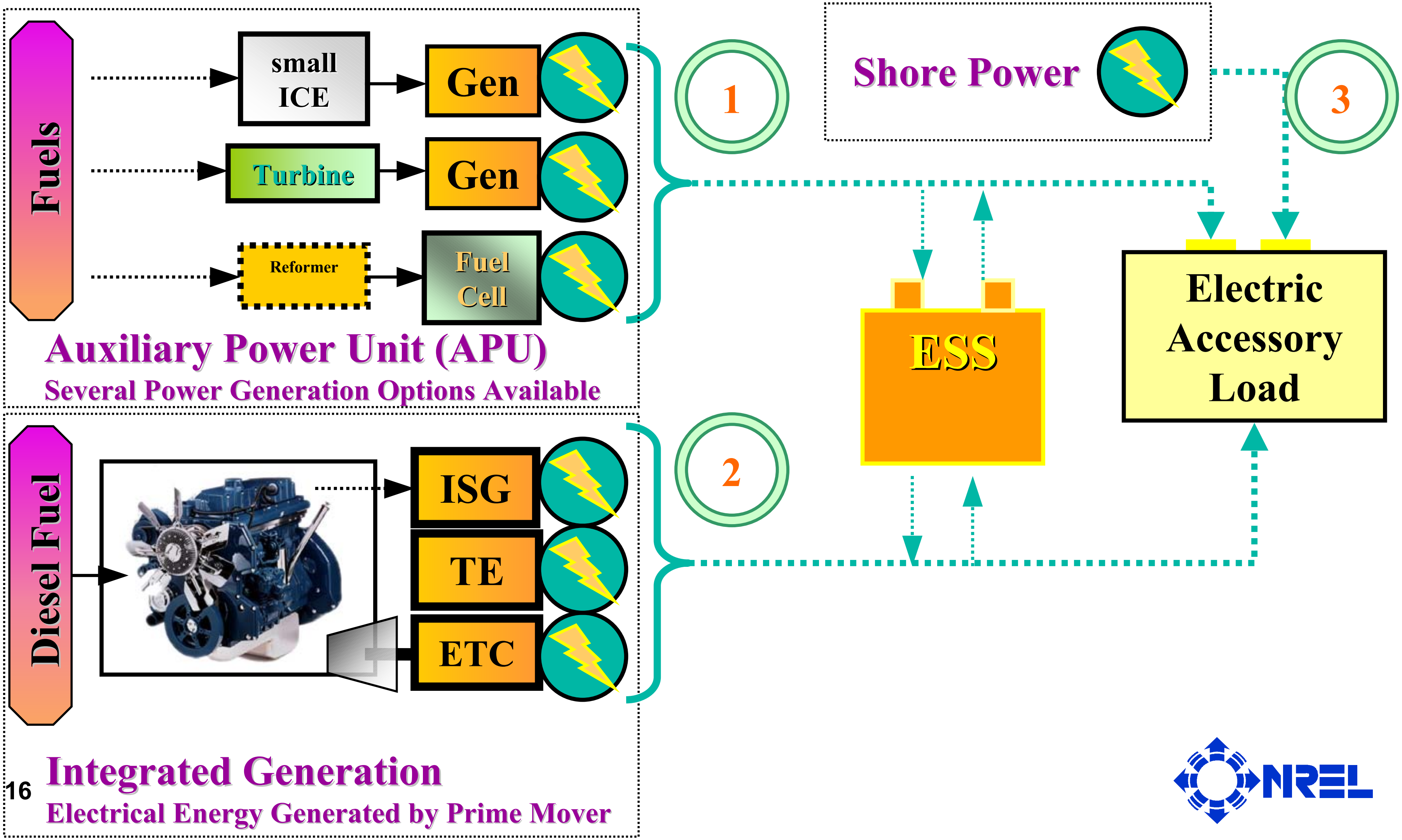


- Background
- Scope
- Duty Cycles
- **Energy Tradeoff**
- EPS Benefits
- Conclusions

Conventional Auxiliary Load Setup

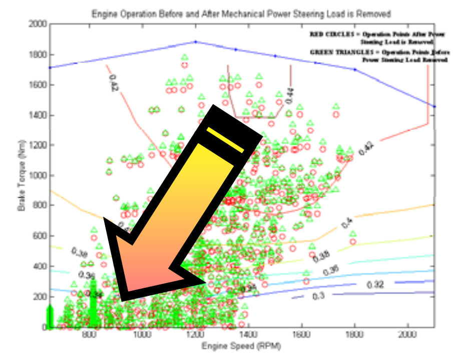


Essential Power System Power Paths

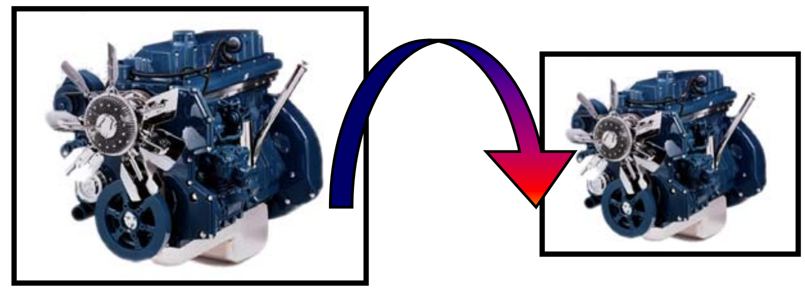


Energy Impacts of Auxiliary Electrification

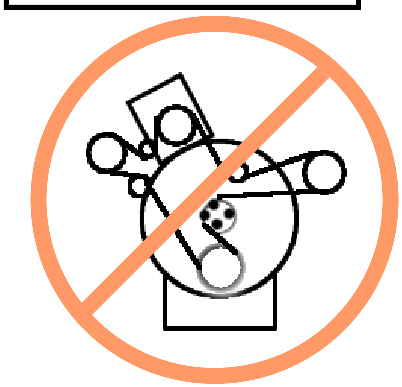
- **Engine Unloading** — 1 — $\eta\downarrow$



- **Engine Resizing** — 2



- **Removal of Inefficient Belt-Driven Loads** — 3



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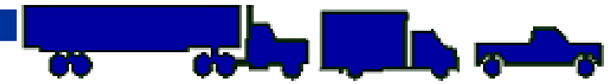
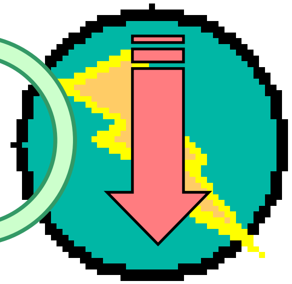
Energy Impacts of Auxiliary Electrification



- Satisfying auxiliary needs electrically

4



- energy saved by reducing base auxiliary power requirement

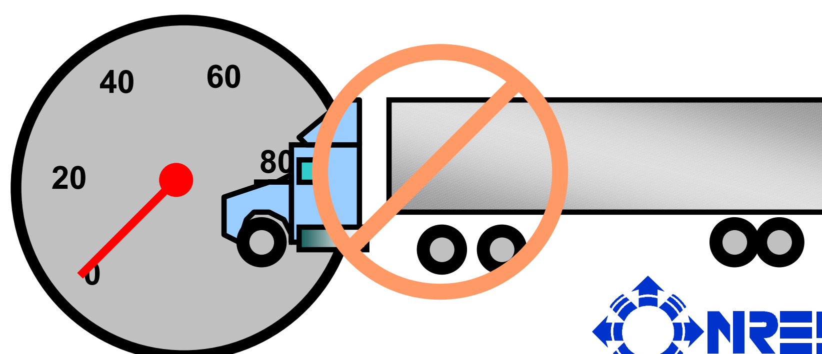
7

- mass effects

5

- idling reduction and anti-idling technology

6



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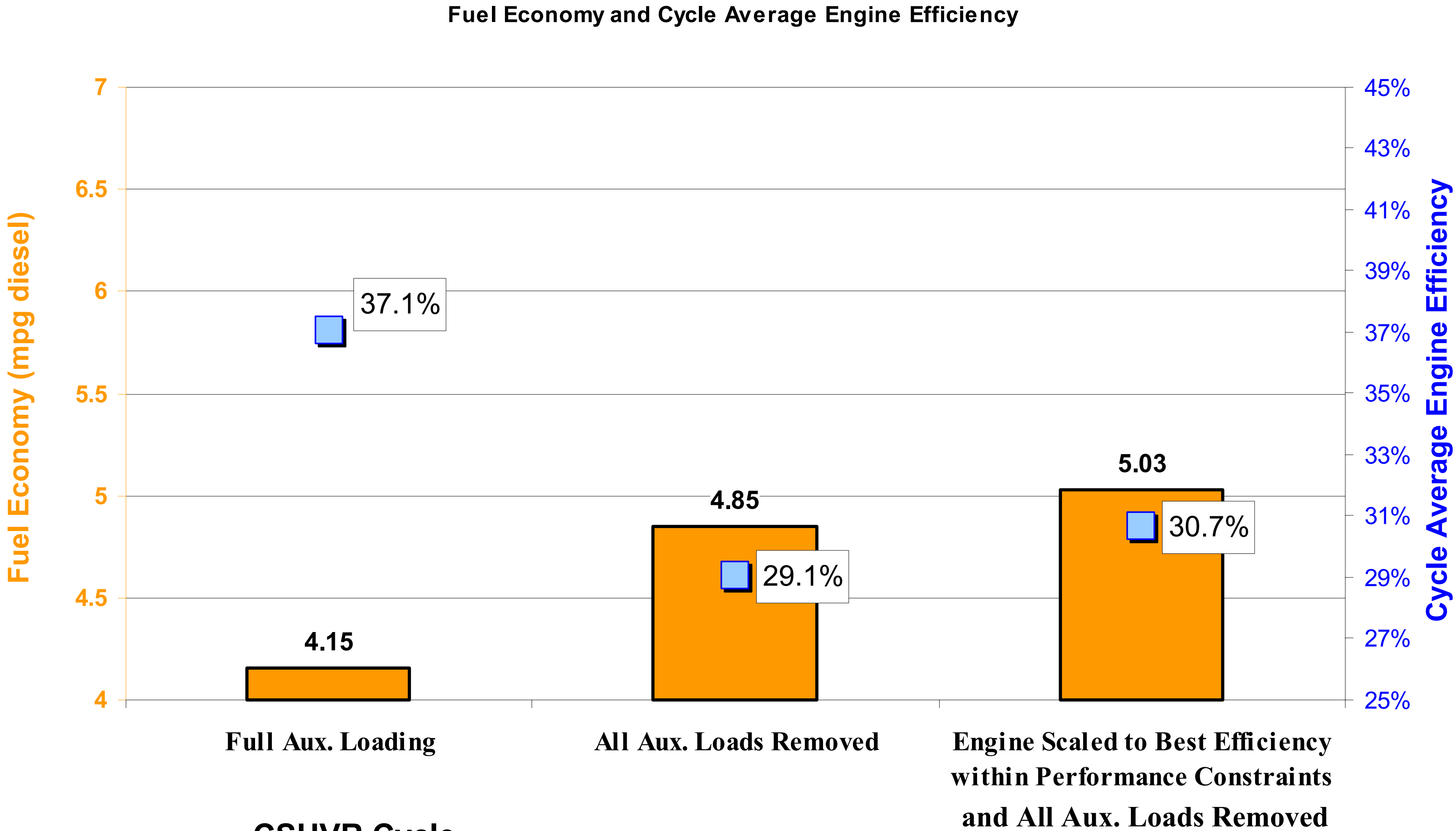
Energy Savings Tradeoff

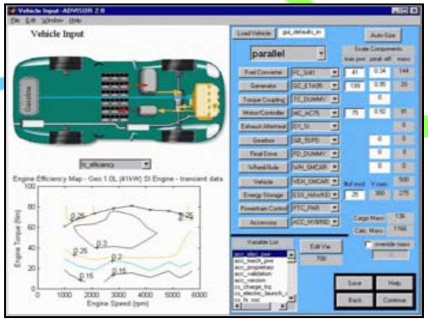
Interaction of Engine Unloading, Resizing, and Auxiliary Removal



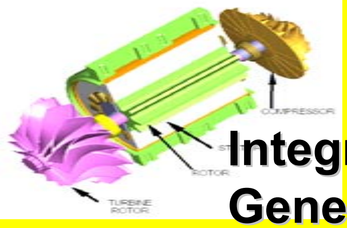
CSHVR Cycle

Simulated EPS Benefits from ADVISOR

- Background
- Scope
- Duty Cycles
- Energy Tradeoff
- **EPS Benefits**
- Conclusions



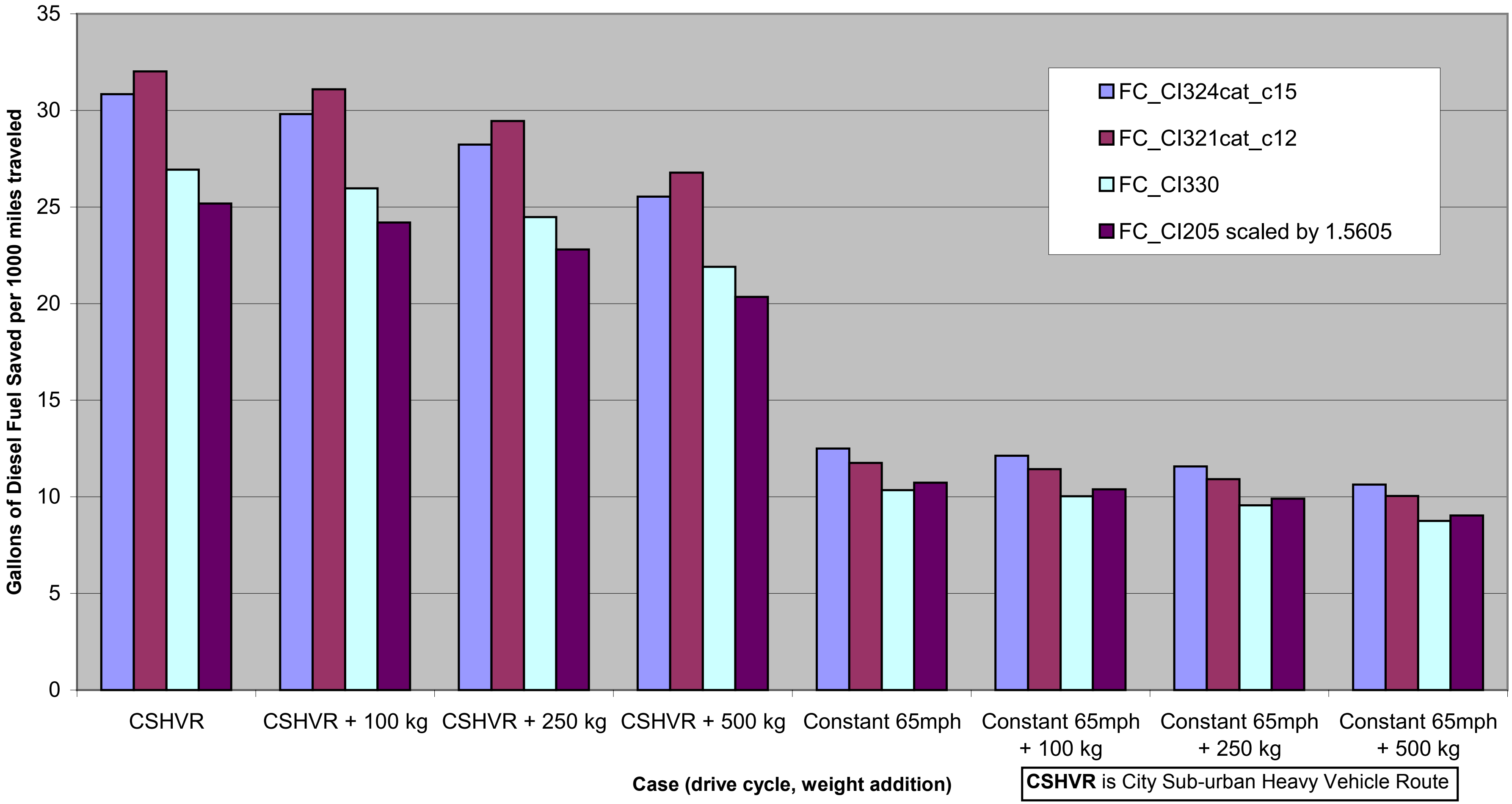
http://www.ctts.nrel.gov/analysis



Integrated Generation

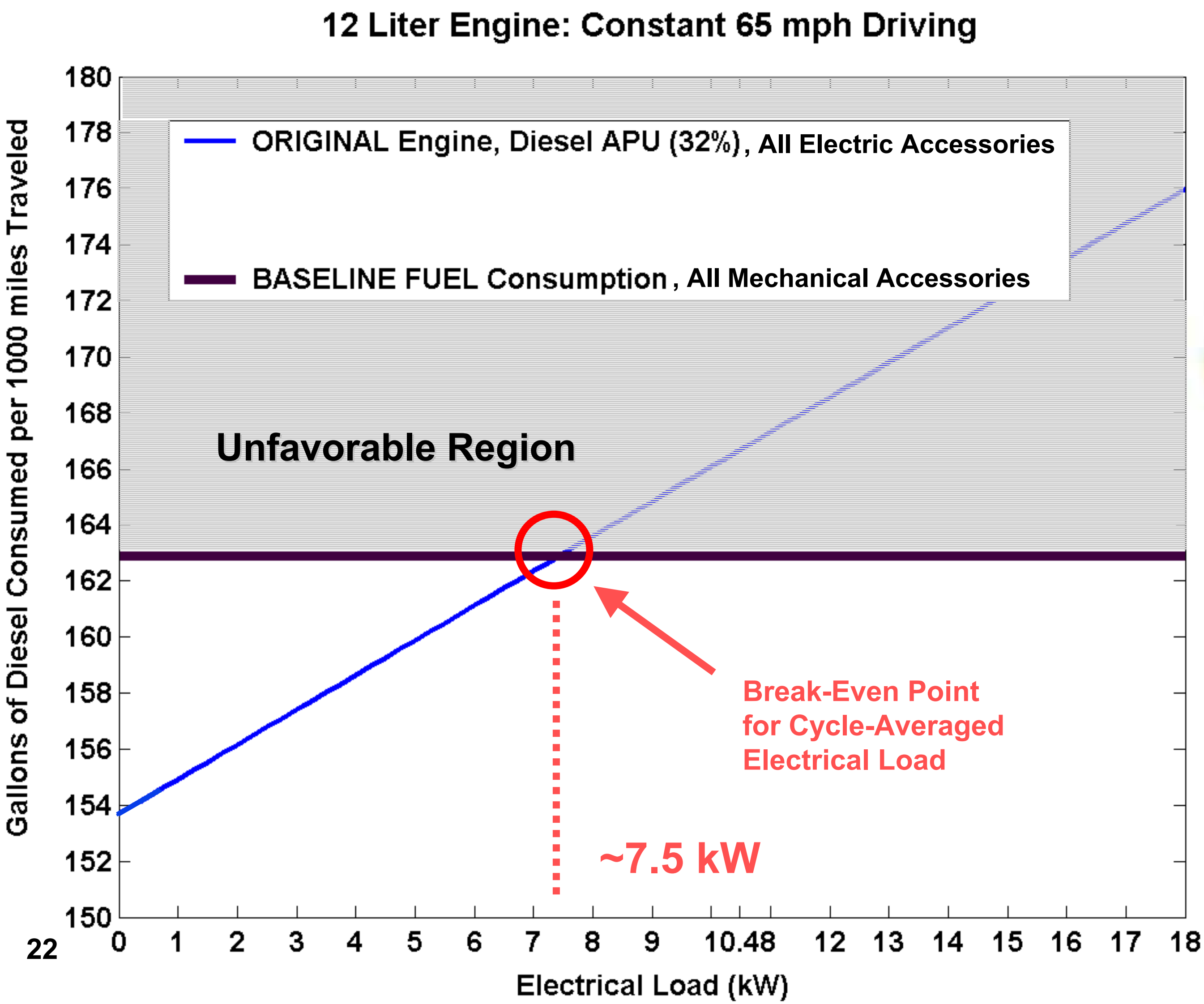
Maximum Fuel Savings

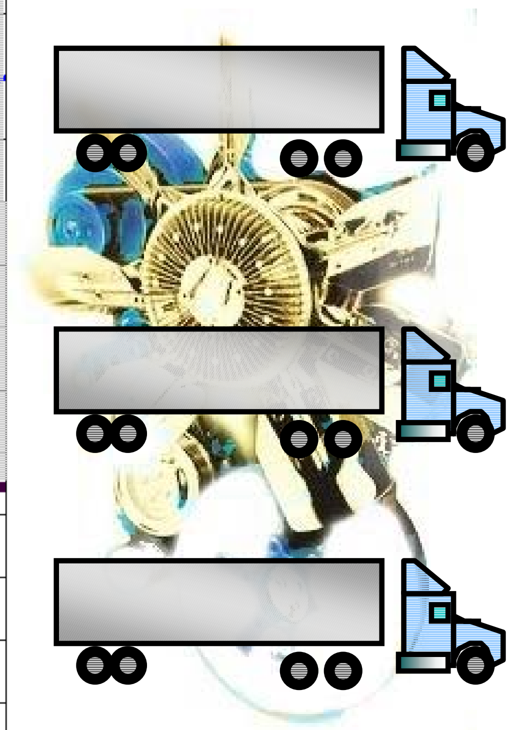
Using Waste Energy to Generate Electricity



CSHVR is City Sub-urban Heavy Vehicle Route

Break-Even Analysis
Auxiliary Power Unit

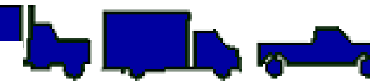




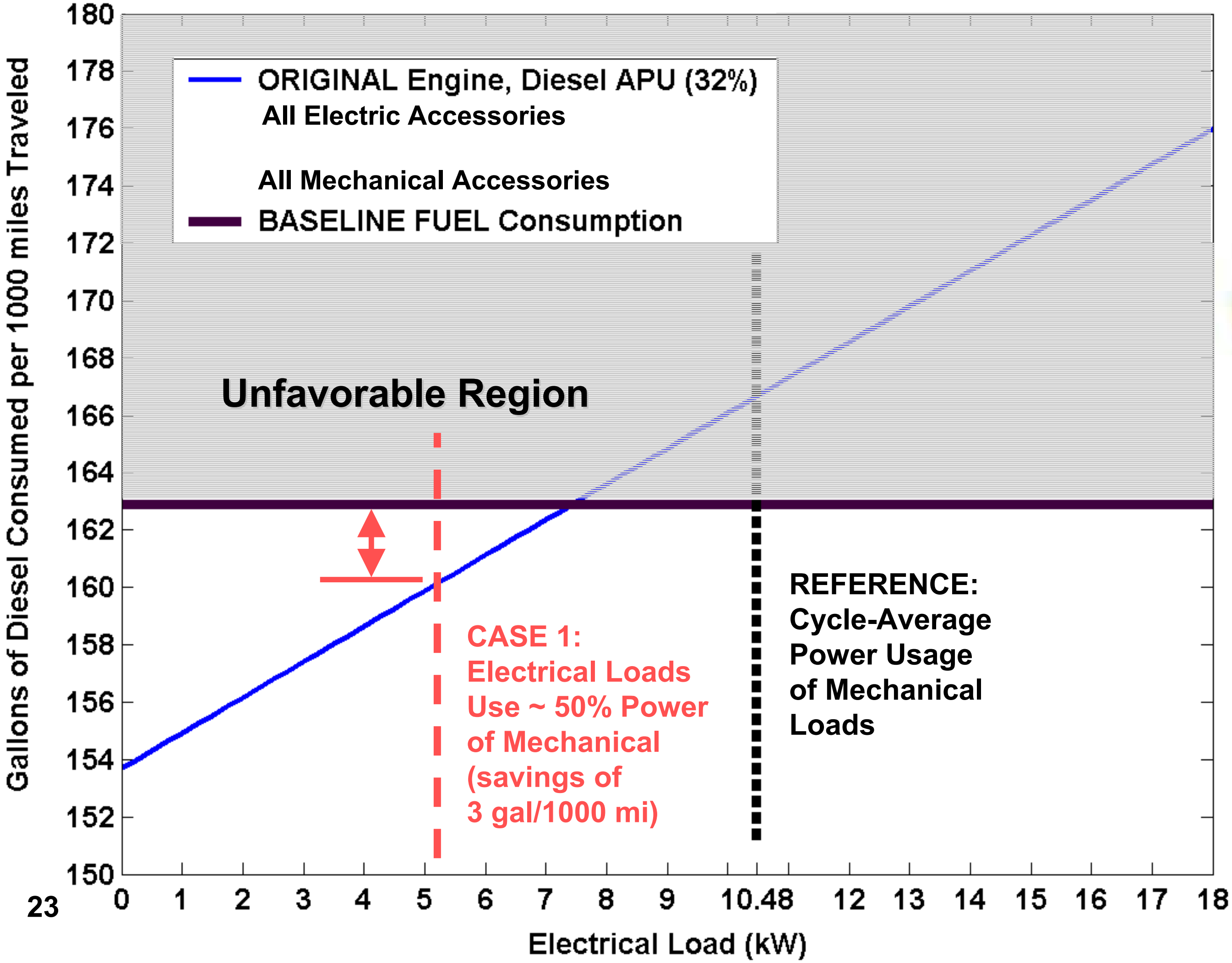
Auxiliary Power Unit

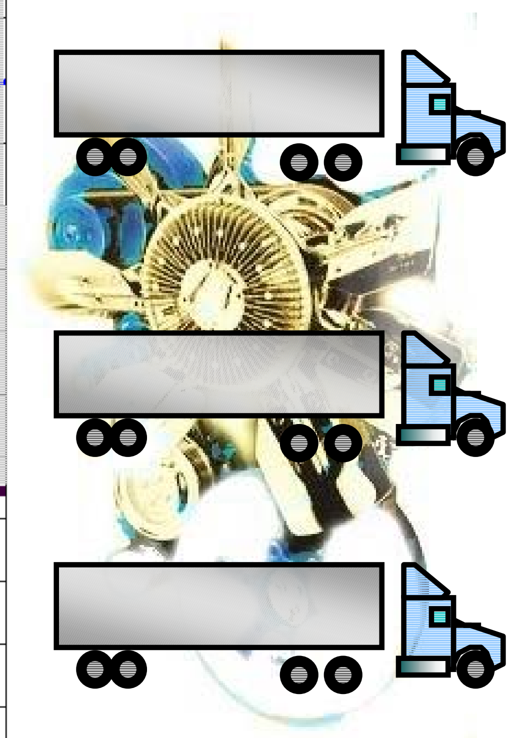
Break-Even Analysis

Auxiliary Power Unit



12 Liter Engine: Constant 65 mph Driving

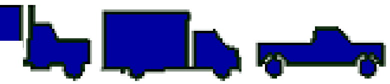




1.8% fuel savings

Break-Even Analysis

Auxiliary Power Unit



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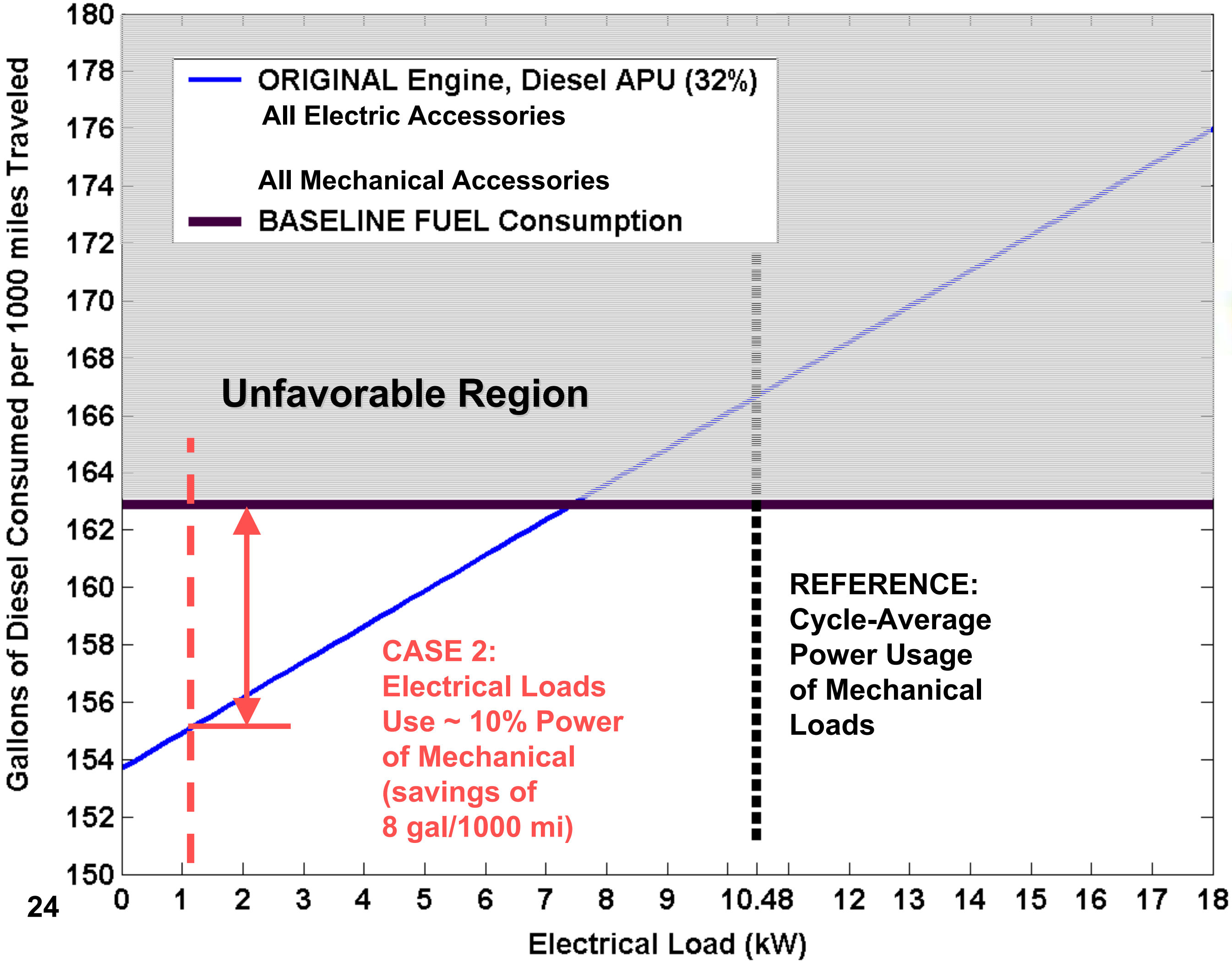
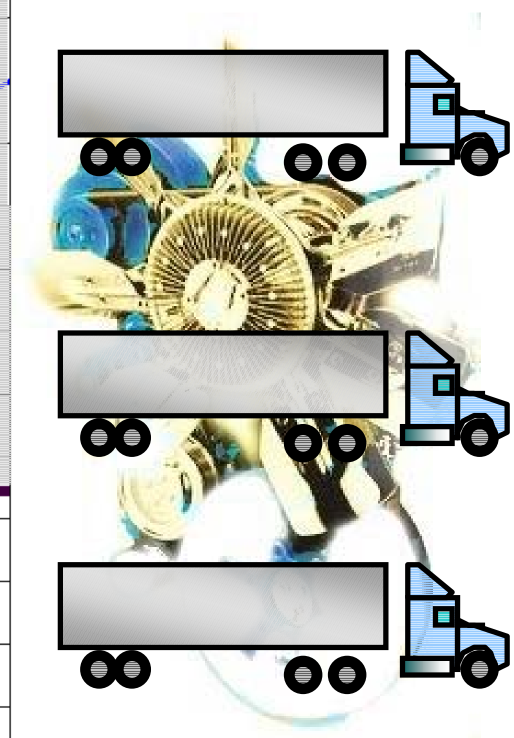




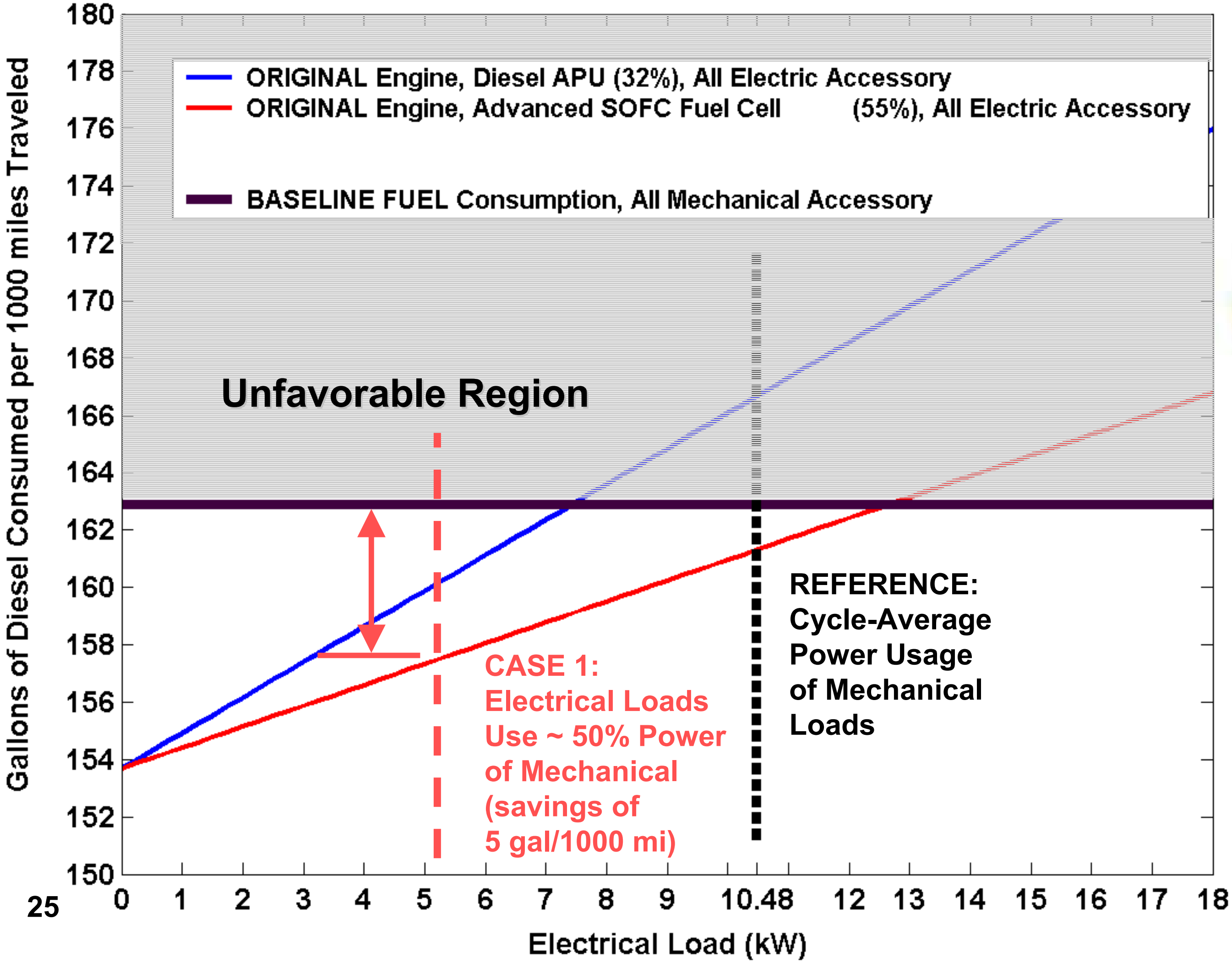
4.9% fuel savings

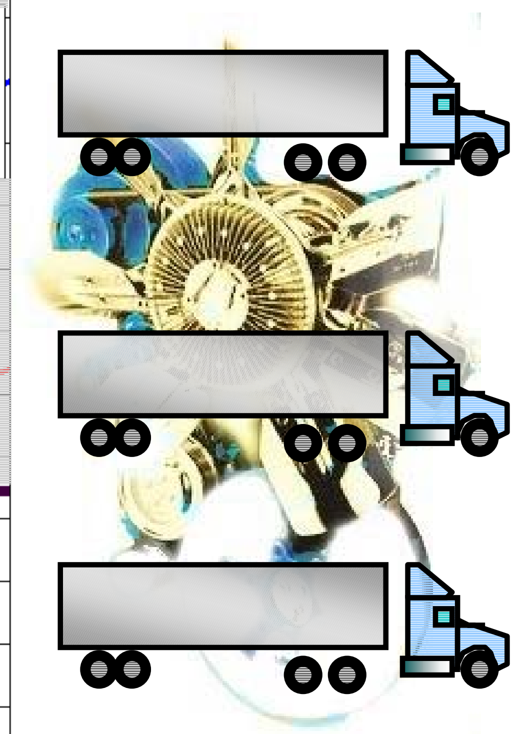
Auxiliary Power Unit

Break-Even Analysis

Auxiliary Power Unit

12 Liter Engine: Constant 65 mph Driving

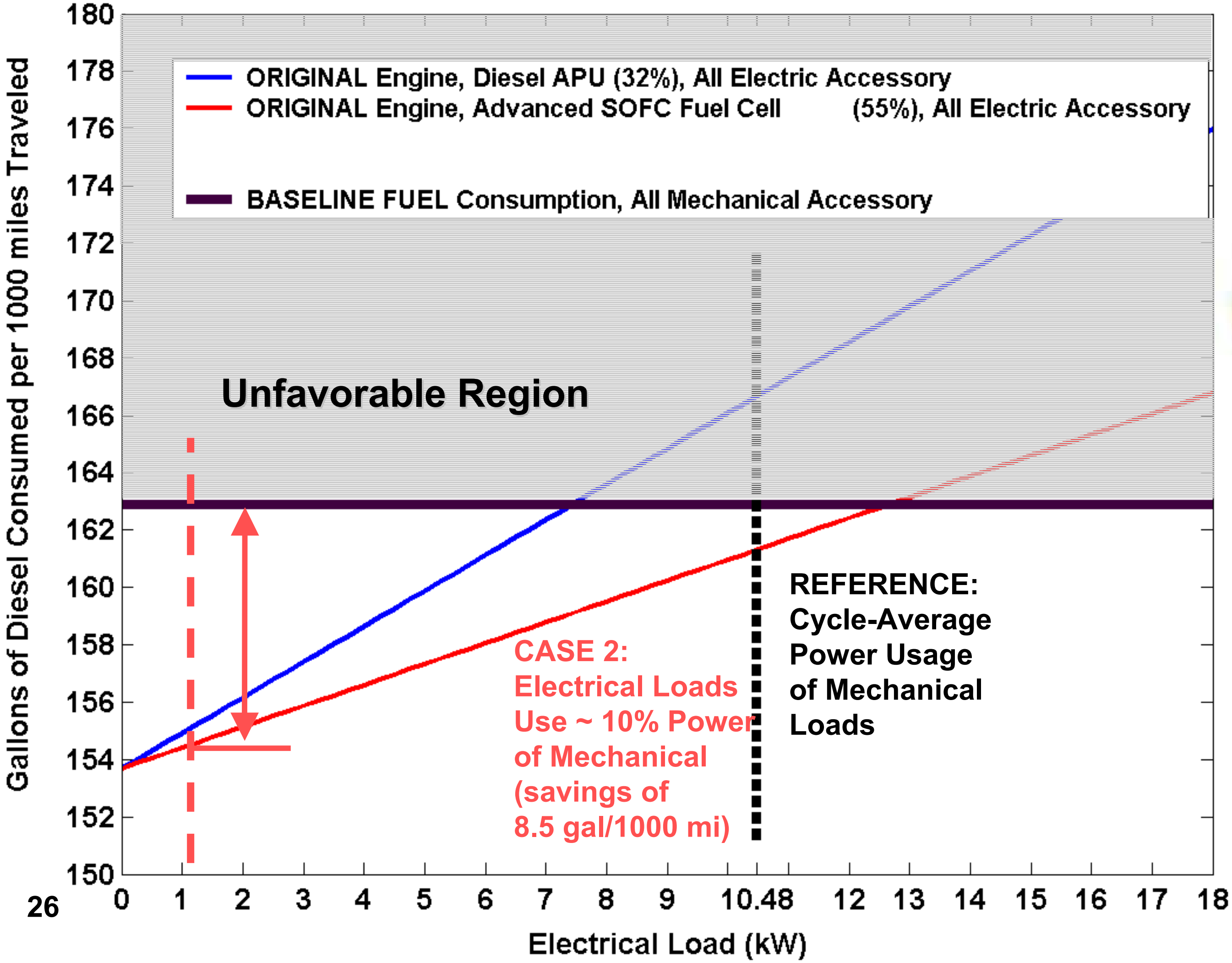


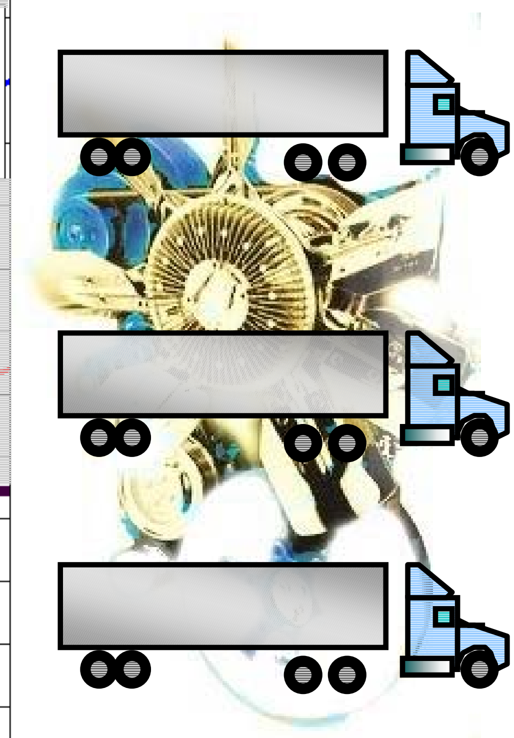


3.1% fuel savings

Break-Even Analysis

Auxiliary Power Unit

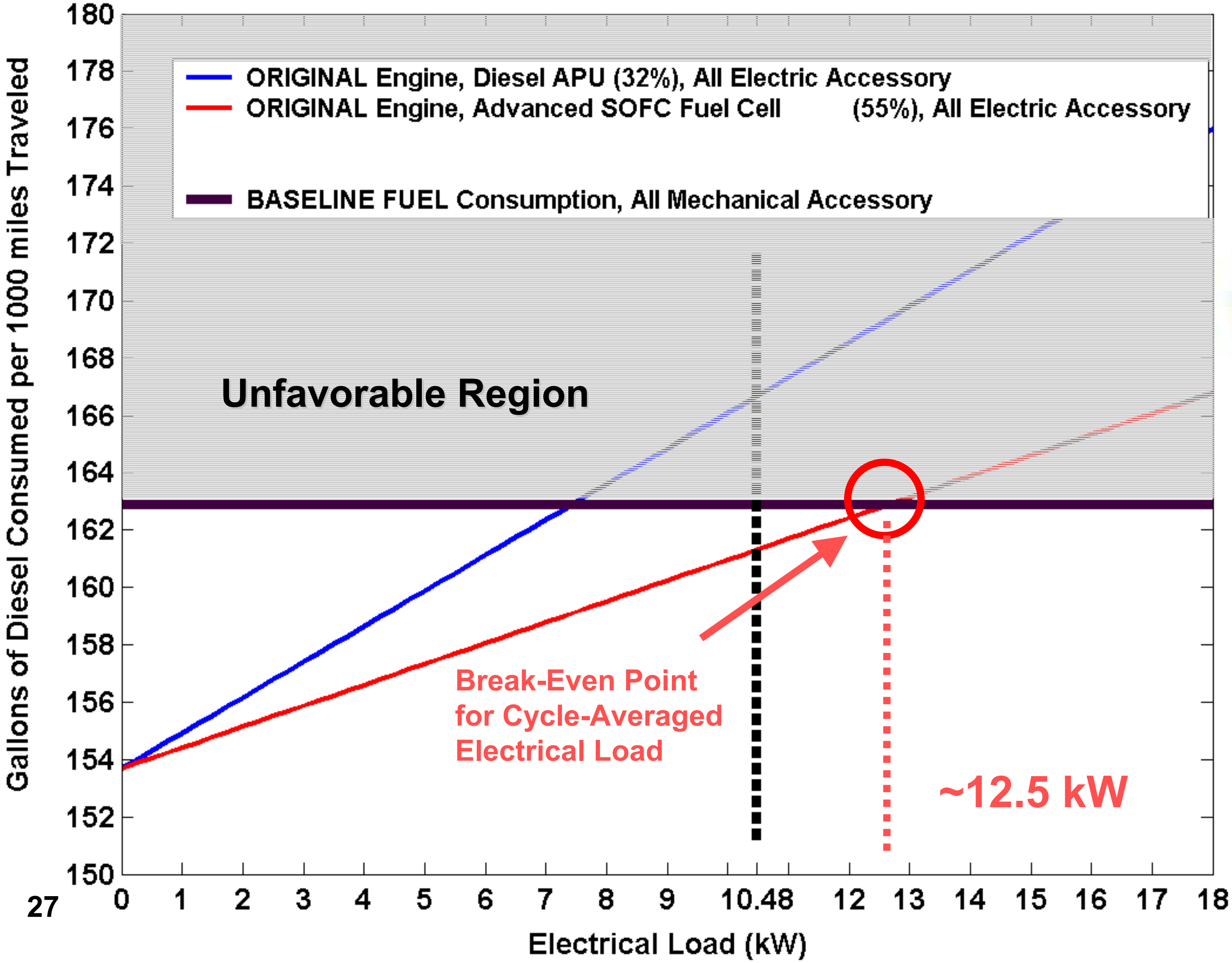


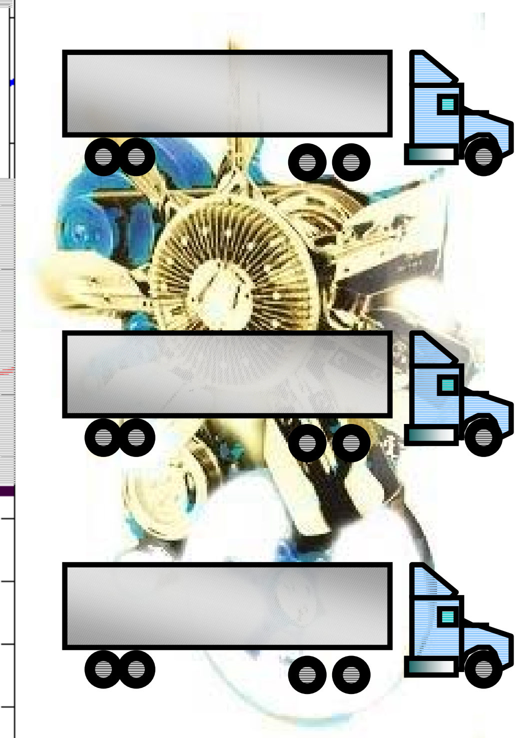


5.2% fuel savings

Break-Even Analysis
Auxiliary Power Unit

12 Liter Engine: Constant 65 mph Driving



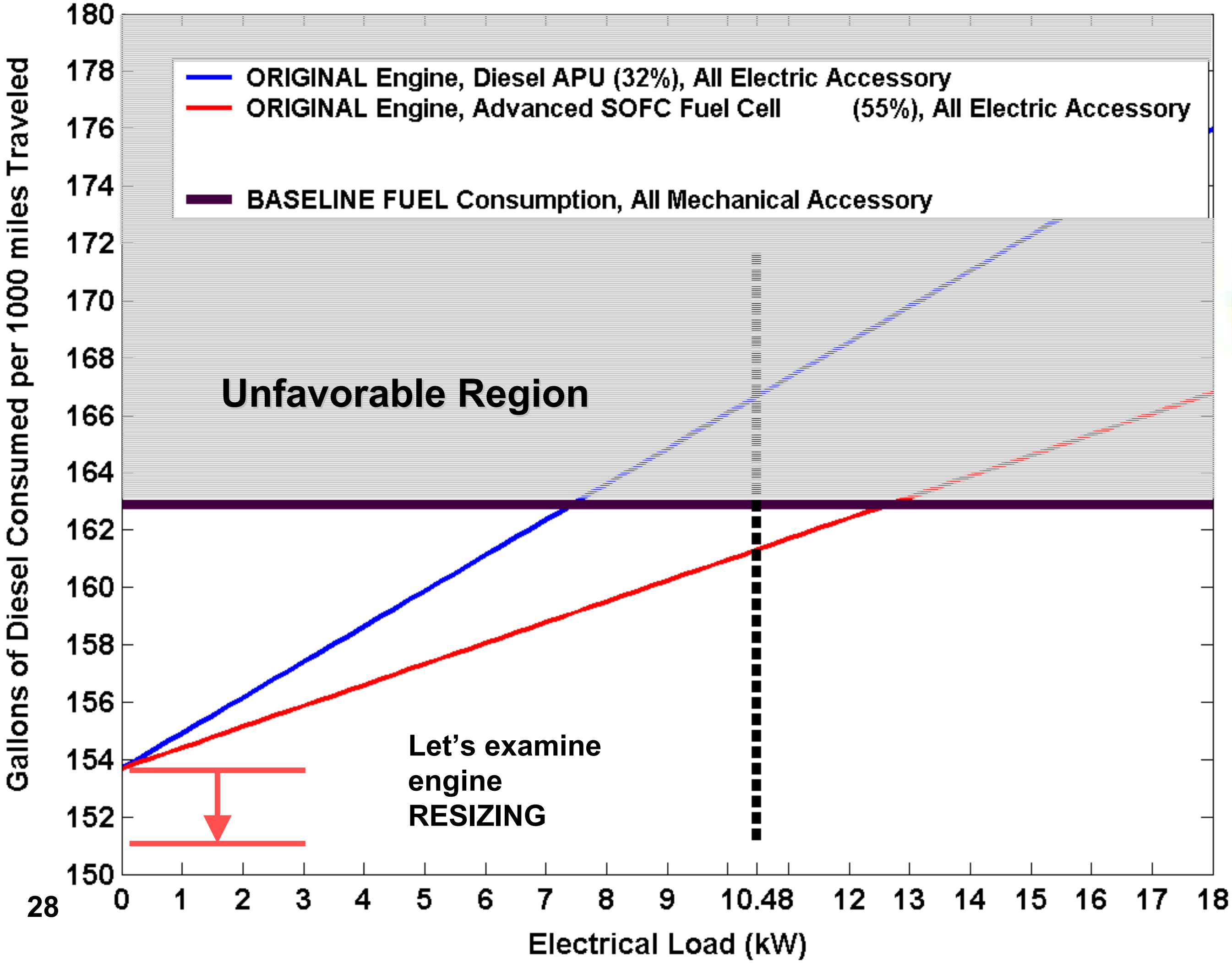


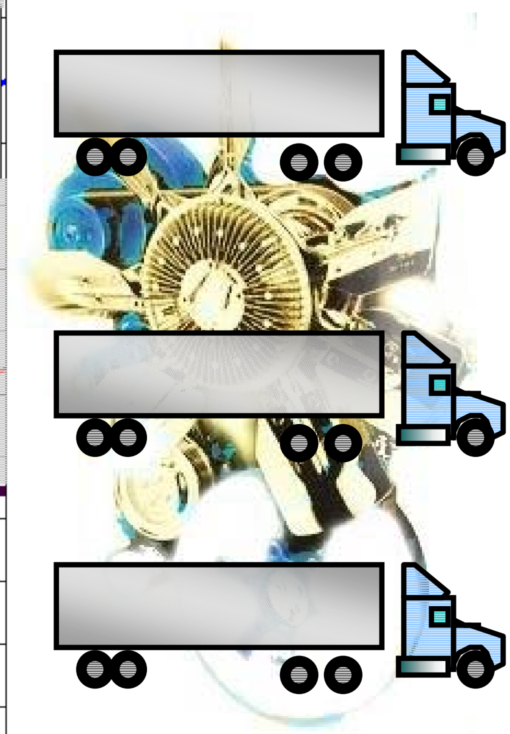
5.2% fuel savings

Break-Even Analysis

Auxiliary Power Unit

12 Liter Engine: Constant 65 mph Driving

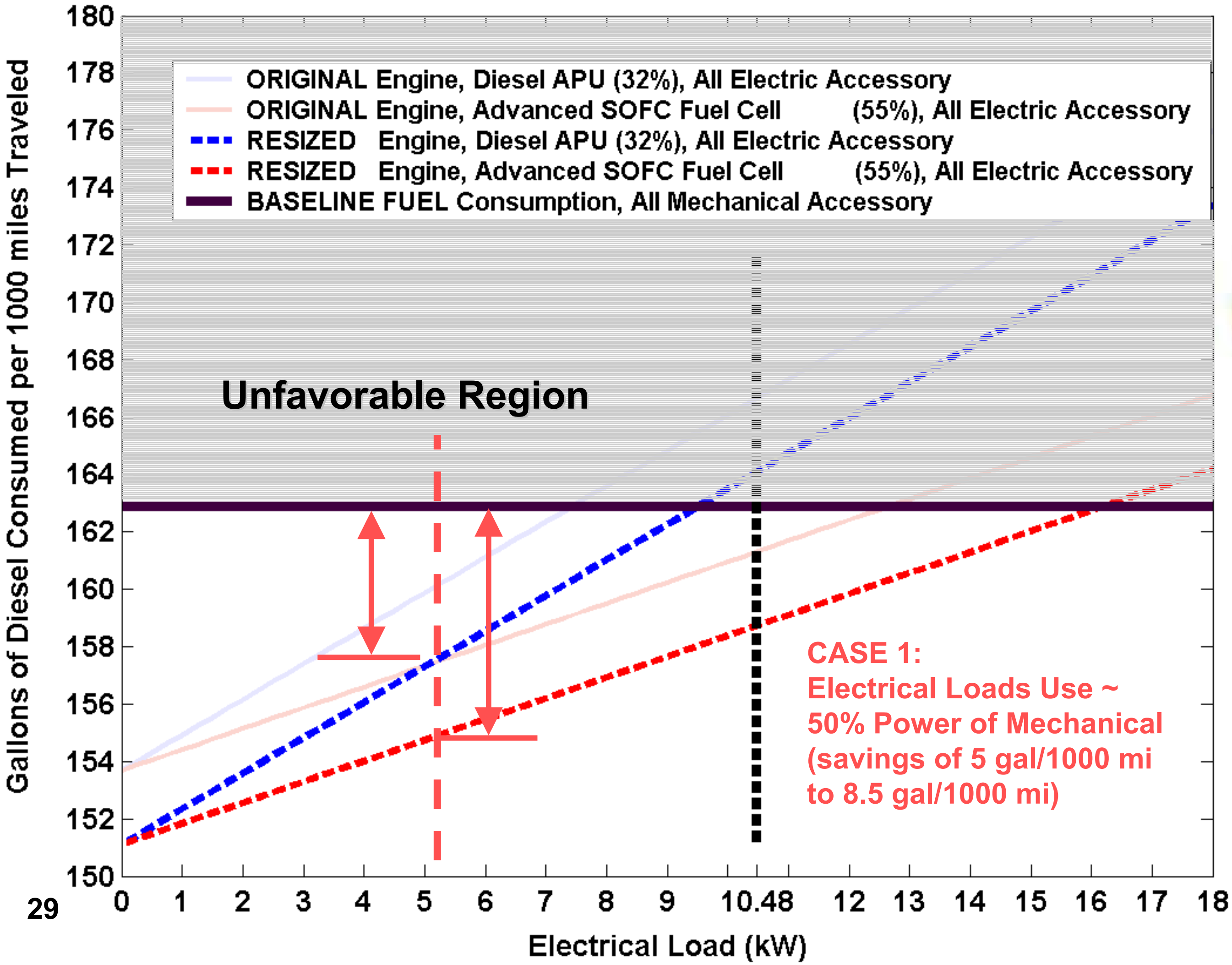


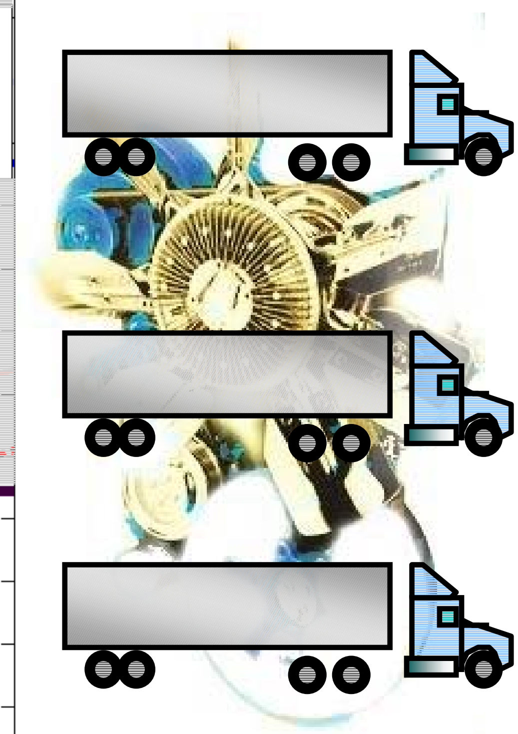


Break-Even Analysis

Auxiliary Power Unit

12 Liter Engine: Constant 65 mph Driving

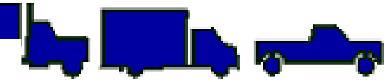




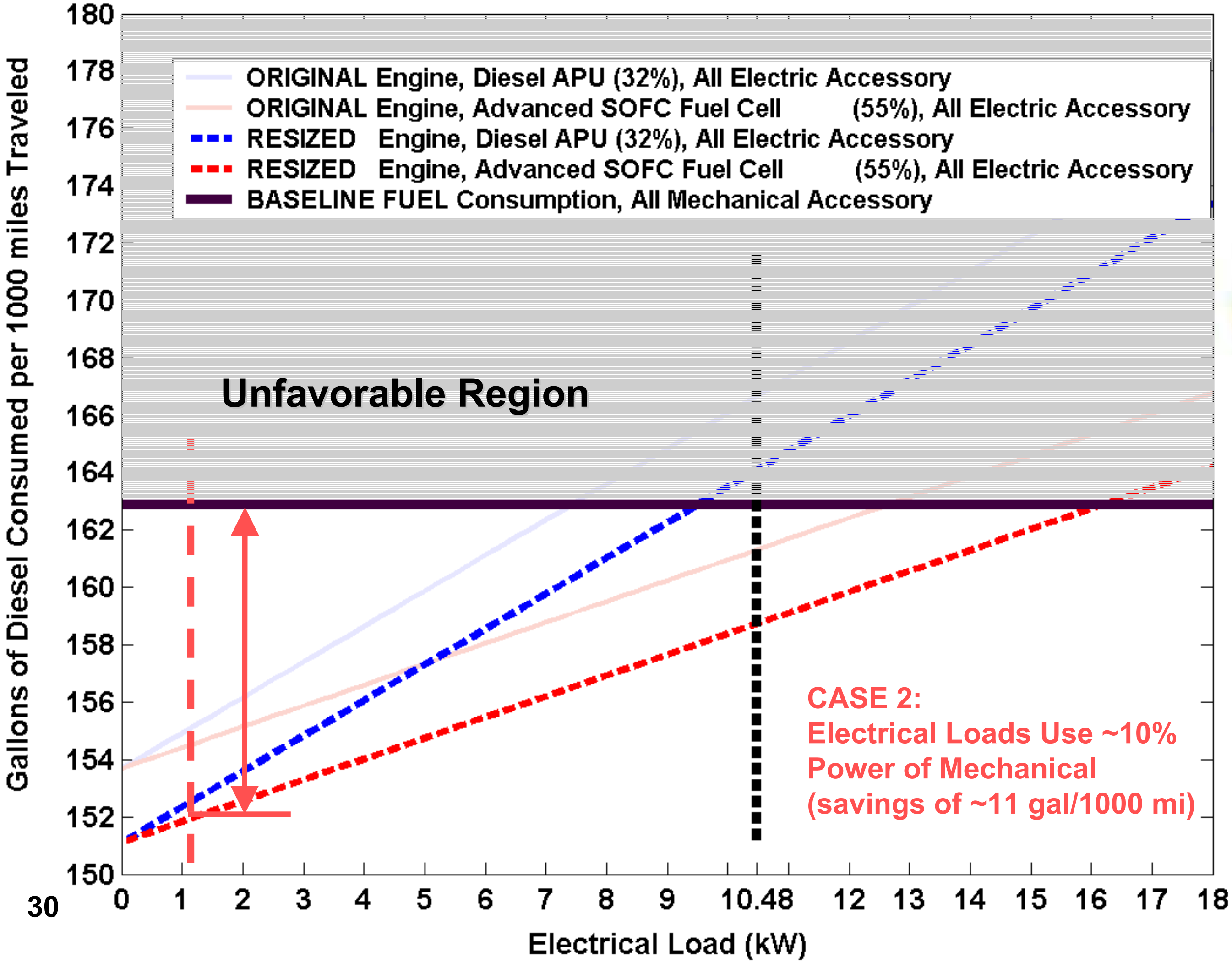
3.1% to 5.2 % fuel savings

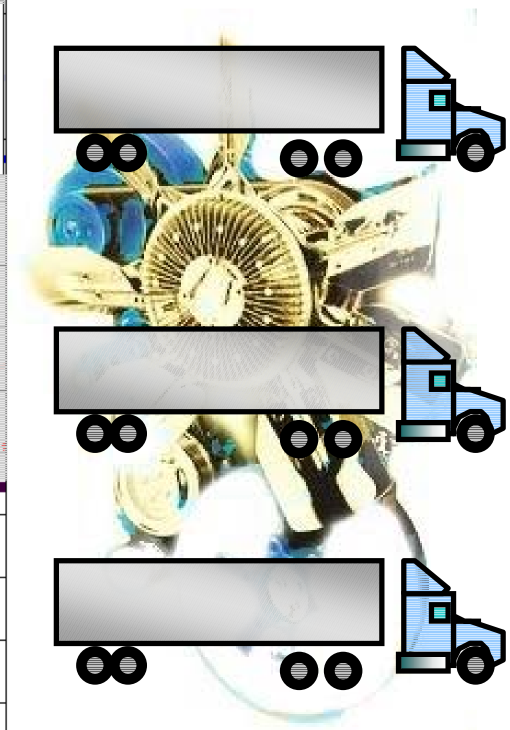
Break-Even Analysis

Auxiliary Power Unit



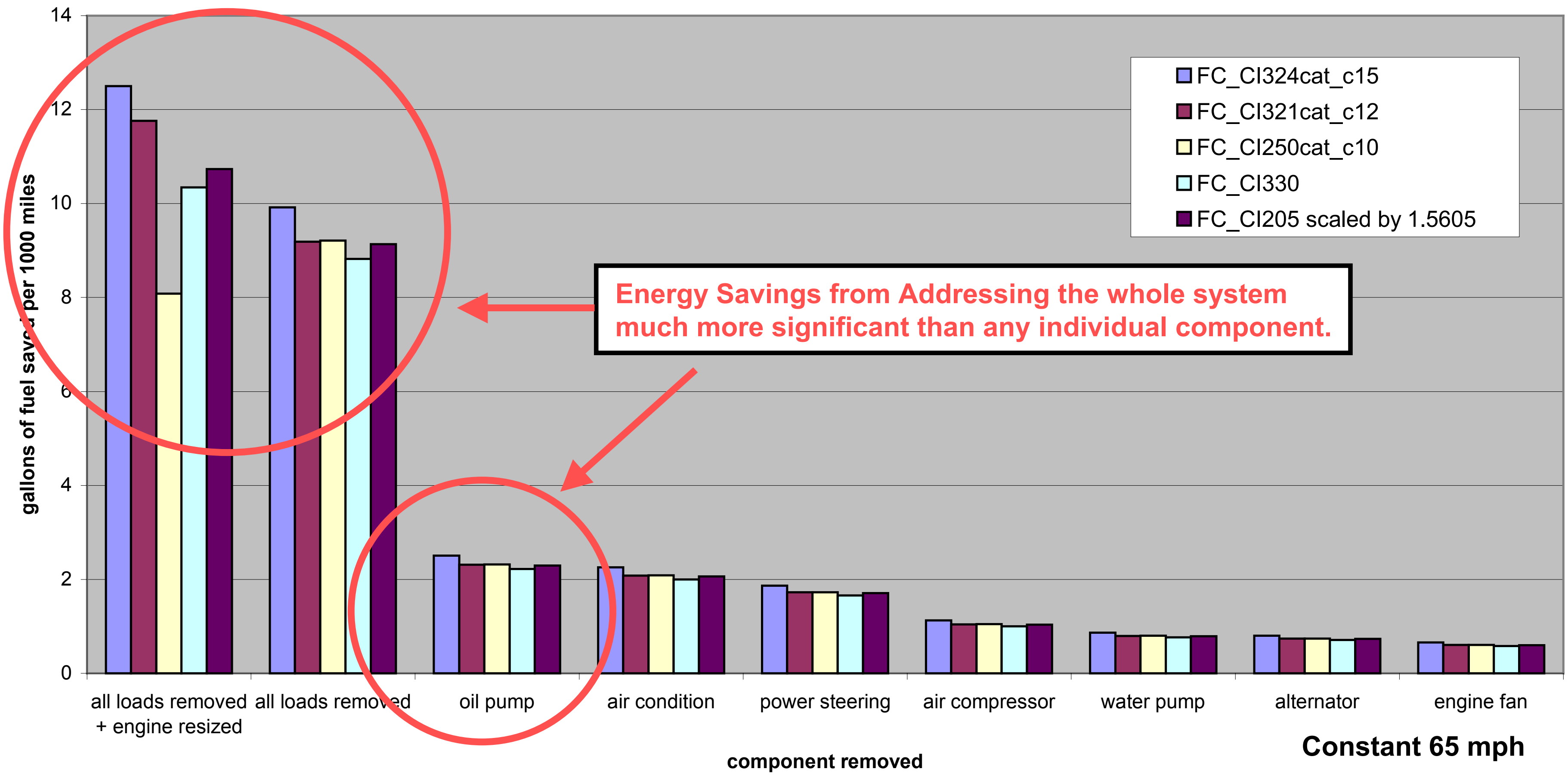
12 Liter Engine: Constant 65 mph Driving





6.7% fuel savings

System vs. Component Benefit



Constant 65 mph

NOTE: Maximum Savings--Integrated Generation with waste energy recovery or 100% efficient APU

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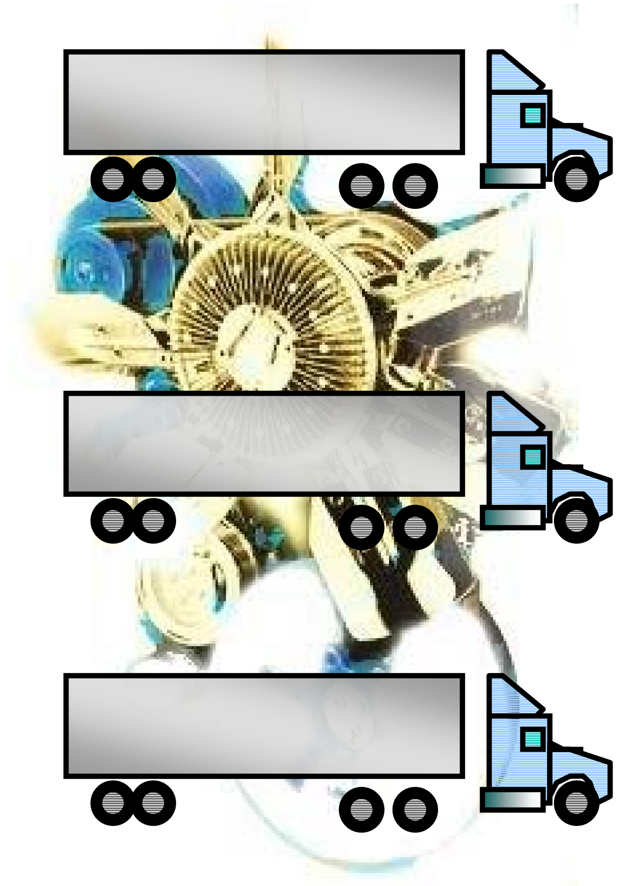
Conclusions

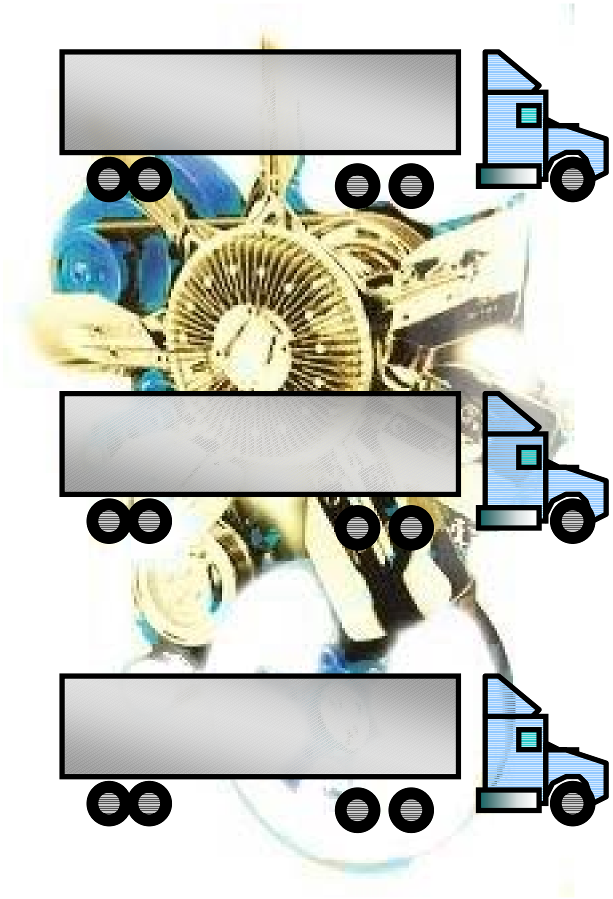
Conclusions

- An **Essential Power System** (EPS) involves intelligent management of essential vehicle auxiliary power
- Simulation predicts significant increase in **fuel economy** through EPS
  - » 9-15% maximum on an urban drive cycle
  - » 5-8% maximum at a constant 65 mph
- Systems approach
  - » system electrification better than single component electrification
  - » optimization of benefits and tradeoffs required



Future Data Needs

- Mechanical accessory duty cycles
  - real-life data
  - especially for extended idle
- Accessory performance requirements
  - e.g., maximum engine temperature a coolant pump must maintain
- Electrical accessory performance
- Better APU models
- Better integrated generation models



Acknowledgements

- David Orr, Caterpillar
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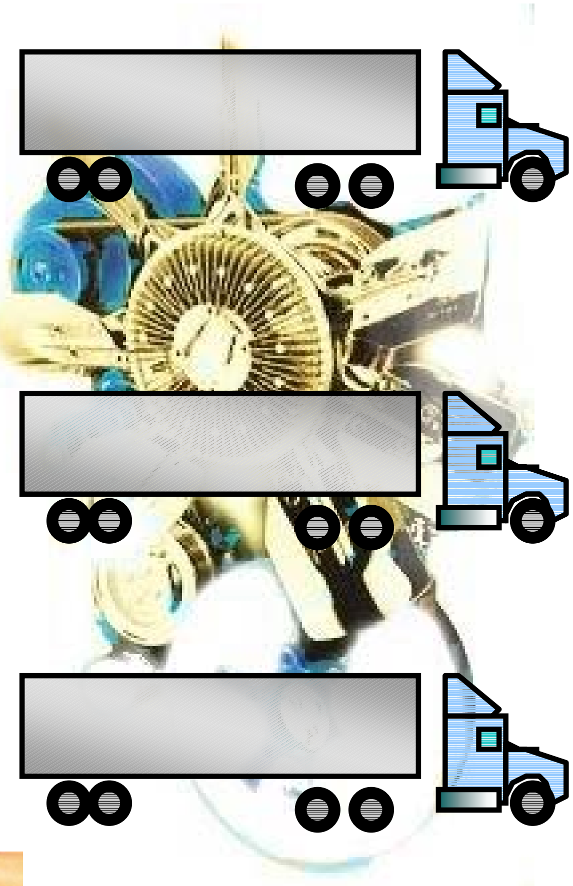
- Freightliner
- Susan Rogers and Sid Diamond, DOE
- Jud Virden, PNNL



Thank You!