

# Applications & Opportunities of High-Efficiency Thermoelectrics at Caterpillar

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**CATERPILLAR®**

# Outline

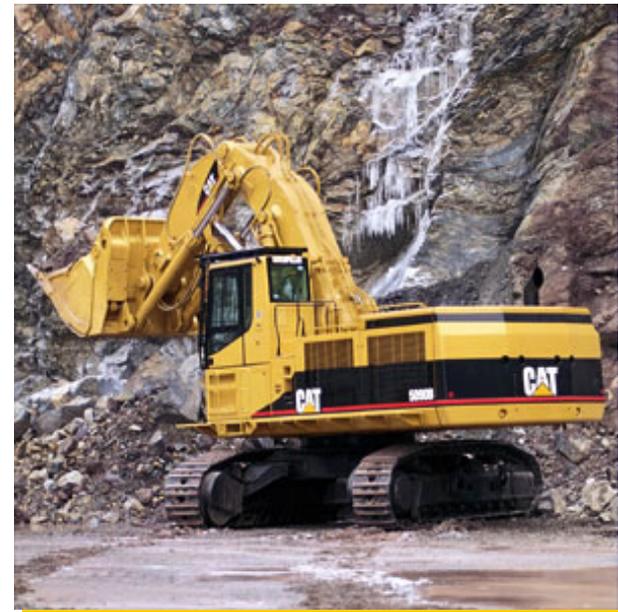
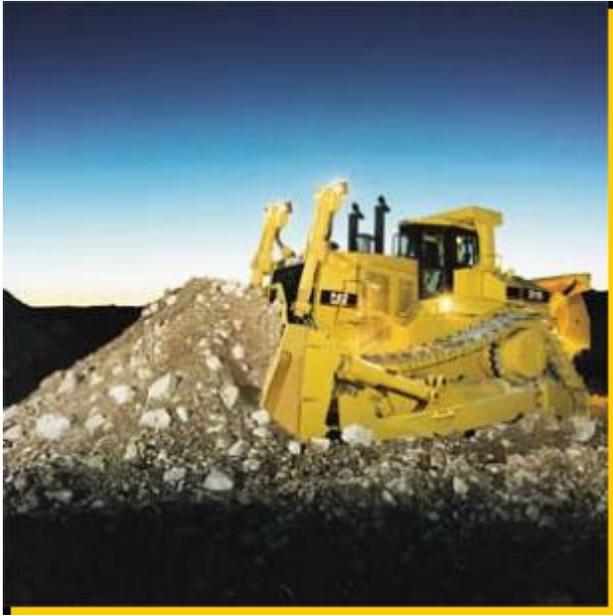
- Caterpillar Inc.
- Applications & Opportunities for High-Efficiency TE at Caterpillar
- Needs
- Summary

# Caterpillar Inc.

- Headquarters: Peoria, IL
- Sales: \$22.7B
- Employment: 69,169
- More than 300 products sold in 200 countries worldwide
- Products manufactured in 50 US facilities and 65 other locations worldwide
- Marketing offices in 15 cities in 11 countries



# Earth Moving Equipment



# Building & Construction Equipment



# Engine Technology

4000 kW →



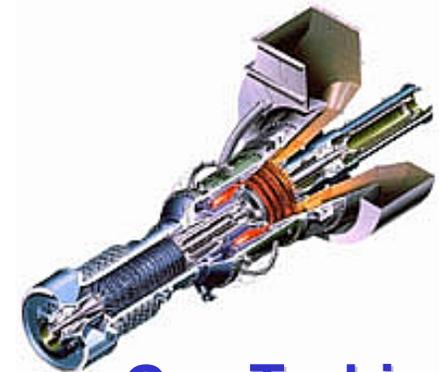
15 kW →



**Diesel/HFO**



**Natural Gas**



**Gas Turbine**

# Engine Business Segments



**CAT Machines**



**On highway Trucks**



**Marine**



**Locomotive**



**Petroleum**



**Power Generation**



**Industrial &  
Agricultural**

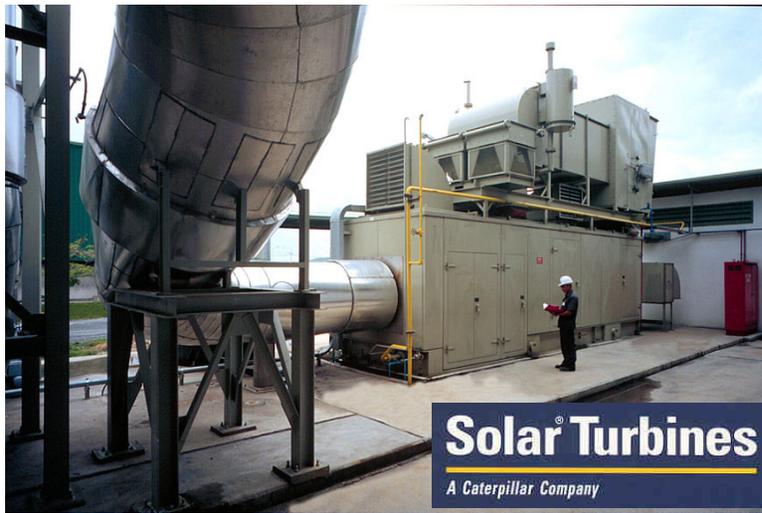
# Electric Power Generation (EPG)



**OLYMPIAN**  
8 EkW to 200 EkW



**Generator Sets**  
200 EkW to 15,000 EkW



**Solar Turbines**  
4000 EkW to 20,000 EkW



**Fuel Cells**  
300 EkW- 3000 EkW

**CATERPILLAR®**

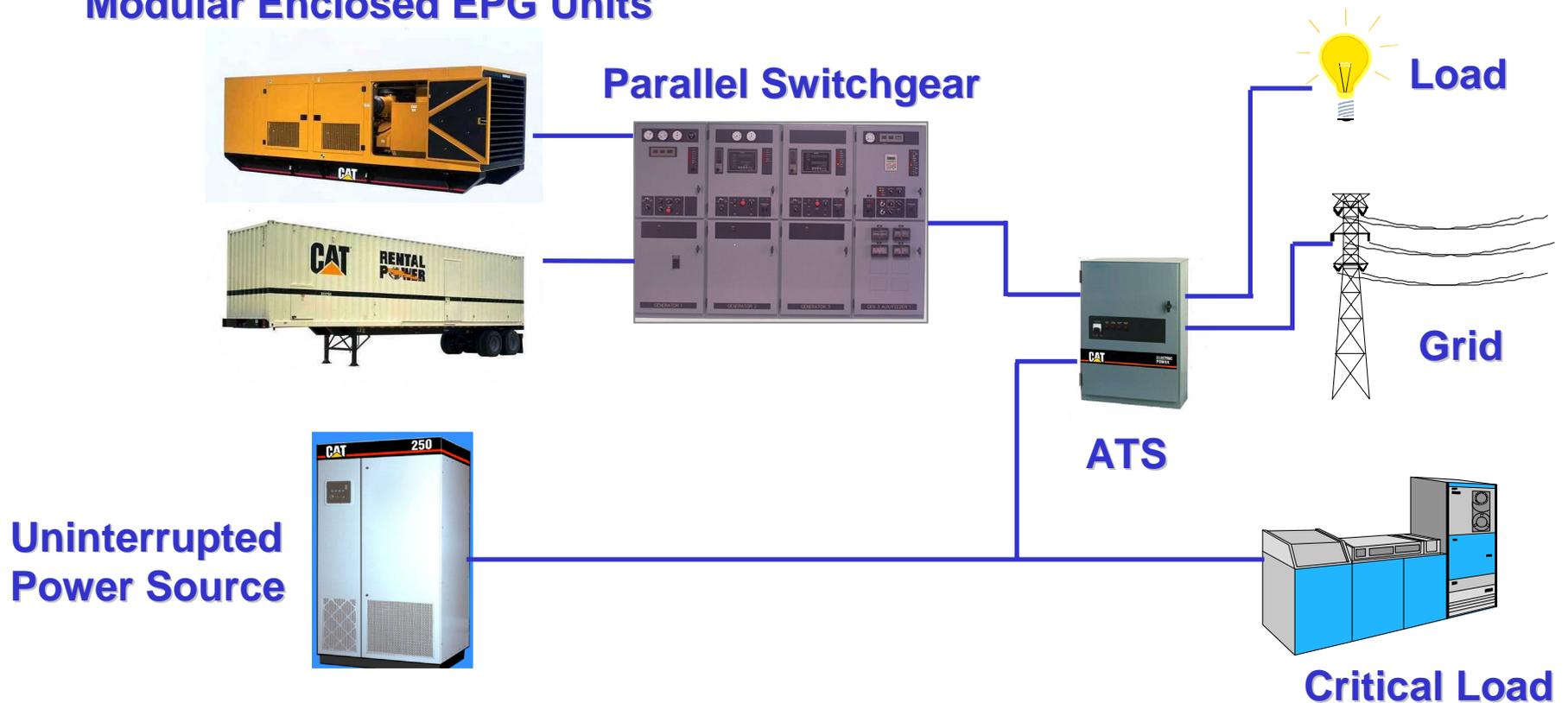


WHERE THE WORLD TURNS FOR POWER

# EPG Vision

- Be a Provider of Best Value Total Solutions
- Be Technology Neutral (Fuel Neutral)
- Exceed or Meet Customer Requirements

## Modular Enclosed EPG Units

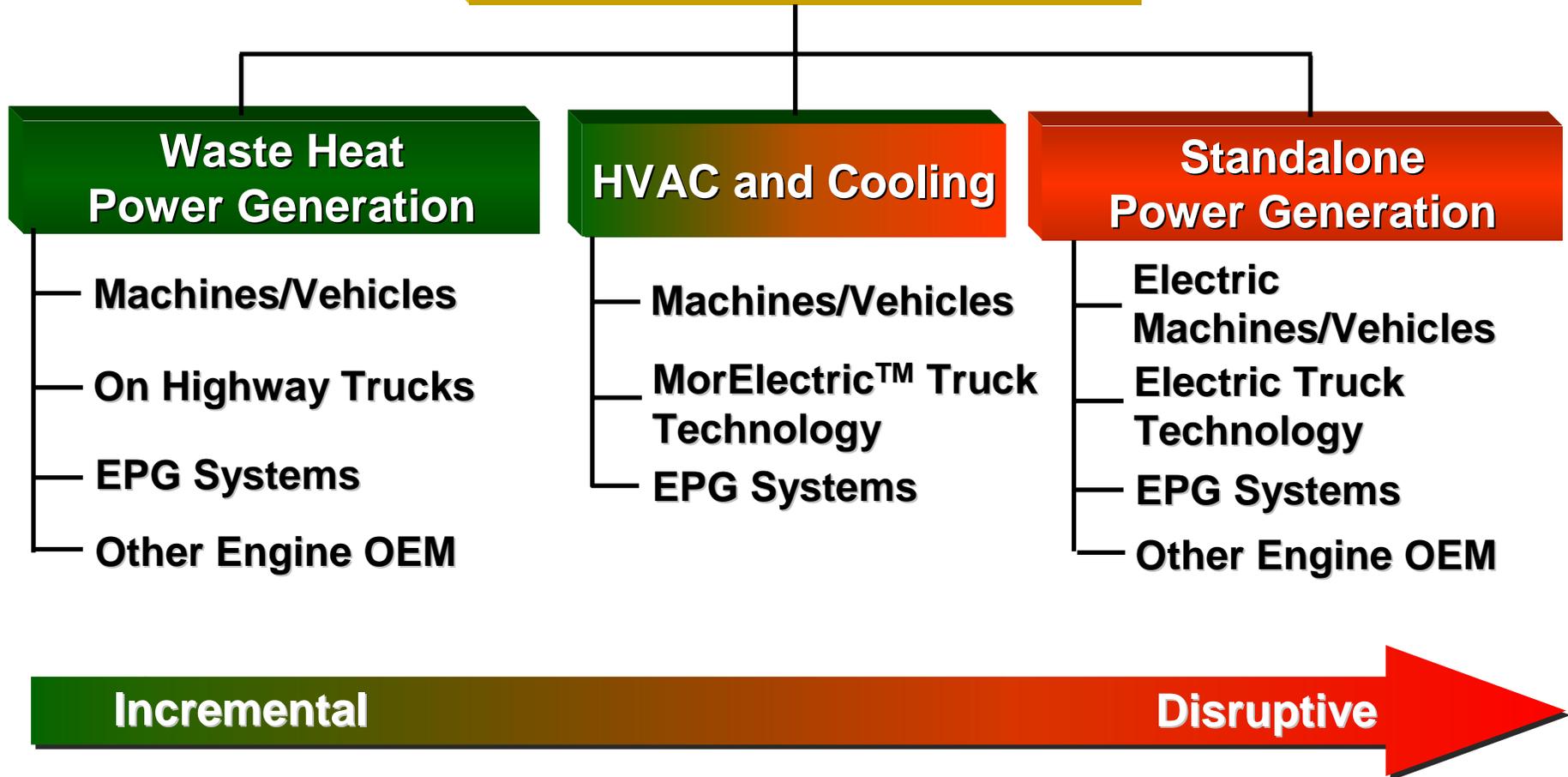


# High Efficiency TE Materials

- No physical limitations on ZT
- ZT barrier of 1 has been overcome:
  - In-plane 2D Quantum Well Thin Films (2DQW) (Hi-Z, PNNL) ZT up to 3
  - Cross plane Thin Film Superlattice (RTI) ZT up to 2.4
  - In-Plane/Cross Plane Quantum Dot Super Lattice QDSL (MIT-LL) ZT 1-2
  - Filled skutterudite-based materials (University of MI, Marlow, JPL)
- Future breakthroughs will likely result from nano-engineered materials

# Applications for High-Efficiency TE

## High-Efficiency TE Systems

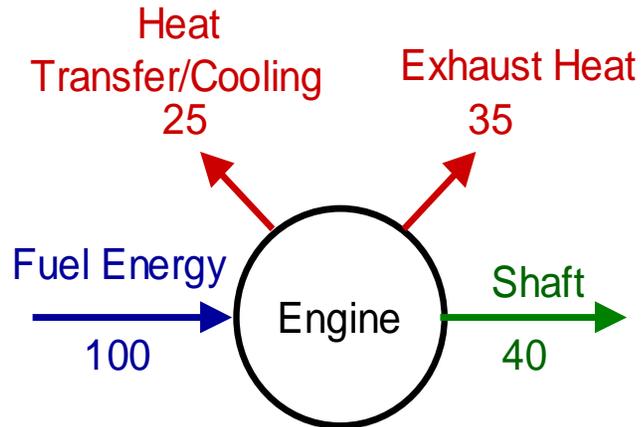


# Waste Heat TE Power Generation

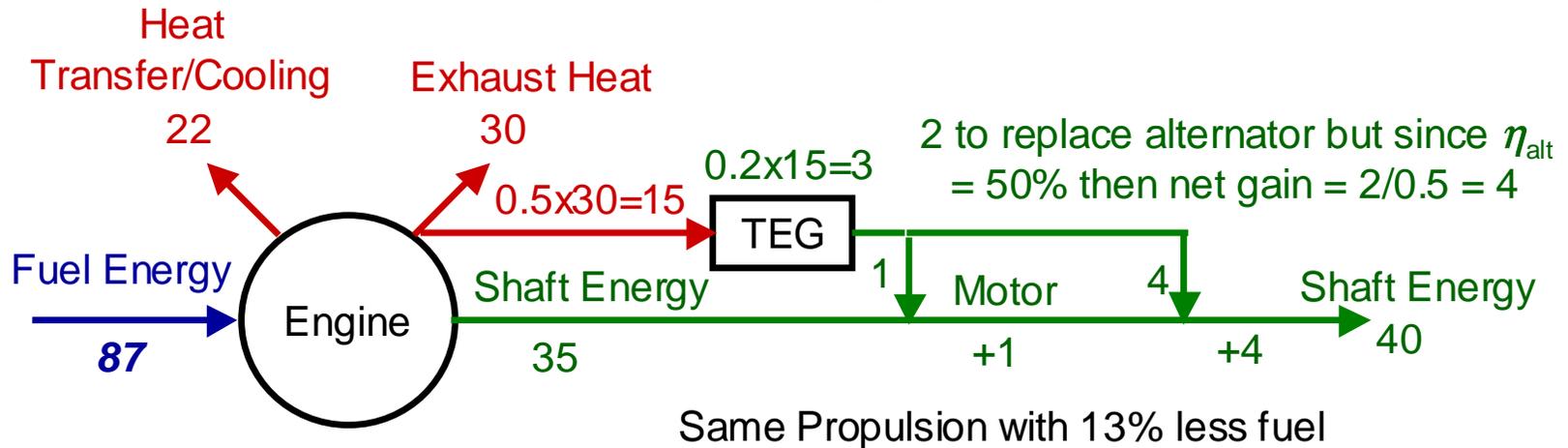
- Idea:
  - Convert exhaust waste heat into electricity
- Driver:
  - Improve fuel efficiency for customers
- Impact:
  - Lower Operating Costs
  - Enable Hybrid Technologies
  - Contribute to Lower Emissions

# Waste Heat TE Power Generation

Baseline



With TEG added to Driveline motor and used in place of alternator



# TE HVAC

- Idea:
  - Use solid-state high efficiency TE devices to replace belt driven AC units
- Driver:
  - Improved reliability and durability for customers
- Impact:
  - 80% less parts to assemble
  - Lower maintenance requirements
  - Sustain the environment
  - Potential “No-Idle” HVAC solution in support of MorElectric™ Technology

# MorElectric™ Technology

Comprised of three key components:

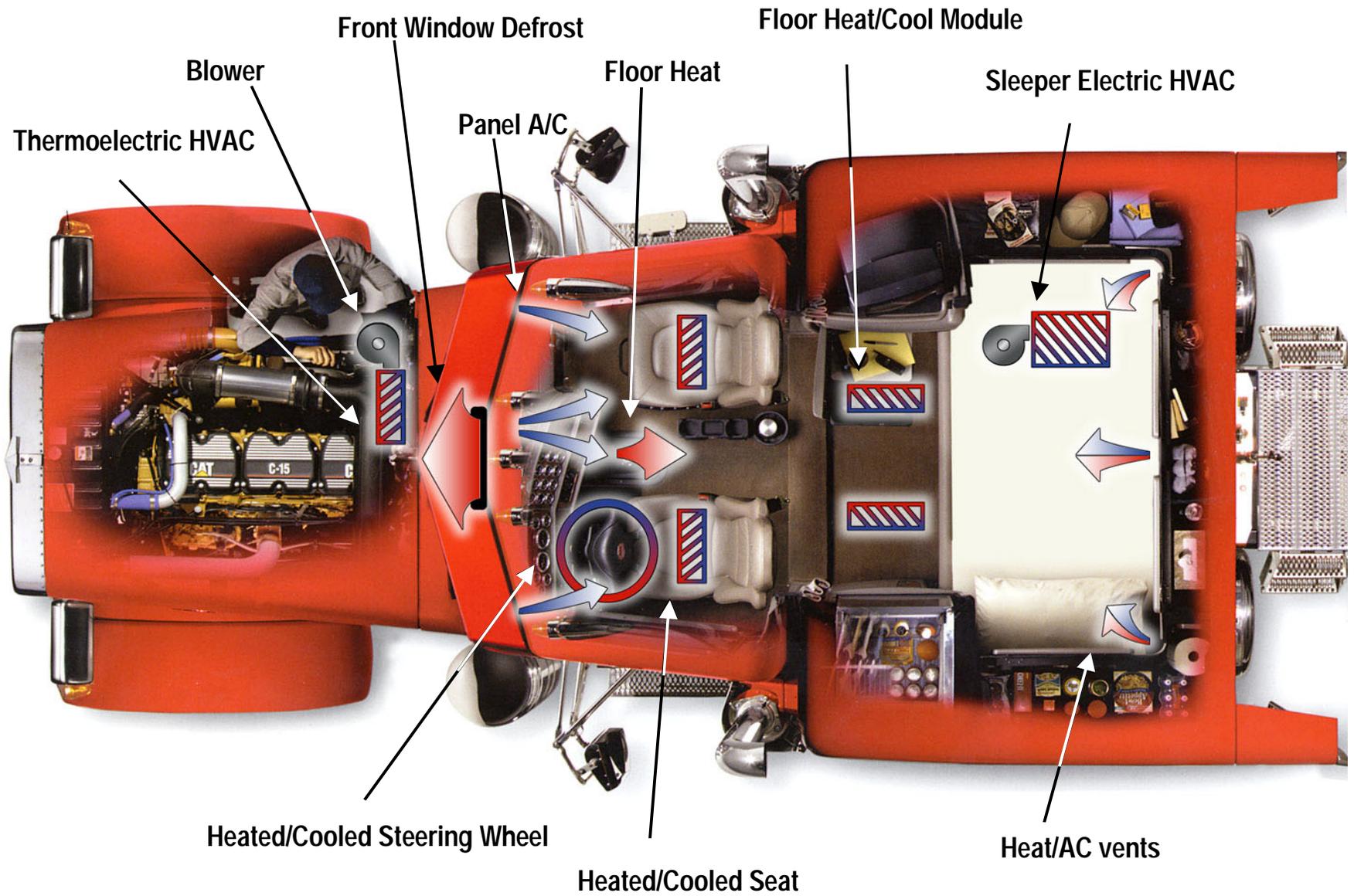
- HVAC
- Generator
- APU

- Highly-integrated APU
- Provides no-idle power source for electric HVAC

- Electrically driven AC compressor
- Eliminates more than 65 parts
- Permanently sealed refrigeration system
- 5x reliability and 3x durability improvement
- More comfortable and quieter environment
- Up to 1% fuel savings

- Belt-driven: replaces the alternator
- Water-cooled design
- Allows removing A/C compressor from engine
- Use with any engine
- 4x the power and 2x the efficiency of existing alternators
- 2x reliability and 2x durability
- Up to 1% fuel savings

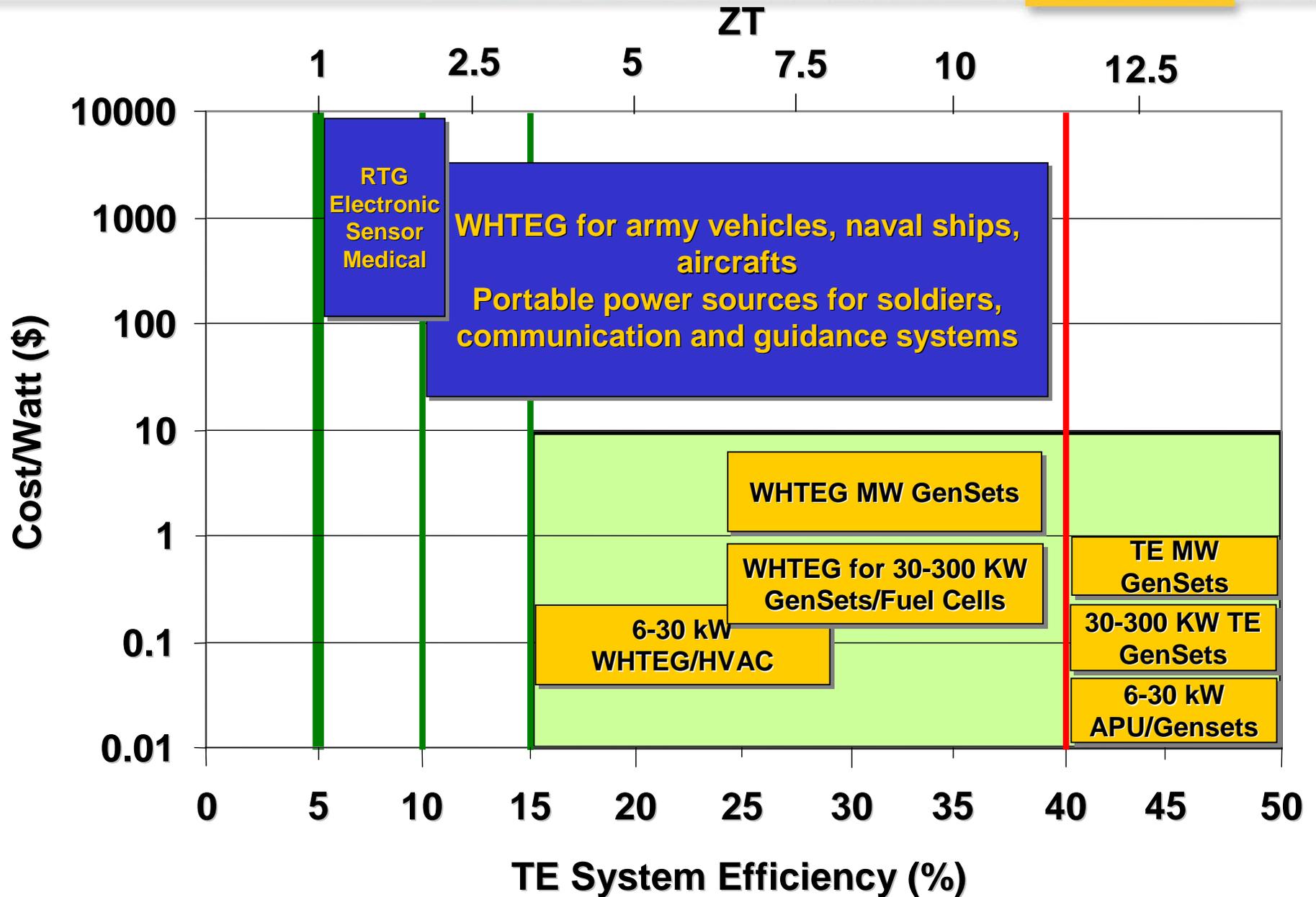
# TE HVAC



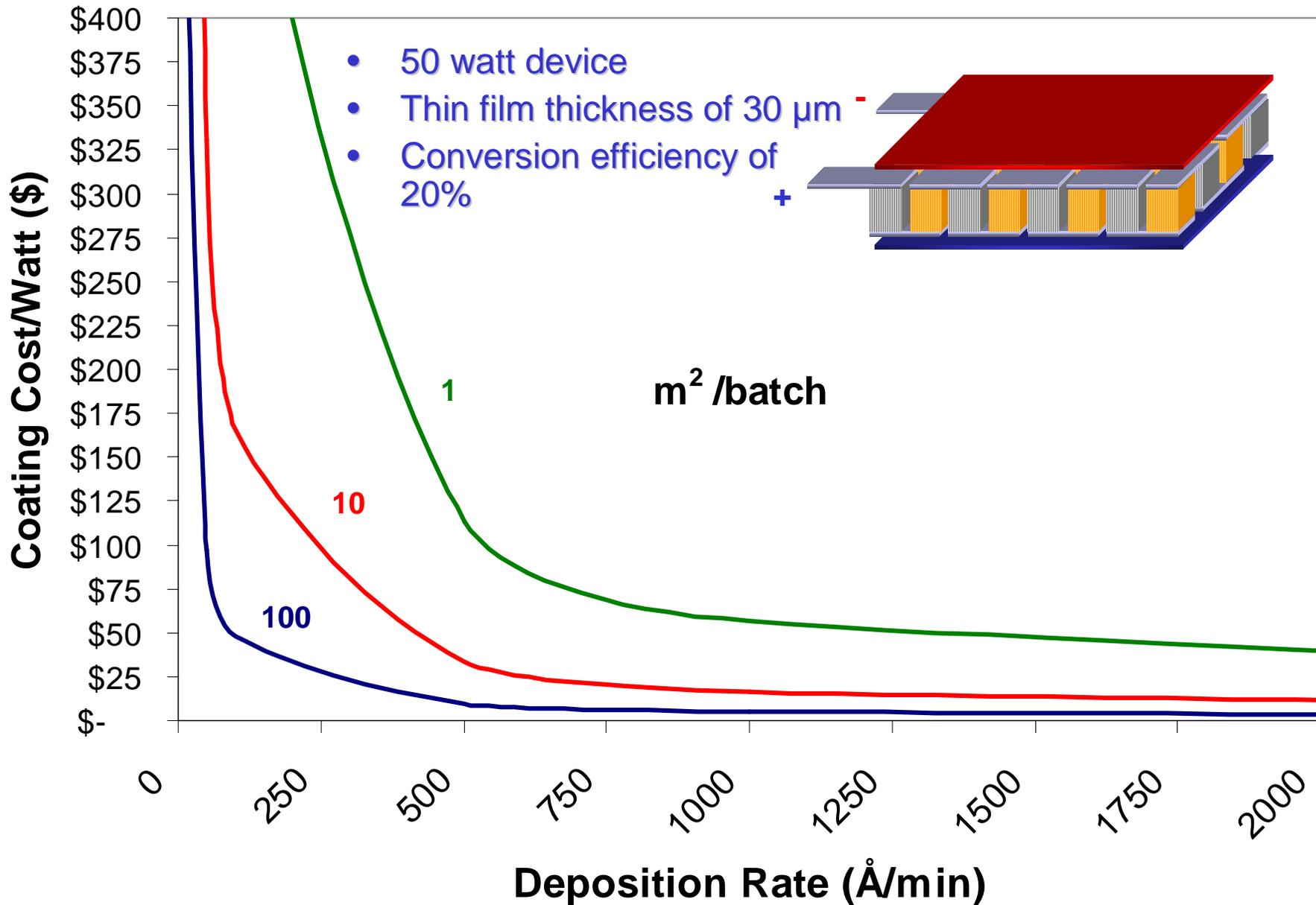
# Standalone Power Generation

- Idea:
  - Replace Internal Combustion/Turbine Engines with TEG/Electric Motor
- Driver:
  - Improved reliability and durability for customers
- Impact:
  - Disruptive to existing power generation units
  - Reduce emissions
  - Potentially reduce system complexity

# Opportunities for High Efficiency TE



# Vacuum Deposition Cost



# Needs

- Unifying Framework for Material Testing
  - Standardization of Testing Equipment
  - Standardization of Operational Definitions
  - Innovative Testing Processes
- Independent Authority/Committee for Validating Conversion Efficiency Figures
- Innovative Processes for Large Volume Manufacturing of High-Efficiency TE Materials

# Summary

- Caterpillar recognizes the potential of High Efficiency TE in some of its core applications to enhance customer value
- The support of the DOE and other government agencies is essential for minimizing commercial risk

## More Information

- Caterpillar Products:

- [www.cat.com](http://www.cat.com)

- MorElectric™ Technology:

- [www.cat.com/shared/technology\\_products/cat\\_electronics/morElectric/\\_ebrief/contents/index.html](http://www.cat.com/shared/technology_products/cat_electronics/morElectric/_ebrief/contents/index.html)