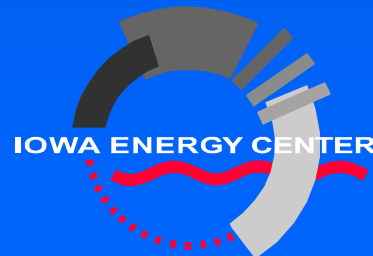


# ***Midwest Transportation Consortium***

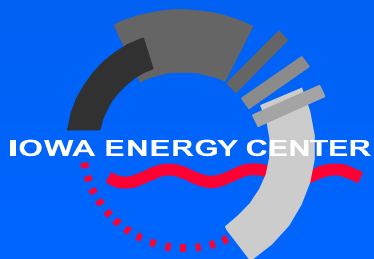
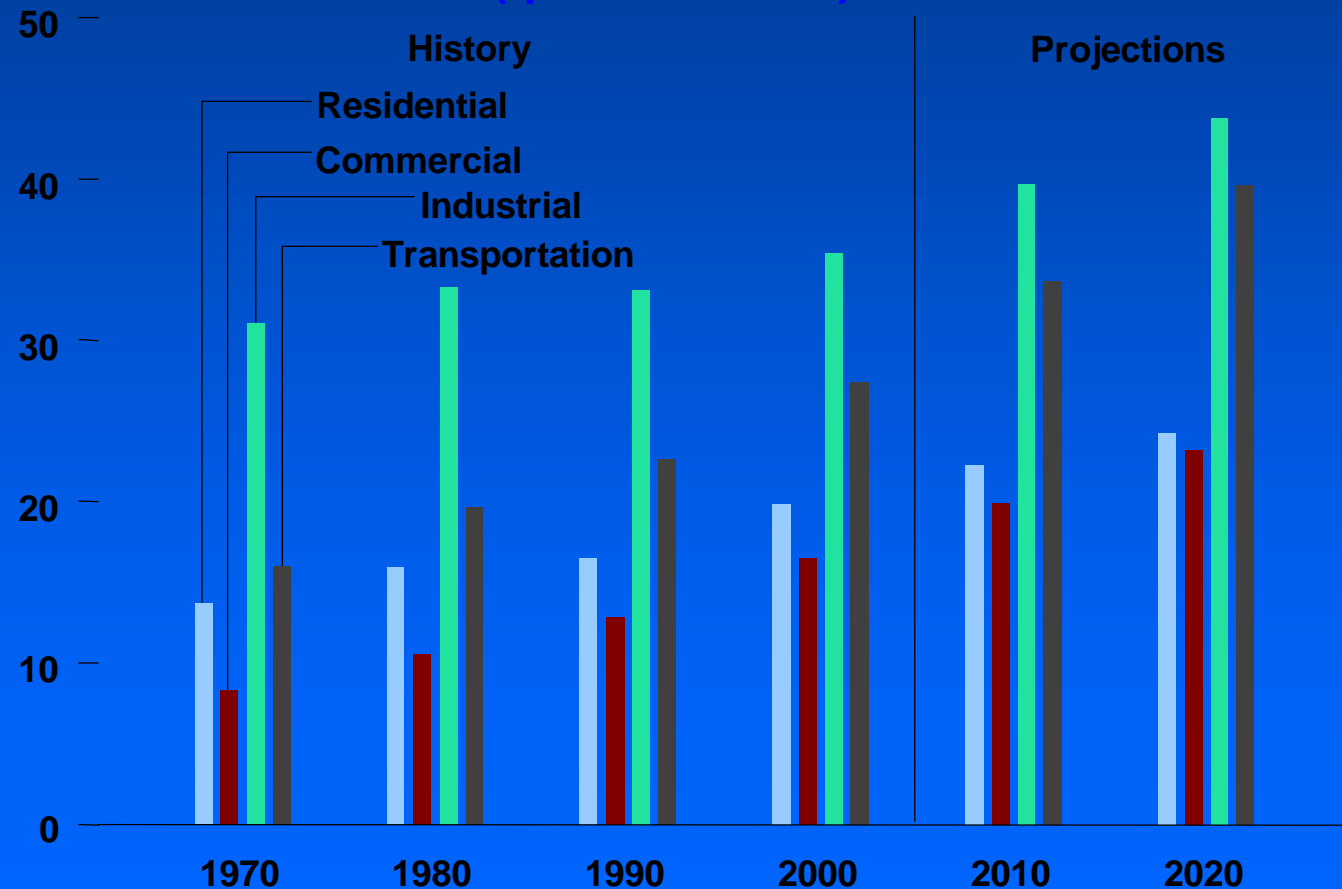
## **Energy Issues in Transportation**

**Floyd E. Barwig**



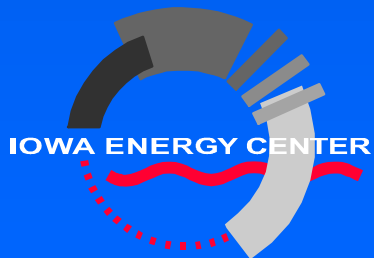
# *US Energy Use for Transportation*

Figure 2: Primary Energy Consumption by Sector,  
(quadrillion Btu)



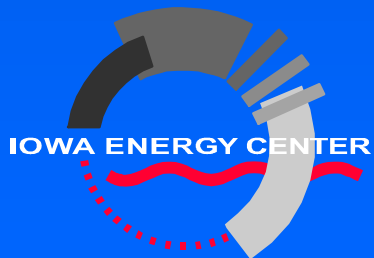
# ***US Oil Use for Transportation***

- US uses roughly 25% of world's oil production
- Take a snapshot using Energy Information Administration data for week of 02/15/02
- All values are barrels (42 gallons) per day



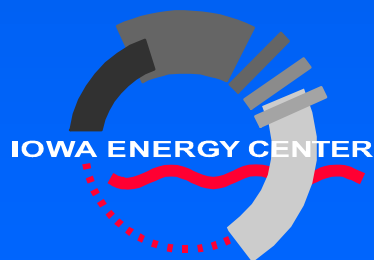
# ***Inputs***

- Crude oil 14,388,000
  - Crude Oil Imports 8,034,000 (58%)
  - Domestic Crude Production 5,927,000 (42%)
- 
- Totals do not add due to movements in and out of Strategic Petroleum Reserve and other inventories

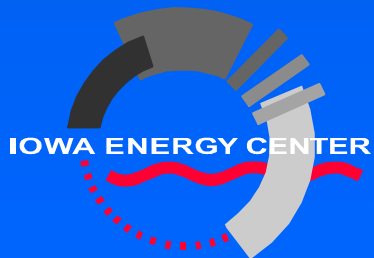


# ***Products Supplied***

■ Gasoline	8,428,000
■ Jet Fuel	1,666,000
■ Distillate Fuel Oil	3,891,000
■ Residual Fuel Oil	850,000
■ Other Oils	4,947,000
■ Total	19,782,000



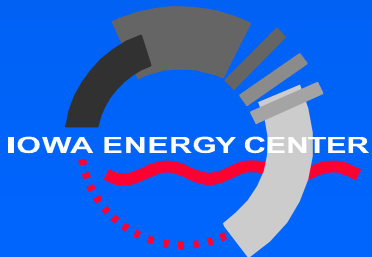
# *Visualizing 19,782,000 barrels*



# ***Environmental Impact***

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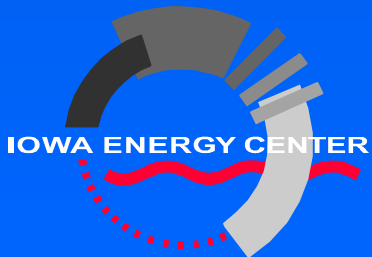
- **“The extraction and use of energy is the single largest impact on the environment.” Peter Berle, former President of the Audubon Society**



# ***Environmental Impact***

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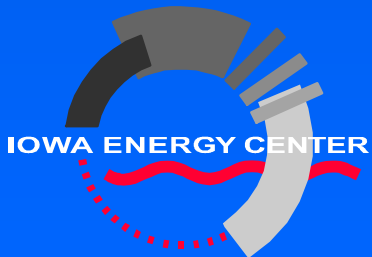
- **Particulates**
- **VOCs (Volatile Organic Compounds)**
- **SOx (sulfur compounds including sulfuric acid)**
- **NOx (nitrogen compounds including nitric acid)**
- **Heavy metals**



# ***Environmental Impact***

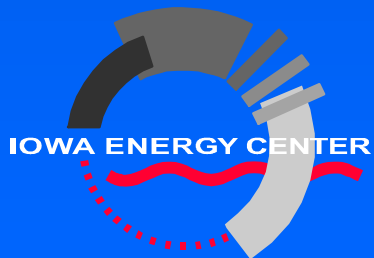
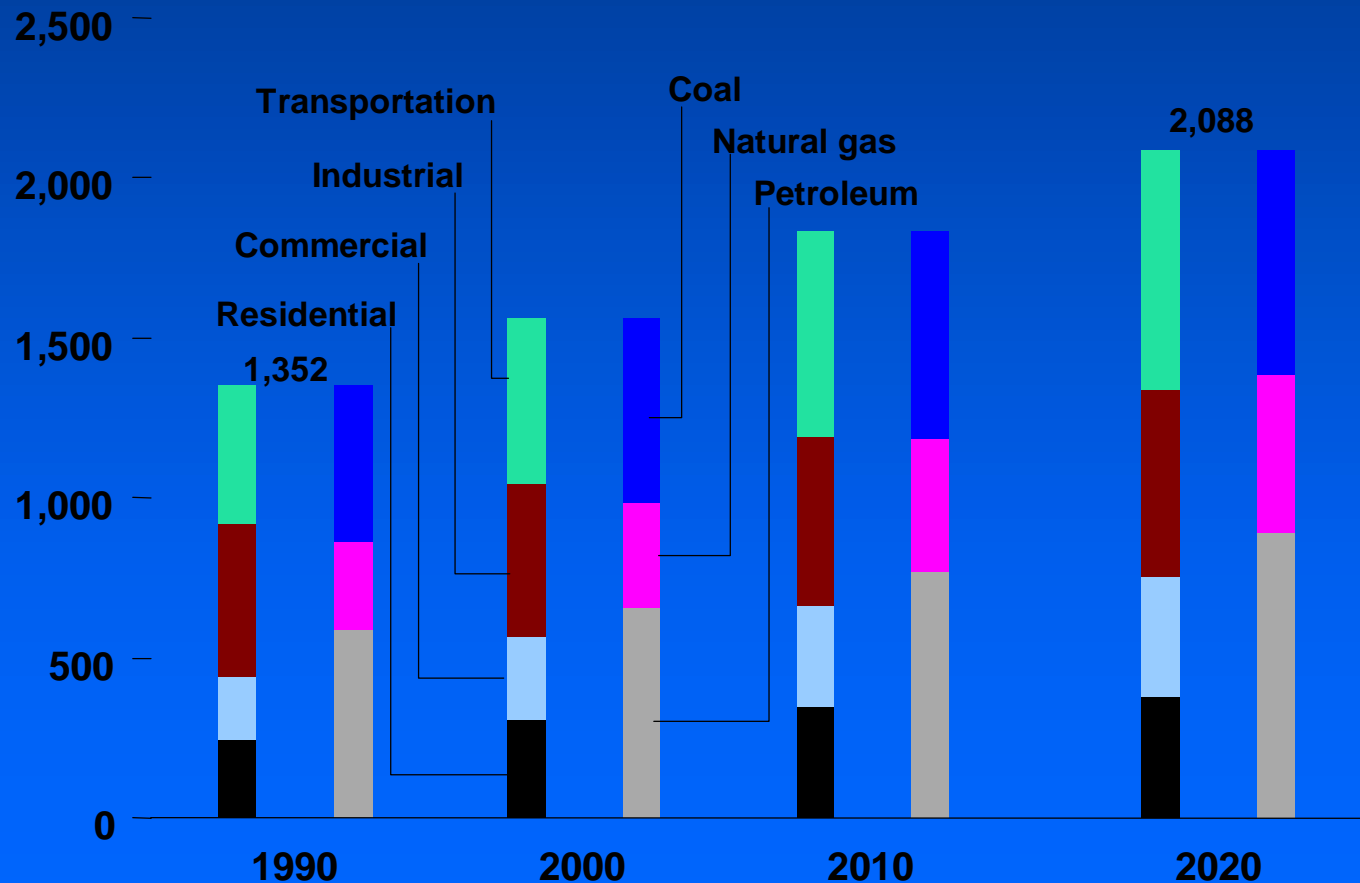
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- Greenhouse gases: global warming
- Primarily carbon dioxide
- One third of US greenhouse gas emissions trace to transportation



# Carbon Dioxide Emissions

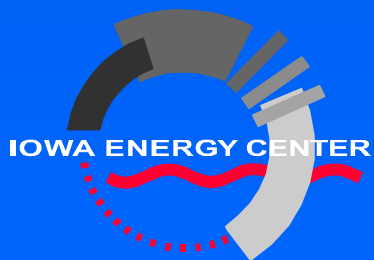
Figure 4: Projected U.S. Carbon Dioxide Emissions by Sector, Fuel, 1990-2020 (million metric tons carbon equivalent)



# *How Can We Respond?*

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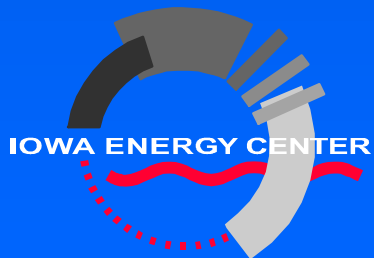
- A technological revolution
- Hydrogen and fuel cells
- Freedom Car



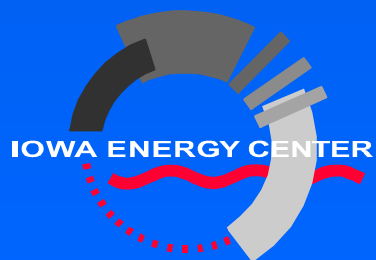
# ***Technological Revolution***

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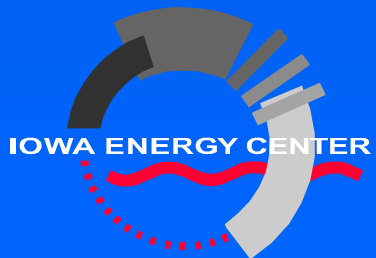
- A new technology outperforms an old one and takes over
- Is it that simple?
- An example in transportation



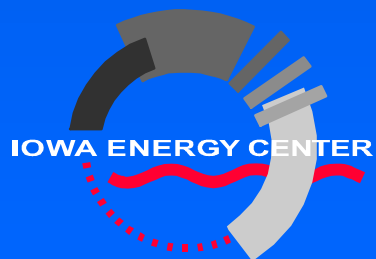
# *The Dinosaur*



# *A Contender*



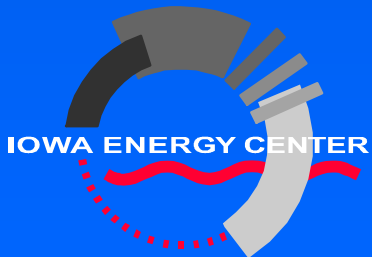
# *The Winner*



# ***Steam to Diesel: A Sudden Switch?***

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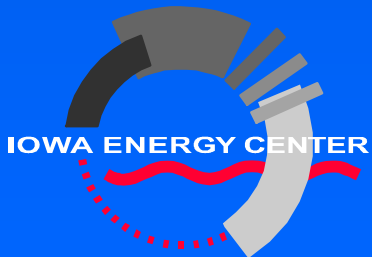
- Steam from 1820s to 1940s-1950s
- Diesels took over in 1940s-1950s
- Electrification in early 1900s (tunnels, cities)
- Diesels even took market from electricity in 1940s and beyond



# *Some History*

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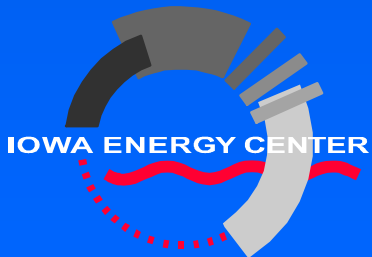
- Diesel engine developed in late 1800s
- Small diesel locomotives appeared in 1920s in cities, industrial plants
- Diesels quite well developed just before WW2
- War interrupted transition: US needed huge transportation increase; steam production capacity in place; infrastructure in place; technology known



# *Some History*

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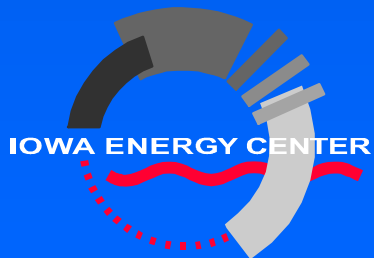
- At end of WW2, many steam locomotives worn out
- Economy transitioned to civilian needs
- Time for change arrived
- Steam “suddenly” replaced by diesels
- “Suddenly” was preceded by over 50 years of research, demonstration



# ***Fuel Efficiency***

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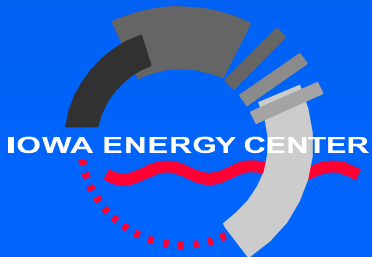
- **Steam locomotive 7-8 percent efficient**
- **Electric locomotive connected to a coal-fired power plant 20-25 efficient**
- **Diesel locomotive 25-30 percent efficient**
- **Was this the issue that drove transition?**



# ***So What Killed the Dinosaurs?***

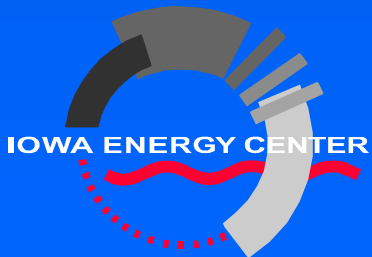
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- Pollution – as a local nuisance and fire hazard, not a national clean air or global warming issue
- Labor intensity
- Infrastructure
- Lack of braking power
- All tied to maintenance costs



# ***What Happened to Electrics?***

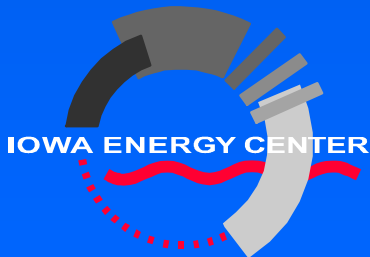
- **Expensive, maintenance intensive infrastructure: wires or third rails**
- **Only justifiable for high volume traffic in areas where pollution is a concern**
- **Not a total technological loser; a diesel locomotive is really an electric locomotive carrying its own diesel engine and generator: no wires**



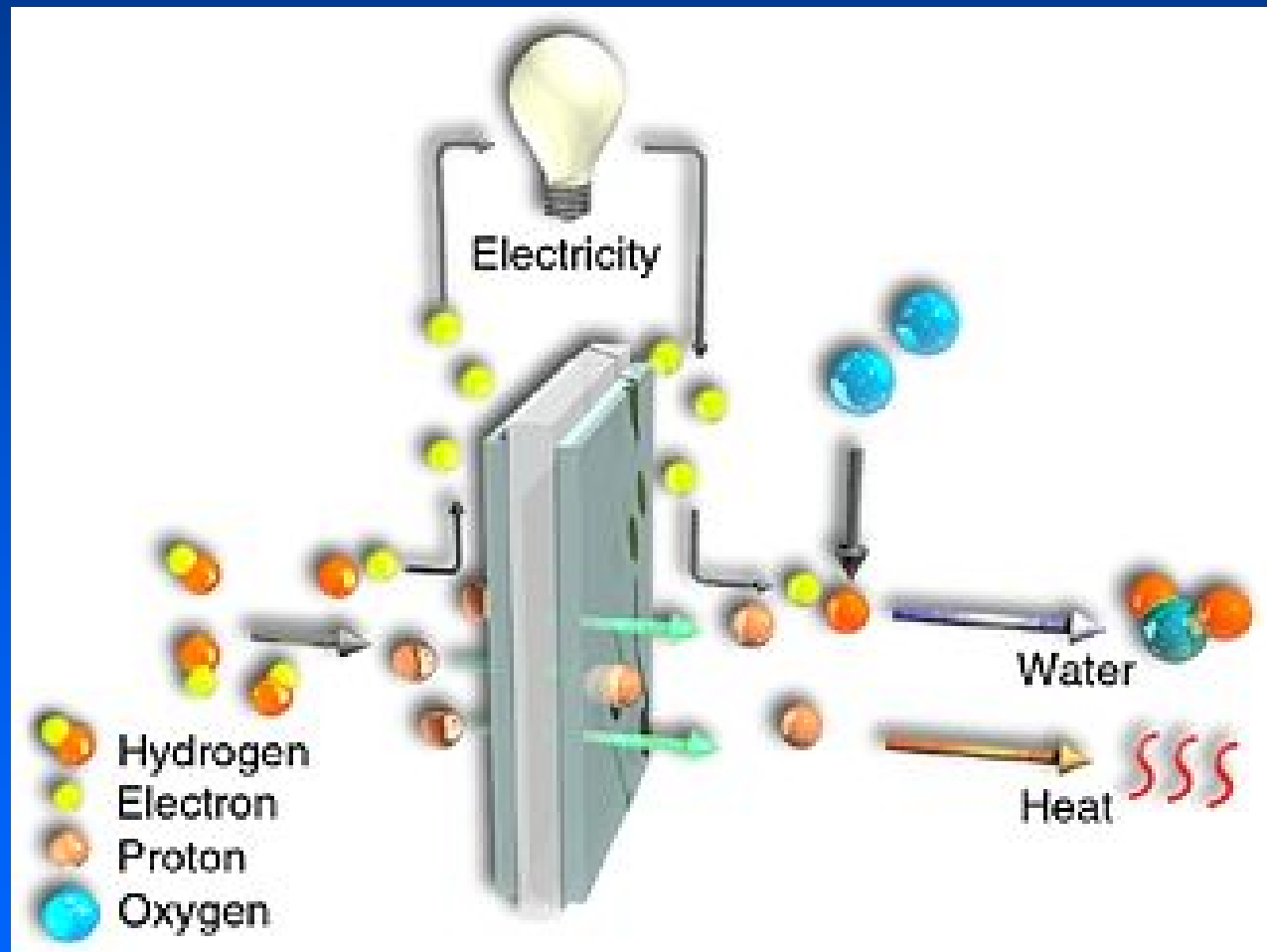
# ***Fuel Cells: The Answer?***

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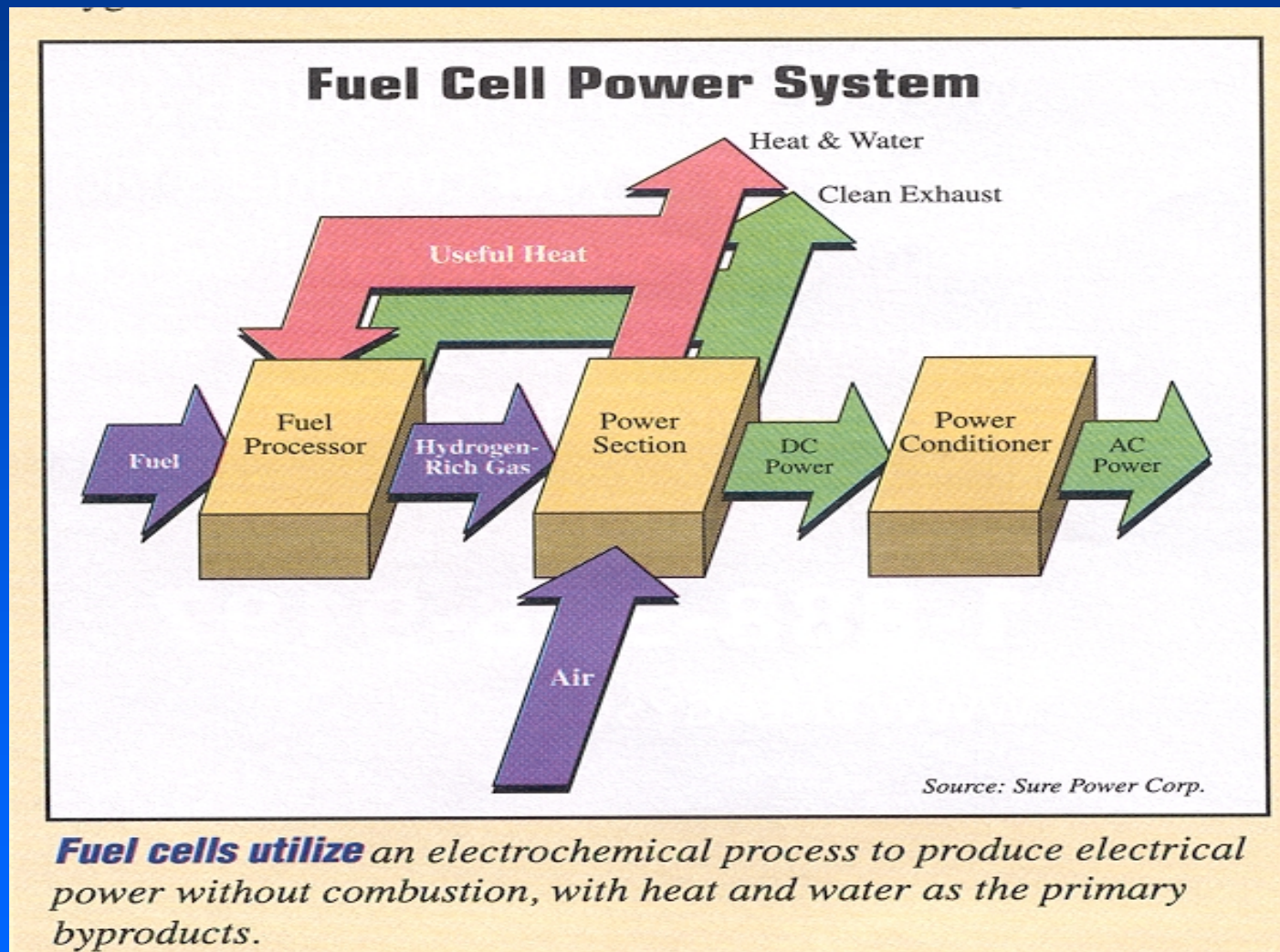
- Fuel cell powered by hydrogen
- Fuel cell makes electricity that can power a vehicle
- Highly scalable to different sizes
- Fuel cell exhaust is water plus heat
- Potential replacement for internal combustion engine



# ***Fuel Cell Basics: PEM Technology***



# Fuel Cell Basics



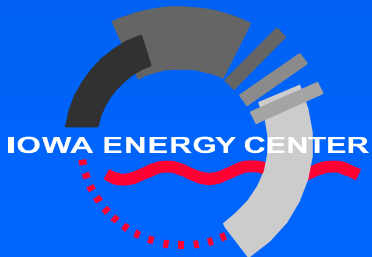
# *Ford Concept Car*



# *Hypercars*

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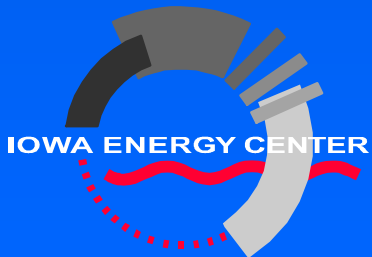
- Concept stated by Amory Lovins of Rocky Mountain Institute
- Light weight, carbon fiber cars
- Powered by fuel cells running on hydrogen from renewable sources
- High efficiency systems



# *Hypercars*

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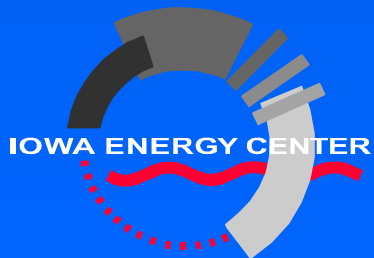
- Plug in a parked Hypercar, leave it running
- Hypercar can make electricity for the grid
- Owner gets paid by the parking meter
- Power plants follow people around
- Mobile distributed generation
- GM “skateboard” concept car



# *Efficiency – Gasoline Engine*

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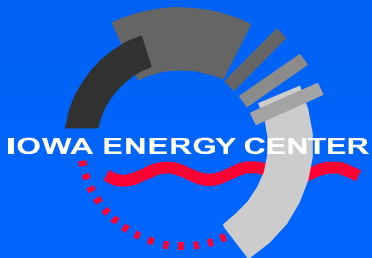
- About 20 percent
- Much of energy converted to heat and wasted through radiator
- Significant parasitic loads (pumps, fans, etc.)



# ***Efficiency – Fuel Cell Car***

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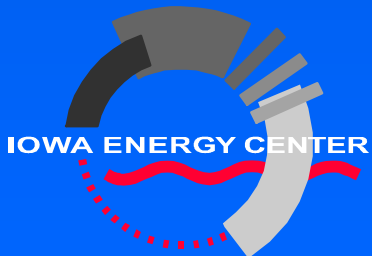
- Fuel cell 70-80 percent efficient
- Inverter and motors 80 percent efficient
- Total system 56-64 percent efficient



# *Efficiency – Fuel Cell Car*

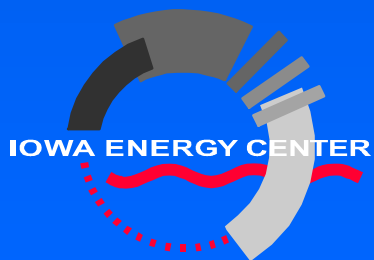
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- But if hydrogen is made by a reformer that is 30-40 percent efficient, total system efficiency drops to 17-26 percent efficient
- If hydrogen made by renewables or from fossil fuels at centralized reformers, hydrogen storage is an issue



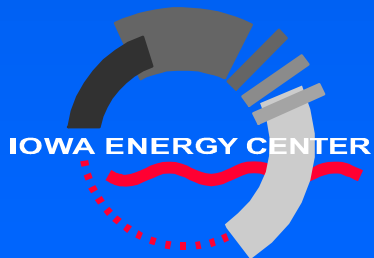
# *Efficiency – Electric Battery Car*

- Inverter and motors 80 percent efficient
- Batteries 90 percent efficient
- System 72 percent efficient



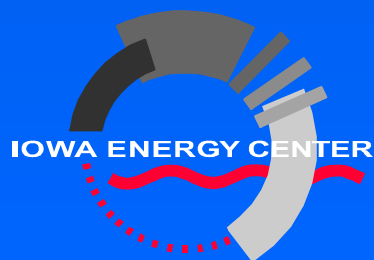
# *Efficiency – Electric Battery Car*

- But if batteries recharged by coal fired power plant at 33 percent efficiency, system drops to 24 percent efficient
- Unless battery performance improves, vehicle range is an issue



# *Side by Side Comparison*

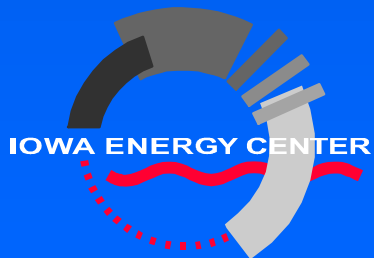
■ Internal combustion engine	20%
■ Fuel cell	17-64%
■ Batteries	24-72%



# ***The Dilemma***

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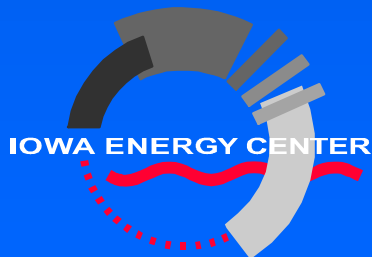
- Fuel Cell produces water and heat for exhaust
- Battery powered car has no exhaust
- But...



# ***The Dilemma***

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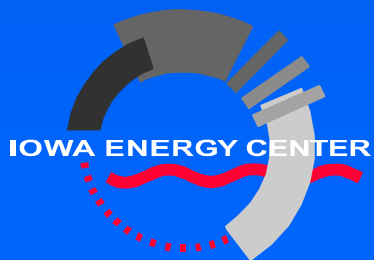
- Will the fuel cell car run on hydrogen produced by renewable resources like wind or solar or...
- ...will it run on gasoline processed through a relatively low efficiency reformer?
- Will the electric battery car be recharged by renewable technologies like wind and solar or...
- ...will it really be powered by coal?



# ***The Dilemma Restated***

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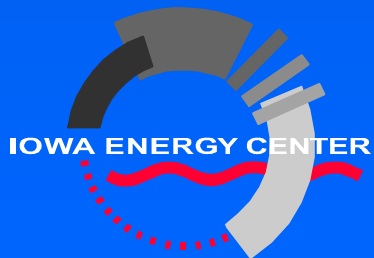
- If fuel cell powered automobiles use no less fossil fuel per mile than internal combustion engine powered cars do today, where are the energy and pollution savings?



# ***What is the Best Solution***

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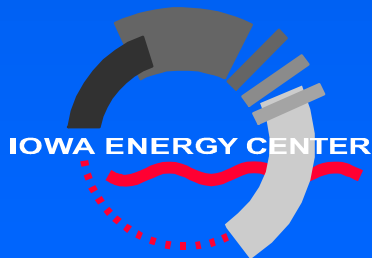
- A fuel cell powered car getting 17 miles per gallon (Ford's projection for their fuel cell SUV)?
- A hybrid electric (like the Honda Insight) that gets 60+ miles per gallon?



# ***Policies and Subsidies***

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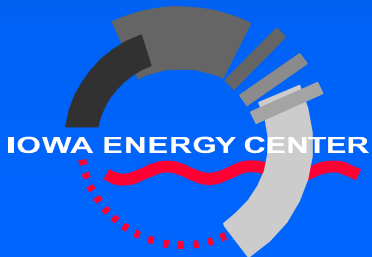
- Virtually all energy production is subsidized
- A maze of tax incentives
- Nuclear research and waste disposal
- Military protection of oil
- CAFÉ (Corporate Average Fuel Efficiency)
- Pollution



# ***Policies and Subsidies***

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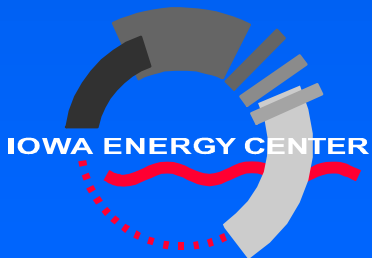
- Have shaped the energy system we have
- Can shape the energy system of the future
- What do we as a nation want?



# ***Midwest Transportation Niches***

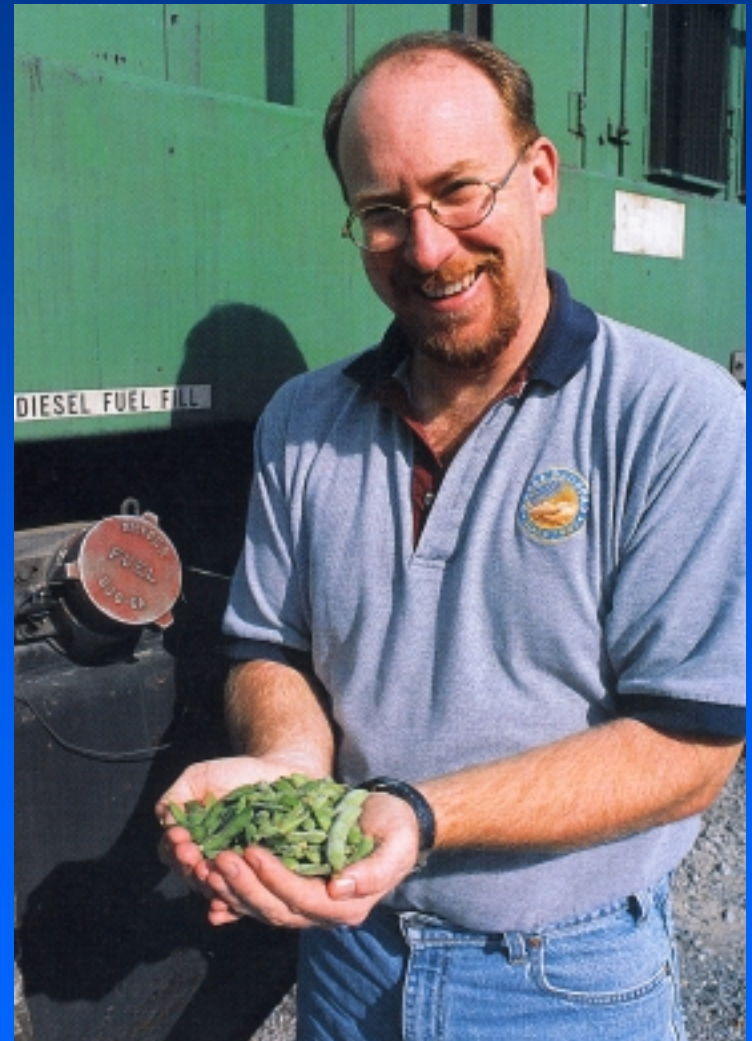
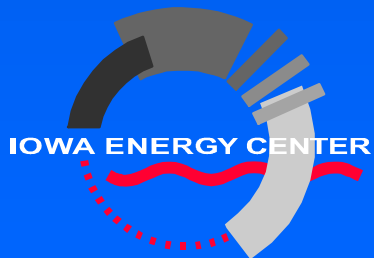
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- **Alternative fuels**
- **Alternative lubricants**
- **Transporting biomass-based fuels and chemicals**
- **Idle reduction**



# *Alternative Fuels*

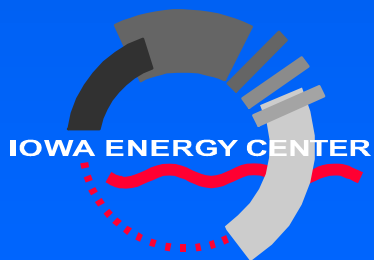
- Ethanol
- Biodiesel



# ***Ethanol***

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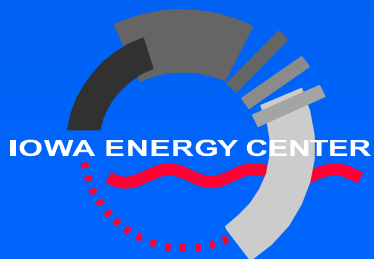
- Now made from corn kernels
- Animal feed is byproduct
- Used as an oxygenate in gasoline
- Flexible Fuel Vehicles can run as high as 85% ethanol
- Less energy per gallon than gasoline
- Subsidized



# ***Ethanol***

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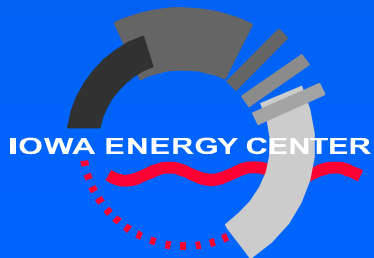
- Research on making ethanol from alternative crops (e.g. sweet sorghum, sugar beets)
- More alcohol per acre
- Research on making ethanol from cellulose such as corn stalks
- Lower cost feedstock



# ***Ethanol***

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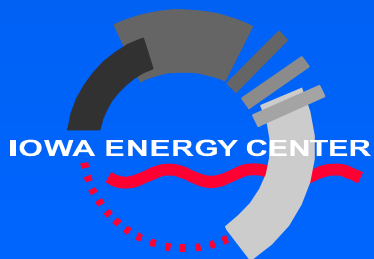
- Commercial plants operating throughout Midwest
- Problems with MBTE oxygenate (groundwater contamination) may open market for more ethanol



# ***Biodiesel***

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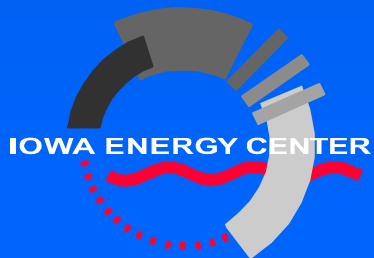
- Made by reacting plant or animal oil with alcohol
- Soy oil commonly used in Midwest
- Canola oil commonly used in Europe
- Glycerin is byproduct



# ***Biodiesel***

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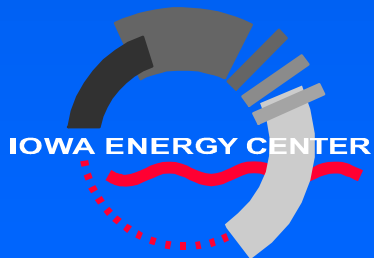
- Less energy per gallon than petroleum diesel
- Poor cold weather performance
- Expensive
- Research on using waste animal fats as cheaper feedstock
- Research on improving quality/value of glycerin



# ***Biodiesel***

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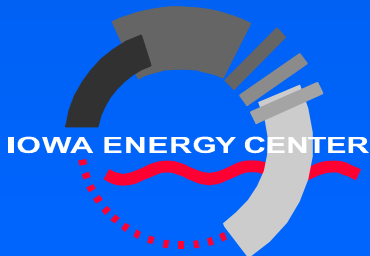
- First commercial plants operating
- National Biodiesel Training Facility established in Nevada, Iowa
- EPA requirement to remove 97% of sulfur from petroleum diesel in 2006 will open market for biodiesel additive as lubricant



# ***Lubricants***

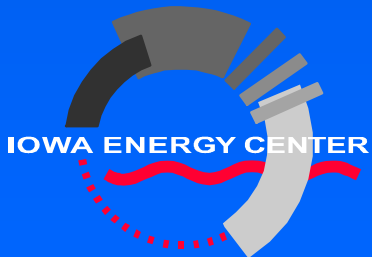
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- Soy based oils and greases
- Hydraulic oil
- Fifth wheel grease
- Rail grease
- Other applications
- Agriculture-Based Industrial Lubricants (ABIL) program at University of Northern Iowa



# *Transporting Biomass*

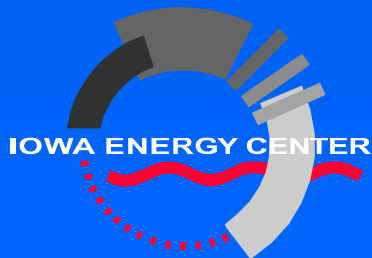
- Great potential to make chemicals and fuels from biomass waste materials
- Biomass wastes difficult to transport (low energy density)
- Optimizing production/transport a problem that is not resolved
- Has implications for economic development pattern



# ***Idle Reduction***

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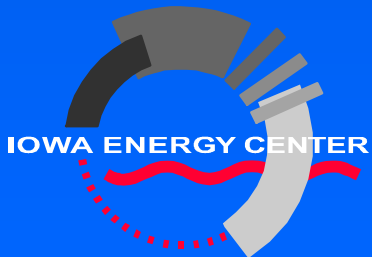
- Trucks typically idle their engines at truck stops to provide heat, power equipment, keep engine warm
- “Long-haul trucks idling overnight consume 838 million gallons of fuel annually” Argonne National Laboratory
- Idling produces large amounts of pollution
- Idling increases wear on engine



# ***Idle Reduction Approaches***

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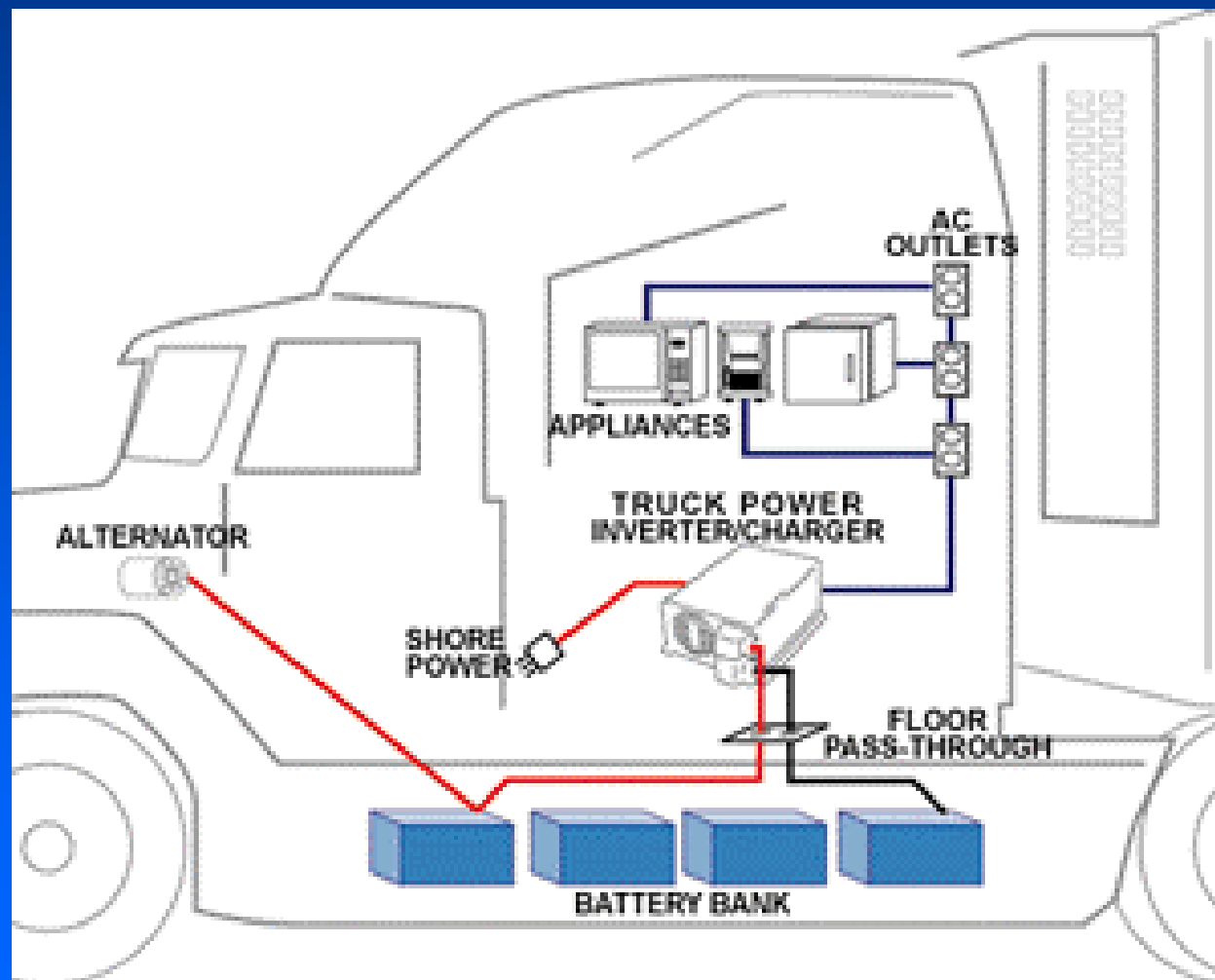
- On board auxiliaries
- Shore power
- IdleAir Technologies



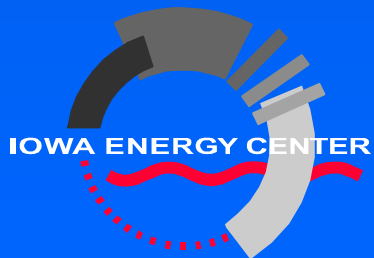
# *On Board Auxiliaries*



# *Shore Power*



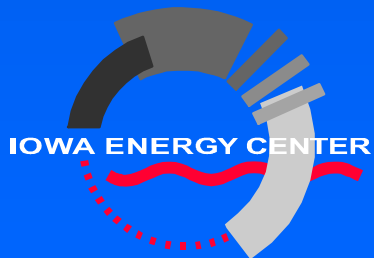
# *IdleAir Technologies*



# ***Idle Reduction***

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- Diesel locomotives even worse
- Seldom shut down except for repair
- Far fewer locomotives than trucks, but each locomotive bigger energy consumer



# *Questions and Discussion*

