



Benefits of Hybridization for Class 2B Trucks

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Outline

- **Silverado 1500 Pickup Truck (Class 2A) Validation**
- **Extension to Silverado Pickup Truck (Class 2B) Validation**
- **Effect of 21st Century Truck Loss Goals**
- **Effect of Dieselization**
- **Effect of Hybridization**
- **Conclusions**

Silverado 1500 Pickup Truck (Class 2A) Validation

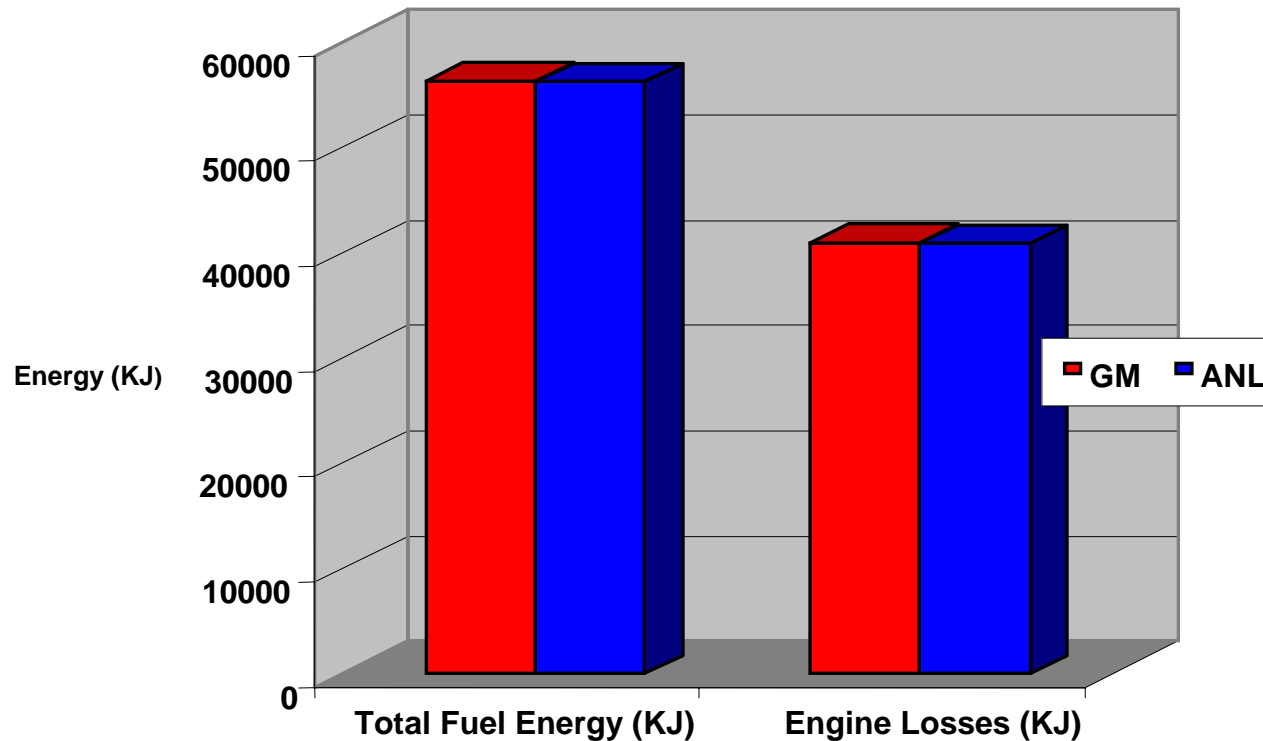
- **Used GM Loss Data from Truck and Bus 2000 Presentation for**
 - MY2000 4WD Silverado 1500 Pickup
 - Class 2A
 - 5.3L V8 285 hp Spark-Ignition Engine
 - 4 speed Automatic Transmission

2000 4WD Silverado 1500 EPA Combined Cycle Energy Losses

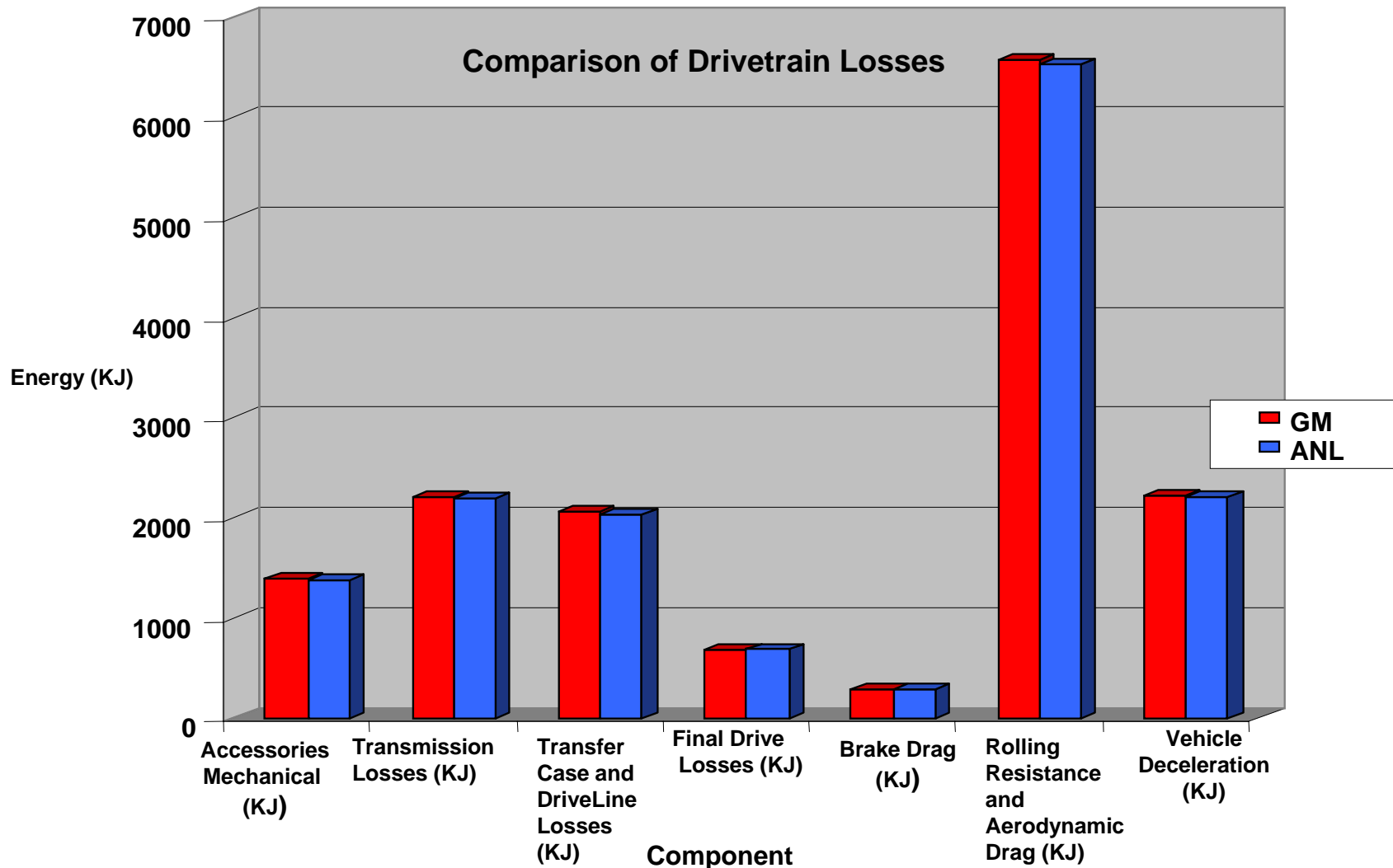
Total Fuel Energy	56277 kJ
Engine Losses	40973 kJ
Mechanical Accessories	1391 kJ
Transmission Losses	2202 kJ
Transfer Case and Driveline Losses	2063 kJ
Final Drive Losses	672 kJ
Brake Drag	287 kJ
Rolling Resistance	1726 kJ
Aerodynamic Drag	4849 kJ
Vehicle Deceleration	2114 kJ

Engine Losses Are Validated To Within 5% For The Silverado 1500 (Class 2A)

EPA Combined Fuel Energy (GM)	EPA Combined Fuel Energy (ANL)	Relative Error
56277kJ (19.1 mpg)	56261kJ (18.9 mpg)	< 1%



Single Component Drivetrain Losses Are Validated To Within 5%



Class 2B Methodology

- **Conventional Class 2B**
- **Conventional Class 2B Using 21st Century Truck Losses**
- **Conventional Class 2B Using 21st Century Truck Losses and 20% Reduced Mass**
- **Hybrid Class 2B Using 21st Century Truck Losses and 20% Reduced Mass**
- **Combined EPA Cycle (CAFE)**

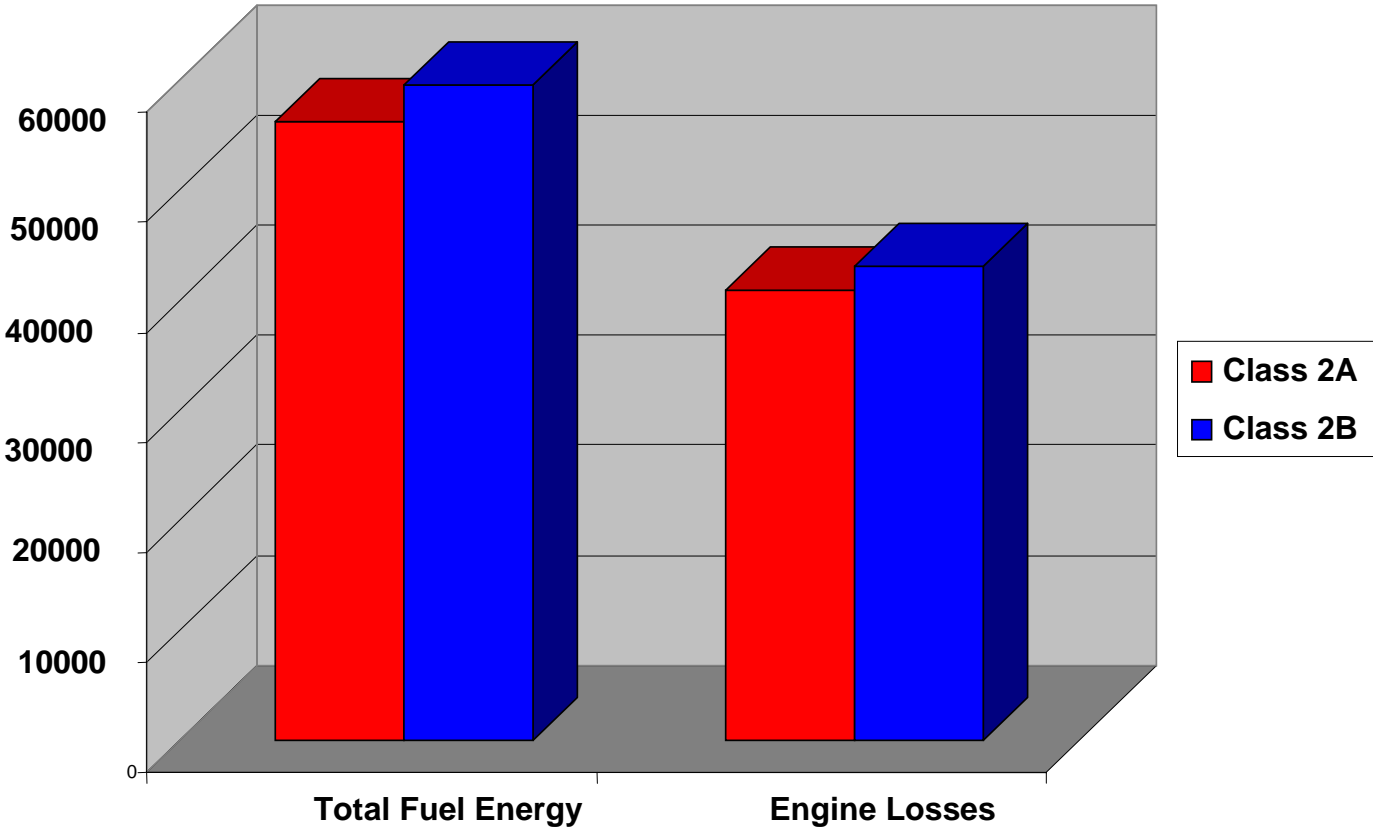


Transforming the Class 2A Model Into A Class 2B

- **Predicted Class 2B Fuel Economy Using Class 2A Results**
 - Changed Vehicle Mass to Reflect Class 2B Heavier Frame, Suspension and Axles
 - Used Same
 - *5.3L SI Engine*
 - *4-Speed Automatic Transmission*
 - *Transfer Case*
 - *Final Drive*

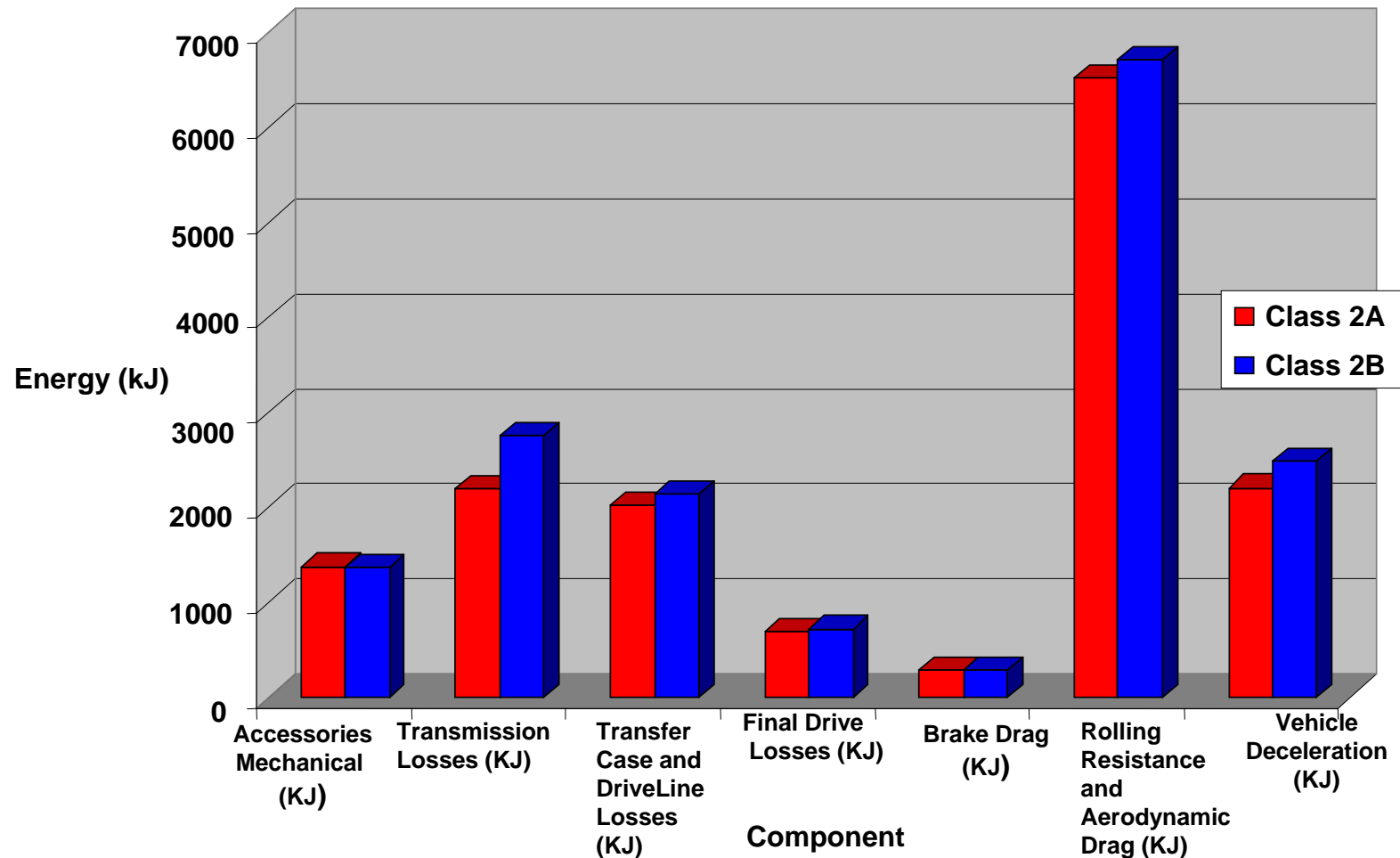
Results of Class 2B Simulation For The Engine

EPA Combined Fuel Economy (Class 2B)	17.8 mpg
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Component Losses Are Increased Due to Increased Vehicle Mass

Comparison Class 2A with Class 2B Losses



Component Losses Are Increased On Average By 7%

Class 2B Energy Results	ANL Class 2A Losses	ANL Class 2B Losses	Increase In Losses
Total Fuel Energy	56261 kJ	59619 kJ	6%
Engine Losses	40898 kJ	43077 kJ	5%
Mechanical Accessories	1375 kJ	1369 kJ	-0.4%
Transmission Losses	2195 kJ	2759 kJ	26%*
Transfer Case and Driveline Losses	2027 kJ	2134 kJ	5%
Final Drive Losses	685 kJ	721 kJ	5%
Brake Drag	285 kJ	285 kJ	0%
Rolling and Aerodynamic	6526 kJ	6719 kJ	3%
Vehicle Deceleration	2205 kJ	2489 kJ	13%

* Heavier torque converter duty cycle

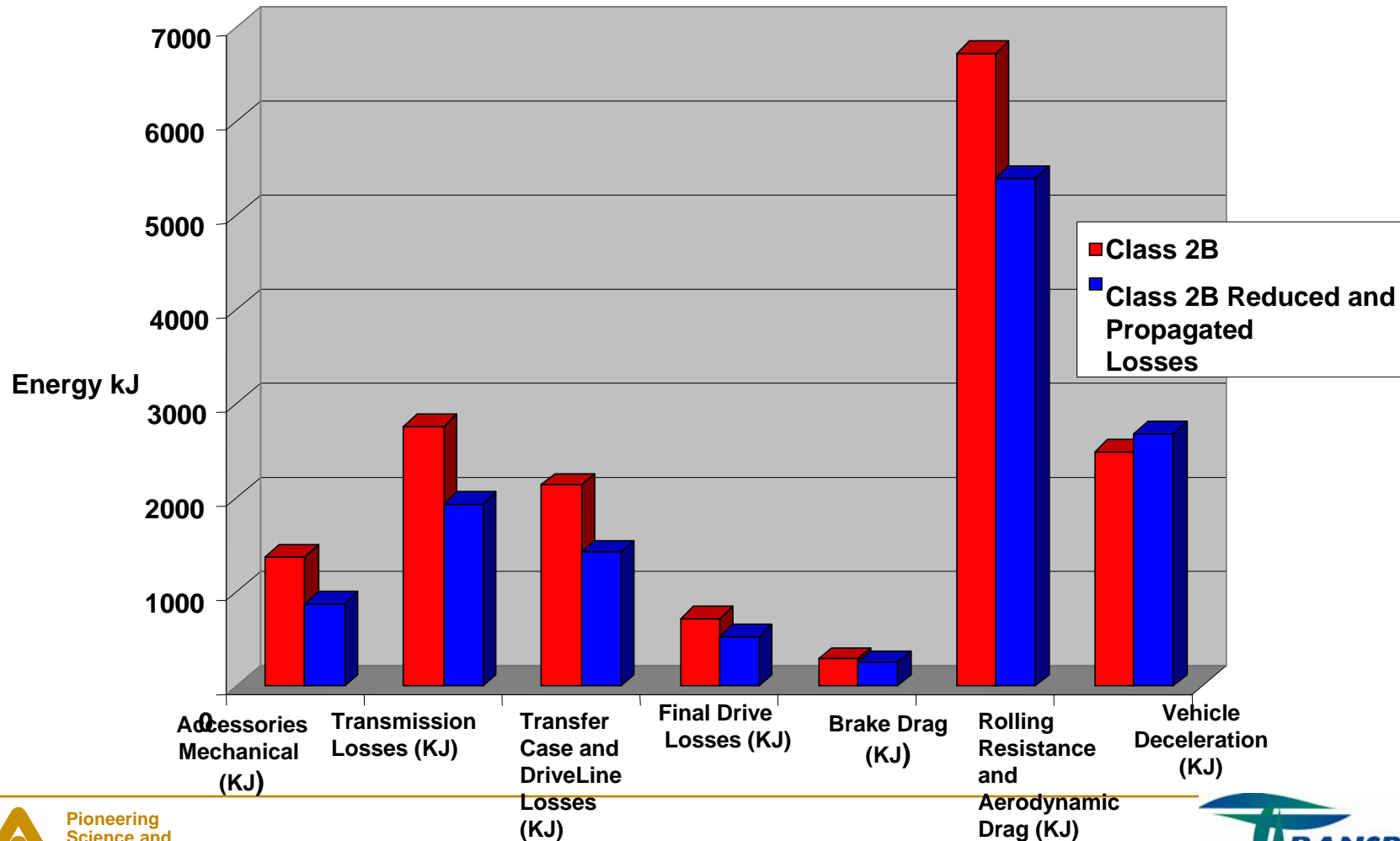
21st Century Truck Loss Targets For the Class 2B

Drivetrain Component	Baseline Class 2B Losses	Reduction Goal	Class 2B Reduced and Propagated Losses
Accessories	1369 kJ	-35%	871 kJ
Transmission Losses	2759 kJ	-20%	1935 kJ
Transfer Case and Driveline Losses	2134 kJ	-20%	1420 kJ
Final Drive Losses	721 kJ	-20%	531 kJ
Brake Drag	285 kJ	-20%	243 kJ
Aerodynamic Drag and Rolling Resistance	6719 kJ	-20%	5393 kJ

Impact of 21st Century Truck Loss Reduction Targets

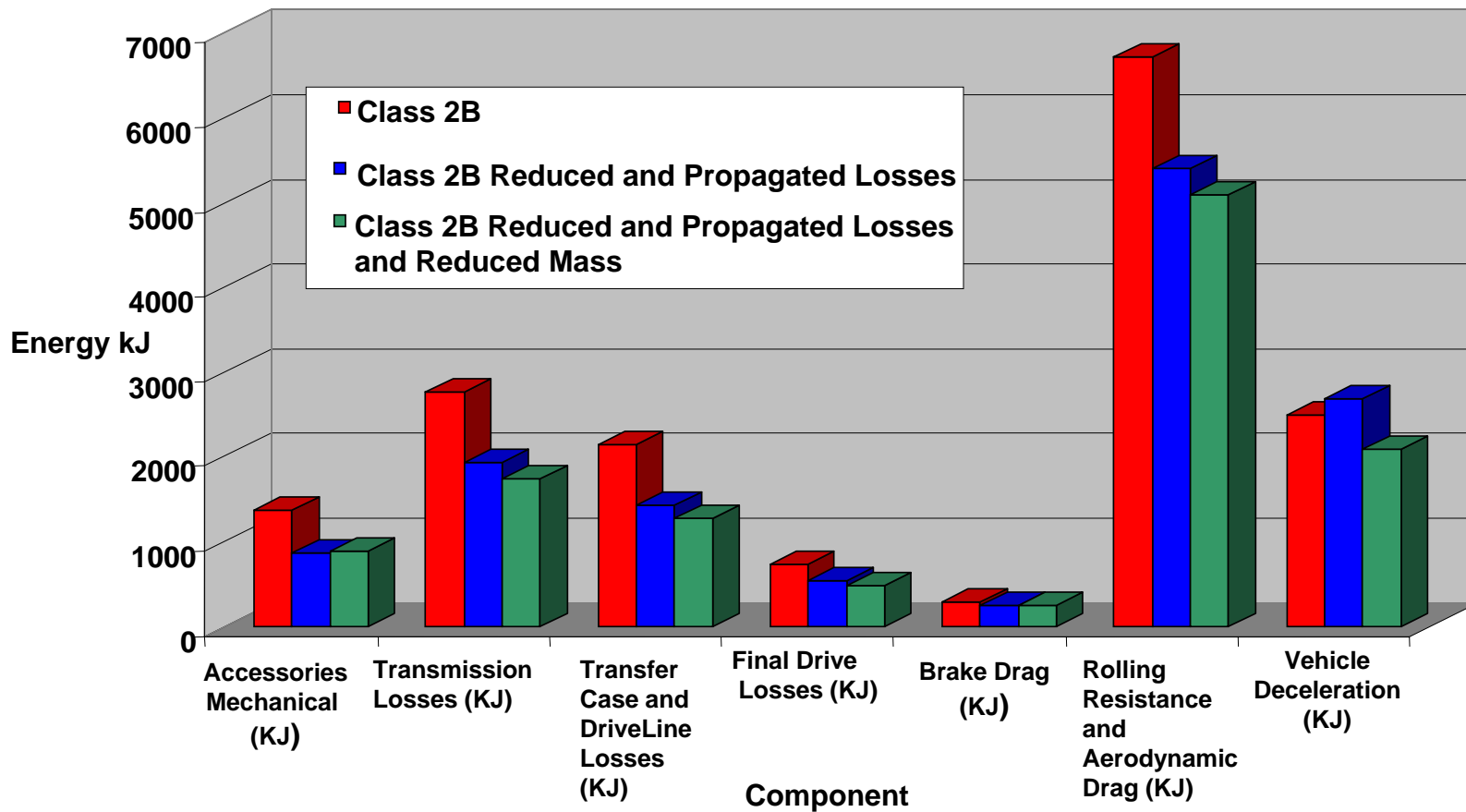
EPA Combined Fuel Economy	21.8 mpg
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Class 2B Reduced and Propagated Losses Compared to Baseline Class 2B



Additional Impact of 20% Mass Reduction

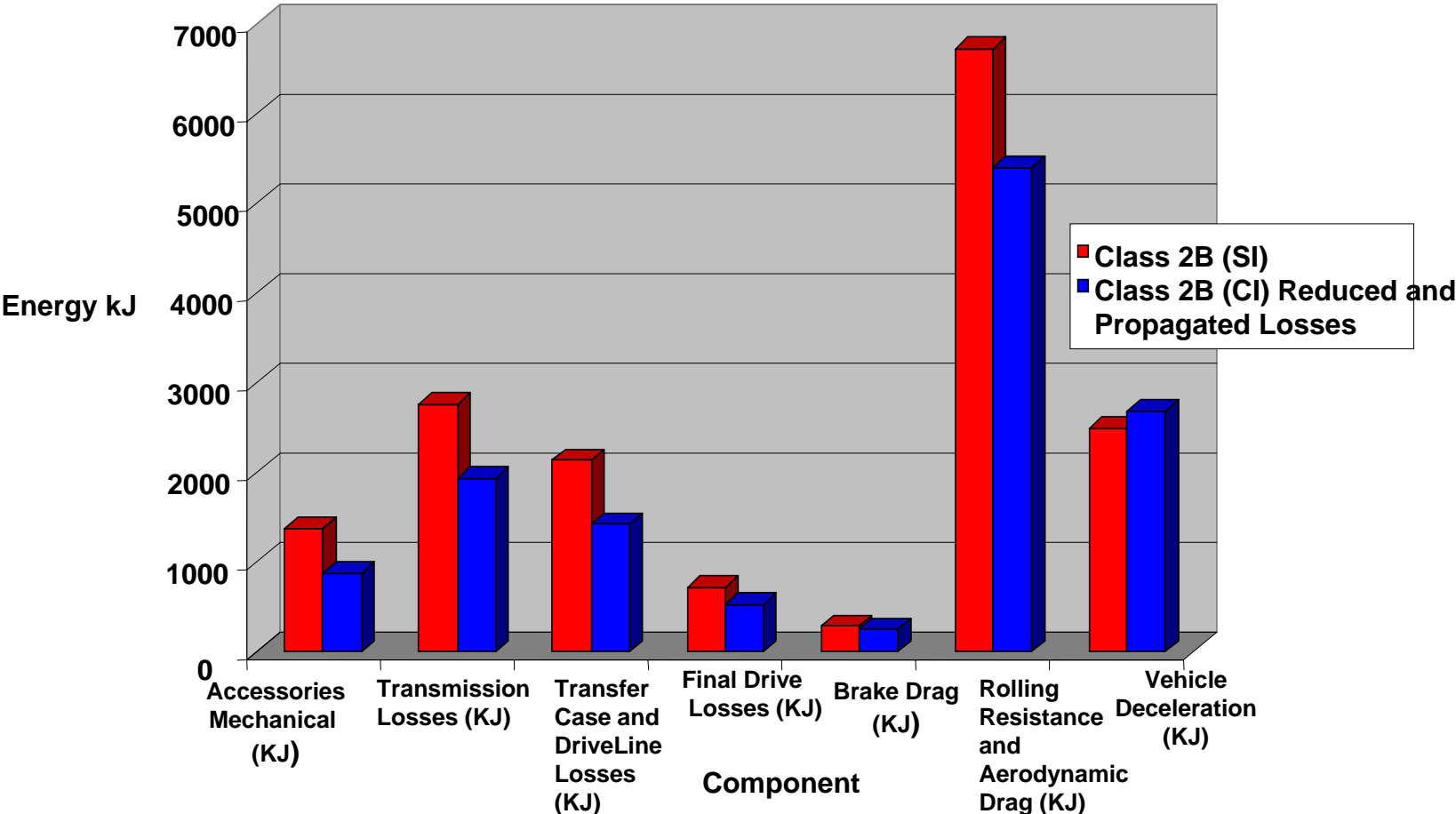
EPA Combined Fuel Economy	23.6 mpg
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Effect of Dieselization

EPA Combined Fuel Economy	26.7 mpg (gas equivalent)
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Class 2B Reduced and Propagated Losses Compared to Baseline Class 2B (SI)



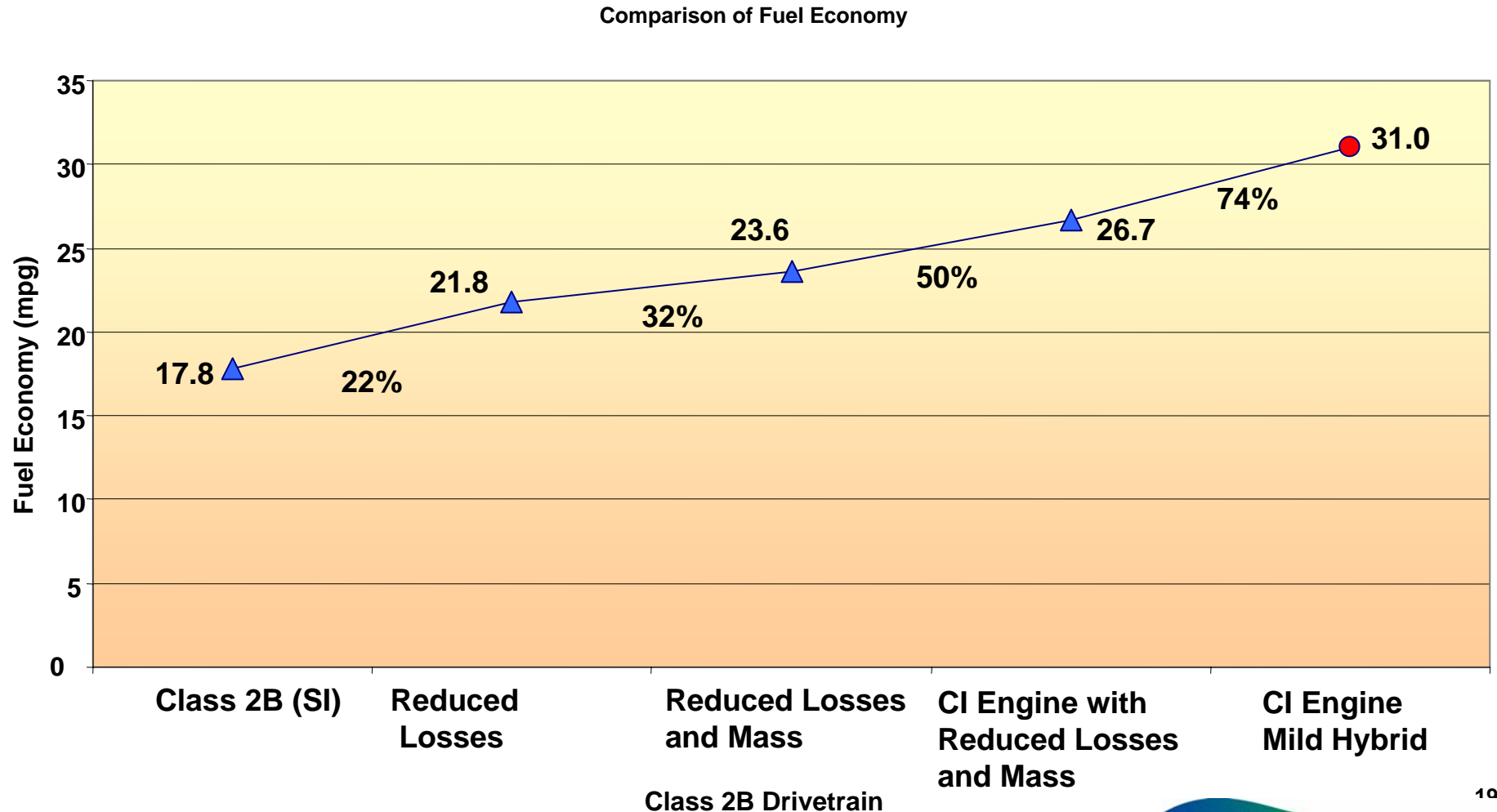
Class 2B Parallel Hybrid

- **Starter Alternator Parallel Configuration**
- **6.5L CI Engine**
- **144 volt, 6Amp-hr, NiMH Battery**
- **16kw Permanent Magnet Motor**
- **Automatic Transmission**
- **Used 21st Century Drivetrain Losses and Vehicle Mass Reduction Targets**

Control Strategy of Parallel Hybrid

- **A Mild Hybrid Control Strategy**
- **Zero Idle**
- **Regenerative Braking**
- **Mild Assist 60 N-m of Assist**

Mild Hybridization Improved Class 2B Fuel Economy By an Additional 16%



Conclusions

- 21st Century Truck targets lead to a 50% gain in fuel economy when compared to the baseline class 2B on the EPA Combined Cycle
 - A 22% gain in fuel economy is possible by reducing the losses of each drivetrain component by 20%.
 - An additional 8% gain is obtained by decreasing the mass of the truck
 - An additional 13% gain occurs by changing to a Diesel engine
- Mild hybridization (without engine downsizing) yields an additional 16% gain in fuel economy
- Cumulative gain is 74% over the baseline

Possible Future Studies

- **Hybrid Component Sizing Optimization**
- **Control Strategy Optimization**
- **Different Degrees of Hybridization**
 - Different Drivetrain Configurations
 - Motor after the Torque Converter
 - Motor after the Transmission
- **Class 2B (SI) Hybridization**