Trucks Deliver a Cleaner Tomorrow

Idle-Reduction Technologies

A White Paper To Discuss The Opportunity and the Challenges

Robert Hupfer, July 15, 2009

Agenda

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The targets of this presentation:

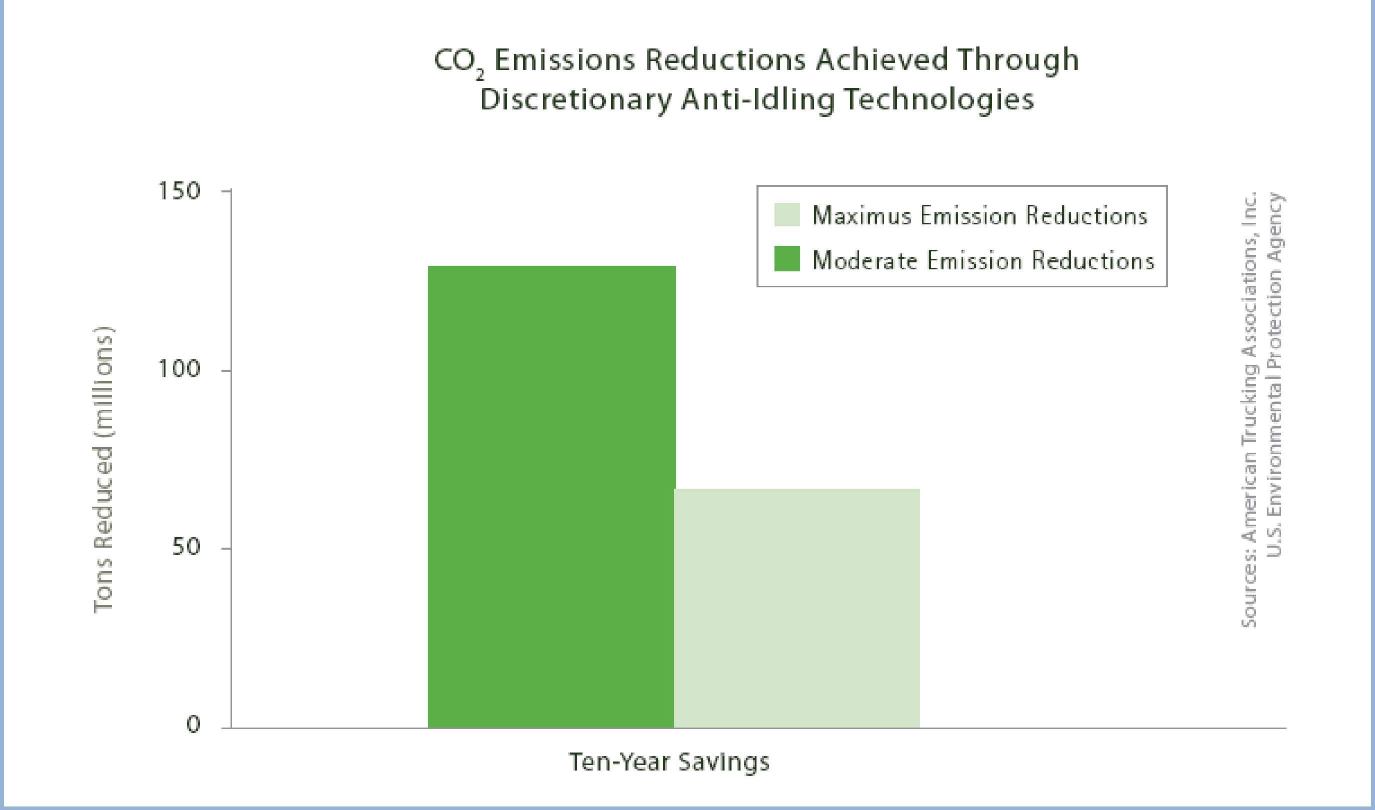
- ❑ Provide information to support decision process for Idle-Reduction Technologies
- ❑ Provide forum, to discuss customer and industry requirements
- ❑ Share our technical knowledge and R&D results

1. The Market Requirements
2. The Product Portfolio Today
3. The Future View
4. Q&A

The Opportunity

Discretionary Idling:

Idling when drivers idle their engines during their **rest period** to provide heat or air conditioning for the **sleeper compartment**, **keep the engine warm** during cold weather, and **provide electrical power** for their appliances



1 gal. Diesel (7 lbs) ⇨ 22.2 lbs CO_2

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The Challenge

Customer checklist:

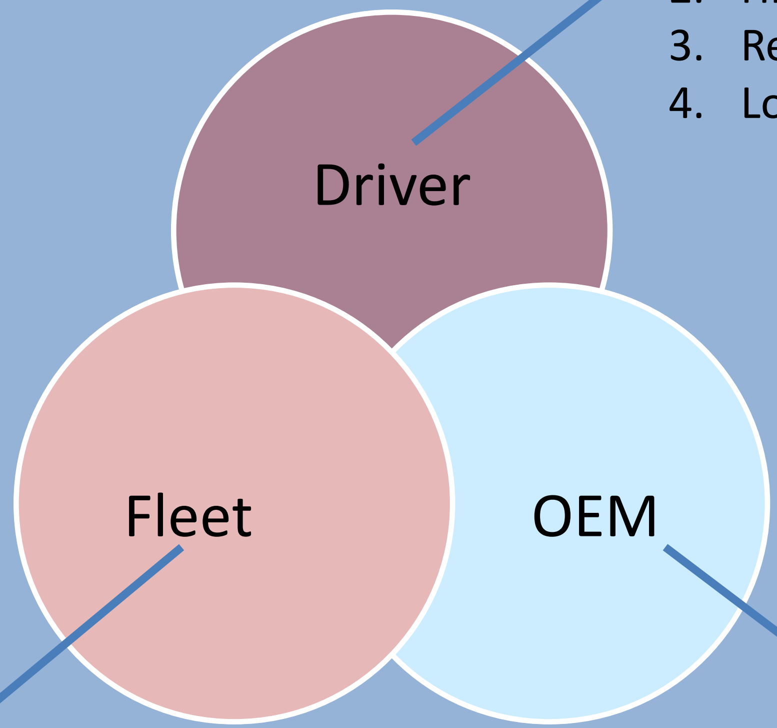
❑Is the product / system providing the target comfort and performance ?

❑Is the product reliable ?

❑What are the lifetime maintenance cost ?

❑What are the installation methods and cost ?

1. Comfort
2. High Performance
3. Reliability
4. Low Maintenance



1. Comfort @ fast ROI
2. Reliability
3. Low Maintenance
4. Easy Installation

1. Cost competitive
2. High Quality
3. Modular

Regulation and Industry Trends

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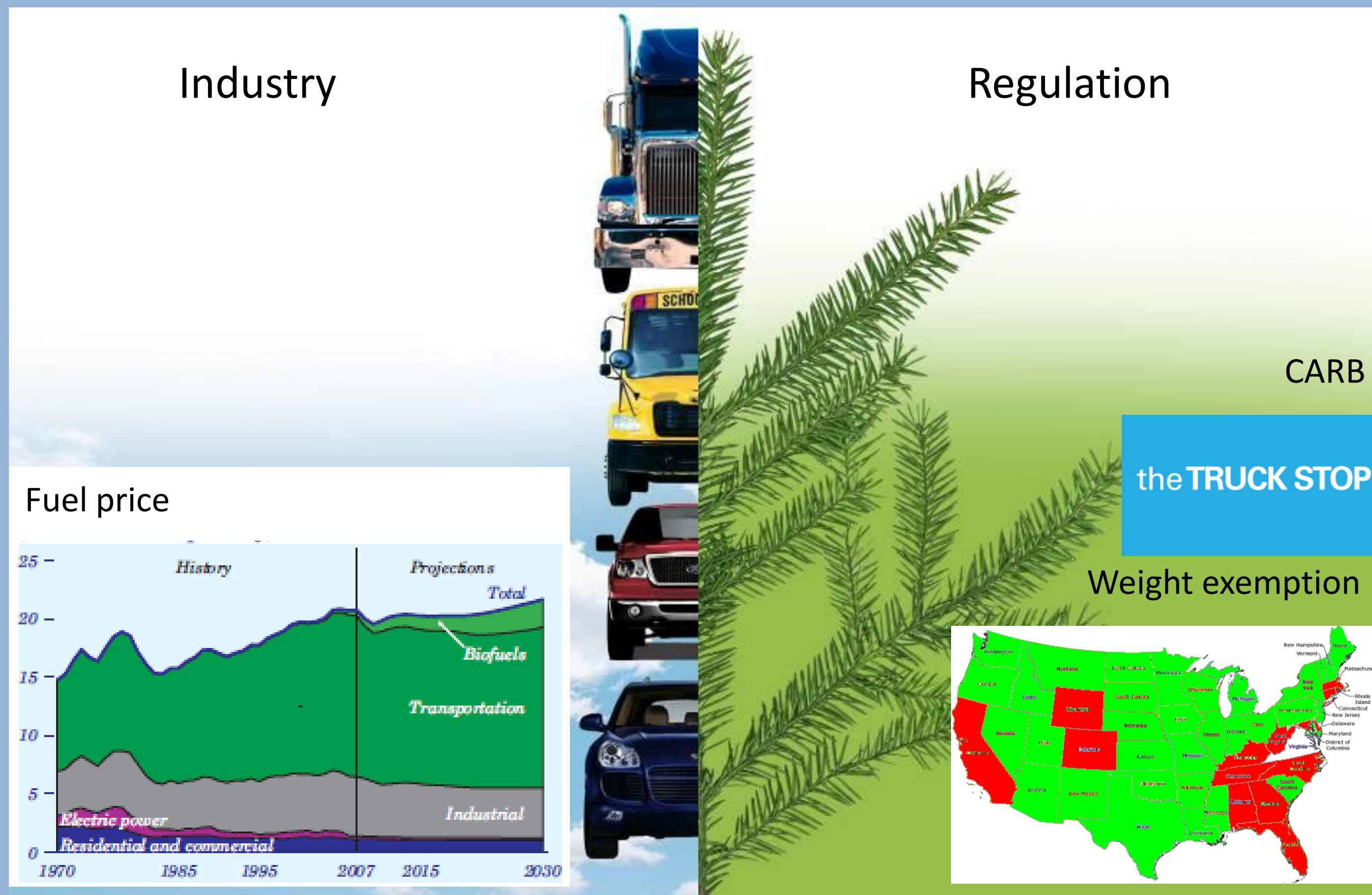
Regulation:

- ❑ Idle-Reduction laws
- ❑ CARB emission regulations
- ❑ Energy Policy Act of 2005: Weight exemption of 400 lbs

Industry:

- ❑ Sustainability requirements
- ❑ Reduce operating cost
- ❑ Reduce waste
- ❑ Carbon Credits



Idle-Reduction Strategies

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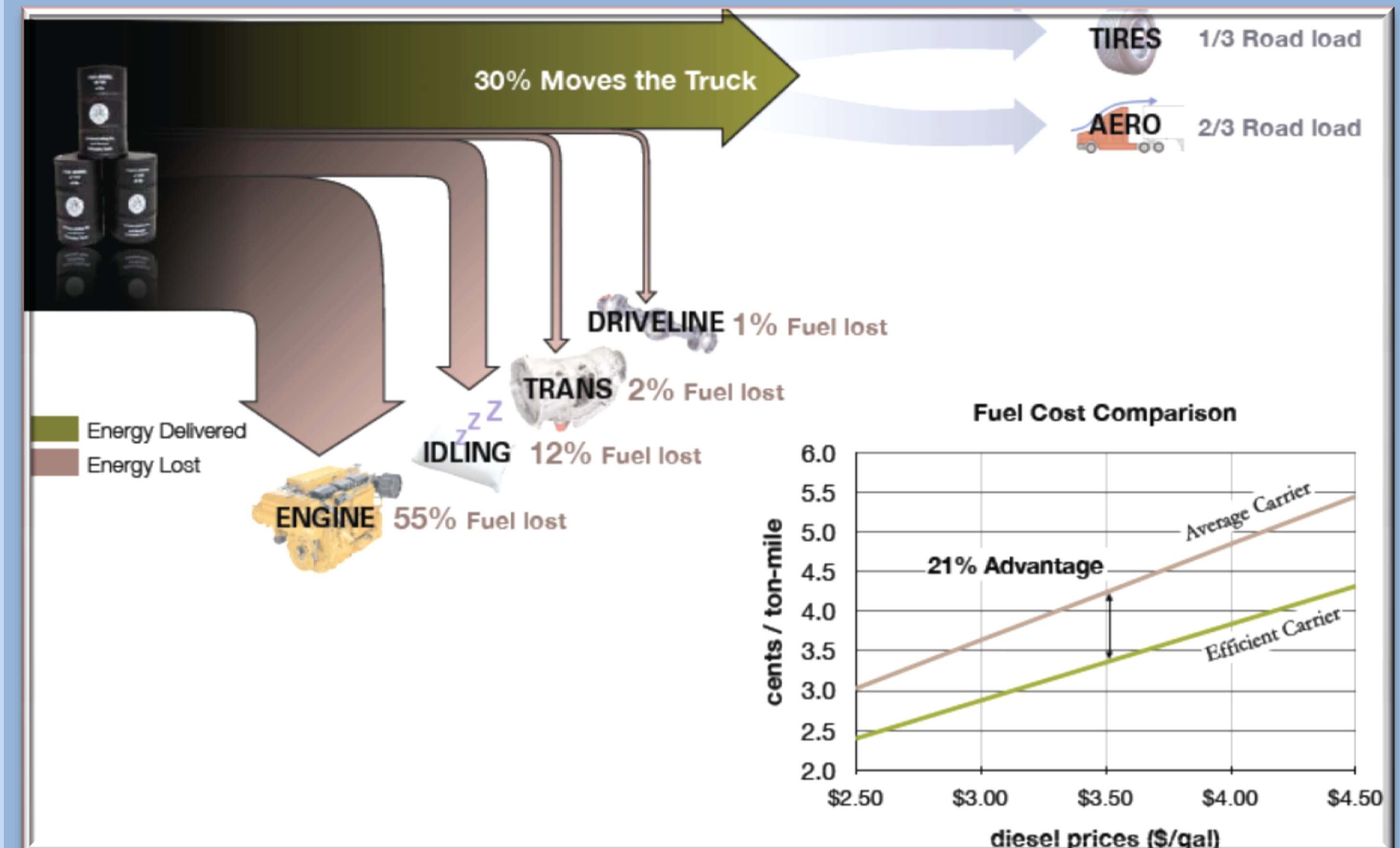
Fleet wide Idle-Reduction Strategies can save up to 12% Fuel !



Efficiency and Ecology

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The advantage of Efficiency and Ecology:

- ❑ Product return very high after ROI phase
- ❑ Reduced CO_2 footprint is a selling advantage and source for future carbon credits
- ❑ Usually technologies do not achieve both targets

Life Cycle Cost

- Investment cost
- Operating cost
- Capital cost

Ecological balance

- ISO 1440 ff.
- CO_2 footprint

Idle-Reduction Technology combines Ecology with Economy

Influencing Parameters

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Comfort is subjective and Performance depends on a large set of influencing parameters:

- ❑ Environment
- ❑ Vehicle
- ❑ Driver

Influence on heating and/or cooling power demand		
Driver	Parking the vehicle	- sun or shade, -if sun: orientation towards sun
		- choice of surface
	Cabin	- using bunk curtains
		- using electrical consumers
		- keeping doors/windows/hatch open or closed
	Driver himself	- activity
		- number of persons in cab
		- preparation of cab (pre-cooling)
		- personal preferences of cab-temperature setting
Environment	Sunshine	- intensity (time of year, time of day, latitude, altitude, wheather)
		- radiation angle to cabin
	Wind	- increased heat transfer to cabin
	Temperature	- increased heat transfer to cabin
	Parking Surface	- temperature and radiation intensity of surface
		- surfaces beside and under the vehicle
	Heat sources	- neighbor vehicles
Vehicle	Cabin	- size / color
		- size and transparency of glass surfaces
		- insulation
		- bunk curtains
		- heat sources (electrical applications)
	Engine	- position of cab/transmission (esp. under-cab)

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Current Product Portfolio

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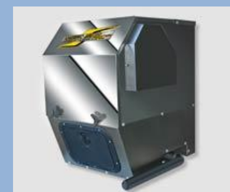
A variety of systems are available on the market:

- ❑ APU
- ❑ Cooling systems
- ❑ Heating systems

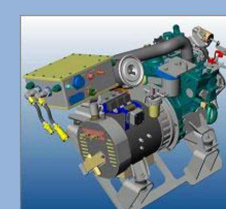










System – Technology - Benchmark

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To compare different technologies it is necessary to evaluate the complete system and lifecycle:

- ❑ Energy consumption
- ❑ Efficiency
- ❑ Performance
- ❑ Lifecycle cost

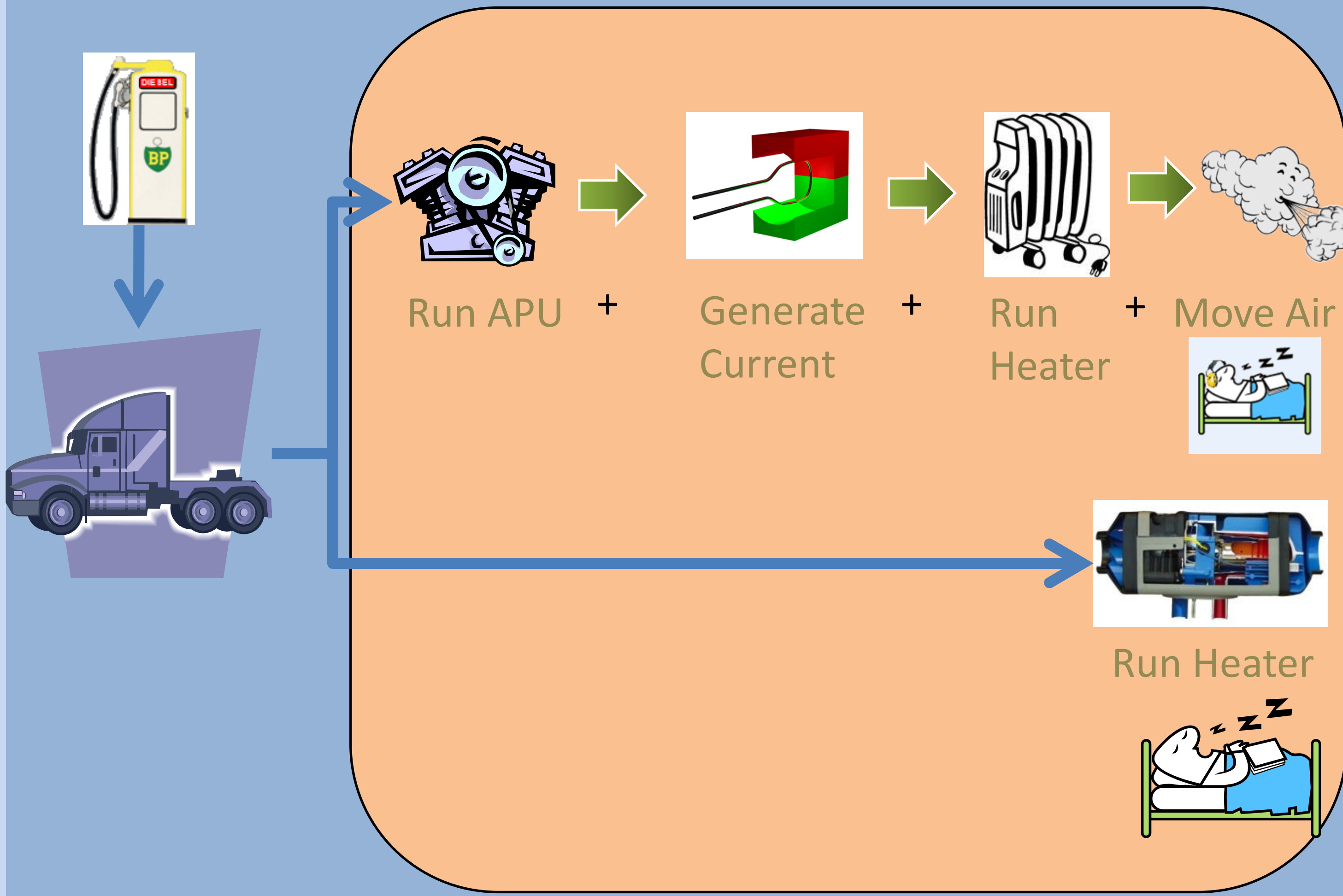
Energy Source → Energy Conversion → Energy Storage → Heating – Cooling- Electric Application

Energy Source	Energy Conversion	Energy Storage	Heating – Cooling- Electric Application
Diesel Gasoline Ethanol ….	Combustion APU Engine Alternator E-Inverters E-Converters	Batteries Graphite / Water ….	Parking Cooling Parking Heating

Benchmark – Parking Heating

Decision criteria for the benchmark APU vs. Fuel-Operated Heater:

- ❑ Investment
- ❑ Maintenance
- ❑ Efficiency
- ❑ Emissions
- ❑ Noise
- ❑ Environmental impact
- ❑ Regulatory requirements

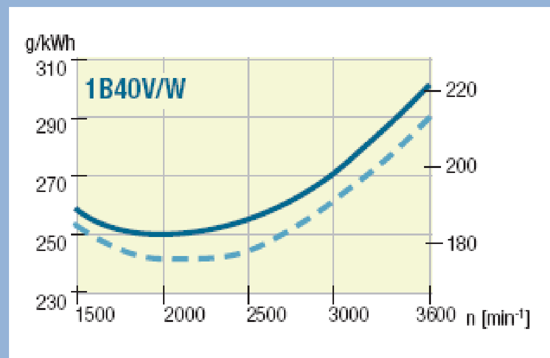


Parking Heating – Most efficient combustion process

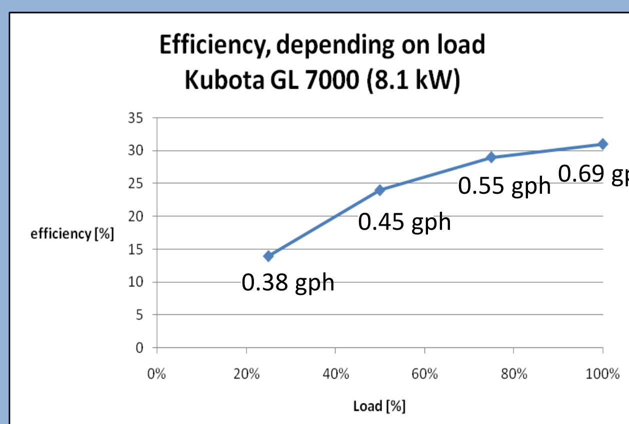
A Fuel-Operated Cabin Air Heater provides the highest efficiency:

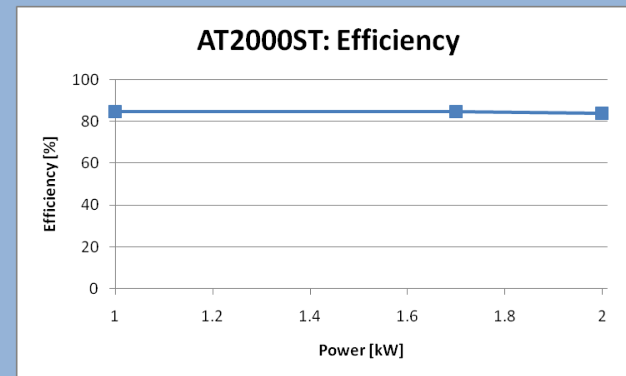
- ❑ Direct conversion from fuel into heat
- ❑ Less maintenance parts
- ❑ Lowest fuel consumption
- ❑ Fuel-Operated Water Heater has additional efficiency losses with the conversion from coolant heat to cabin air heat

APU, 7.5 kW



η_{max}=33.9%





FOH: η= 84 … 85%

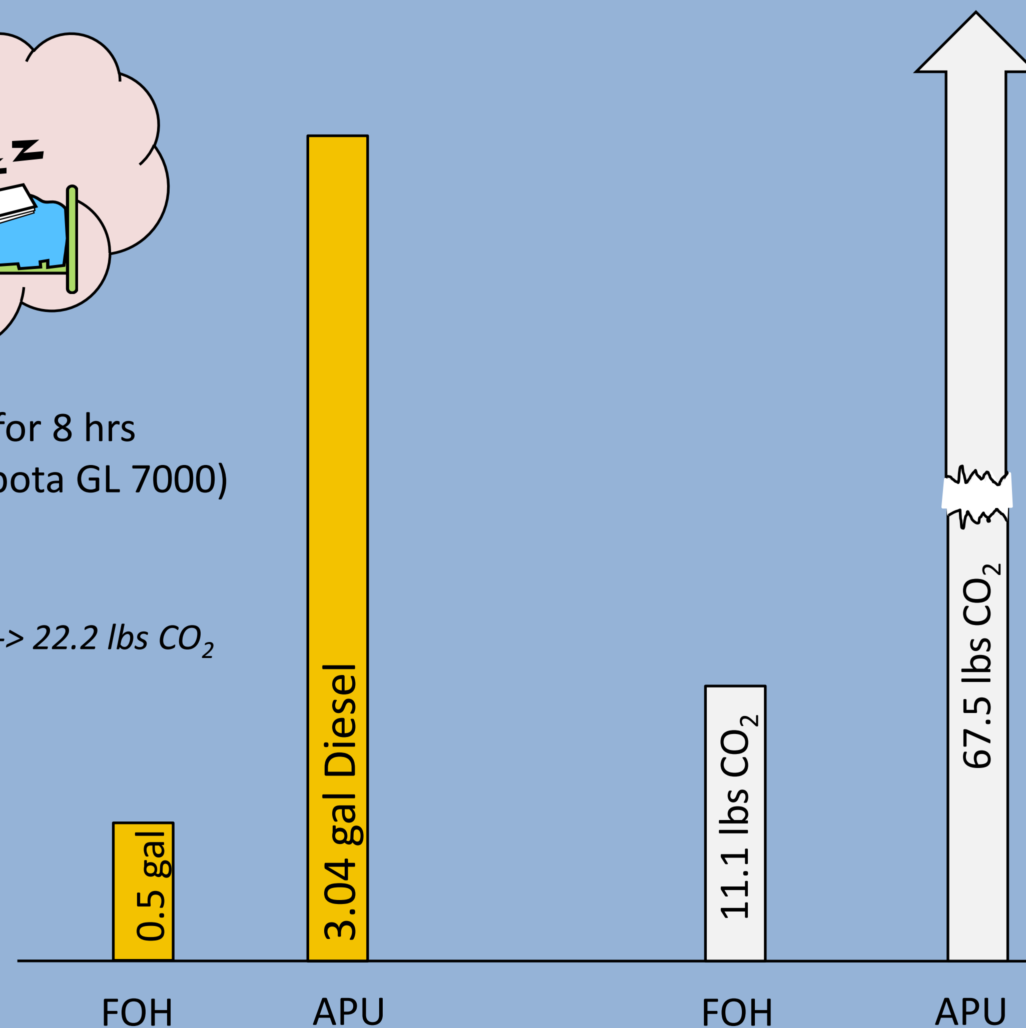
Parking Heating - Emissions

A Fuel-Operated Cabin Air Heater consumes less fuel:

- ❑ Operational cost for a FOH are six-times lower than APU operation

Scenario:
Heating w/ 2 kW for 8 hrs
(w/ data from Kubota GL 7000)

1 gal. Diesel (7 lbs) -> 22.2 lbs CO_2



Parking Heating – Emissions vs. Idling

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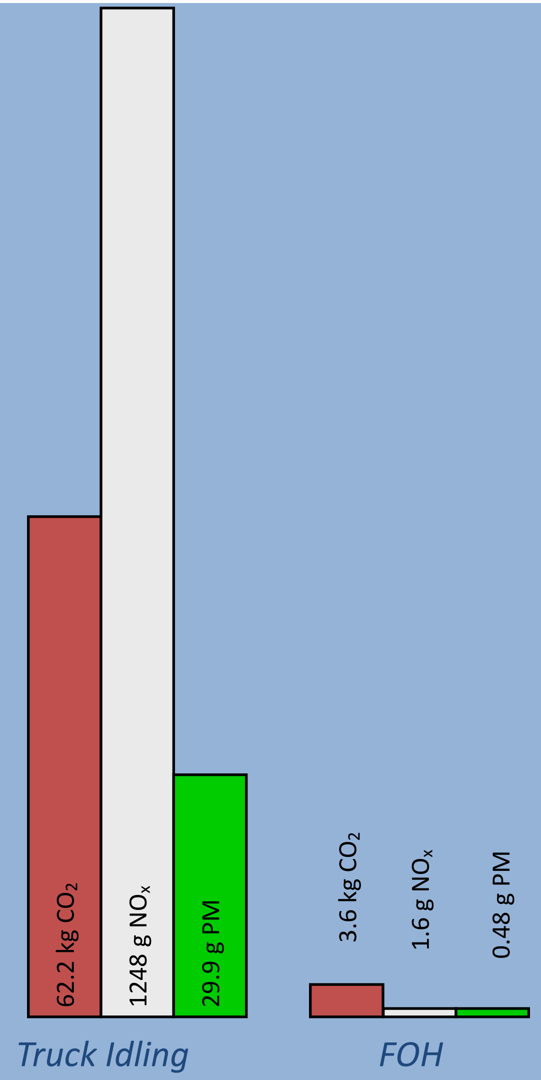
A Fuel-Operated Heater has the best emission rating:

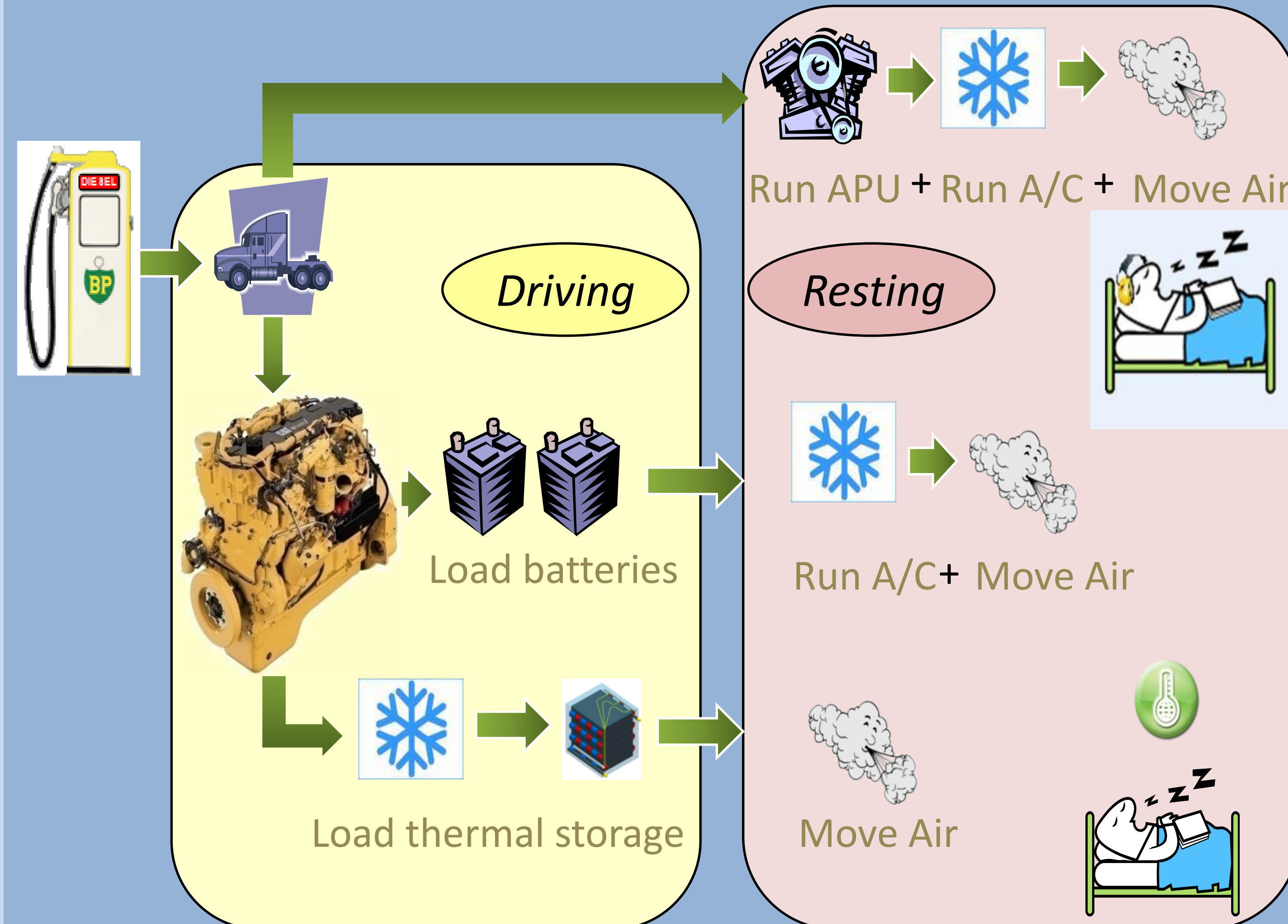
- ❑ Emissions per 8 hrs of heating
- ❑ CARB applies ULEVII levels for the approval of Idle-Reduction technology



Benchmark – Parking Cooling

Decision criteria for the benchmark APU vs. Electric vs. Thermal Storage Core:

- ❑ Investment
- ❑ Reliability
- ❑ Maintenance
- ❑ Efficiency
- ❑ Emissions
- ❑ Noise
- ❑ Volume / Weight



Parking Cooling Benchmark – System efficiency

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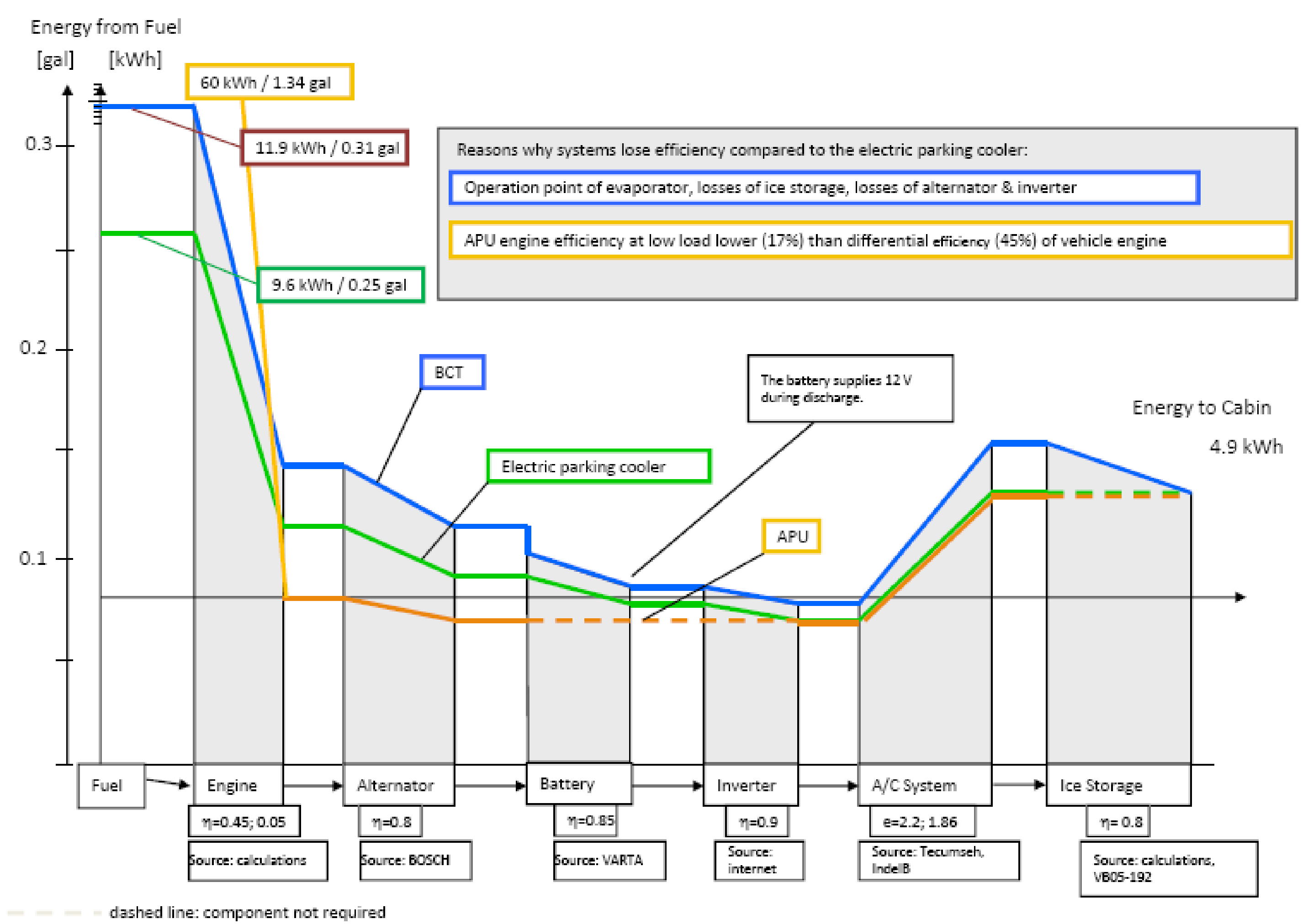
The system efficiency compares the energy input to accomplish a specific cooling energy output:

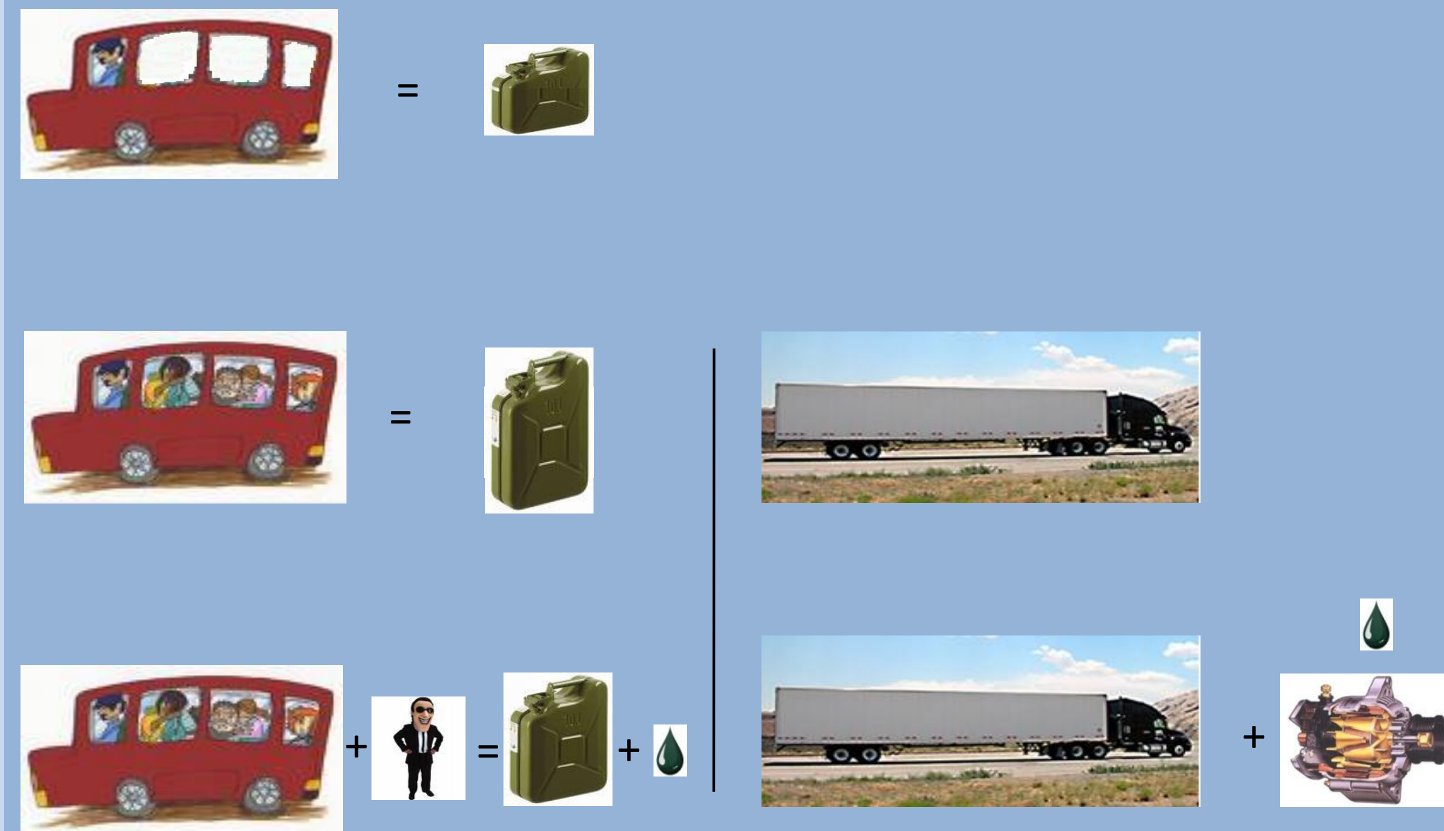
- ❑ Cooling energy to the cabin: 4.9 kWh
- ❑ Disadvantage of APU due to differential efficiency advantage of truck engine
- ❑ Electric and Thermal Storage Core are close together (0.6 gal)



Differential Efficiency

To charge the batteries or the Thermal Storage Core you only need a drop more of fuel:

- ❑ Running the APU consumes approx. 1 gal of fuel more energy to achieve the same cooling.



60 A / 1 HP

Benchmark Parking Cooling – APU Efficiency

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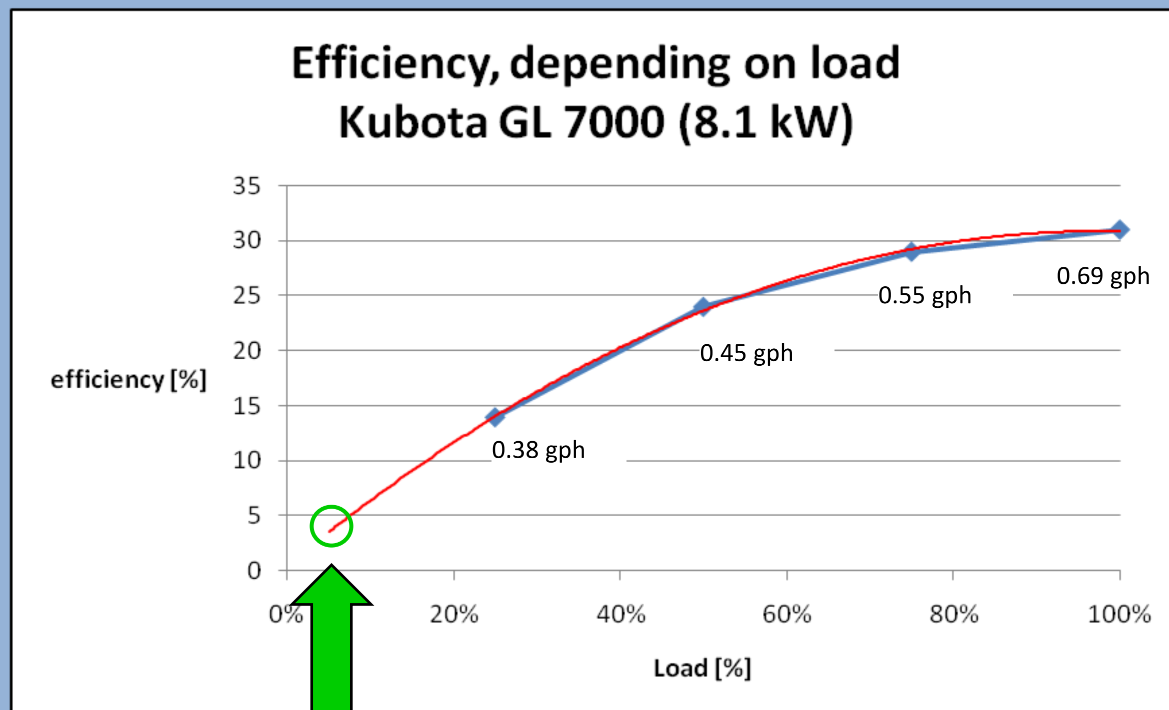
To cool the cabin with 600W the APU operates at a very low efficiency point.

- ❑ Typically no additional load is required during sleeping
- ❑ APUs usually designed for peak load



http://www.kub engine.com/products/gl/gl7000.html

Point of operation for 600 W A/C power

Benchmark Parking Cooling – Energy Storage Efficiency

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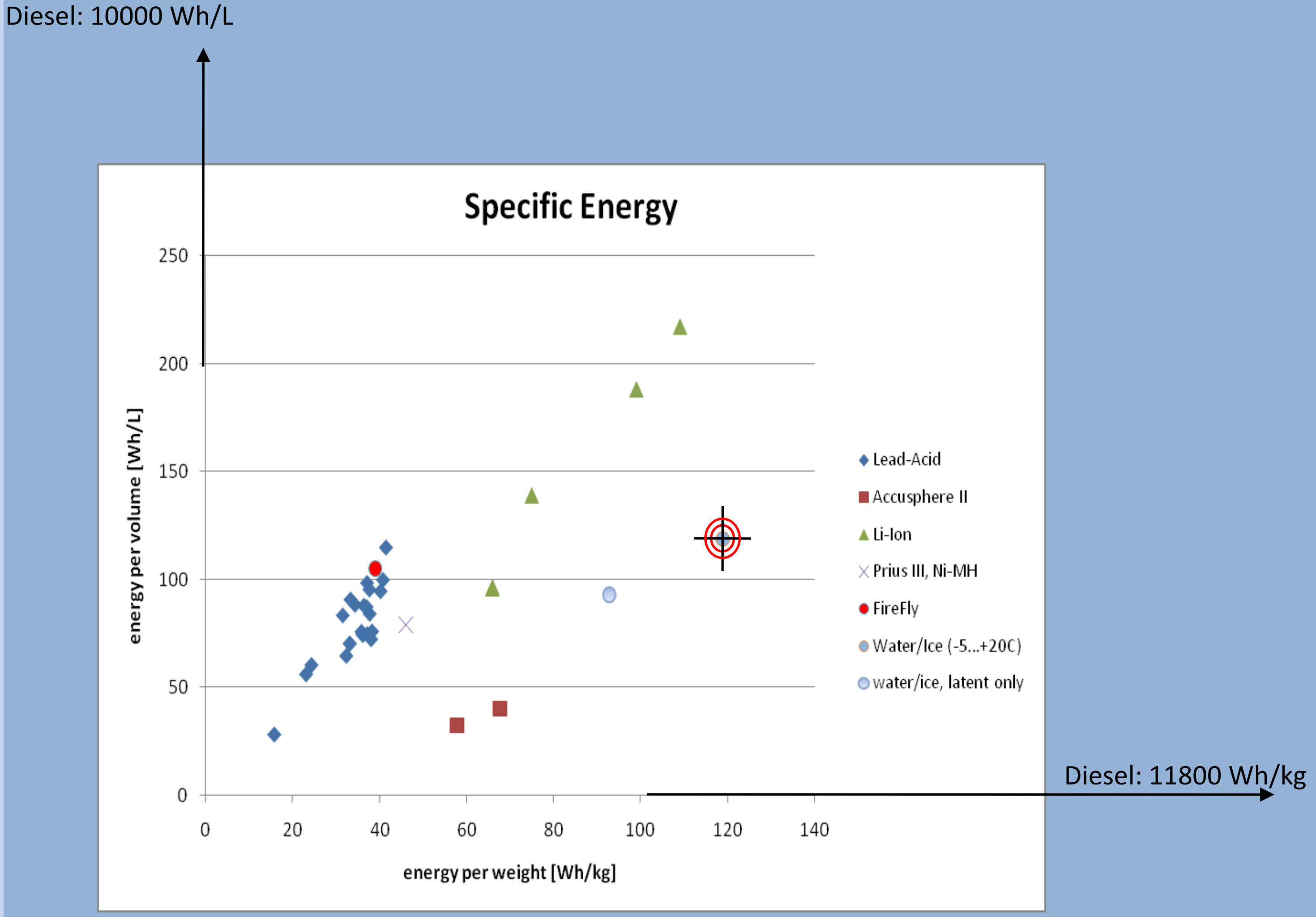
Thermal Storage Core has similar potential like Li-Ion batteries for energy storage, providing more advantages:

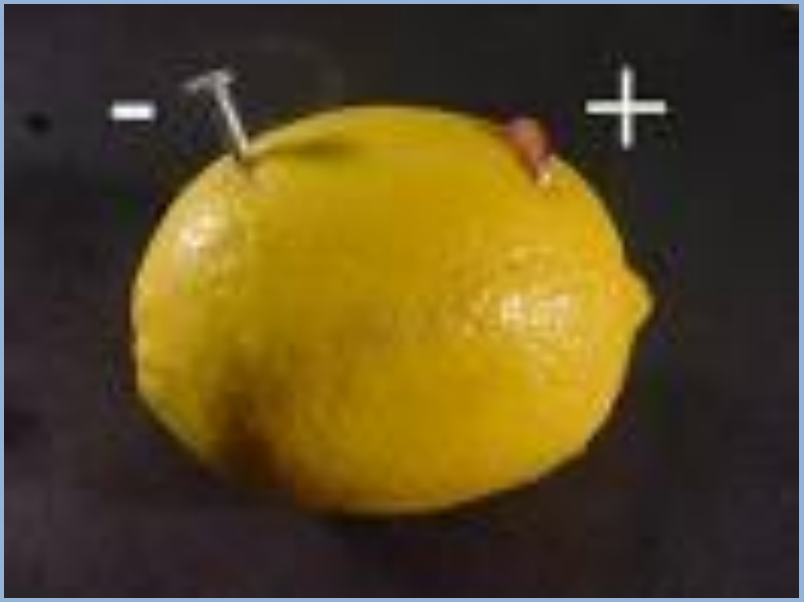
- ❑ Li-Ion very difficult to maintain (temperature, charging)
- ❑ Lead-Acid batteries have weight disadvantage
- ❑ Thermal Storage Core can achieve volume target of lead-acid batteries

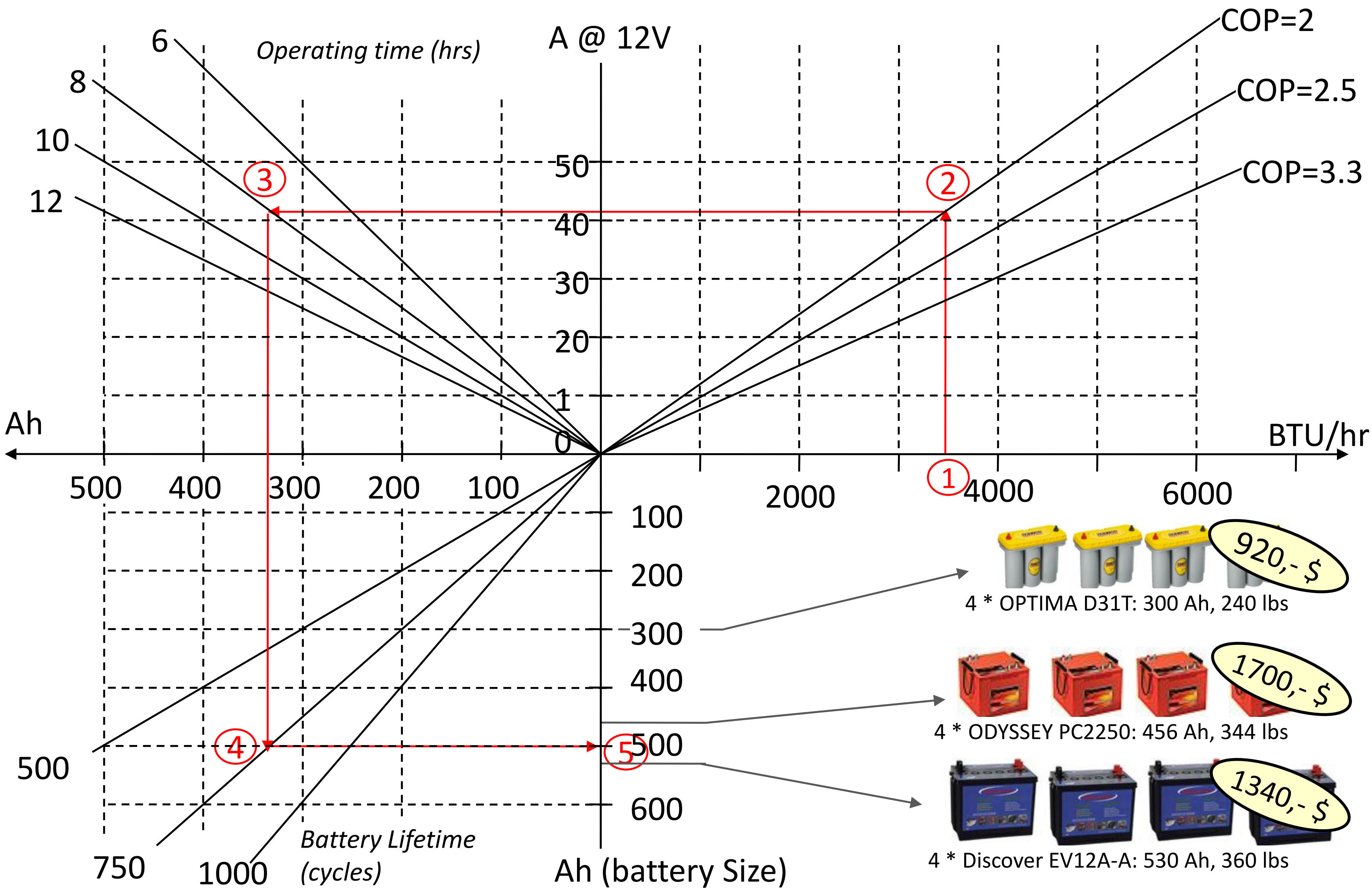


Benchmark Parking Cooling – Battery Lifetime and Size

Battery State-Of-Charge (SOC) and State-Of-Health (SOH) are very complex characteristics to measure and maintain:

- ❑ Temperature
- ❑ Voltage
- ❑ Current
- ❑ Charge and discharge history




A @ 12V
Operating time (hrs)
6
8
10
12
COP=2
COP=2.5
COP=3.3
50
40
30
20
1
0
Ah
BTU/hr
500
400
300
200
100
2000
4000
6000
1
2
3
4
5
100
200
300
400
500
600
500
750
1000
Battery Lifetime (cycles)
Ah (battery Size)
920,- $
4 * OPTIMA D31T: 300 Ah, 240 lbs
1700,- $
4 * ODYSSEY PC2250: 456 Ah, 344 lbs
1340,- $
4 * Discover EV12A-A: 530 Ah, 360 lbs

Benchmark Parking Cooling – Battery Charging

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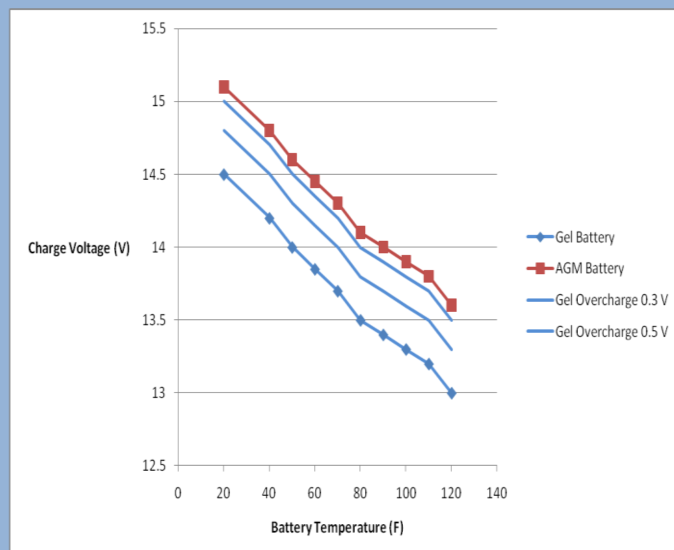
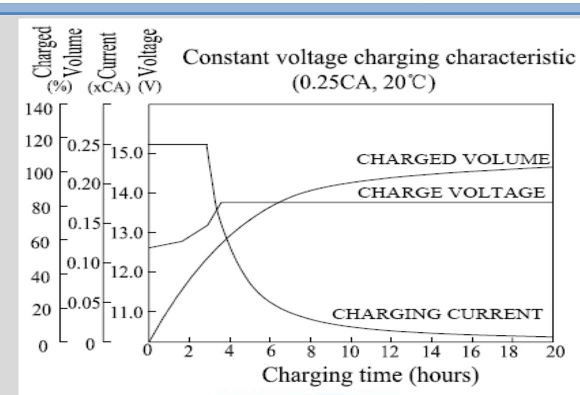
Critical parameters for battery lifetime:

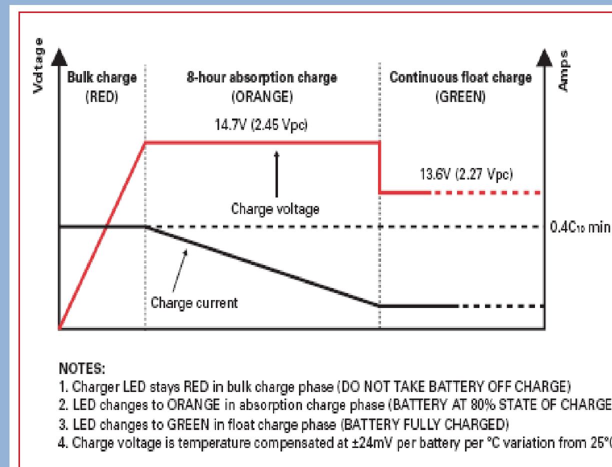
- ❑ Temperature
- ❑ Voltage monitoring
- ❑ Constant charging current and voltage
- ❑ Size and condition of alternator
- ❑ Charge management systems needed

0.5 V overcharge: Lifetime reduction > 20%
0.3 V overcharge: Lifetime reduction > 7%





Discover



ODYSSEY
THE EXTREME BATTERY

Benchmark Parking Cooling – Battery Lifetime

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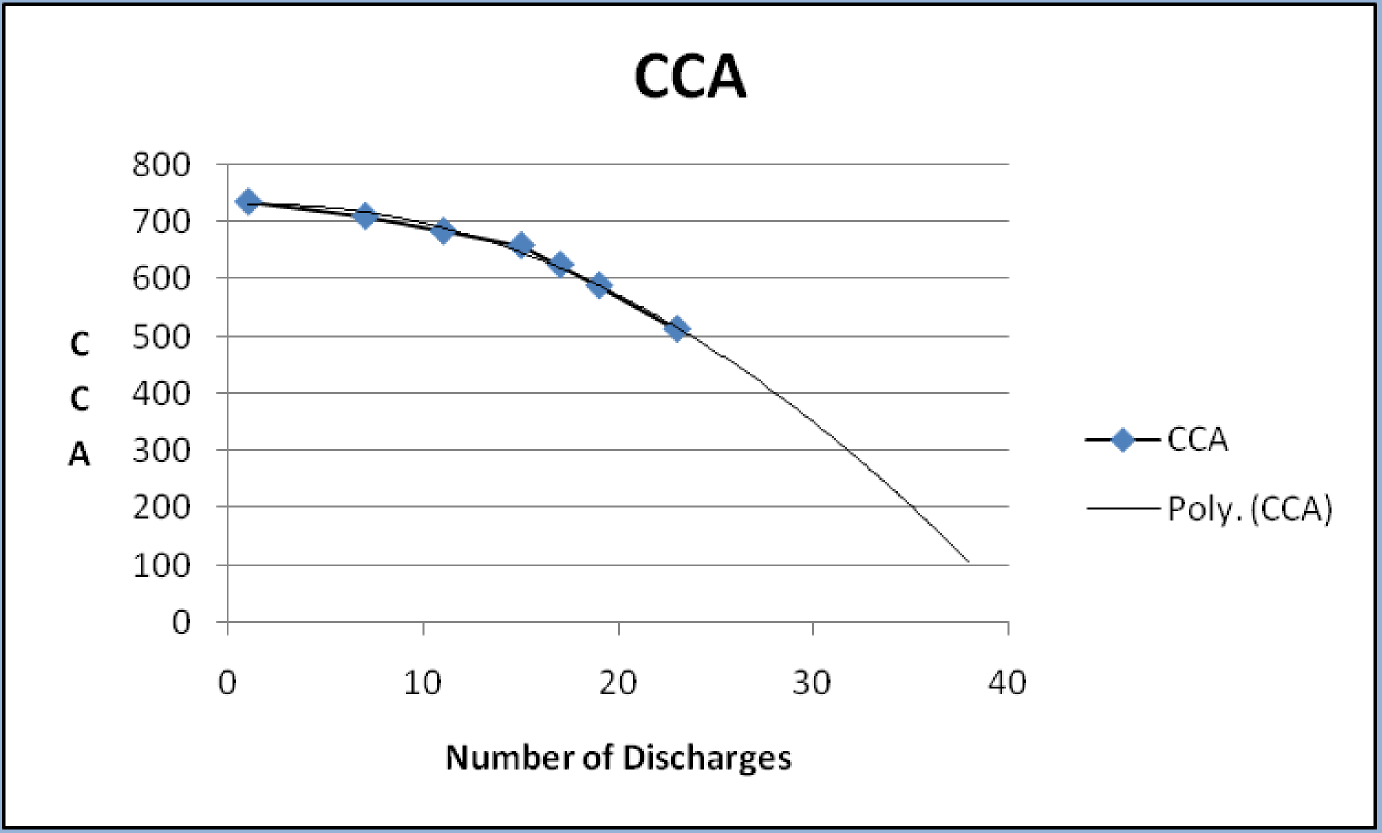
Critical parameters for battery lifetime:

- ❑ Temperature
- ❑ Voltage monitoring
- ❑ Constant charging current and voltage
- ❑ Size and condition of alternator
- ❑ Charge management systems needed



Running an electric parking cooler from a starter battery.

Benchmark Parking Cooling – Battery Calculator

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Results of the battery calculator:

- ❑ How many batteries do you need to achieve a certain cooling performance ?
- ❑ What is the additional weight of the batteries ?
- ❑ What alternator size is required to charge the required batteries ?

	Electric Parking Cooler	BCT
1: Input: cooling power requirement [W]	950	
2: Input: assumed COP of AC system	1.88	
3: Input efficiency of DC/DC converter [%]	90	
4: Result: necessary electric power	567.5 W	BCT: 75 W
5: Input: required cooling time [hrs]	10	
6: Result: necessary electric energy (BCT: for discharge)	472.9 Ah (12V)	BCT: 62.5 Ah (12V)
7: Input: requ. number of cycles (450, 600, 1000)	600	

600:must be >=450

8: Result: admissable DoD; necessary battery capacity depending on type; estimated weight

Battery choice	number		weight [kg]	
OPTIMA D31T, AGM, 75 Ah (C20), 27.2 kg	8.4	BCT: 1.1	229	BCT: 30
Discover EV12A-A, AGM, 133 Ah (C10), 40.6 kg	4.7	BCT: 0.6	192	BCT: 25
Eastpenn 8G8DM, Gel, 198 Ah (C6), 71.1 kg	3.2	BCT: 0.4	226	BCT: 30

	Electric Parking Cooler	BCT
9: Input: battery efficiency [%]	80	
10: Result: necessary charge energy	591.1 Ah	BCT: 78.1
11: Input: estimated vehicle driving time [hrs]	10	
12: Result: necessary alternator current	252 A (40% CN)	BCT: 33 A (40% CN)
13: BCT: add 65 A during charging (4.5 hrs)		BCT: 98.3 A

Benchmark Parking Cooling – CO_2-Emissions

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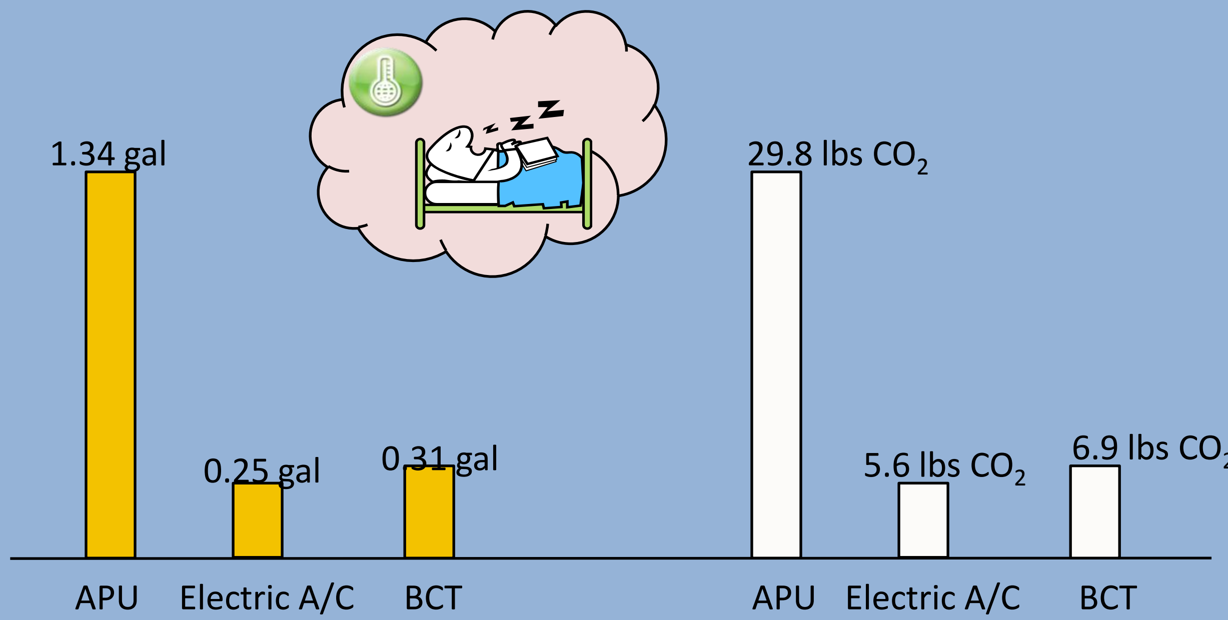
An electric parking cooling system has the best CO_2 performance:

- ❑ Scenario: Cooling w/ 0.61 kW for 8 hrs (=4.9 kWh)



Benchmark Parking Cooling – Overview

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Depending on the requirements all systems have their advantages:

- ❑ If most comfort is needed, APU is best decision
- ❑ If fastest ROI is required Thermal Storage Core is best solution
- ❑ If lifecycle cost is not important, Electric parking cooling is the best option

Criteria	**Electric driven R134a cycle + lead acid battery**	**Power Generators (APU)**	**Thermal storage system**
Weight	**- - (30+180)**	**- (170 kg)**	**+ (136 kg)**
Volume	**+(40 gal)**	**- (57 gal)**	**- (60 gal)**
Capacity and discharging time	**-**	**+ +**	**-**
Electric Power consumption	**- -**	**++**	**+**
Performance	**+**	**++**	**+**
Charging time / complexity	**- -**	**n/a**	**+**
Noise during discharging	**+**	**- -**	**+**
Degree of efficiency and environmental impact	**+ (-)**	**- -**	**+**
Maintenance	**- (-)**	**- -**	**+**

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The Future

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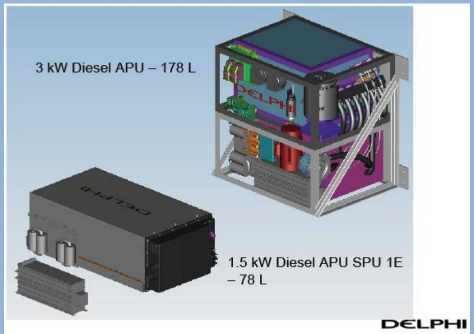
What will the future bring:

- ❑ Solar cells can support energy demand, but not completely fulfill it.
- ❑ Li-Ion batteries are not available in the next 3-5 years at reasonable cost
- ❑ Focus on energy efficient cabin design (see energy efficient house construction)
- ❑ New technologies (fuel cells, high energy storage systems) will be long-term targets

Solar roofs

Li-Ion / Energy efficient cabin design

Fuel cells / Gas Hydrates



Overview

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The decision for the Idle-Reduction Technology is in the hands of the customer, but not deciding is loosing money !

	Cost for low-idlers	Cost for high-idlers	Reduces global emissions	Reduces local emissions
APU	Fair	Good	Good	Good
Heater	Good	Excellent	Excellent	Excellent
Thermal Storage Core / Electric Cooling	Good	Excellent	Good	Excellent
EPS (single)	Excellent	Fair	Good	Excellent
EPS (dual)	Good	Good	Good	Excellent

Key: ● ● Excellent ● ● Good ● Fair

Department of Energy Argonne Labs

The Idle-Reduction Fleet Checklist

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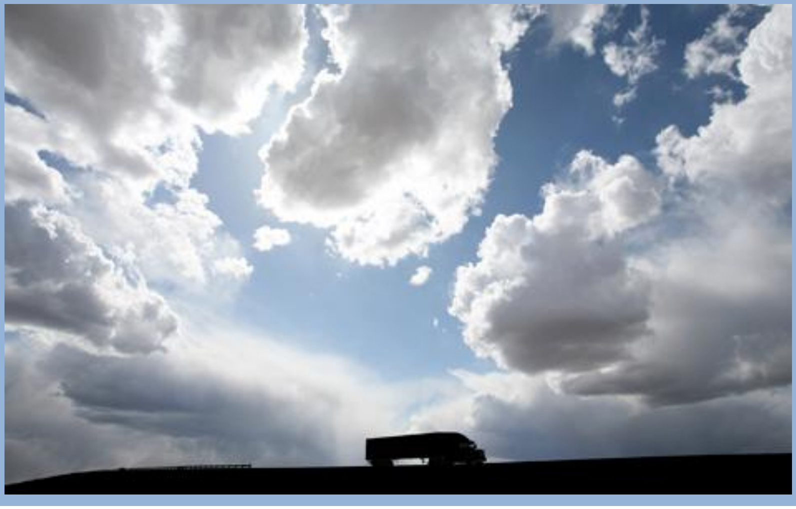
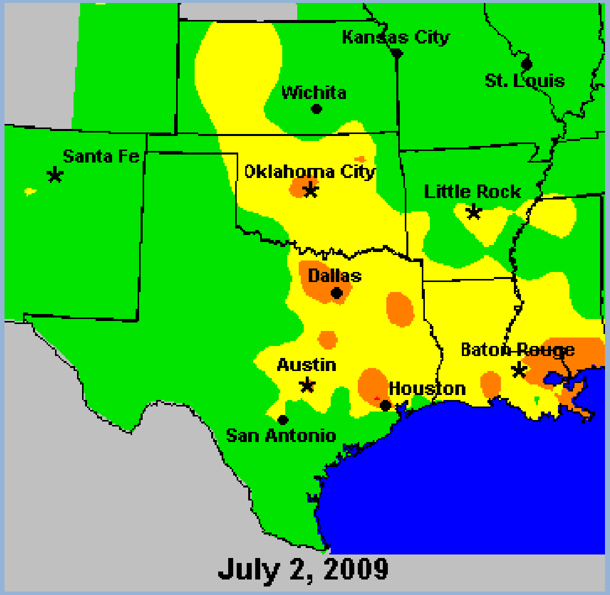
With emission reduction to improved fuel efficiency

☑ Cost effective way to contribute to corporate sustainability and manage emissions from mobile sources (Carbon Credits)
☑ Fast ROI
☑ Low acquisition and lifecycle / operating cost
☑Truck Blue Book residual values after 4 years: e.g. $100 on FOH
☑ Global OE approved technology and OE experienced engineering and technical support (tailored solutions for specific fleet requirements)
☑SmartWay (EPA) and CARB approved technology



Our Social Responsibility

Whatever the regulation is today, we will be judged by future generations, if we implemented the necessary activities to save the world for generations to come !



Thank You !

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Backup Slides

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Reduce Dependency On Foreign Oil

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- *8.0%* of the national daily consumption is attributed to idling
- US dependency on foreign oil can be cut significantly by addressing idling

US NATIONAL IDLING ANALYSIS							
	Average Hours One Vehicle Spends Idling Per Year	***Number of Vehicles Idling Entire Fleet***	***Hours Idling Entire Fleet***	***Annual Fuel Consumption for Idling (Gallons) Entire Fleet***	***Annual Barrels of Oil Consumed for Idling Entire Fleet***	***Daily Barrels of Oil Consumed for Idling Entire Fleet***	***Per-centage of the 20 Million Barrel a Day National Use that is Being Used to Idle***
HEAVY DUTY TRUCK	2142	2,,984,008	5,292,437,180	5,292,437,180	529,243,718	1,449,983	7.25%
SCHOOL BUS	181	412,539	74,669,583	74,669,583	7,466,958	20,457	0.102%
LIGHT DUTY	30	60,309,709	1,809,291,259	1,157,946,406	59,078,898	161,860	0.809%
TOTAL ALL	*2353*	63,706,356	7,176,398,022	6,525,053,169	595,789,574	1,632,300	8.161%