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Adaptation of Common, Modular Electric Drive System Elements to Class 8 Port Trucks, Yard Tractors, and School Buses

TransPower®

Mike Simon, CEO

California Energy Commission
Technology Merit Review
Medium- and Heavy-Duty Vehicle Project Success
December 2, 2015

TransPower Company Snapshot

- **Developing electric propulsion technologies and products for large vehicles**
- **Secondary utility-scale stationary battery energy storage business**
- **Business model:**
  - Near term (thru 2016): turn-key vehicle conversions
  - Longer term (2017-): high volume sales of systems/components to OEMs, augmenting conversions

TransPower Business Areas

R&D

Efficient Propulsion

Energy Storage

Controls

Vertically Integrated Manufacturing

Component Manufacturing

Subsystem Assemmbly

Vehicle Conversion

Current Target Vehicle Markets

Class 8 On-Road Trucks

Yard Tractors

School Buses

Cargo Handling Equipment

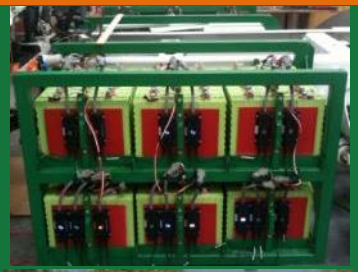
CEC M-HD and Related Projects – First 5 Years

TransPower

2011	2012	2013	2014	2015

CEC-FUNDED MEDIUM & HEAVY DUTY VEHICLE PROJECTS

Vertically Integrated Manufacturing



Electric Drayage Demonstration

Electric and CNG Hybrid Trucks for Siemens eHighway (Catenary)

V2G Electric School Bus Demo

KEY RELATED PROJECTS

High Power Electric Terminal Tractor

Economical Electric School Bus

IKEA Electric Yard Tractor

Port of Los Angeles Electric Yard Tractor

CEC M-HD and Related Projects – Next 5 Years

TransPower

2016	2017	2018	2019	2020

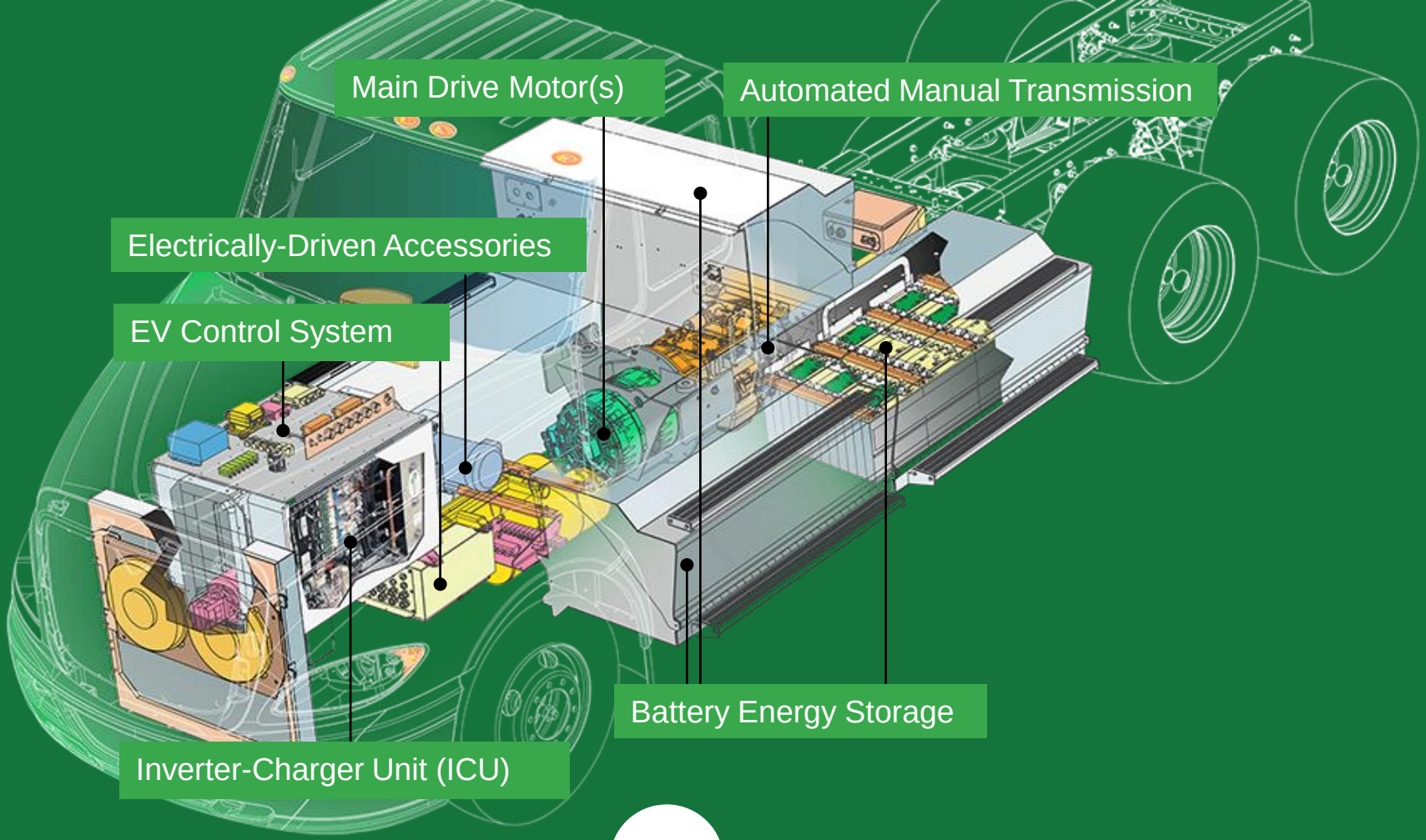
CEC-FUNDED MEDIUM & HEAVY DUTY VEHICLE PROJECTS

- Heavy-Duty Electric Vehicle Manufacturing Initiative
- Advanced Battery-Electric Port Vehicles
- Heavy-Duty Electric Yard Tractors
- Heavy-Duty Electric Refuse Trucks

KEY RELATED PROJECTS

- Electric Drayage Trucks with CNG Hybrid Range Extenders
- Electric Drayage Trucks with Hydrogen Fuel Cell Range Extenders

PROPOSED: Expansion of electric drayage truck, yard tractor, and school bus fleets (GGRF, Prop 1B, Carl Moyer, federal funds, and commercial purchases)



Electric drive system layout in a typical Class 8 On-Road Truck

Vehicle Conversion: TransPower vs. OEMs

Company's strategy is to move to kit sales to OEMs for high-volume market penetration, but to continue our own vehicle conversion business indefinitely

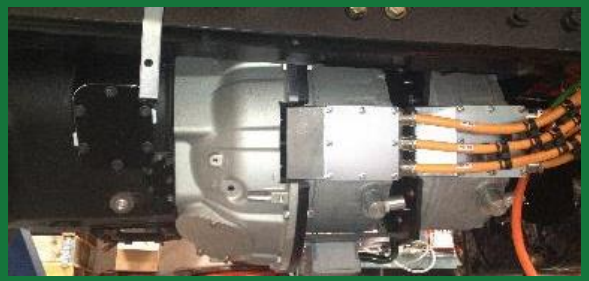
Costs will be minimized when OEMs install drive systems on their own assembly lines

Sustaining our own vehicle conversion business will enable TransPower to:

- **Continue experimenting with new components and technologies**
- **Adapt drive systems to new truck models**
- **Satisfy demand for specialized vehicle configurations not produced in adequate volumes for OEM manufacturing**

Vertically Integrated Business Approach

Core business manufacturing subsystems…



Motive Drive

Energy Storage

Power Control & Accessories

…enables efficient vehicle conversion by TransPower

…and will help vehicle OEMs install our systems once we begin delivering "kits" in high volume

Innovations in Every Subsystem

Motive Drive Subsystem

- Advanced motors integrated with proprietary automated manual transmission
- Best performance and lowest cost of any system in its class

Power Control and Accessory Subsystem

- Integrated controls featuring unique inverter-charger unit
- Simplifies assembly, operation, and charging while enhancing reliability and energy efficiency

Energy Storage Subsystem

- Unique modular design with advanced battery management
- Greatest operating range and battery life at lowest cost

RESULTS: Electric Class 8 On-Road Trucks

First (only?) fully-functional electric trucks of this class

- On the road and hauling goods **TODAY**
- CNG hybrid and fuel cell hybrid variants in pipeline
- California state funding
  - $16M received to date for 20 trucks (16 port drayage trucks, 3 refuse trucks, 1 futuristic delivery truck)
  - Requesting additional funding for further expansion of drayage fleet
  - OEM partners: Navistar, Peterbilt
- Various incentive programs will stimulate commercial adoption starting in 2017

RESULTS: Electric Yard Tractors

Proven, efficient electric yard tractors in use today

- First commercial-grade tractor completed first year of use at IKEA's California distribution center (15,000+ miles)
- Four additional tractors currently in use
- $4M received in 2015 for 7 additional tractors, to be operated by IKEA, Dole, Grimmway Farms, and Harris Ranch
- Seeking additional funds for distribution center and port tractors in 2016-17
- Expanding relationship with Kalmar for large scale manufacturing

RESULTS: Electric School Buses

High-power electric school buses, proven in service

- Converted largest bus model (40’) to electric drive in 2013 – approved by California Highway Patrol and used to transport high school students in 2014
- Partnered with Clinton Global Initiative and funded ($2M) to convert six mid-sized (26’) buses for use by three California school districts starting in 2016
- Seeking funding and major OEM support for an expanded (~35 electric bus) demonstration in 2016-17

RESULTS:
Independent Testing of our Electric Truck

TransPower electric truck being tested on chassis dynamometer at UC Riverside, 2014

UCR Test Conclusions:

- "In all cases, the electric HDV [TransPower heavy-duty vehicle] had favorable performance, reduced fuel consumption, improved fuel economy, and significant emission reductions compared to current model year conventional-diesels."
- "For typical drayage drive cycles, usage costs for the TransPower electric HDV are projected to be less than one-quarter of the costs for a comparable conventional truck, resulting in estimated cost savings of more than $350,000 over a ten-year operating life (assuming 30,000 miles of operation per year).."

RESULTS:
Independent Testing of our Electric Yard Tractor

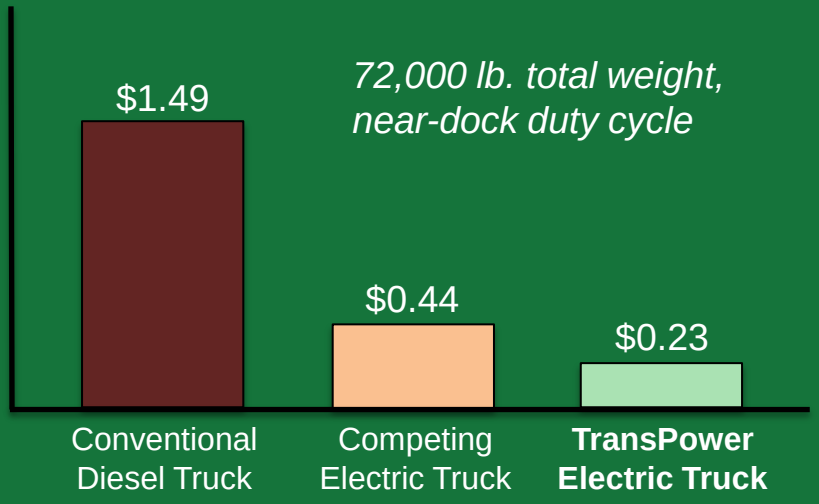
TransPower electric tractor being tested on chassis dynamometer at UC Riverside, 2014

UCR Test Conclusions:

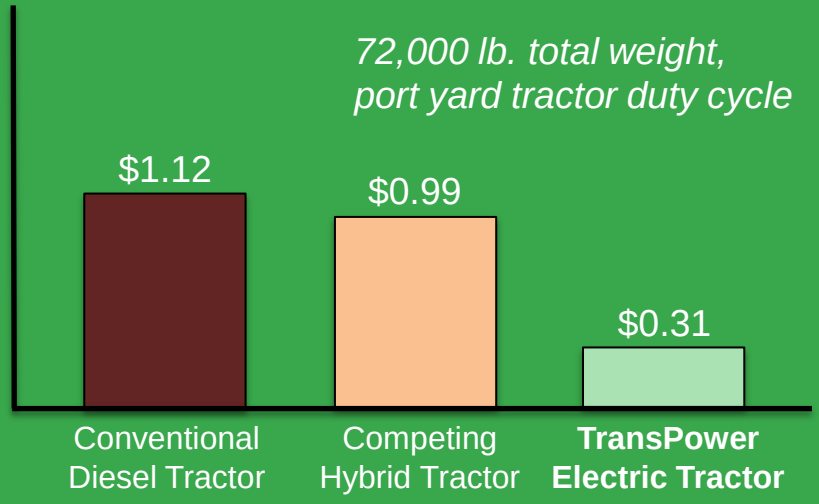
- "In all cases, the YT [TransPower yard tractor] had favorable performance and emission reductions compared to the conventional-diesel and hybrid-diesel YTs previously tested."
- "…performance is well matched to a conventional vehicle."
- "The electric YT showed cost savings during all test cycles, as compared with conventional and hybrid-electric YT technologies."

UCR Test Results: The Bottom Line

Energy Cost Per Mile – Class 8 On-Road Truck



Energy Cost Per Mile – Class 8 Off-Road Yard Tractor



Source: UC Riverside/CE-CERT Dynamometer Lab.

$378,000 in energy savings over 300,000 miles

$121,500 in energy savings over 150,000 miles

Expanding List of Committed Fleet Operators

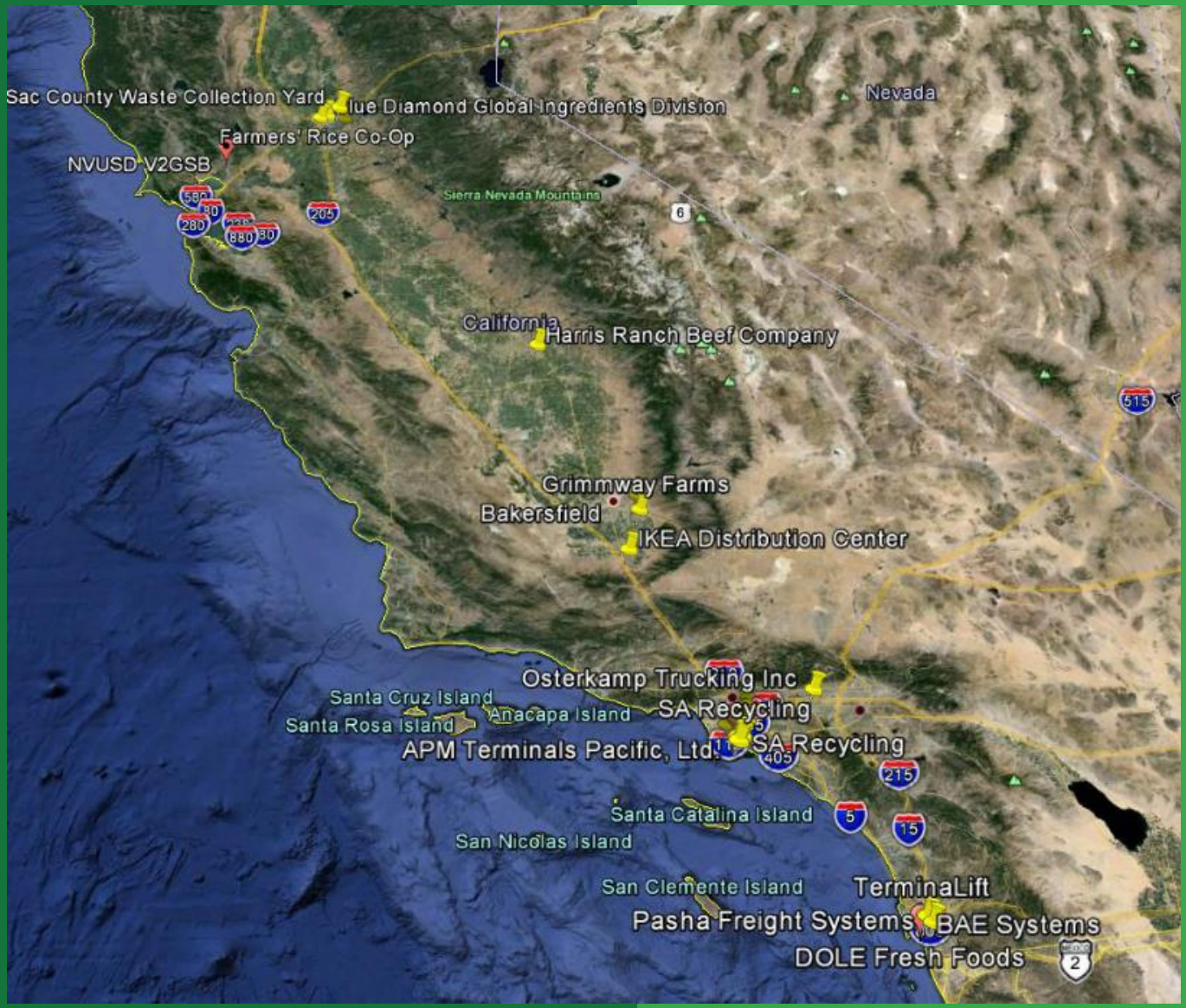
2011-2014

- 2011
  - None
- 2012
  - HEB
- 2013
  - Total Transportation Services, Inc.
  - Terminalift
- 2014
  - Walmart
  - IKEA
  - APL Terminals
  - SA Recycling
  - Dole Fresh Foods

2015

- Harris Ranch
- Grimmway Farms
- Blue Diamond Almonds
- Knight Transportation
- Central Valley Ag
- California Cartage Company
- APM Terminals
- Evergreen Terminals
- Farmer’s Rice Cooperative
- BAE Systems
- Waste Management
- County of Sacramento
- Devine Intermodal
- Osterkamp Group
- Pasha
- NRT Transportation

Geographic Distribution of Committed Fleets



Medium & Heavy-Duty Vehicle Fleet Expansion

Total TransPower vehicles in California at year-end (actual 2014-15, planned 2016-17):

	2014	2015	2016	2017
Prototype Vehicles in Testing – All Types	*3*	*5*	*8*	*12*
Vehicles in Full Service				
Electric Class 8 Trucks	2	6	16	41
Electric Yard Tractors	3	5	14	26
Electric School Buses	0	1	10	42
Hybrid Class 8 Trucks	0	0	8	12
Other Cargo Handlers	1	1	2	4
TOTAL VEHICLES IN OPERATIONAL SERVICE	**6**	**13**	**50**	**125**

Medium & Heavy-Duty Vehicle Project Metrics

Summary of key metrics relating to vehicle fleet expansion (actual 2014-15, planned 2016-17):

	2014	2015	2016	2017
TransPower employees	*22*	*30*	*69*	*139*
TransPower EV miles (CA)	10,000	25,000	250,000	750,000
CO_2 eliminated (tons)	110	275	2,750	8,250
Petroleum displaced (gal)	2,500	6,250	62,500	187,500
State income tax revenue generated ($, approx)	150,000	250,000	500,000	1,500,000
M/HD funding invested ($)	750,000	2,500,000	7,000,000	7,000,000
M/HD $/ton CO_2 eliminated	6,800	9,000	2,500	850
M/HD $/gal petroleum eliminated	300	400	112	37
M/HD funds recovered in state income taxes (%)	20%	10%	7%	21%

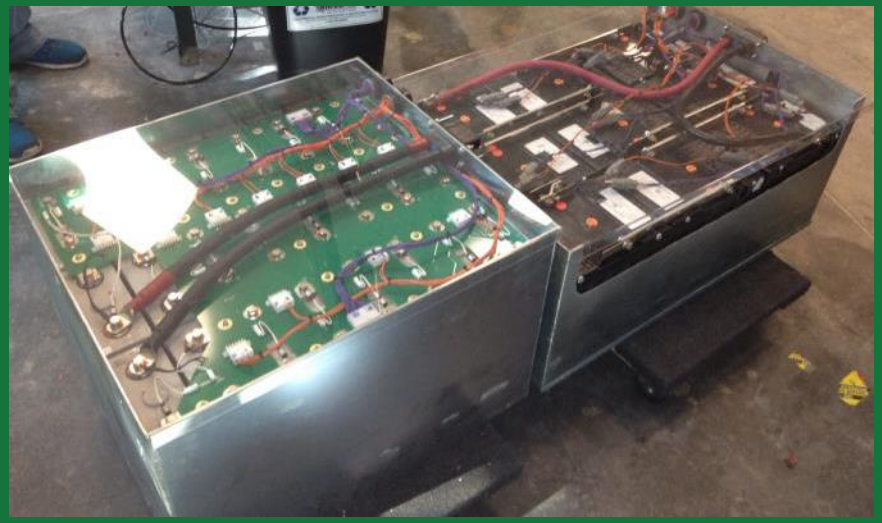
U.S. Market Potential – Electric Drive Systems

(TransPower estimates)	U.S. Addressable Market (Annual)	
	Units	Revenue
Port Drayage Trucks	4,000	$1,000M
Refuse Trucks	10,000	$2,500M
Local Delivery Trucks	20,000	$5,000M
Yard Tractors/Cargo Equipment	2,500	$500M
School Buses	10,000	$2,000M
TOTAL	**46,500**	**$11,000M**

Stationary Energy Storage

Adapting our vehicle technologies…

- Battery integration
- DC to AC conversion
- Energy management controls



To new stationary applications

- Renewable energy integration
- Disaster preparedness
- Wayside energy storage for trains

Stationary Energy Projects Underway

Grid-Saver Prototype

- $2M contract, California Energy Commission
- Largest battery system ever tested at Sandia National Laboratory (660 kWh, 1MW)

Subway Traction Energy Storage

- $2M in contracts from NYC Transit and NYSERDA
- 800 kW hour battery system to be deployed in midtown Manhattan in mid-2016

US Navy renewable energy storage system in California

- Displaces diesel generators on remote islands
- Navy objective: produce 50% of shore based energy from alternative sources

Pursuing additional projects

R&D demonstrations | Wayside storage systems | Commercial scale energy storage for Utilities and IPP's

TransPower Five-Year Revenue Goals

	2020 Revenue Goals		
	Unit Sales	Average Unit Cost	Total Revenue
Specialized Vehicle Conversions	20	$750,000	$15M
Commercial Truck & Bus After-Market Conversions	250	$300,000	$75M
Class 8 Truck Drive System Kits	500	$150,000	$75M
School Bus and Yard Tractor Drive System Kits	500	$100,000	$50M
Stationary Energy Storage Systems	20	$2,000,000	$40M
R&D, Components, & Service & Support	N/A	N/A	$15M
TOTAL			**$270M**

Summary

Energy Commission Medium- and Heavy-Duty Advanced Vehicle Technology program:

- **Provided TransPower with its first funding**
- **Has played a key role in demonstrating the feasibility of eliminating fuel consumption and emissions from vehicles in this class**

Exponential growth in M-HD use of zero-emission technologies over the next five years is possible, and continued public support can help overcome the remaining technical and economic hurdles