| Battery | Hybrid | Fuel Cell |

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Electric Drive Vehicles:
A Huge New Distributed Energy Resource

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The Old and the New..

Old way of thinking:

Electric vehicles are an unnecessary burden to an over-taxed electricity grid

New way of thinking:

Electric drive vehicles will be an integral part of power grid operation and will provide valued services

Grid-Connected Vehicle Can Create Value

Bidirectional Power Grid Interface

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EPRI (Feb. 19, 2001)

The Car of the Future May Help Power Your Home

"Electrified transportation will soon be a necessity rather than an option"

The Economist, (Feb 8, 2001)

"We can use the energy unit in this car for homes or stationary power."

"When linked together by smart electronics, our customers can buy and trade energy freely."

Dr. Ferdinand Panik

CARB Zero Emission Vehicle (ZEV) Program

- Leading to mass manufacture of clean vehicles with electric power generation and storage capabilities
- Three Vehicle Types in Program
  - Full ZEV: true zero emissions (EV, FCEV)
  - Advanced Technology Partial ZEV
  - Partial ZEV: Conventional vehicles with SULEV drive cycle emissions and zero evaporative emissions
- By 2020, there could be 1 million vehicles in California with electrical generation and/or storage capabilities (10,000 MW potential capacity at 10 kW each)

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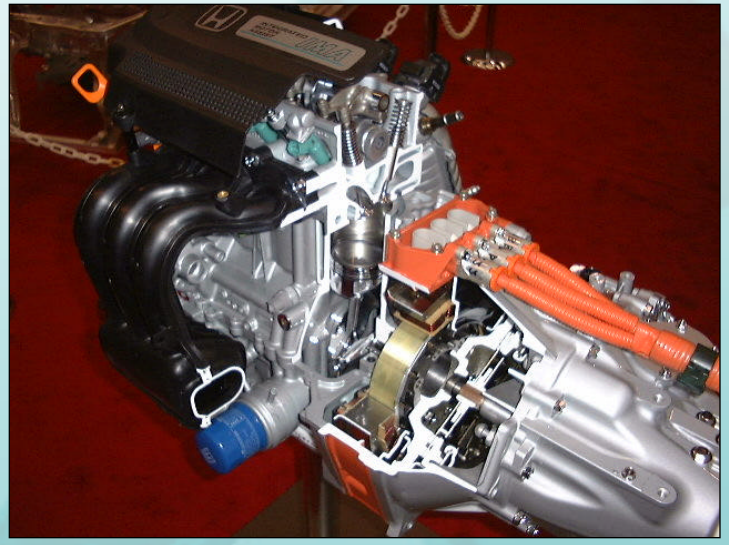
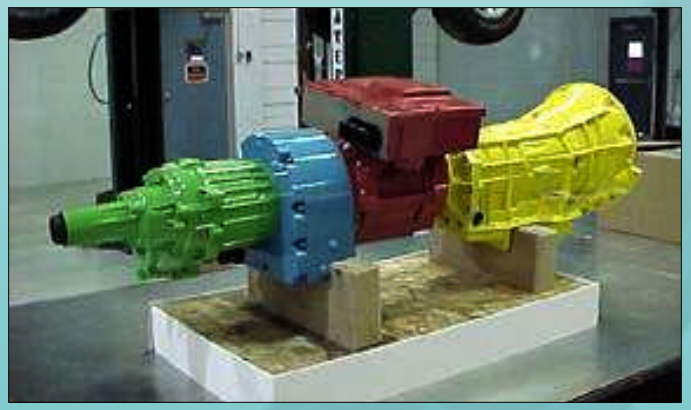
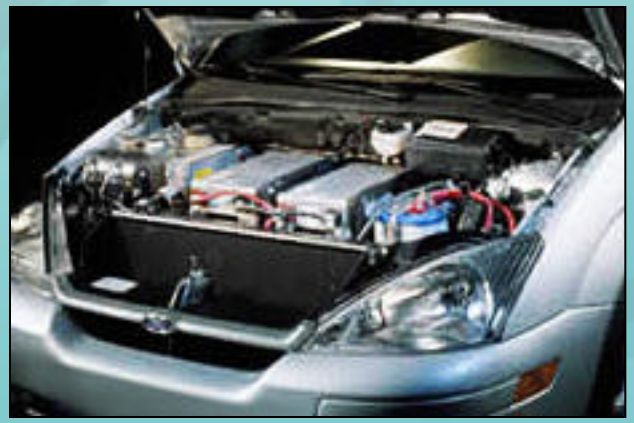
Electric Drive in Vehicles -- All the Ingredients for a Distributed Power System







Vehicle Examples

How Vehicles Can Provide Services

- Vehicles, by their numbers, represent enormous power and energy storage potential
- Electric vehicle charge stations: grid connection points for power and ancillary services delivery
- Vehicles can respond very fast compared to powerplants
- Vehicles could provide:
  - Extra power during demand peaks
  - Spinning reserves
  - Grid regulation (automatic generation control - AGC)
  - Uninterruptible power source for businesses and homes
  - Active stability control of transmission lines
  - Dispatchable reactive power

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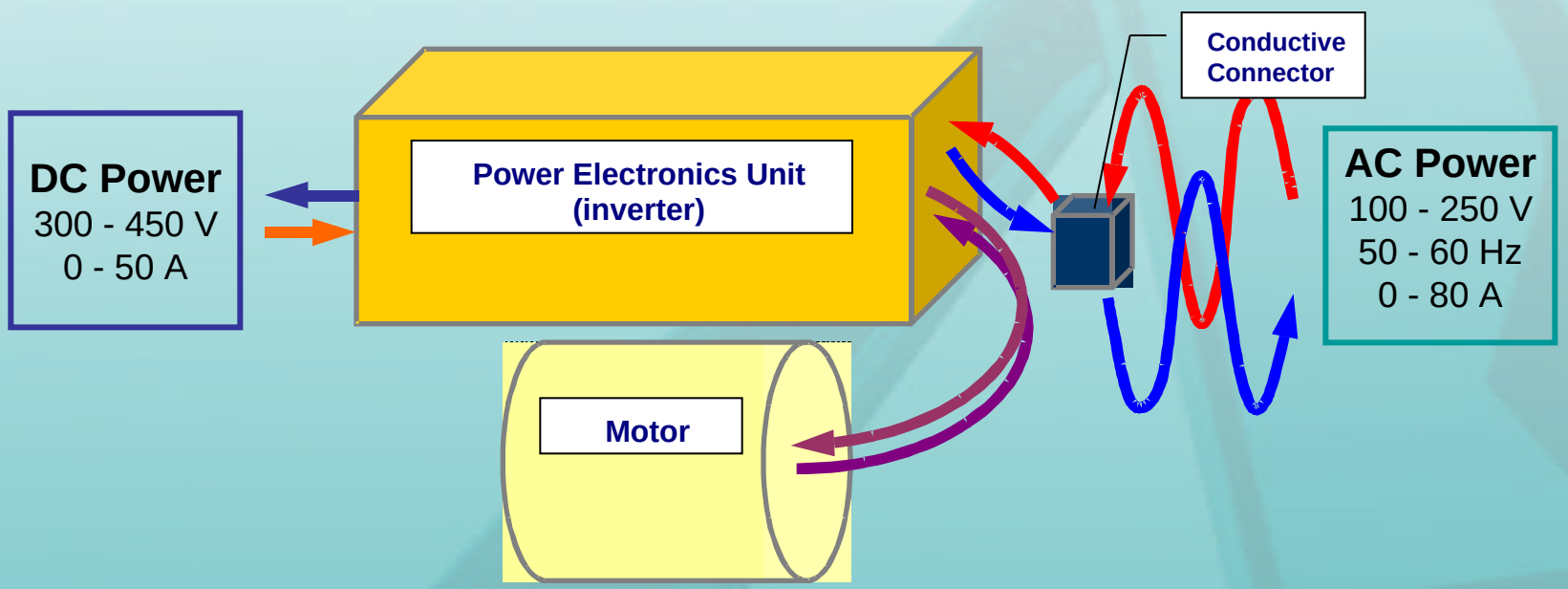
Enabling Technologies, Regulations, and Standards

- Vehicle-to-grid bi-directional power interface
- Wireless internet communication
- Global Positioning System (GPS)
- Systems for tracking a large number of small transactions
- Vehicle interconnection standards
- Bi-directional energy metering at the retail level
- Appropriate tariffs

Vehicle to Grid Enabling Technology

Electric Propulsion System with Integrated Bi-directional power grid interface



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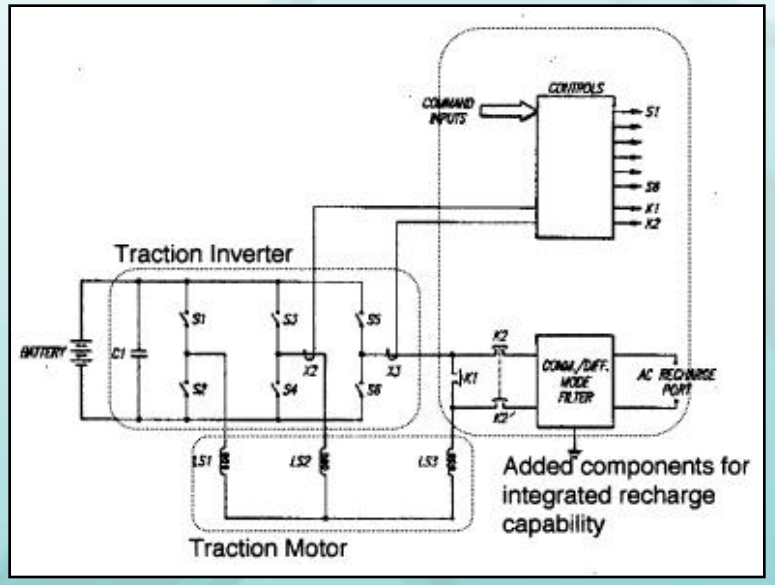
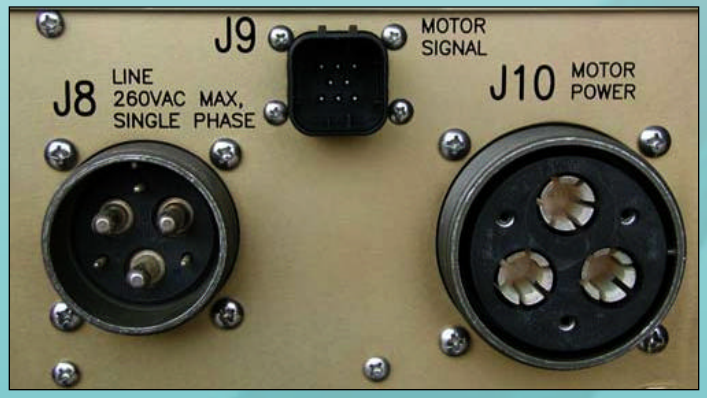
AC Propulsion Integrated AC Power Interface

- Traction inverter and motor are re-configured to provide AC power interface
- Systems delivered for over 8 years
- 20 kW bi-directional power
- Grid-connected or stand-alone

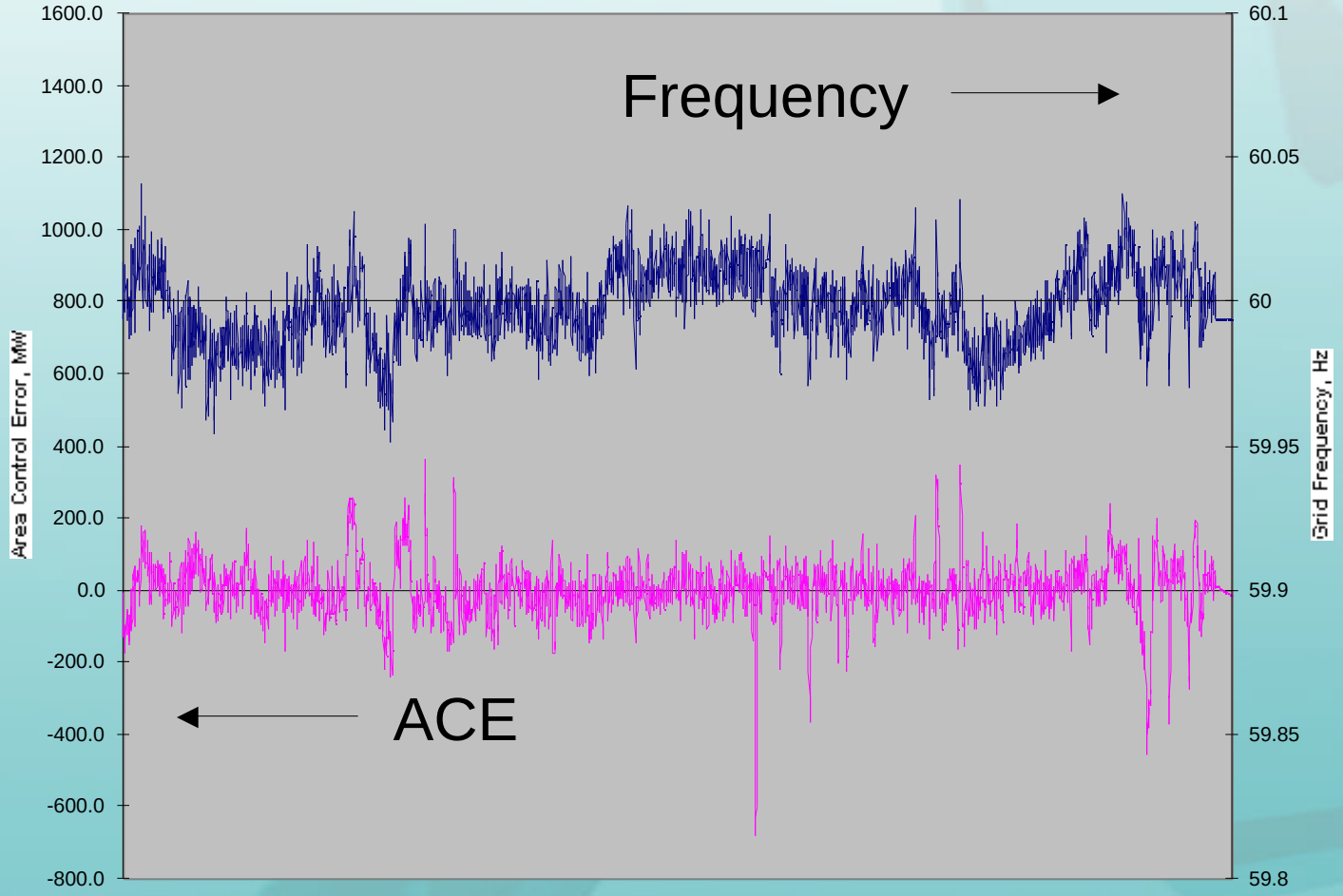




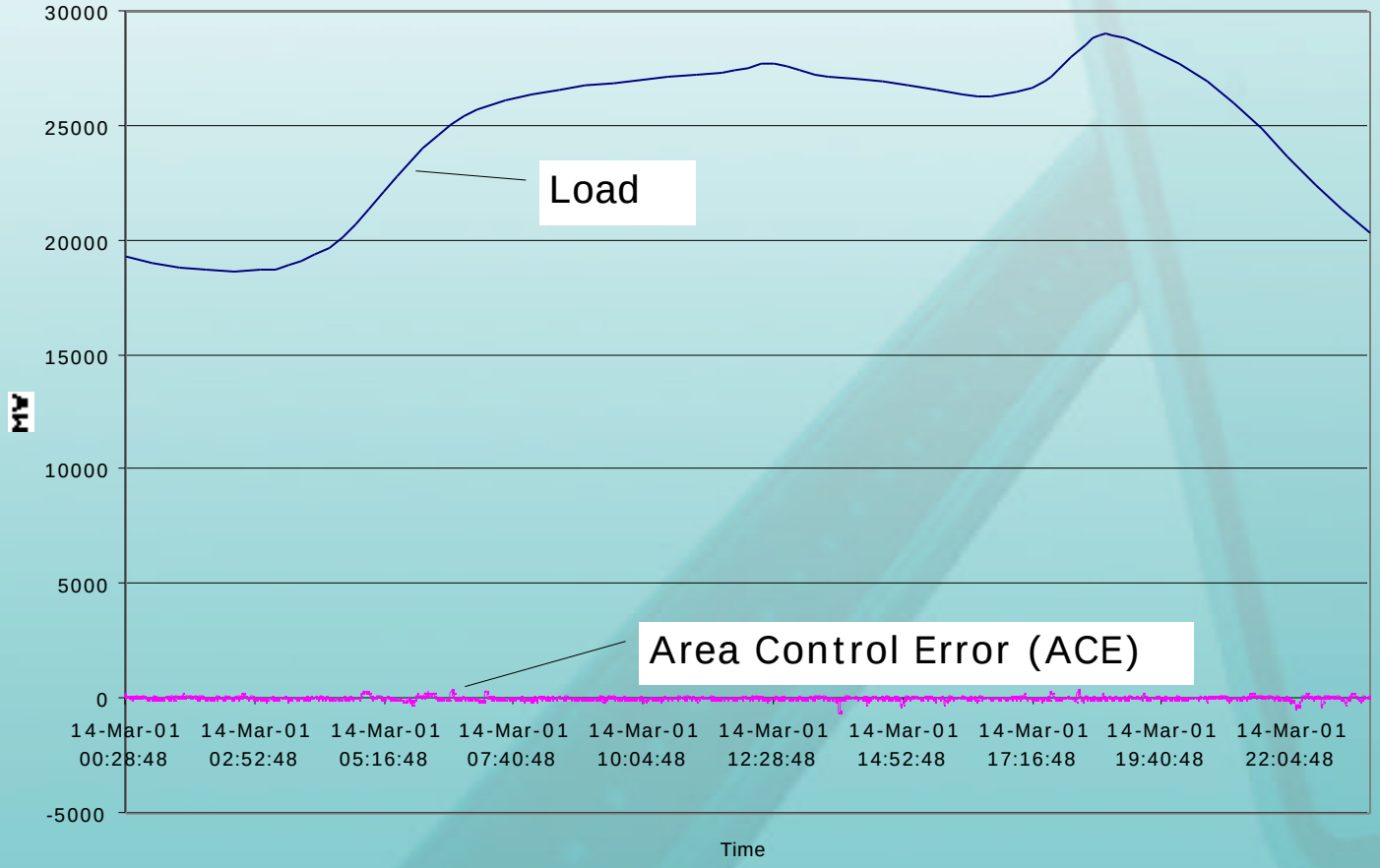
Regulation Ancillary Service

- Regulation is the continuous matching of supply with demand in a control area
- Area Control Error (ACE), is a measure of quality of operation of the grid
- ACE includes a frequency regulation component
- ACE must be kept within grid operating requirements
- Powerplants provide regulation today
  - Slow response
- Real-time control of powerplant output by grid operator

Example Frequency and ACE Profile 3-14-01

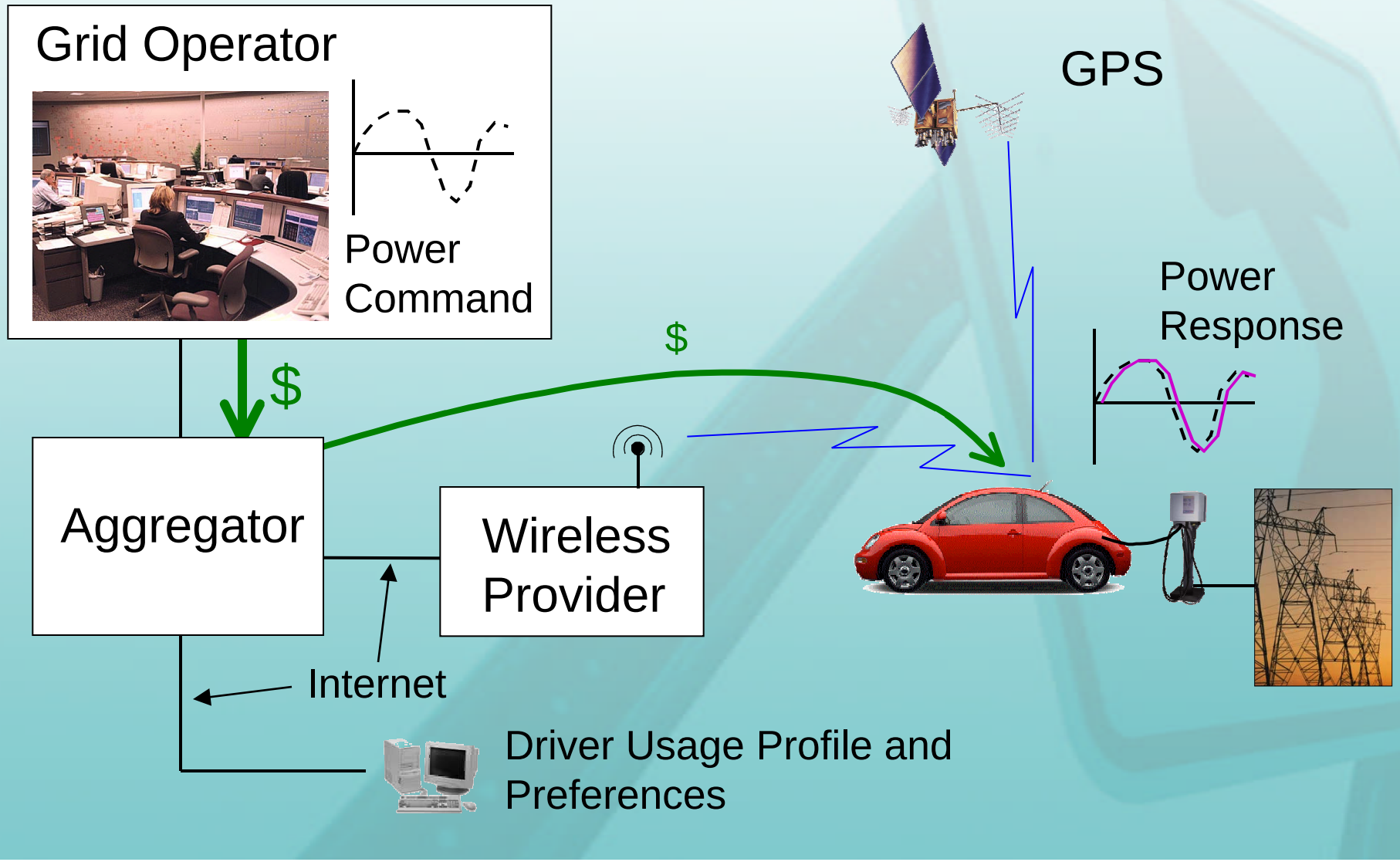


California Load and Area Control Error for March 14, 2001



How EVs Can Provide Regulation

- EVs could regulate area control error by sourcing or sinking power according to grid operator real time commands
- 50,000 to 100,000 connected EVs could perform all of California's regulation - with faster response than powerplants
- Battery state of charge would be maintained above a driver-selected minimum level
  - regulation doesn't require net energy - just energy back and forth at the right time


Grid Operator
Power Command
$
$
GPS
Power Response
Aggregator
Wireless Provider
Internet
Driver Usage Profile and Preferences

EV Grid Regulation Demonstration Project

- Demonstrate an EV providing a grid ancillary service
- VW Beetle EV fitted with bi-directional grid interface and wireless internet connection
- California ISO power command: wireless internet through aggregator to vehicle
- Vehicle responds to command with power to or from grid
- Vehicle automatically maintains battery state of charge to comply with driver usage requirements
- Project started October 2001 with CARB funding. Project participants California ISO and Volkswagen

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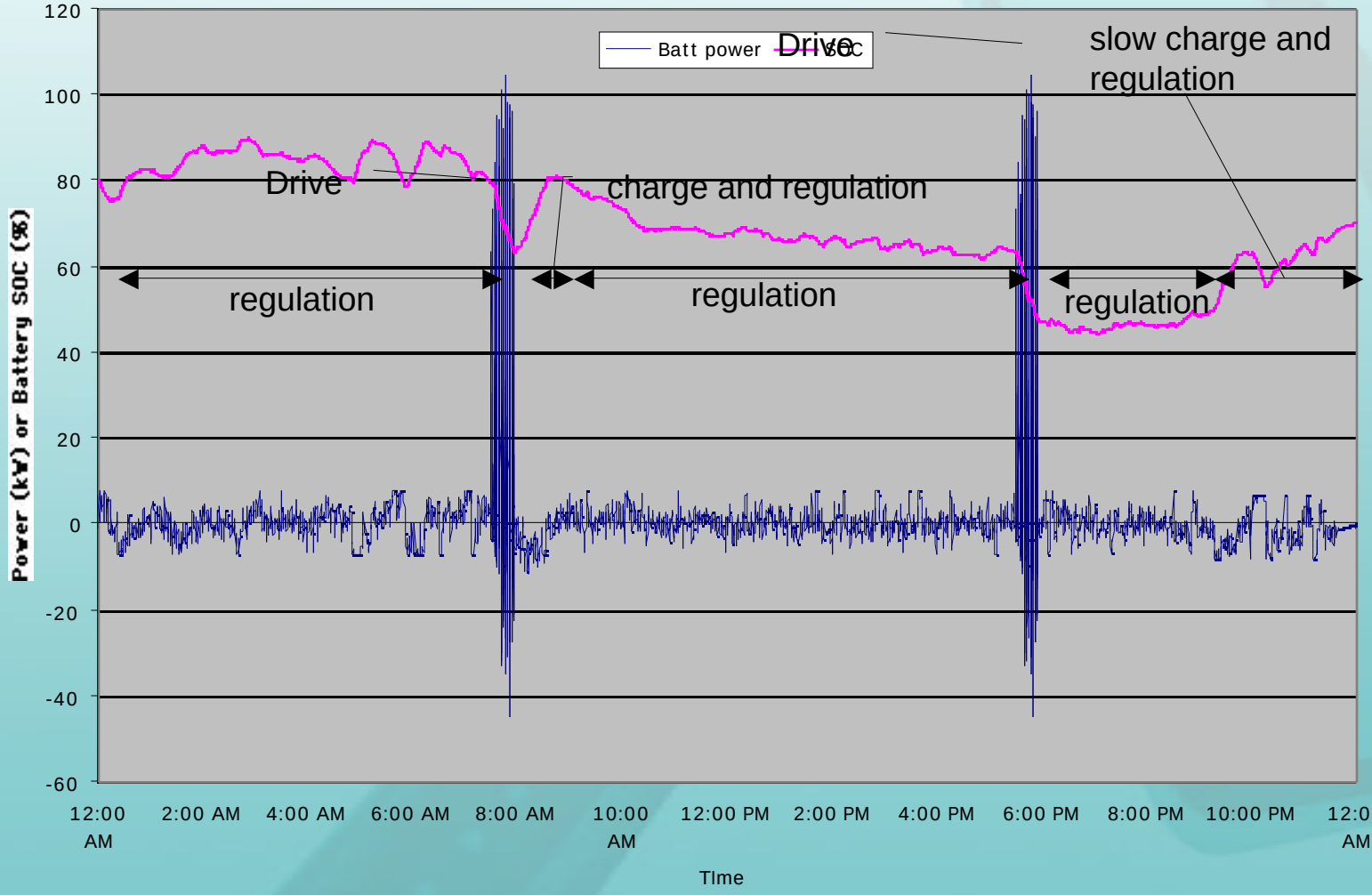
Typical Power Profile - Driving, Charging, and Grid Regulation



The Vision: the V2G EV in the Market

- Customer buys EV ready to go
  - OEM supplies the car
  - V2G service aggregator supplies and owns the battery
- Customer agrees to keep the EV plugged in to grid 20 hours/day on average
- V2G service aggregator warrants battery and pays for recharge electricity for as long as the customer keeps the vehicle and plugs in the required time

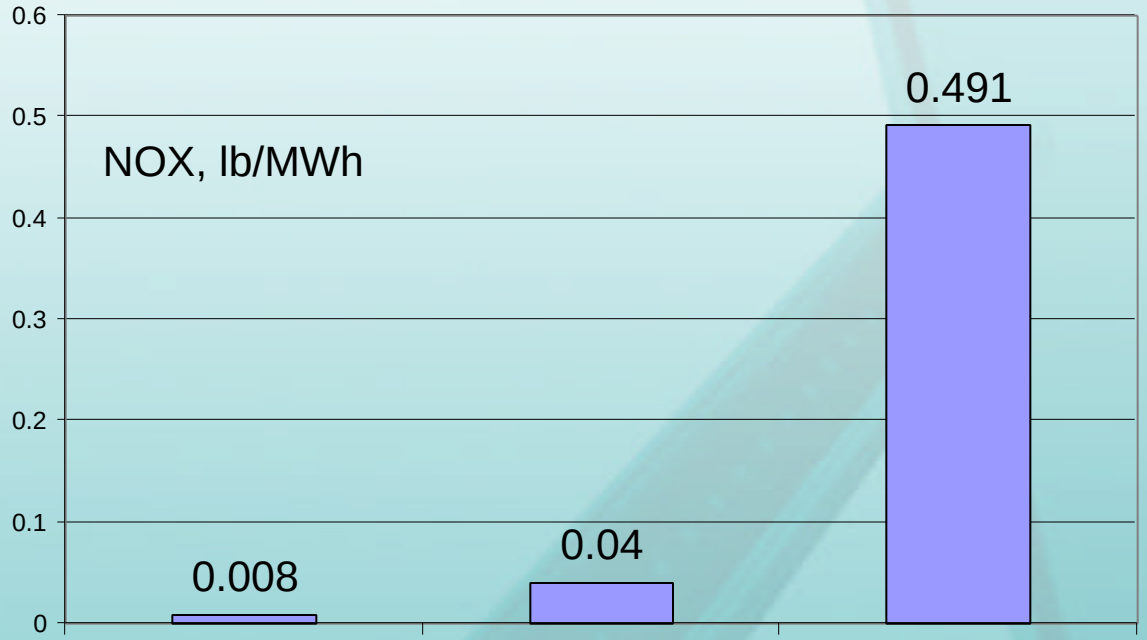
→ **Zero battery cost to driver for life of vehicle**

→ **Zero energy cost to driver for life of vehicle**

Grid Connected Hybrid Vehicle Project

- Charge batteries at night in off-peak hours
- Most driving on battery energy
- Clean distributed generation while parked
- Tri-fuel
  - Electricity from grid for local driving
  - Gasoline for longer trips
  - Low pressure natural gas for power generation while parked (no storage on-vehicle)
- Project started November 2001
  - Funded by CARB, South Coast AQMD, NREL, Volkswagen
  - VW Jetta
  - Lead acid battery - 9 kWh
  - 30 to 40 miles EV range

Vehicle-Based Generation is Clean



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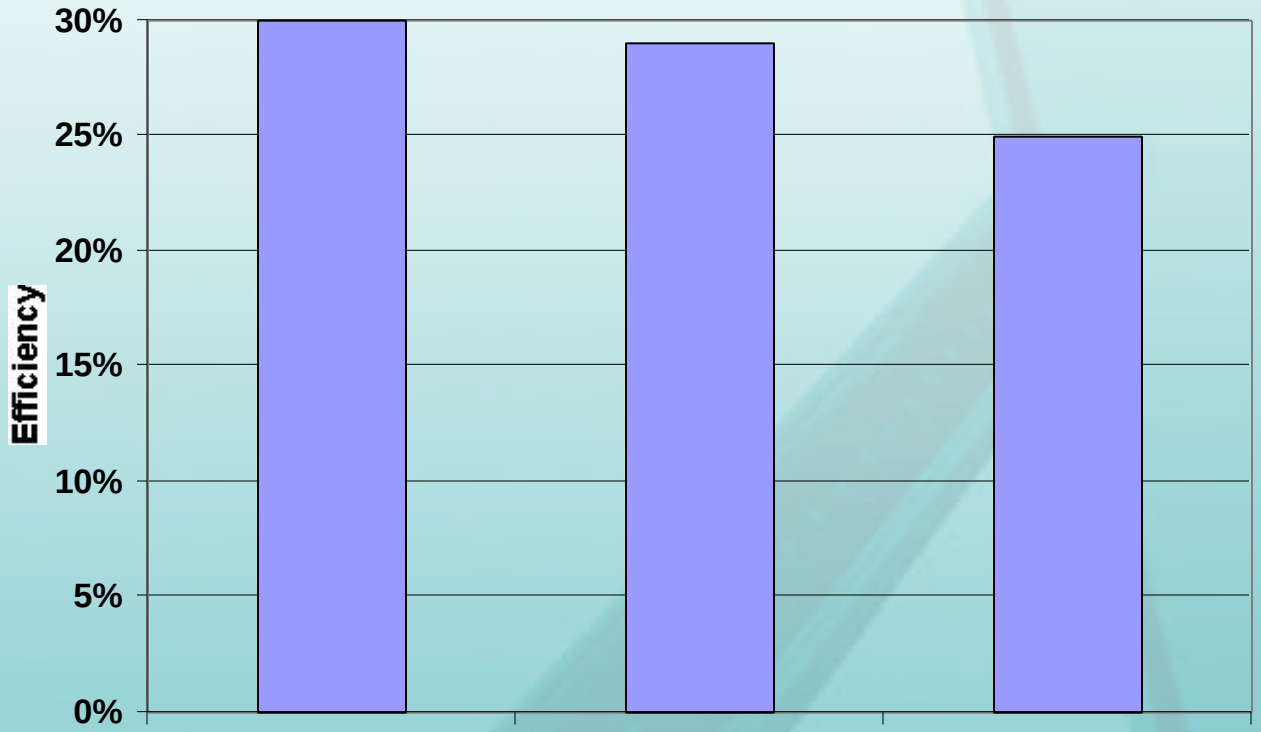
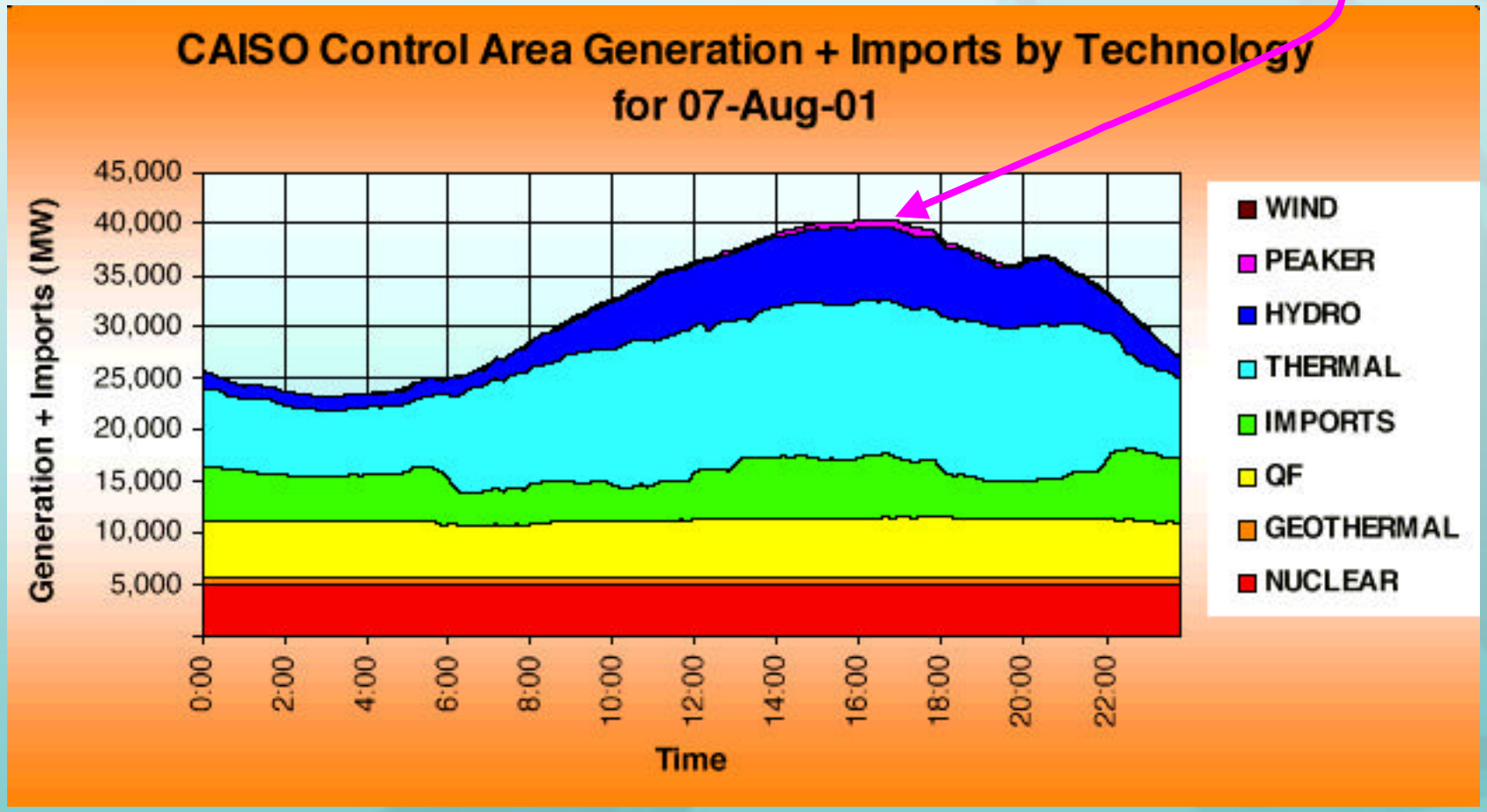
Vehicle-Based Generation is Efficient



Vehicles as Peak Power Resources



Source: Calif ISO 2001/2002 Winter Assessment

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System Vision for 2020

- Most new vehicles come with grid power connection standard
- Vehicles connected to grid from home and workplace
- Peak grid power needs are met with vehicle-based generation and/or storage.
- Vehicles provide valued ancillary services to the grid, offsetting operating costs
- Vehicles provide high-reliability power for businesses and uninterruptible power for homes