

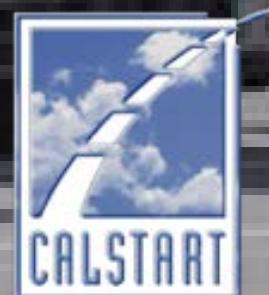
Current Status of Alt Truck Technologies

December 3, 2015

Barriers and Opportunities to
Commercialize M/HD Truck Tech in California

STEPS

Bill Van Amburg, CALSTART



Three Legs of Progress Needed for M/HD Transportation (and alt tech)

- **Vehicle efficiency (and emissions reductions)**
 - decent progress, more needed
- **Decarbonized fuels** – only scratching the surface
- **Energy Efficient Transport Systems (Goods and People Movement)** – just now envisioning

In a Nutshell:

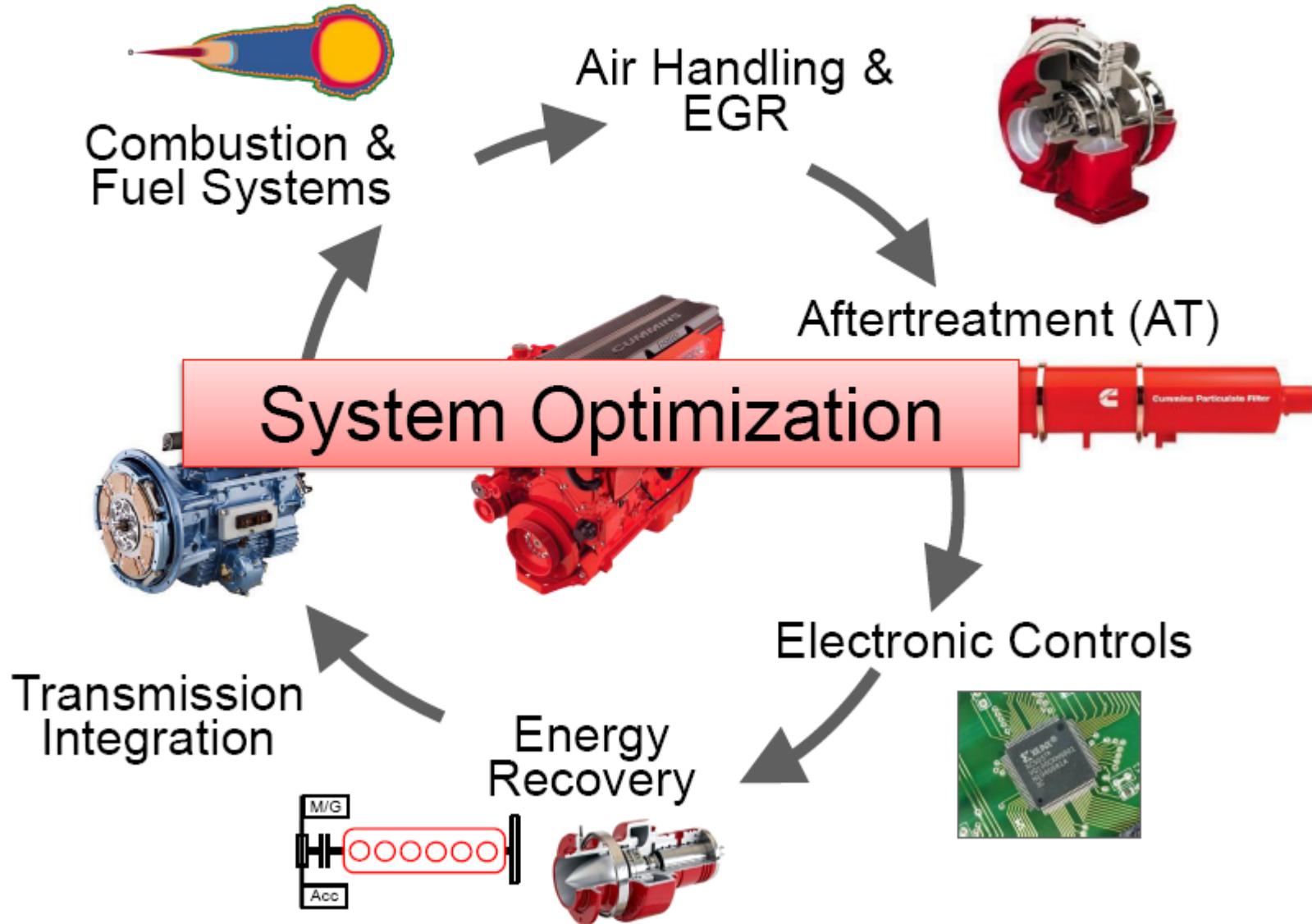
- Conventional truck tech improving via M/HD Phase 1 fuel economy regulations
- Focus increasingly on integration/optimization and smart control technology
- Natural gas expanding – low diesel fuel cost a challenge – but Low NOx engines a reality
- Hybrids – Gen 2 systems and price points emerging in market
- E-trucks – hit market stall but relaunch coming with better market segment focus, support
- Traditional OEMs not as active in hybrid and electric – still waiting to see market – smaller innovative companies leading

New Truck Fuel Economy Rules Phase 2

- New “Phase 2” truck fuel economy rules in draft
- Up to an additional 24% reduction in fuel use for Class 8 by 2027
- Extra 16% for vocational
- **Final rules by mid 2016**



Subsystem Technology Palette



Increase transport efficiency by 50%

Improved combustion System
Turbo Compound
Narrow Band & Downspeeding
Rankine Waste Heat Recovery
20%

- ADAS
- E-horizon
- Driver Coaching

**5%
(bonus)**

- Trailer skirts
- gap & rear fairings
- wheel covers

15%

- Lightweight trailer & tractor
- Composite materials

4,000 lbs



• Idle Reduction
• Improved Auxiliaries
5%

Rear/Side view cameras
Ride height control
wheel & chassis fairings
3%

- Low friction hubs & tires
- Carrier Lube Level control
- High efficiency 6X2
- Low viscosity lubricants

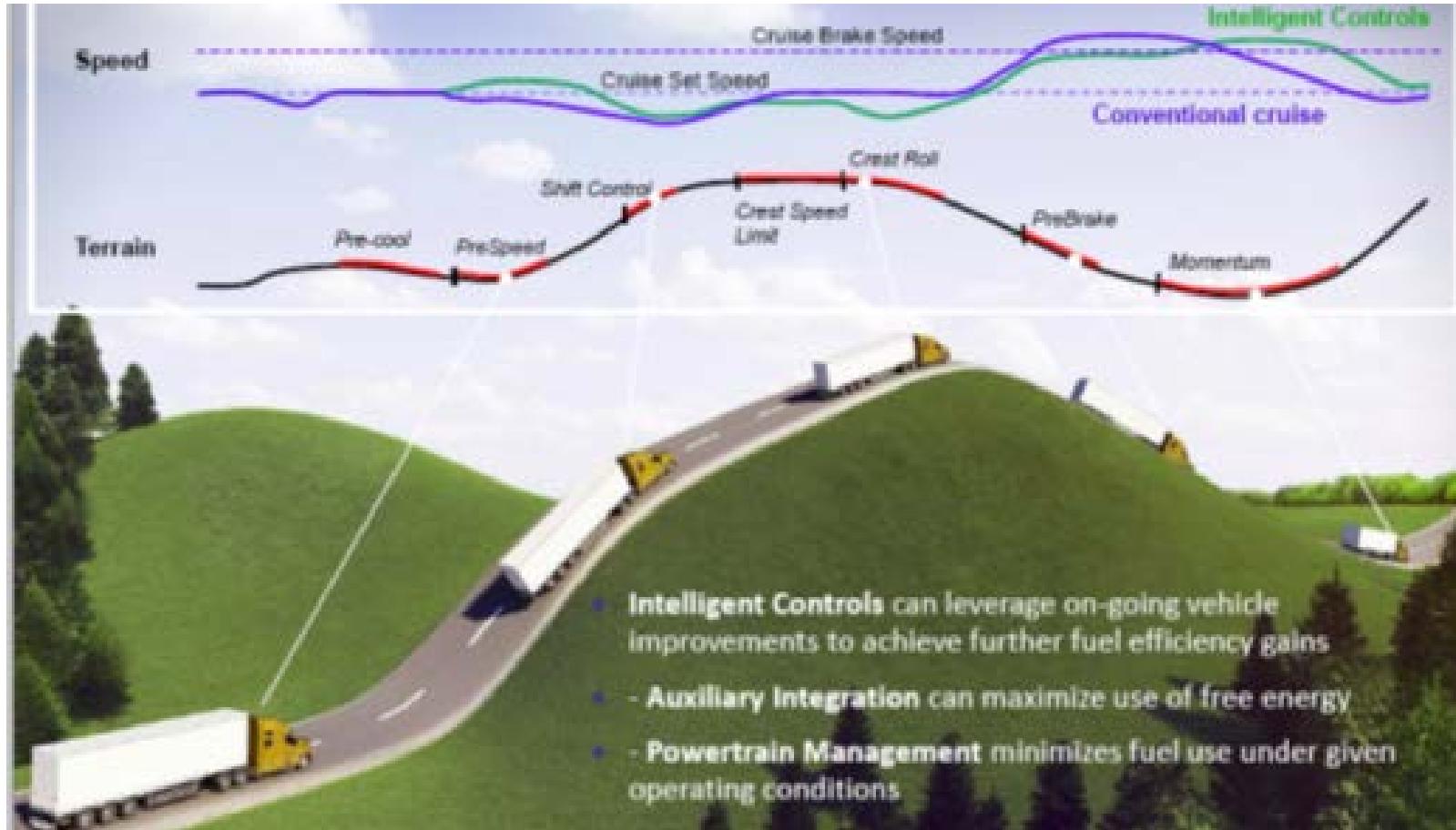
7%

Freightliner Super Truck Breaks 12 mpg

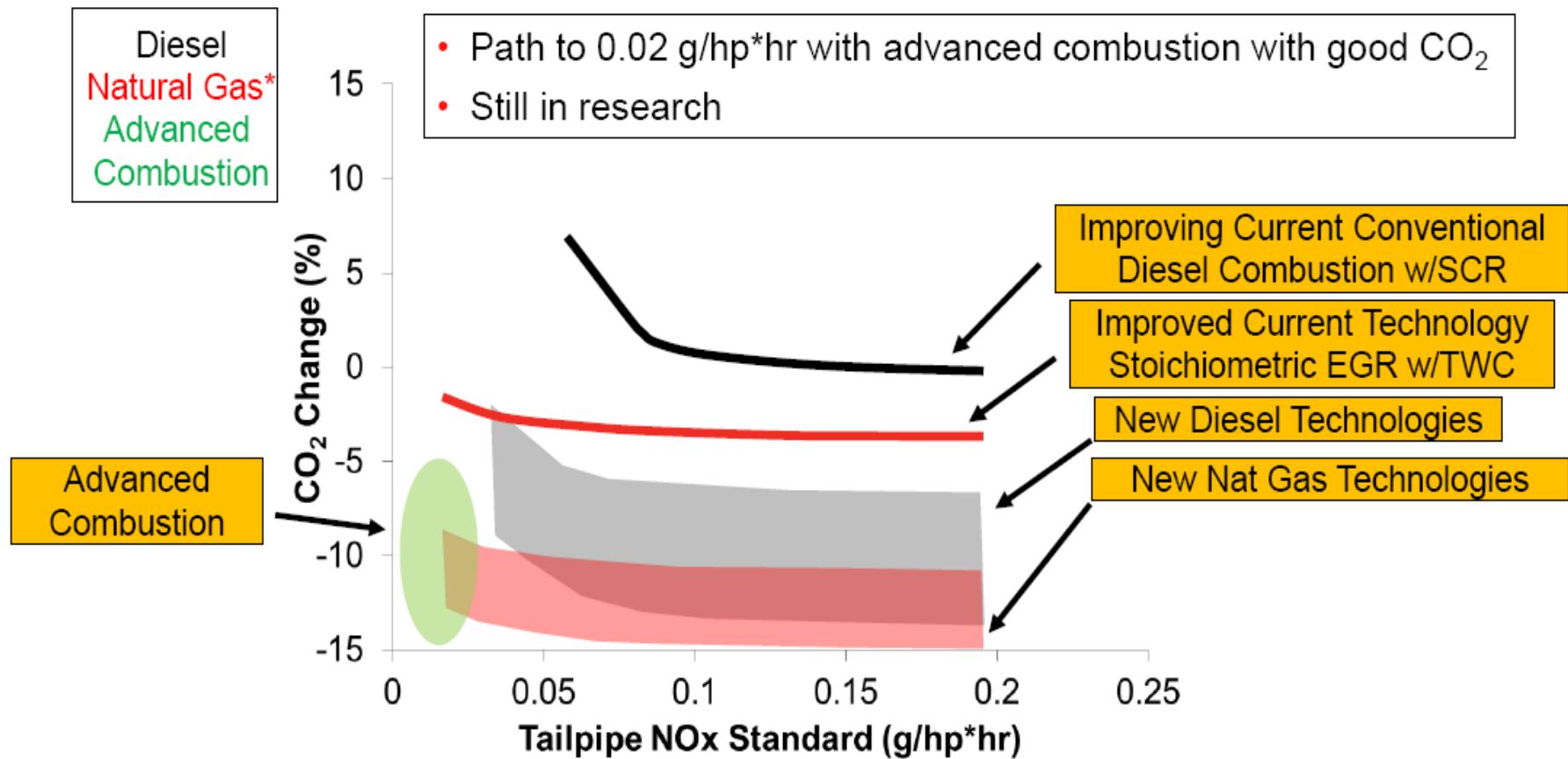


- 115% freight-efficiency improvement, more than doubles Department of Energy's goal of 50%
- Running at 65,000 pounds at 65 mph, truck achieved average result of 12.2 miles per gallon
- Multiple technologies contributed – aero, efficient engine, advanced AMT

Connected & Automated Tech



GHG Penalty at Low Tailpipe NOx



* Includes methane emissions as equivalent CO₂

Ultra Low Emission NG Engine

Certified 0.02 NOx
90% Below
EPA 2010



Production April 2016

Renewable Natural Gas Expanding



- Projects and products growing
- Example: Atlas Disposal using Clean World digester gas and CE renewable pipeline gas to fuel refuse trucks

New Players, Prices: Hybrids, Plug-ins, Work Site Idle

- New, conversion and retrofit options all showing more attractive price points
- Hino, XL Hybrids, Lightning, Parker, Effenco, EDI, others – Ford Start-Stop
- Odyne, Altec, Terex, Time, and others with work site idle reduction systems





Zero Emission buses are in pre-production
Similar driveline size to HD drayage trucks
Provides pathway to ZE HD trucks



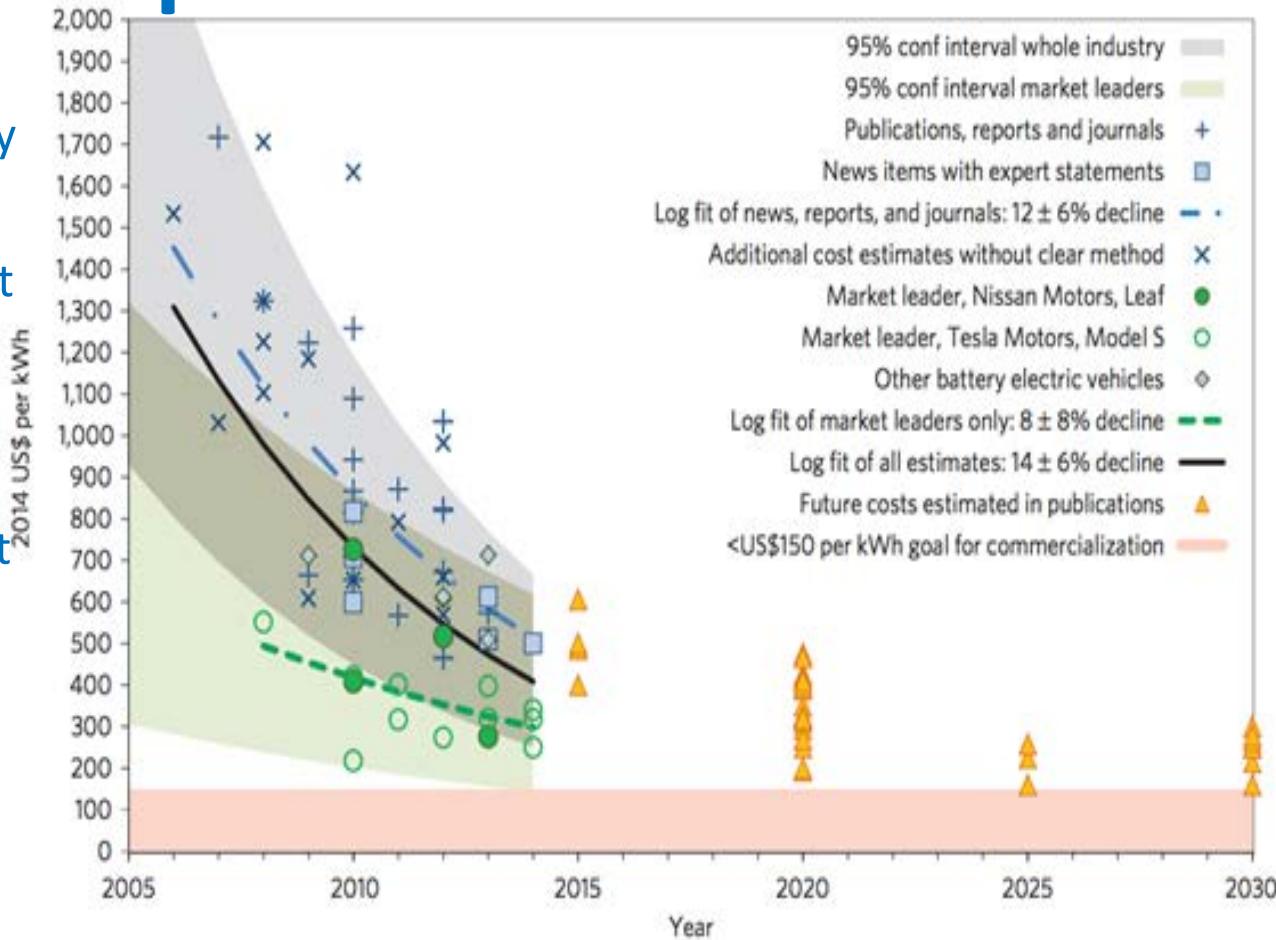
BYD to Zenith – New Electric Options

- BYD, a global battery maker, building e-buses and soon trucks in Classes 5,7 and 8 for US
- Zenith ramping up, Motiv, Orange, Transpower, Phoenix, Adomani, Amp/Workhorse growing



Battery Costs Below 2020 Expectations?

- It's NOT the battery, stupid?
- Report shows battery cost reductions happening faster, steeper than forecast
- Old forecast: \$300/kwh by 2020
- New findings: Industry already \$410/kwh; leaders at \$300/kwh
- Behavioral and market factors may be more of a limiter than batteries now



Nature Climate Change report:

<http://www.carbonbrief.org/blog/2015/03/electric-vehicle-batteries-already-cheaper-than-2020-projections/>

Broad Range of Tech Under Development

- All-electric Class 8 (Transpower)
- NG-range extended elec (Artisan)
- Plug-in Hybrid Class 8 (Mack/Volvo)
- ERV (electric refuse – Motiv)





Cadillac Super Cruise Coming

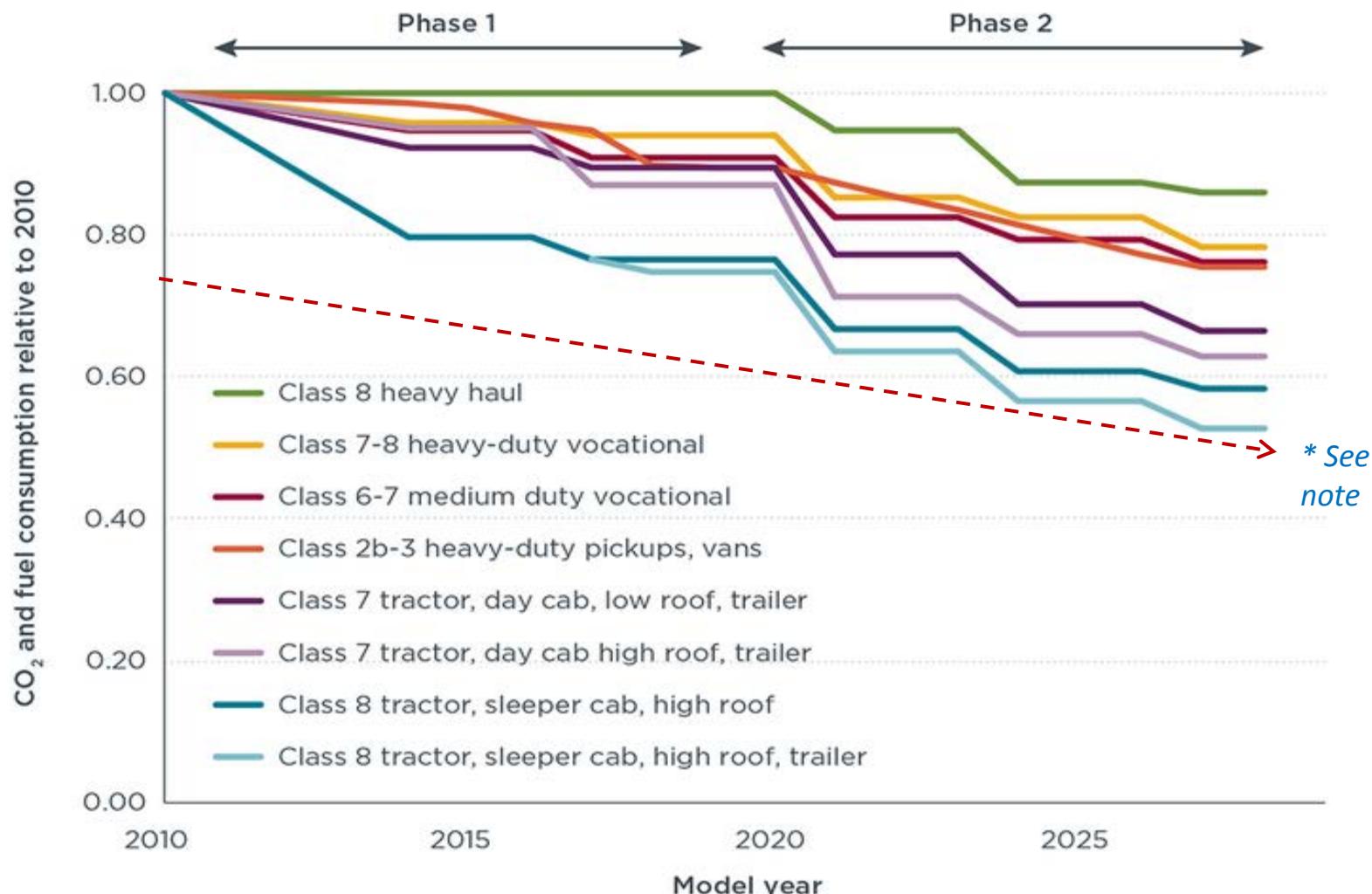




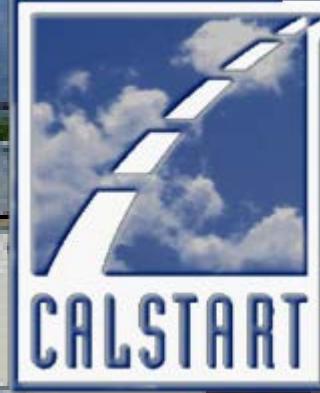
A “LEED” for Fleet

- Developed with NAFA – nation’s major fleet manager organization – **BY AND FOR FLEETS**
- Sets a **standard** to measure fleet progress against specific reduction targets – apples to apples – the **“LEED” of Fleet**
- Metrics: **reduce fuel use; reduce climate and criteria emissions; increase efficiency**
- Provides independent review of fleet progress – gives guidance on strategies – but encourages **innovation**
- **Officially enrolling fleets NOW**

Directional Summary Phase 1 & 2



* Dashed line added by CALSTART; Representative GHG Reduction Slope to achieve 80% reduction from 1990 levels (truck graphs are per vehicle, do not reflect VMT growth or fuel)



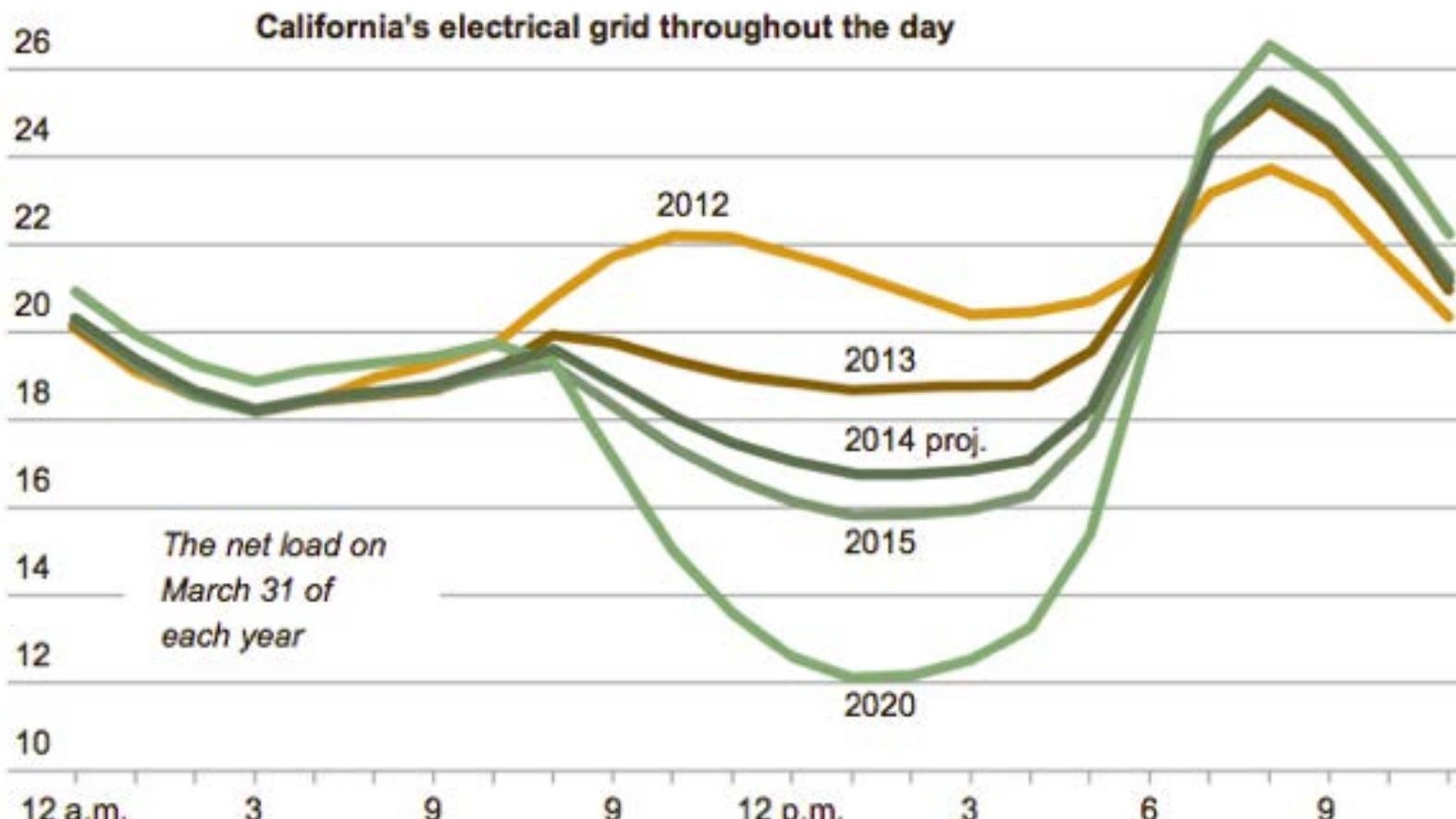
Clean Transportation Coalition

**Leading the Industry
with Initiatives in
Technology Development / Policy /
Technical Analysis / Market
Acceleration**



The “Duck” Curve – New Capabilities

28 thousand megawatts



Source: CalISO

- Solar/renewable energy growing rapidly
- Over capacity in daytime?
- Can PEVs or H2 production balance load?

