

Connected & Self-Driving Cars

SAE automation levels, V2X types and CAV energy impact

ENGINEERING
CHEAT SHEET

Key equations

Quantity	Equation	Notes
Stopping distance	$d = v t_r + v^2 / (2 \mu g)$	t_r = reaction/communication delay. V2V warnings can cut t_r
Time headway	$h = gap / v$	Cooperative adaptive cruise control targets short, stable headways
Range impact of AV compute	Range $\rightarrow$ Range $\times (1 - 0.115)$	AV electrical/electronic loads can cost over 11.5% of range
CAV energy gain	Up to -20% energy use	ARPA-E NEXTCAR: V2X data plus powertrain optimization

Key takeaways

- Four megatrends: **electrification, self-driving, connectivity, shared mobility**.
- There are no Level 5 cars on public roads. Level 4 robotaxis (Waymo, Zoox, Cruise) run in geofenced areas of cities like San Francisco, Phoenix, Los Angeles, Austin, Hamburg and Beijing.
- Tesla Full Self-Driving is currently **Level 2**: the driver must supervise at all times.
- V2X (vehicle-to-everything) covers V2V, V2I, V2P and V2N links. Benefits: safety, traffic management, predictive maintenance, infotainment.
- Connectivity needs cybersecurity: authenticated, encrypted messages, secure over-the-air updates, intrusion detection, and privacy rules for location data.
- A connected car talks to others; a self-driving car steers, accelerates and brakes itself. They complement each other.

SAE levels of automation

Level	Name	Who is responsible
0	No automation	Driver does everything
1	Driver assistance	Steering or speed, not both
2	Partial automation	Steering and speed; driver monitors constantly
3	Conditional	Car drives in set conditions; driver takes over on request
4	High	Car drives itself within a geofenced area
5	Full	Car drives anywhere, no driver needed