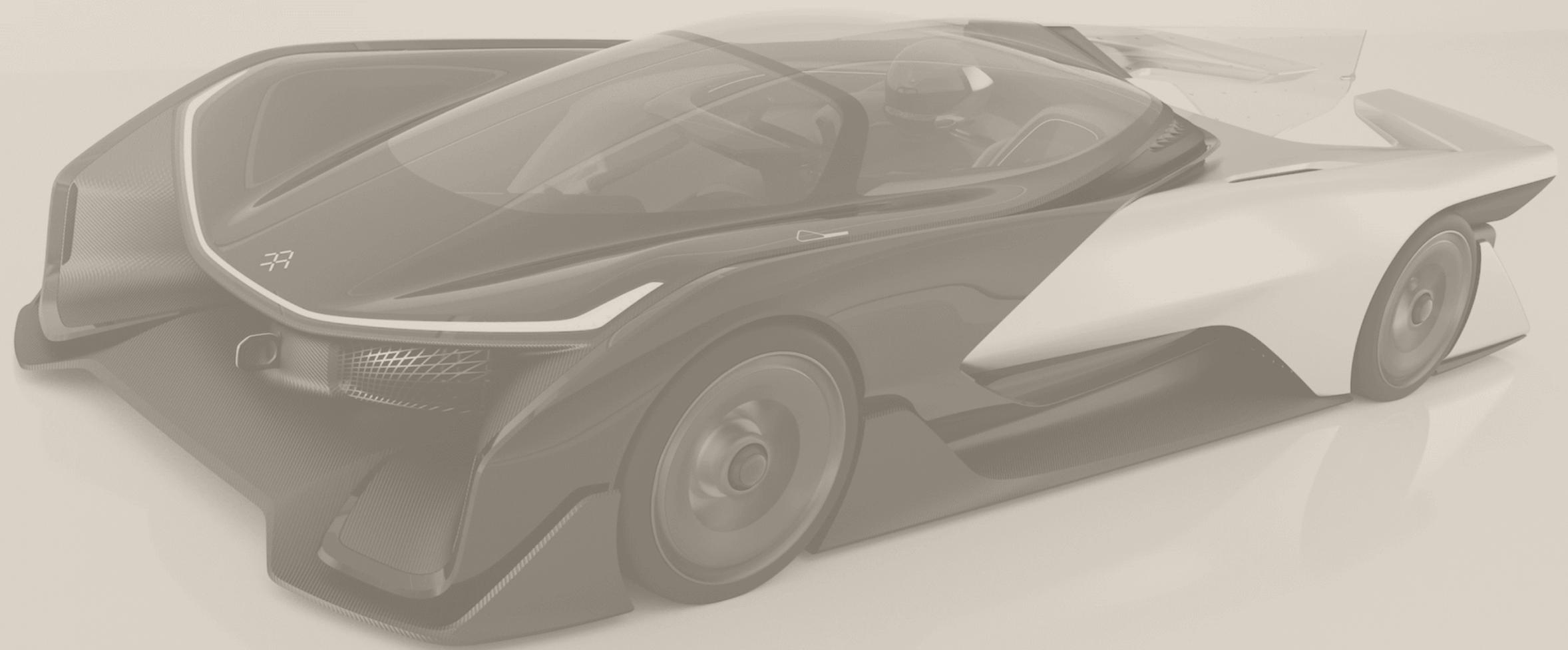




Electric All Wheel Drive

09.27.16



Advanced Clean Cars Symposium Diamond Bar, CA

California Environmental Protection Agency
 **Air Resources Board**

Pete Savagian
VP, Propulsion Systems
Faraday Future



- Agenda
 - Traction
 - Customer Benefits
 - Manufacturer Benefits
 - Societal Benefits



Fundamentals in Traction - The Slip – Mu Relationship



- Tire slip ratio = $1 - \left| \text{Actual Vehicle Speed} / \text{Tire Speed} \right|$
- A little bit of tire slip is necessary to accelerate



Slip = 0.0

Tire Speed



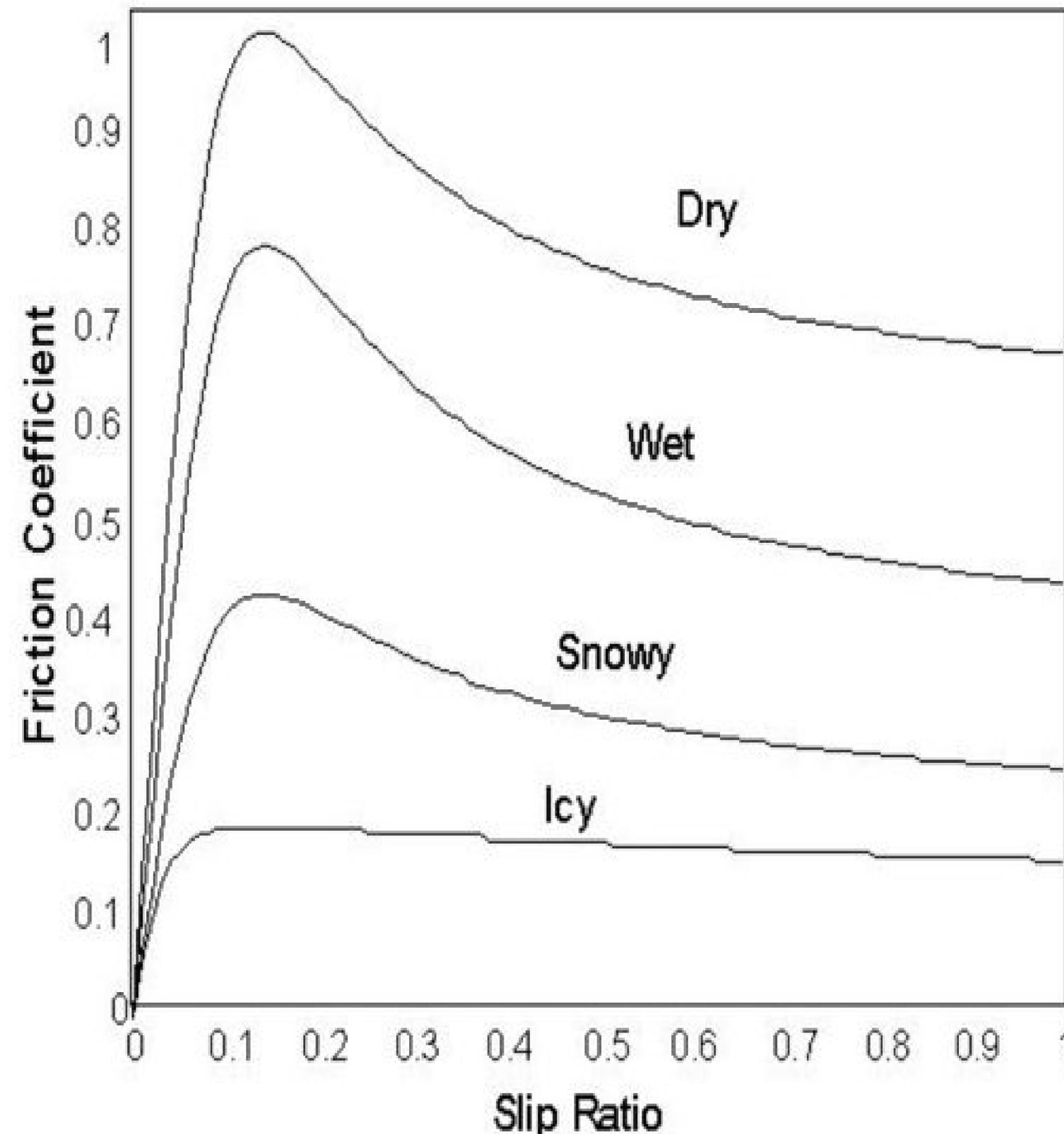
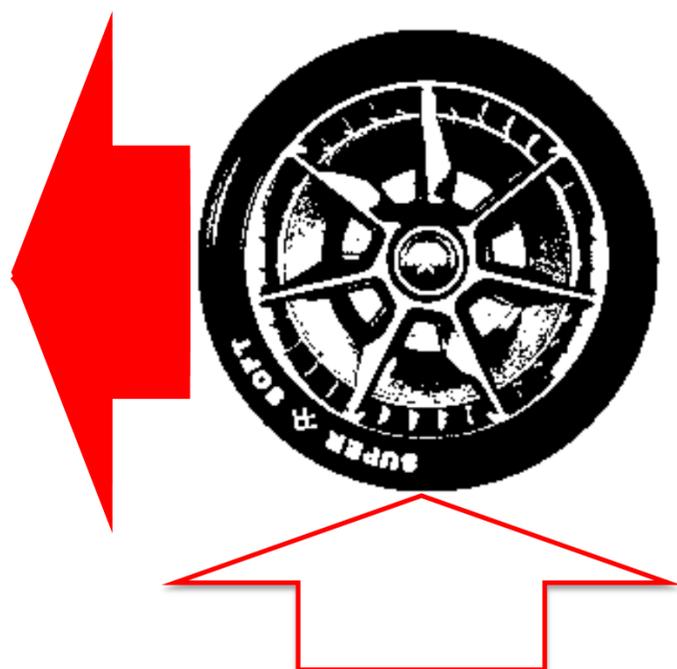
Vehicle Speed ≥ 0



Fundamentals in Traction - The Slip – Mu Relationship



- Tire slip ratio = $1 - \left| \frac{\text{Actual Vehicle Speed}}{\text{Tire Speed}} \right|$
- A little bit of tire slip is necessary to accelerate; slip is measured continuously for each tire
- “Mu” (μ) = Coefficient of Friction
= Driving force the road surface can support / Weight on the tire
- Mu changes with road / tire surface interaction

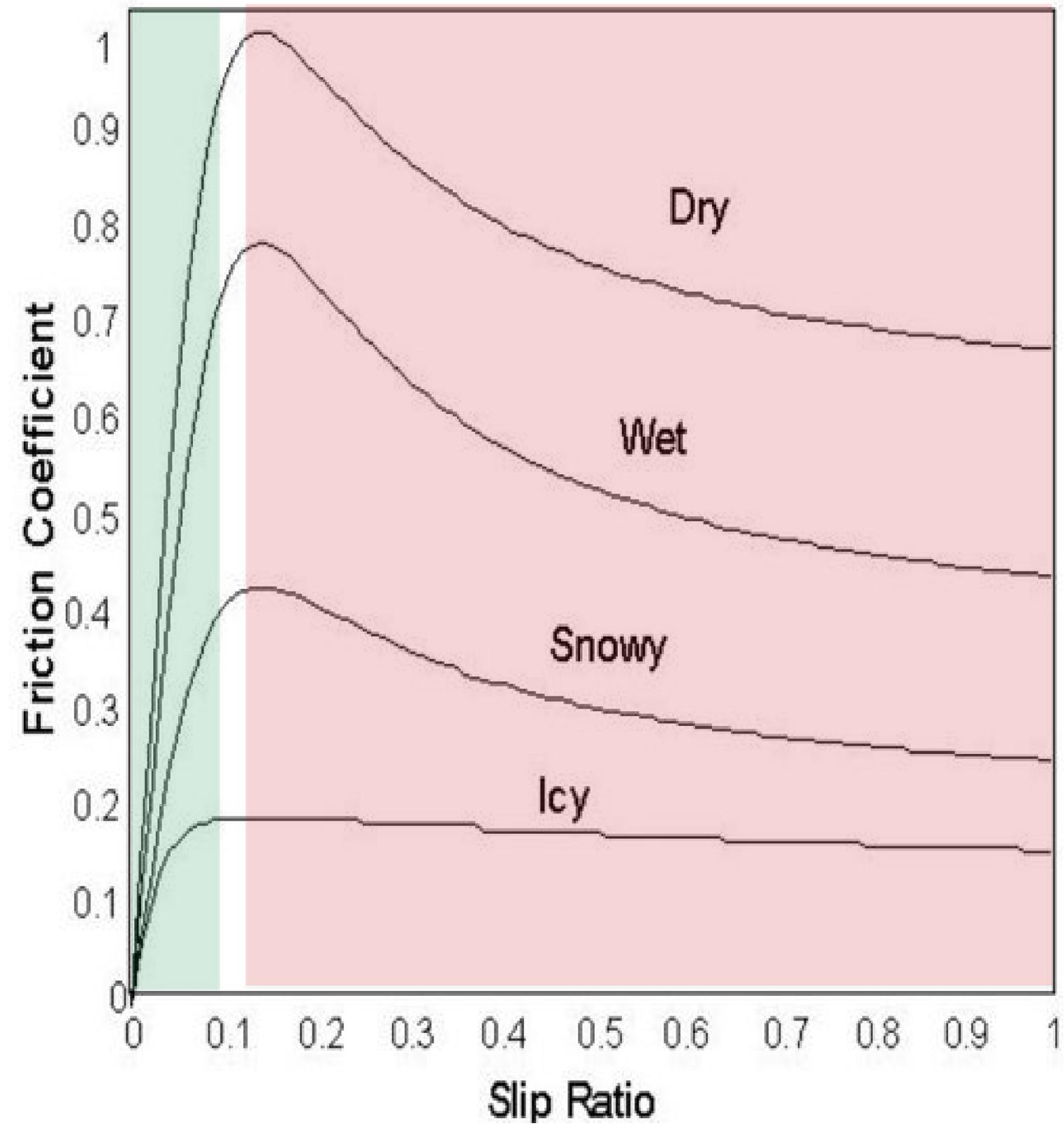


Traction Control Means Maximizing Torque for the Driving Conditions



– A Balancing Act

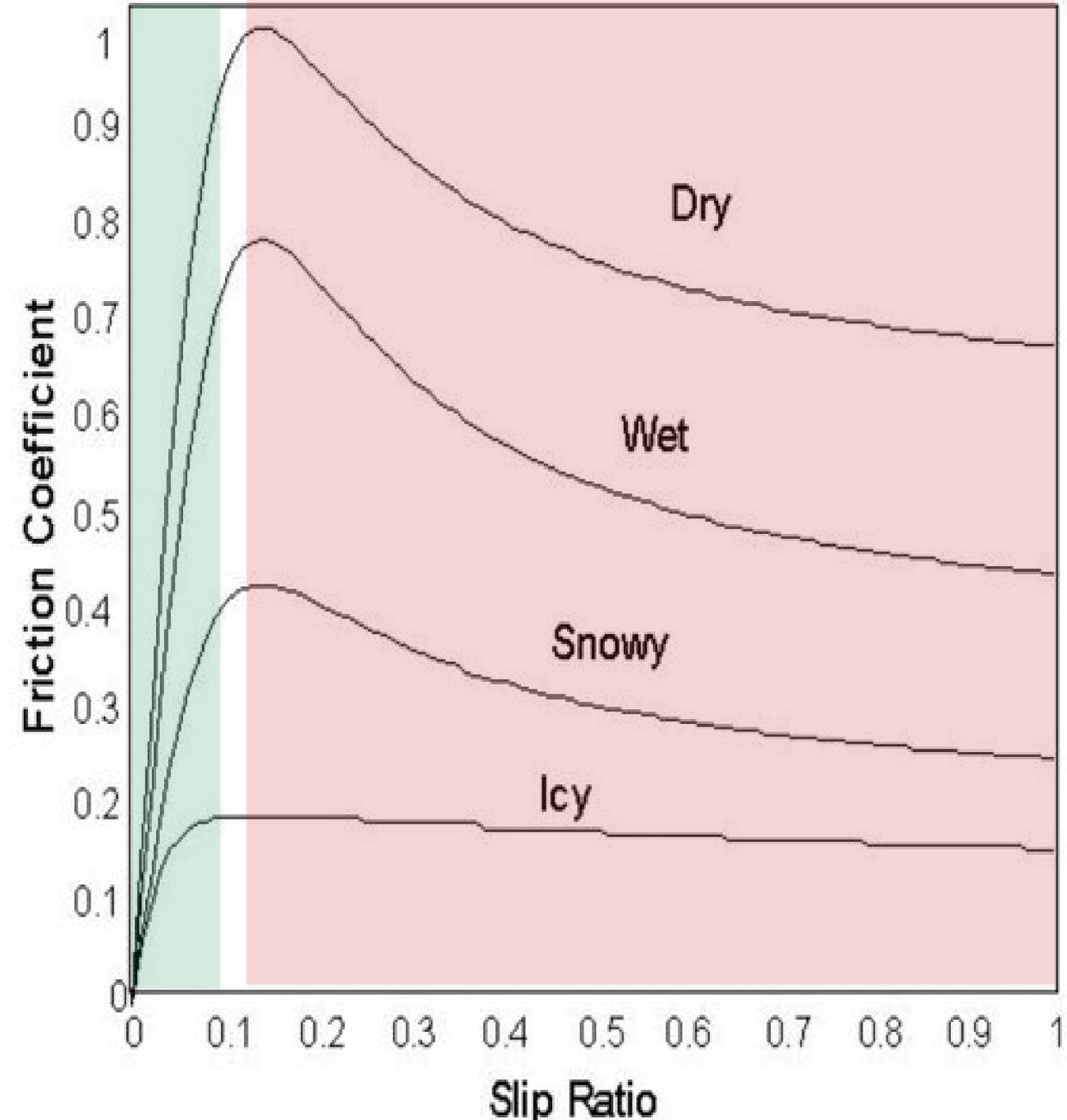
- Torque is controlled to the axles or wheels to maintain grip, eg, Slip less than 0.1
- Traction is controllable in the “Grip” zone – Green
- Traction is lost when in the “Sliding” zone – Red
- Fore – Aft Slip is used for Traction Control to avoid getting stuck and for Anti-lock braking to avoid skidding
- Lateral Slip is used for Electronic Stability controls to aid in handling, avoidance maneuvers and rollover prevention



Driving Benefits - Electric Drive provides Better Balance



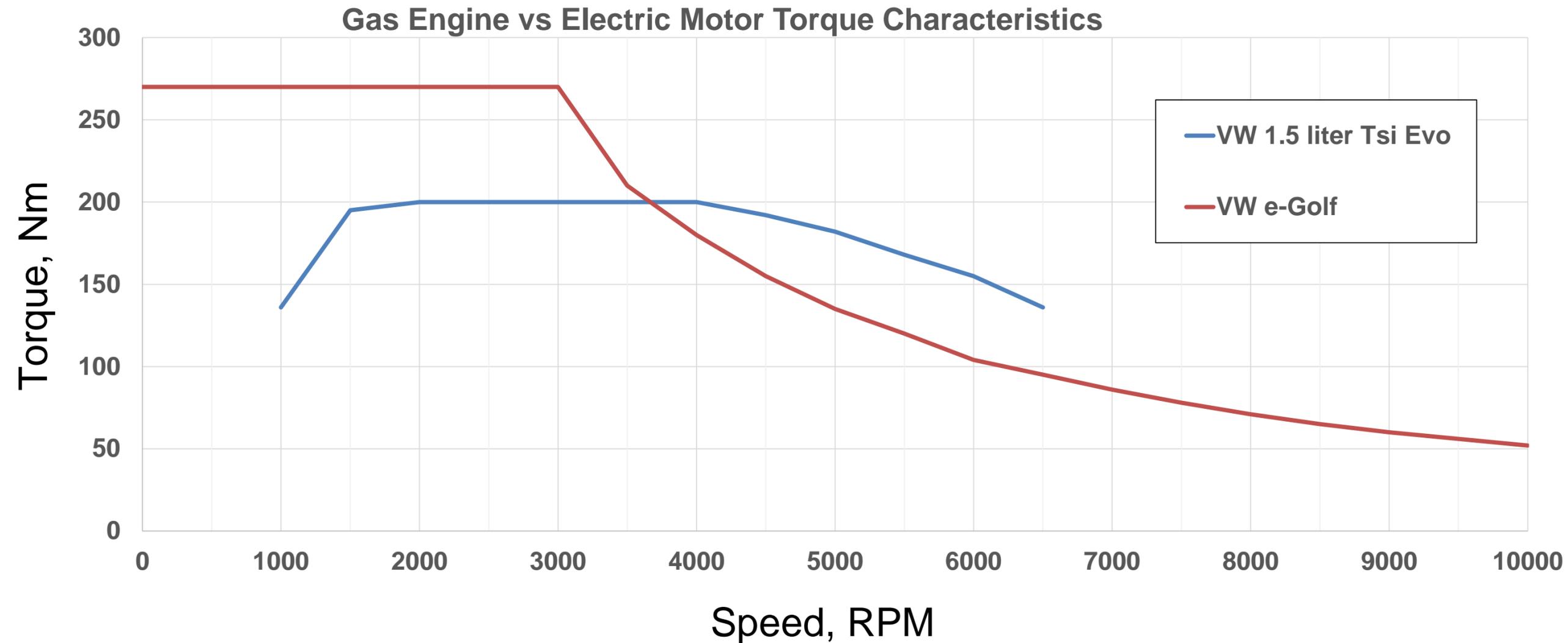
- For maximum traction and control, we need to balance torque to keep below ~0.1 slip ratio
- Torque transient response of an electric motor is a few thousands of a second
- Torque transient response of a gas engine or mechanical coupling system is in several tenths of a second



- **Electric traction response to changing traction conditions is 100X better with electric!**



Driving Benefits – Special Advantage when the Car is “Stuck”



- Gas Engines can only be used above ~1000 rpm; Requires mechanical system to attempt to control
- Gives even poorer “balance” when you are stuck!
- **Electric Motors are controllable to zero speed, great controllability is maintained!**

Manufacturer Benefits of Electric AWD

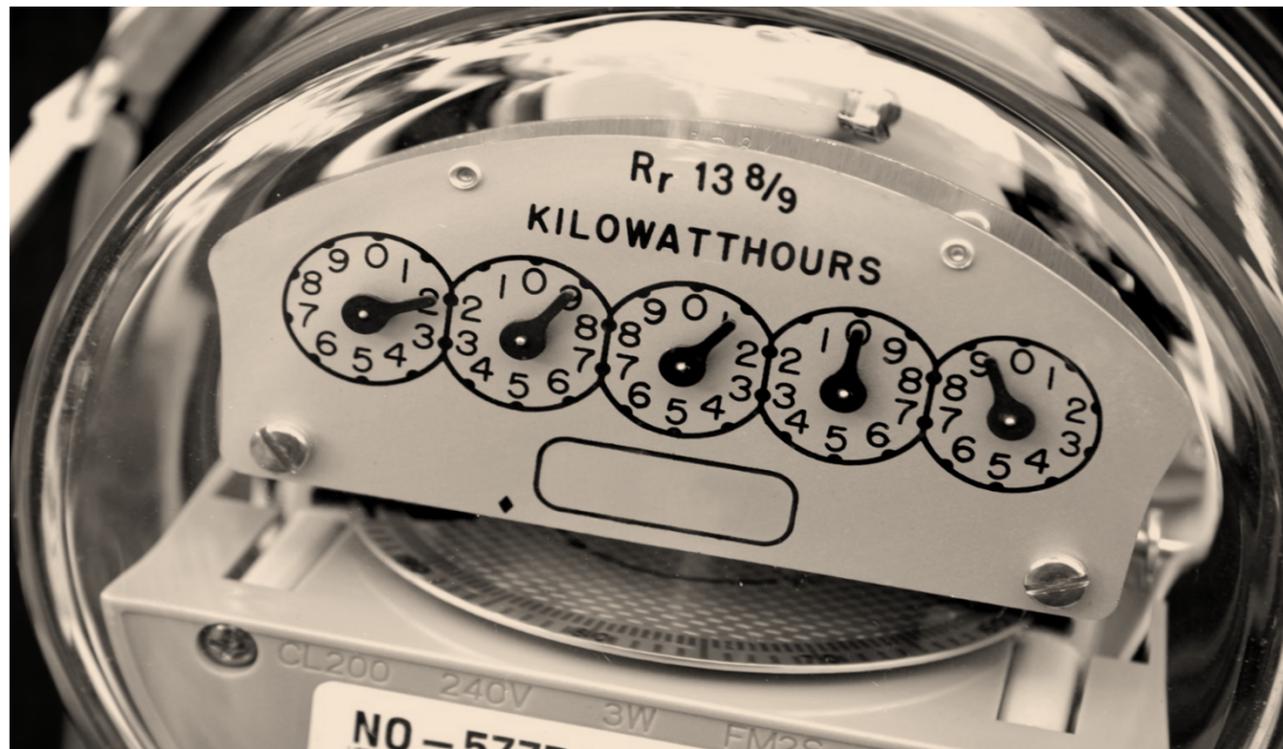
- Easier vehicle package and integration
 - No drive shaft to second axle
 - No decoupling devices or controls are necessary; motor can free-spin
- Less vehicle mass
- Less development expenses and tooling costs:
 - Modular powertrain opportunities for EV FWD, RWD and AWD.
 - Re-use opportunities for motors, gear reductions, electronics and controls



Societal Benefits of Electric AWD



- Safer roadways
 - Better driver controls
 - Tighter ADAS integration
- Less energy consumption
 - Mechanical AWD is typically 5 to 10% worse than 2 wheel drive for efficiency
 - **Electric AWD is neutral to positive efficiency relative to 2 wheel drive!**





Q and A

