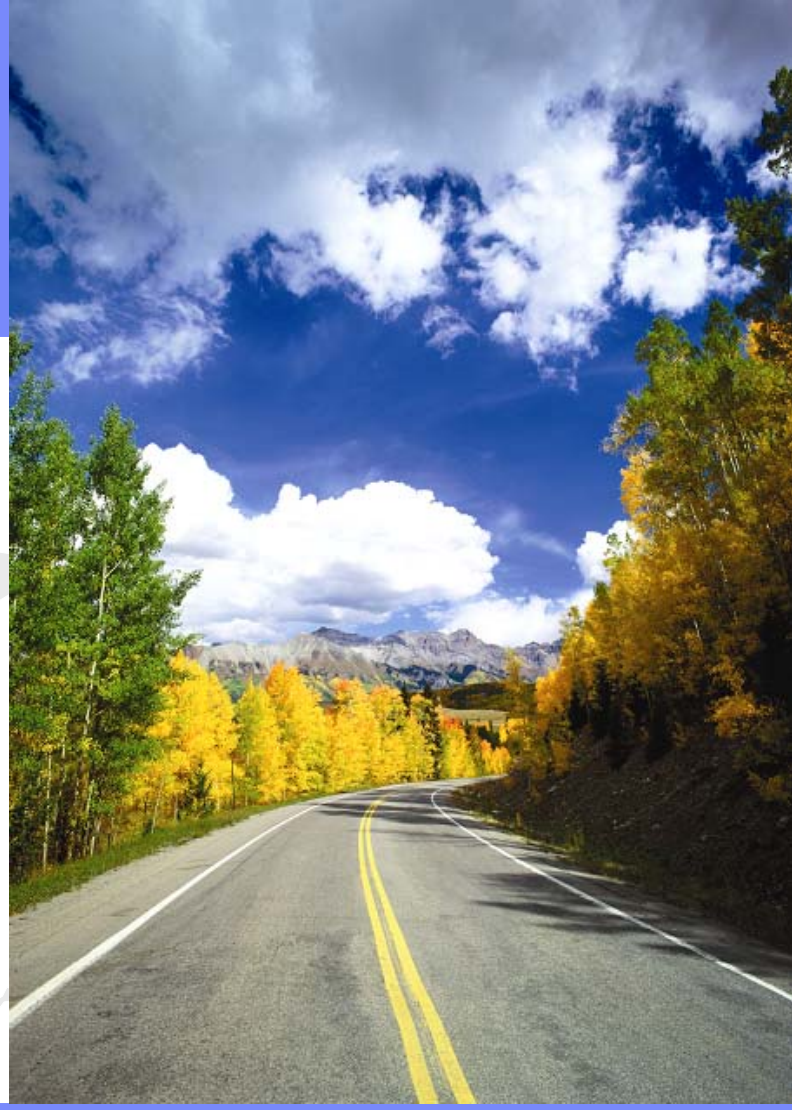
IBM Automotive

Hybridization of Automotive Transportation



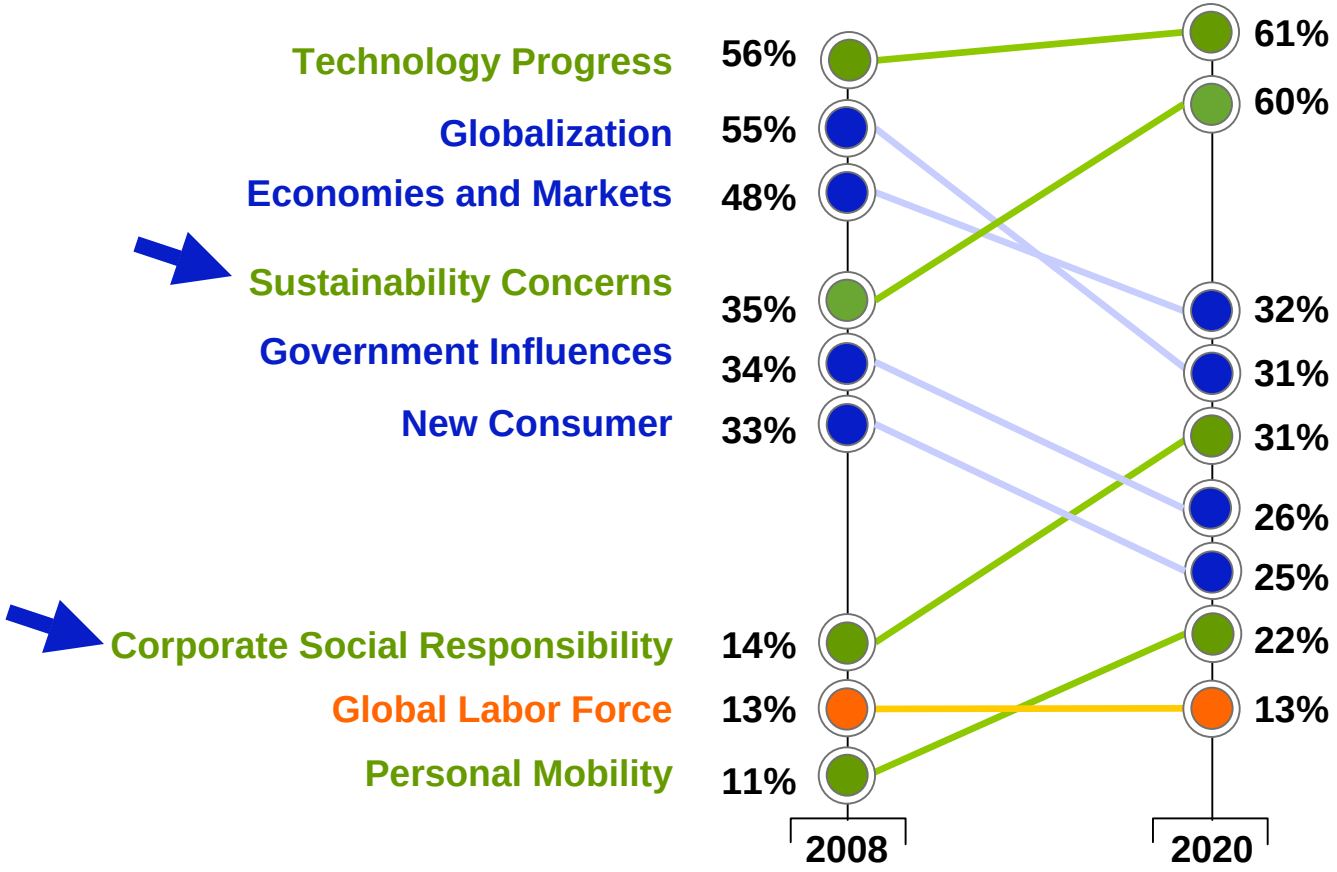
Sanjay Rishi
Vice President and
Global Industry Leader

Agenda

- Future of Transportation Trends
  - Light Vehicle
  - Heavy Truck
  - Heavy Equipment
- Battery technologies
- Innovation ecosystems

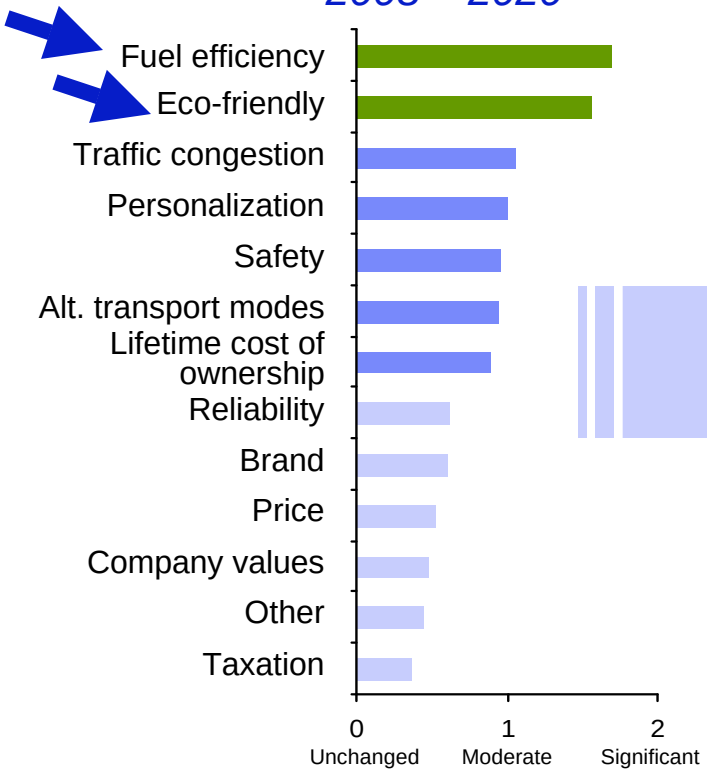
The future of transportation will have experienced a major shift by 2020

Most important external forces that will impact the industry



Changes in consumer buying criteria will drive entirely new personal mobility solutions

Rate the Change in Vehicle Buying Criteria 2008 – 2020



Access to a "garage" of vehicles

Integration with multi-mode transportation

Alternative finance models for early adoption

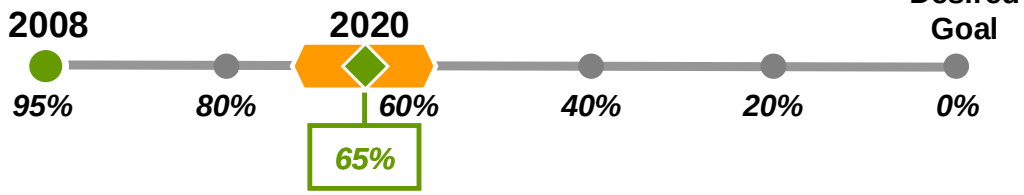
The intelligent vehicle of 2020 will be …. *Green*

- Every new light vehicle will have some level of hybridization
- Li-ion batteries will be dominant
- Hydrogen fuel cell penetration will be limited
- Bio-fuels will continue to evolve

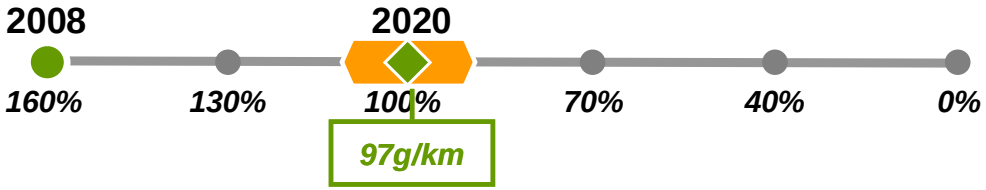
Sizeable investments will pay rich dividends towards sustainability….. but expectations will outpace achievements

Global portfolio of new vehicle production in 2020

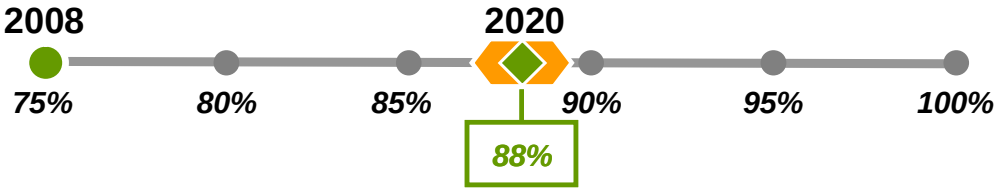
Fuel (% of total fuel is based on fossil fuels)



Air (average level of CO2 emissions per vehicle in g/km)



Recycle-ability (average % of the vehicle is recyclable)



The intelligent vehicle of 2020 will be …. *Connected*

Safety

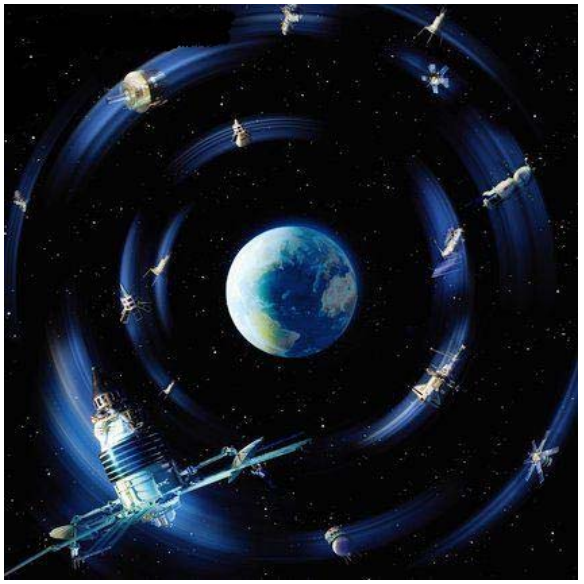
- Intersection control violations
- Lane/road departure
- Road surface conditions
- 360/distance visions

Driver Assistance

- Dynamic route guidance/navigation
- Data downloads (entertainment, media, home network, personal preferences)
- Electronic payments - toll, drive thru, parking, road pricing

Service

- Remote vehicle diagnostics, prognostics and self healing
- Transfer of warranty based data
- Connected customer relations management



The Heavy Truck segment provides significant opportunities for hybrid technologies

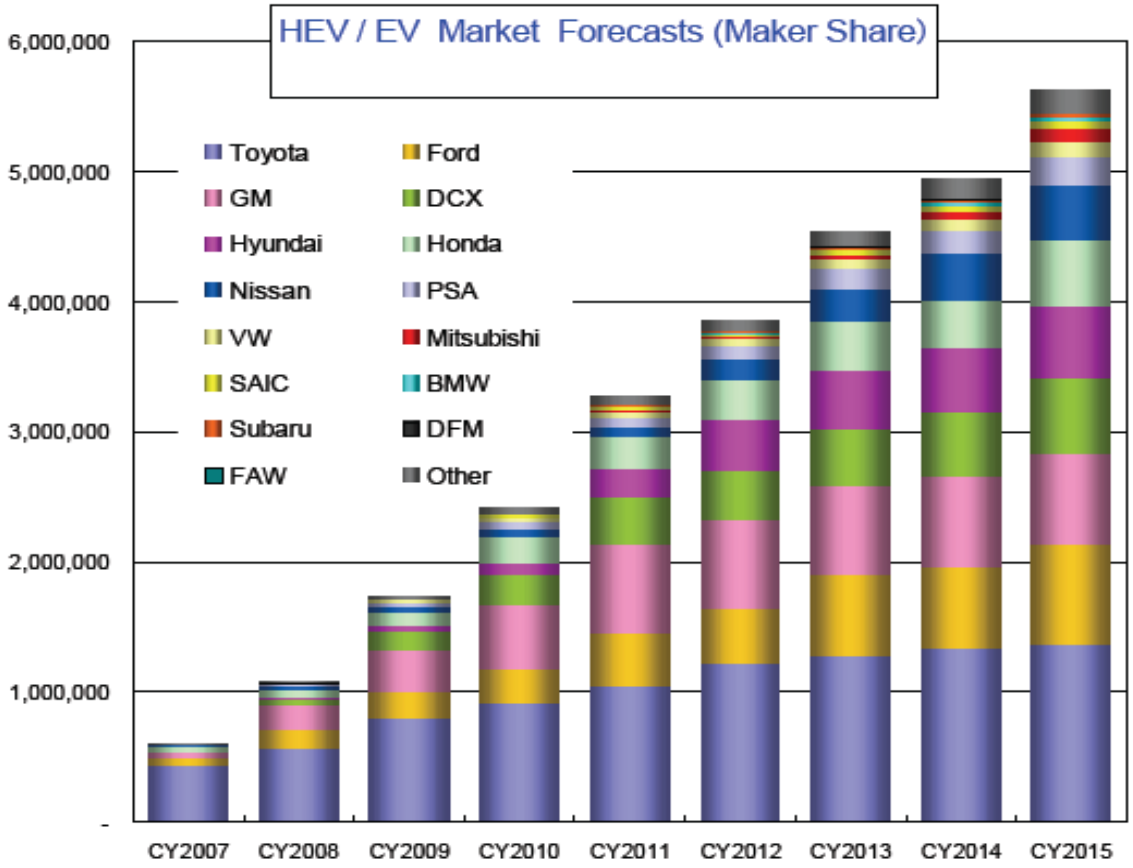
- Heavy Truck
  - 10% of vehicles in the US are heavy trucks and account for 50% of the fuel consumption
  - Public Buses benefit from tax regulations and alternatively powered buses have grown to over 3000
  - Heavy Truck segment stands to benefit especially from solutions that include hydraulic systems applications
  - Mack, International, Peterbilt, and Volvo Trucks (amongst others) have hybrid solutions in their portfolio
  - Typical usage in trucks is Parallel Hybrid Architecture (both engine and motor connected to the drive train)

The Heavy Equipment segment is in relatively early stages of hybridization

- Heavy Equipment
  - Hybrid development within the heavy equipment segment is in its early stages
  - Caterpillar's D7E Crawler Dozer is one of the first electrically driven dozers and can move 25% more material per gallon
  - Volvo Construction Equipment has started manufacturing its first-of-a-kind hybrid wheeled loader with 10% less fuel consumption
  - Komatsu introduced its hybrid excavator with 30% better fuel economy and expects to sell 1500 units by 2010

Robust growth is forecast for the worldwide HEV/EV market, and Lithium ion battery technology will play a major role in this growth

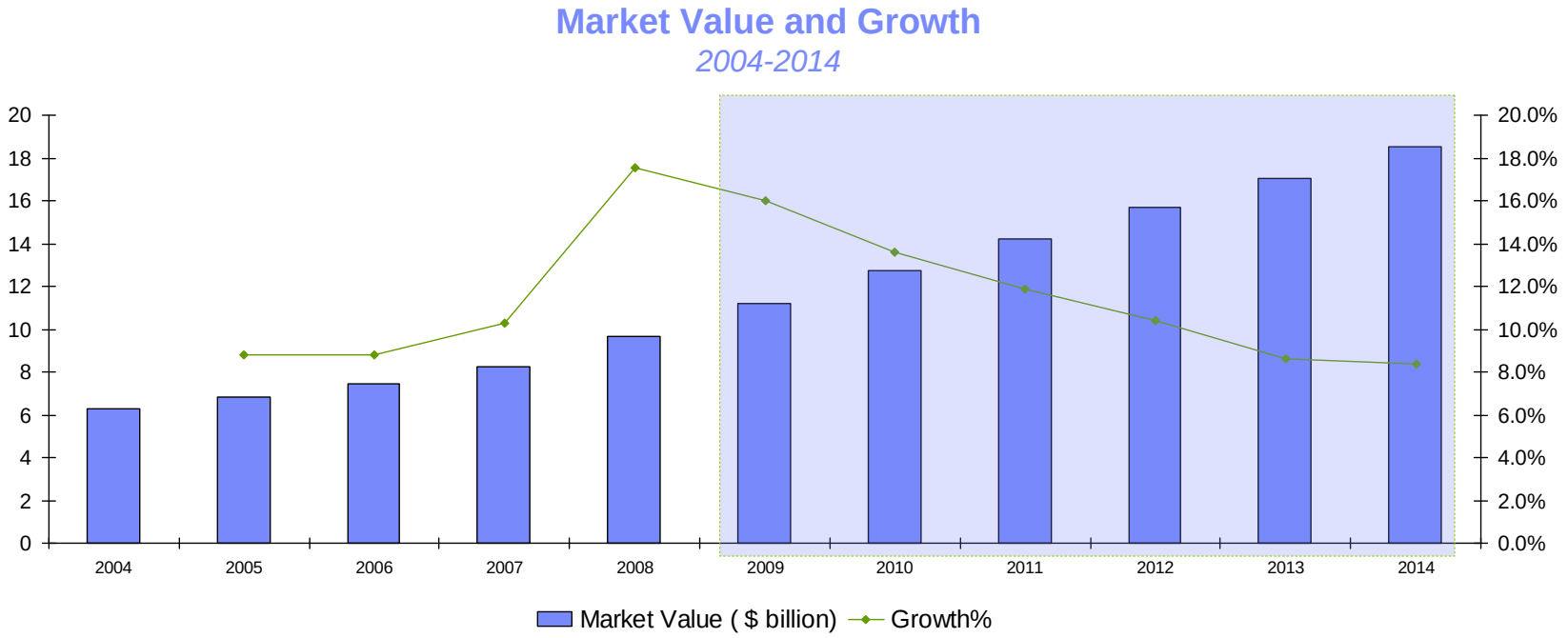
- Notwithstanding fluctuations in oil prices, the shift to alternative powertrains is here to stay.
- Electric powered vehicles (Both Hybrid and pure Electric vehicles) market is expanding by leaps and bounds and is estimated to be over 5.6 million units by the year 2015, and Lithium ion technology is expected to drive this future growth



Source : Hiedge

Latent demand for lithium-ion batteries for plug-in hybrid and pure electric vehicles is $9.7 billion in 2008, and is forecast to reach a value of $18.5 billion by the year 2014

- The **global latent demand** for lithium-ion batteries for **plug-in hybrid and pure electric vehicles** is **$9.65 billion** in **2008**, this representing a compound annual growth rate **(CAGR) of 11.3%** for the period spanning 2004-2008.
- From 2009-2014 the market is expected to grow at a CAGR of 11.4% to a value of **$18.5 billion** by the end of 2014



Source :The 2009-2014 World Outlook for Lithium-Ion Batteries for Plug-In Hybrid and Pure Electric Vehicles : Icon Group; 2008

Automotive Powertrain applications provide a wide range of alternatives

- **Engine Downsize:** Performance is retained by supplementing the power of the IC engine with the electric motor
- **Regenerative Braking:** Recharges the batteries thus recovering energy that would otherwise be lost as heat
- **Electric Launch & Drive:** Propels the vehicle without turning on the IC engine

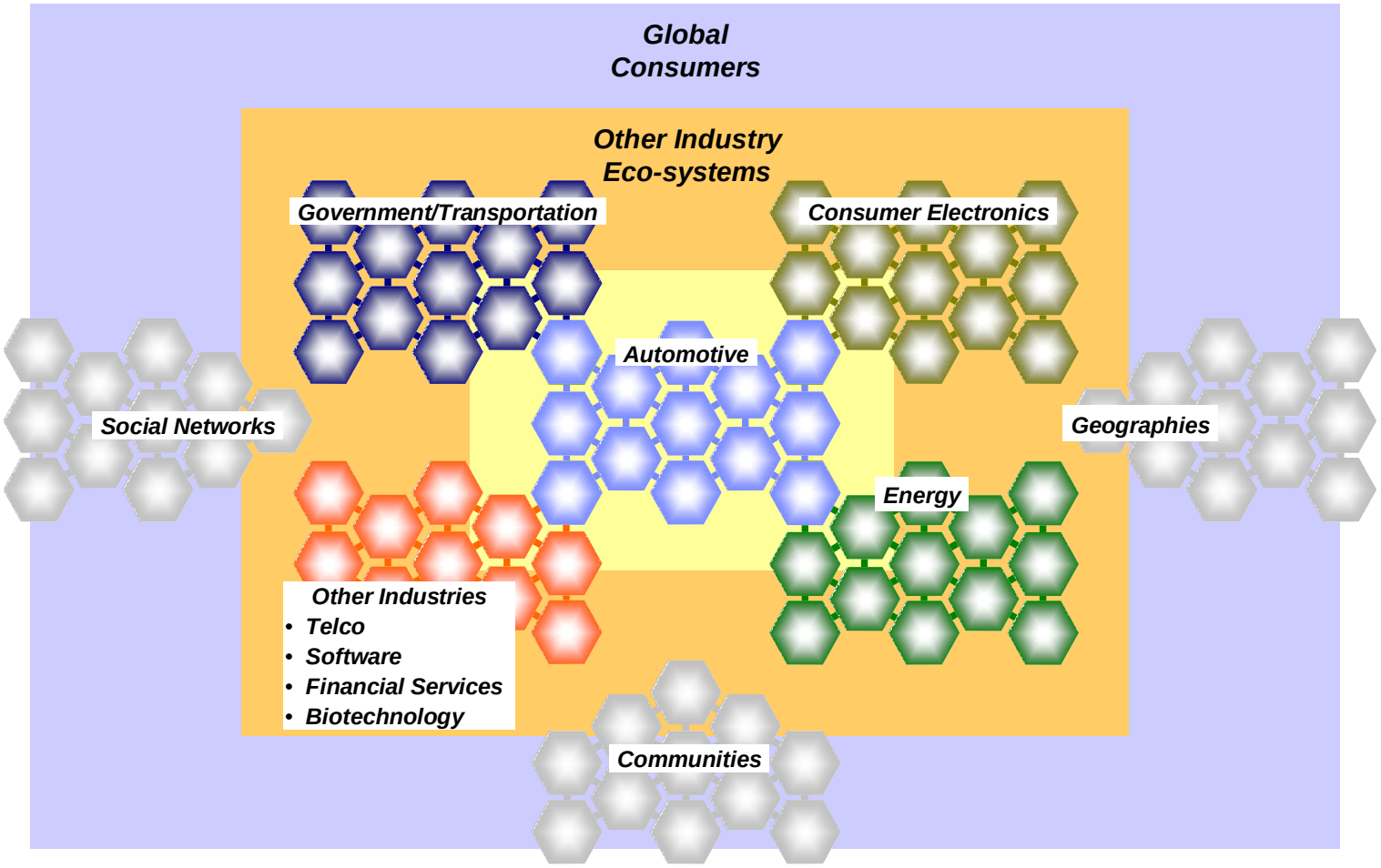
HEVs

Electrification/ Hybridization Level	Engine Shutdown & Restart	Engine Downsize	Regenerative Braking	Electric Launch & Drive
Conventional IC Engine	✓			
Micro Hybrid	✓	✓		
Mini / Mild Hybrid	✓	✓	✓	
Full Hybrid Powertrain	✓	✓	✓	✓
PHEV	✓	✓	✓	✓
R-EV	✓	✓	✓	✓
EV	✓	✓	✓	✓

Automotive Powertrain applications are poised to provide substantial fossil fuel savings

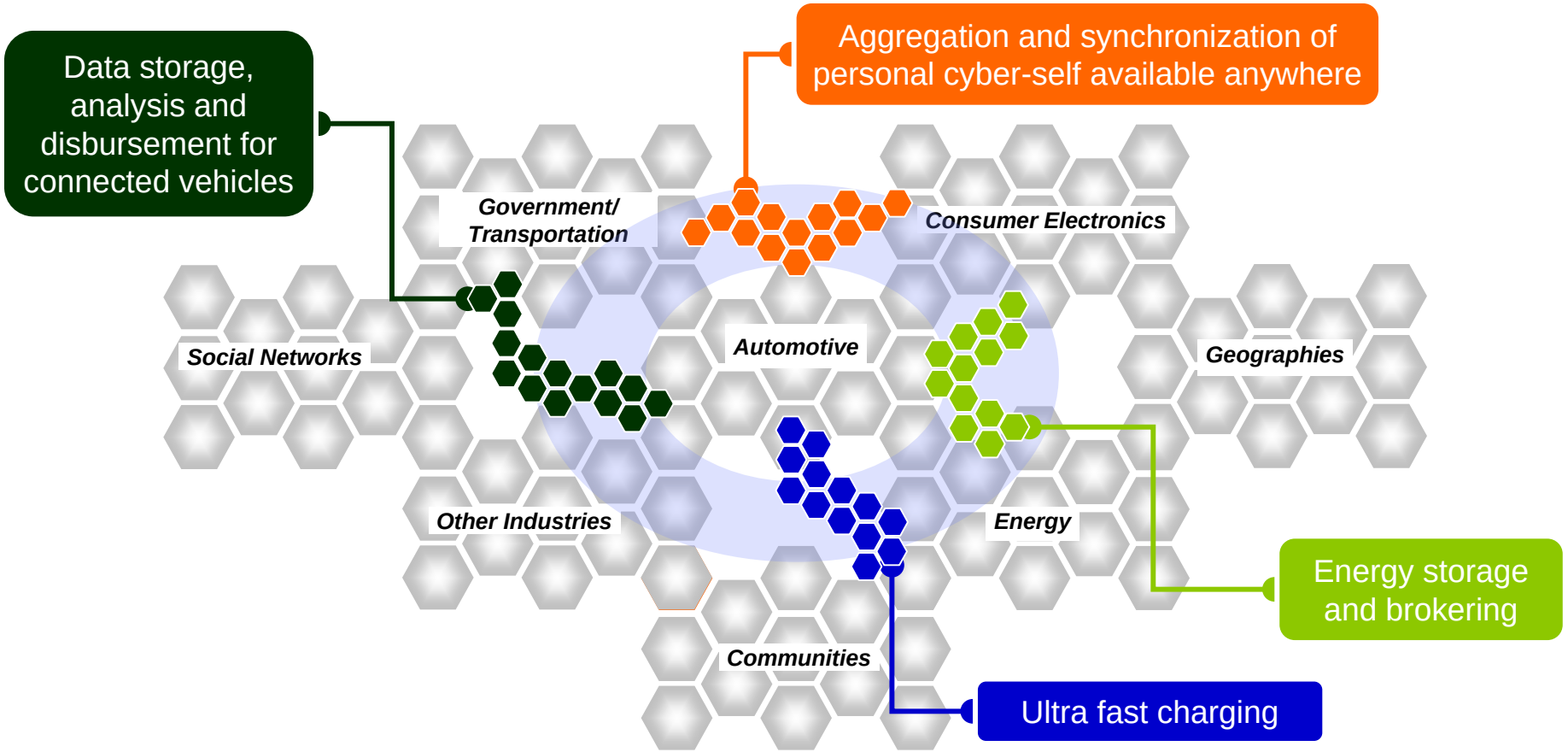
	Conventional Car	Fuel Eco Hybrid	PHEV-REV	Electric Vehicle
Total Range • Electric Range • Gasoline Range	350 miles none 350 miles	450-550 miles < 2 miles 450-550 miles	330-370 miles 30-70 miles 300 miles	100 miles 100 miles none
Fuel Economy	25 mpg	45 - 55 mpg	75-150 mpg (eqv)	100-200 mpg(eqv)
Annual Fuel Savings $4/gallon	Base	$500-$750 15K miles/year, 50%city	$1500-$2500 100%city	$2500-$3000 100% city and long trips
Re-Fueling	Fill-up	Fill-up	Plug-in (daily use) Fill-up (long trips)	Plug-in
Environmental Friendliness (incl. vehicle emissions)	Base	SULEV 	SULEV on gas Zero on Electric 	Zero emissions 
Performance	Base	Equal or better	Equal or better	Equivalent
Price Premium	Base	$2000-$5000	>$8000	>$15000

The need to execute in interdependent ecosystems will be critical and requires the highest degree of change



Source: IBV Analysis, Auto 2020 Global Interviews (n=103)

New business models will emerge at the intersection of industries



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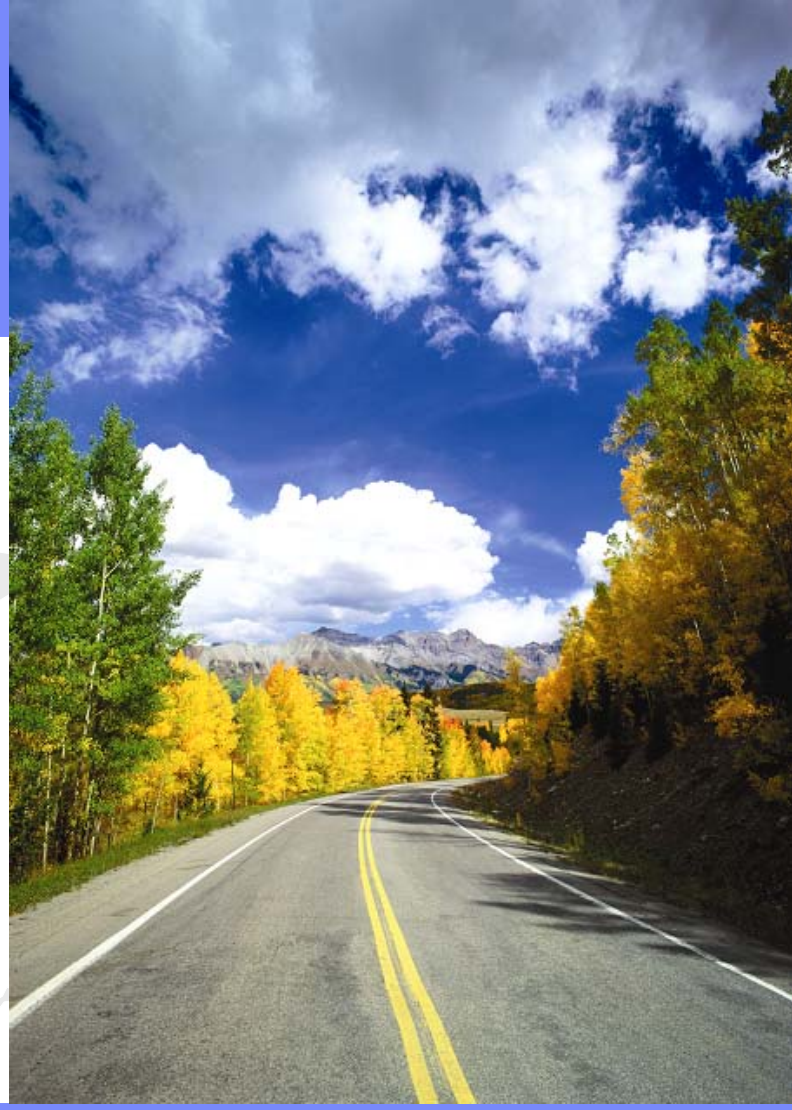
Automotive 2020: Clarity Beyond the Chaos



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Battery Technology Comparison

Cell Couple	Theoretical Limit (Wh/Kg)	Current State (Wh/Kg)
Pb Acid	250	40
Ni-Cd	245	55
Ni- Fe	315	55
Ni- Zn	370	70
Ni- MH	240	80
Al-Air	8100	200
Zn-Air	1350	200
Zn- Br_2	570	70
Na- S	790	180
Li- FeS_2	459	130
Li- Ion	385	200

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Ni-MH vs. Li-Ion – a comparison

Attribute	Ni-MH	Li-ion
Energy Density (Wh/Kg)	80	200
Power Density (W/Kg)	1600	>3000
Volumetric Energy Density (Wh/L)	200	550
Cost ($/kWh)	35	30-35
Self Discharge (per month), %	15%	5%
In/Out Efficiency (%)	90	> 95
Temperature Range	-10 - 40	-30 - 50
Cycle Life	900 (EV) 300K (HEV)	1000 (EV) 300K (HEV)
Calendar Life (years)	> 10	>10

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