



**KEYSIGHT**  
**WORLD 2019**

# Bring Breakthrough Electric Vehicle Innovations to Market Faster

*Tom Goetzl*

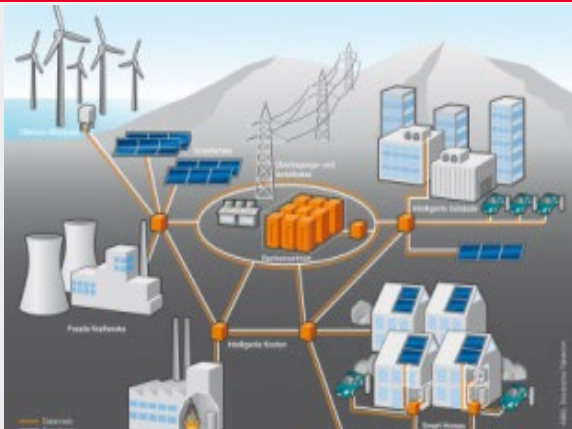
*Automotive & Energy Solutions Business General Manager  
Keysight Technologies*



# Keysight's Energy & Automotive Solutions

INNOVATIONS FOR A RAPIDLY GROWING & CONVERGING MARKET

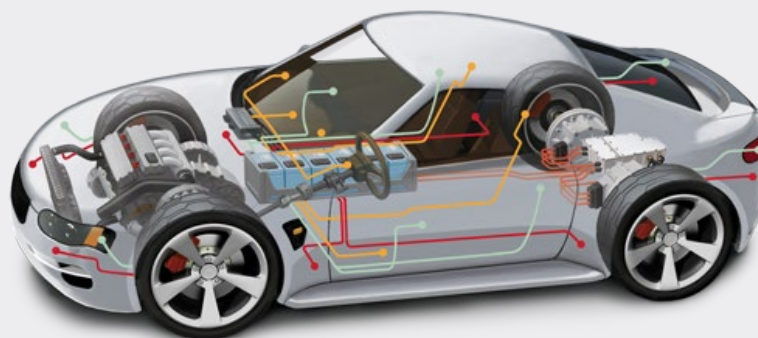
## Energy



Distributed generation of energy is driving innovation

- Alternative energy generation
- Smart consumption
- Storage solutions
- New power semiconductor technology

## Automotive



Electrification is occurring at astonishing speed

- Electrical powertrain
- Autonomous driving
- Connected cars
- Infrastructure buildout for power and communication

# Agenda



The Adoption of  
the Electric Vehicle



The Transformation of  
the Energy Industry



EV Technology Advancements  
and Test Challenges



# The Adoption of the Electric Vehicle



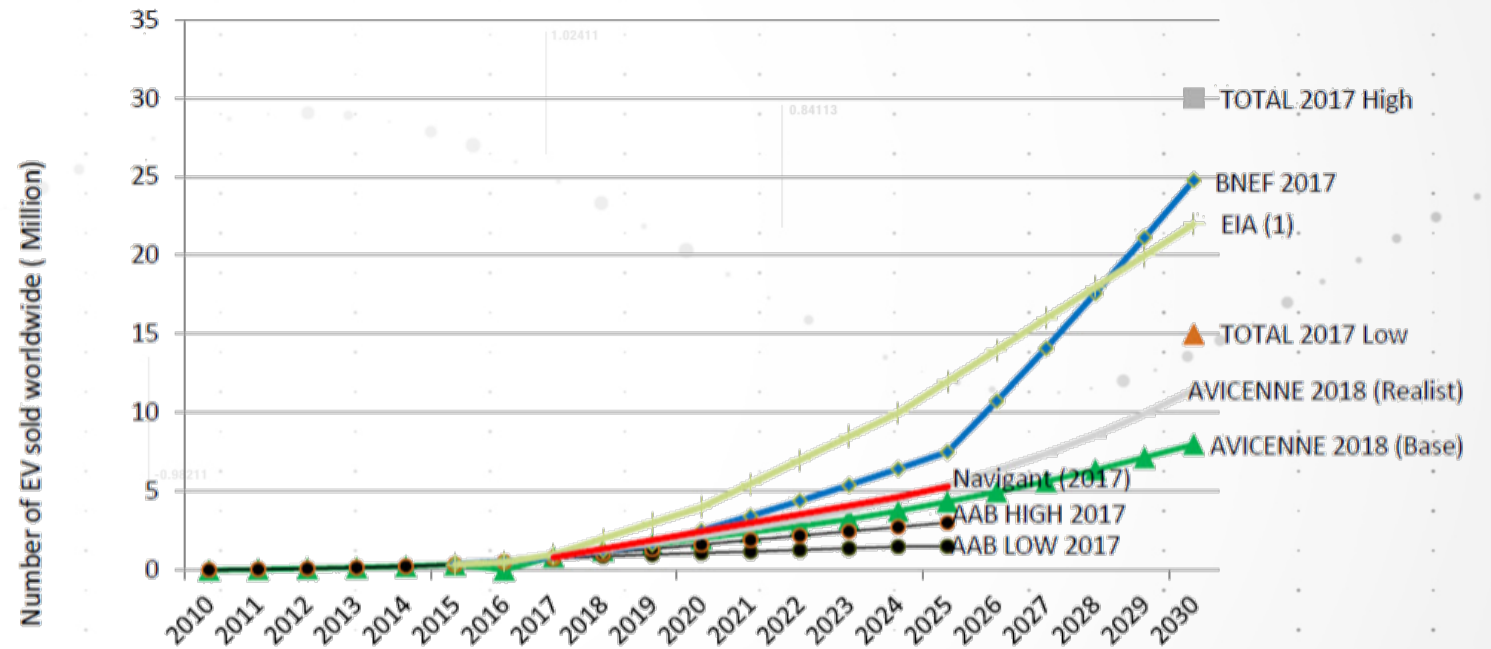
# Adoption Of The Electric Vehicle (EV & HEV)

MARKET FORECASTED TO GROW TO >12M UNITS BY 2030

- Battery Technologies are the critical enabling technology.
- Alternative energy generation is required to generate emission free miles.
- Charging Infrastructure needs to be built up broadly.



EV sold, in million units, worldwide, 2010 - 2030



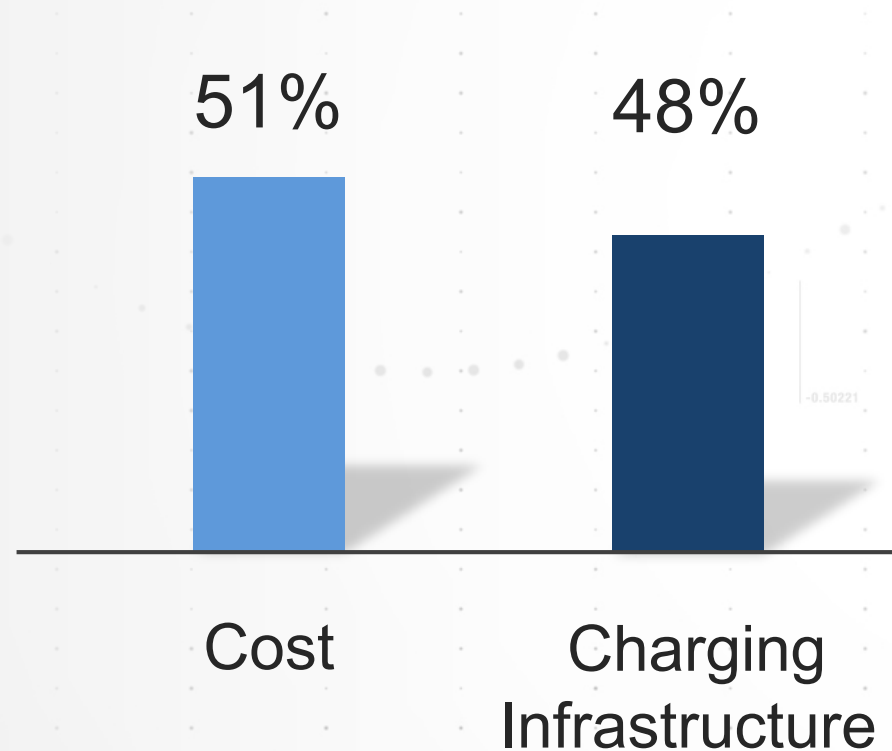
AAB, AABC US, June 2017  
BNEF, BATTERIES 2017, October 2017  
AVICENNE Analysis 2019

(1) EIA – Avicenne estimation based on "Stock" numbers

# Consumer Adoption Of EV Is Still A Challenge

REAL AND PERCEIVED HURDLES TO OVERCOME

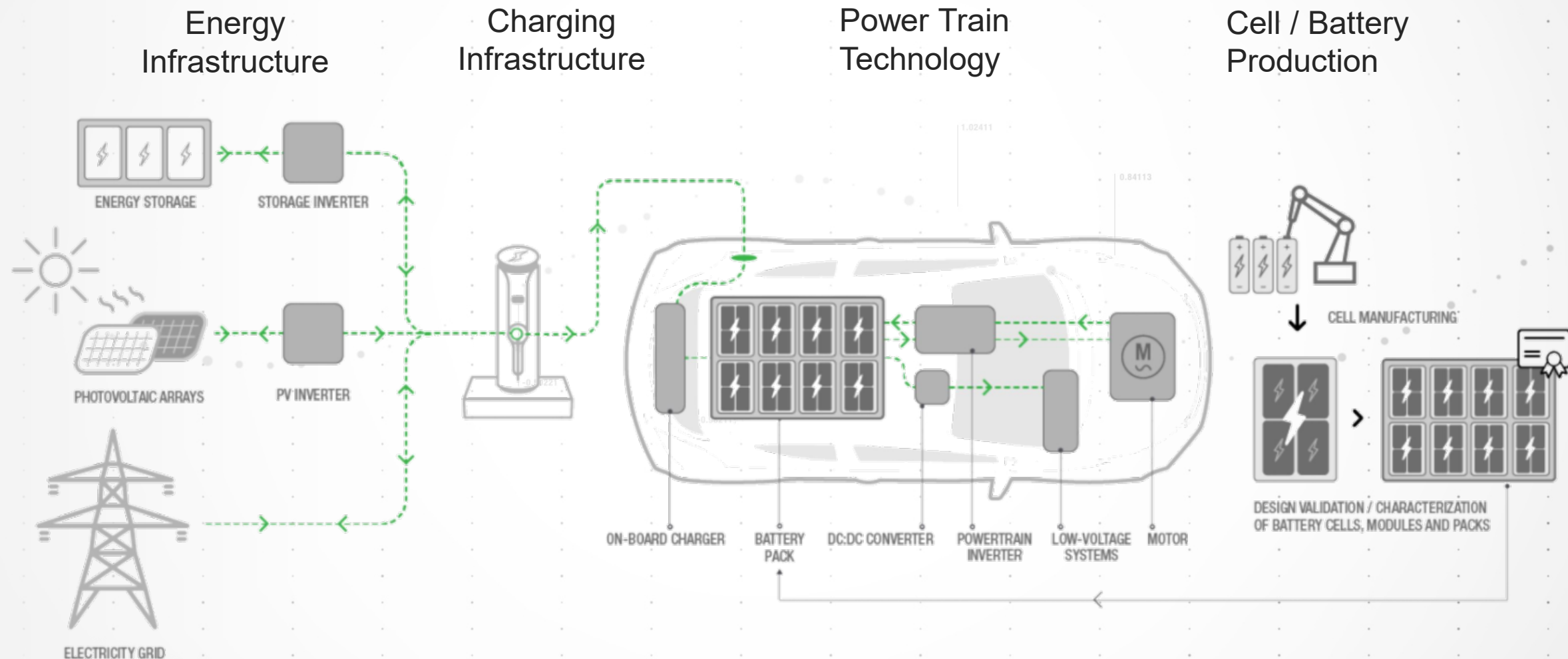
Why would you NOT consider buying or leasing a (plug-in) electric vehicle?



- **51%** of consumers believe EVs are **Too Expensive**
- **48%** struggle with the **Charging Infrastructure**
- **Median EV range** of **300 miles** is necessary for consumer acceptance

# Electric Vehicles Drive Technology Investments

MARKET DRIVERS APPLY PRESSURE ON THE EV ECOSYSTEM





# The Transformation of the Energy Industry





# Readying The Grid For The EV Revolution

## TRENDS SHAPING THE FUTURE OF ELECTRICITY

EVs are adding **3,461TWh of new electricity demand** by 2050!

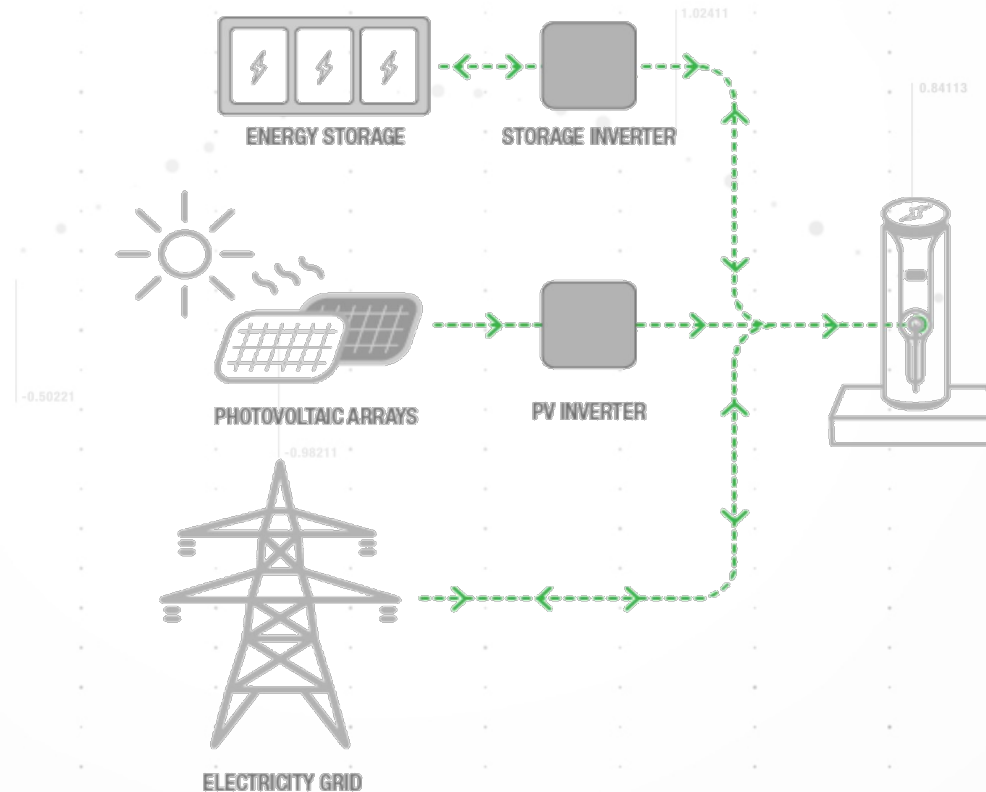
(Bloomberg)

**\$548 billion** investment in **grid-tied battery storage** 2018-2050

(Bloomberg)

**\$11.5 trillion** investment in **renewables** 2018-2050

(Bloomberg)



# Vehicle Electrification Transforming The Energy Industry

## CRUCIAL ELEMENTS OF THE EV REVOLUTION



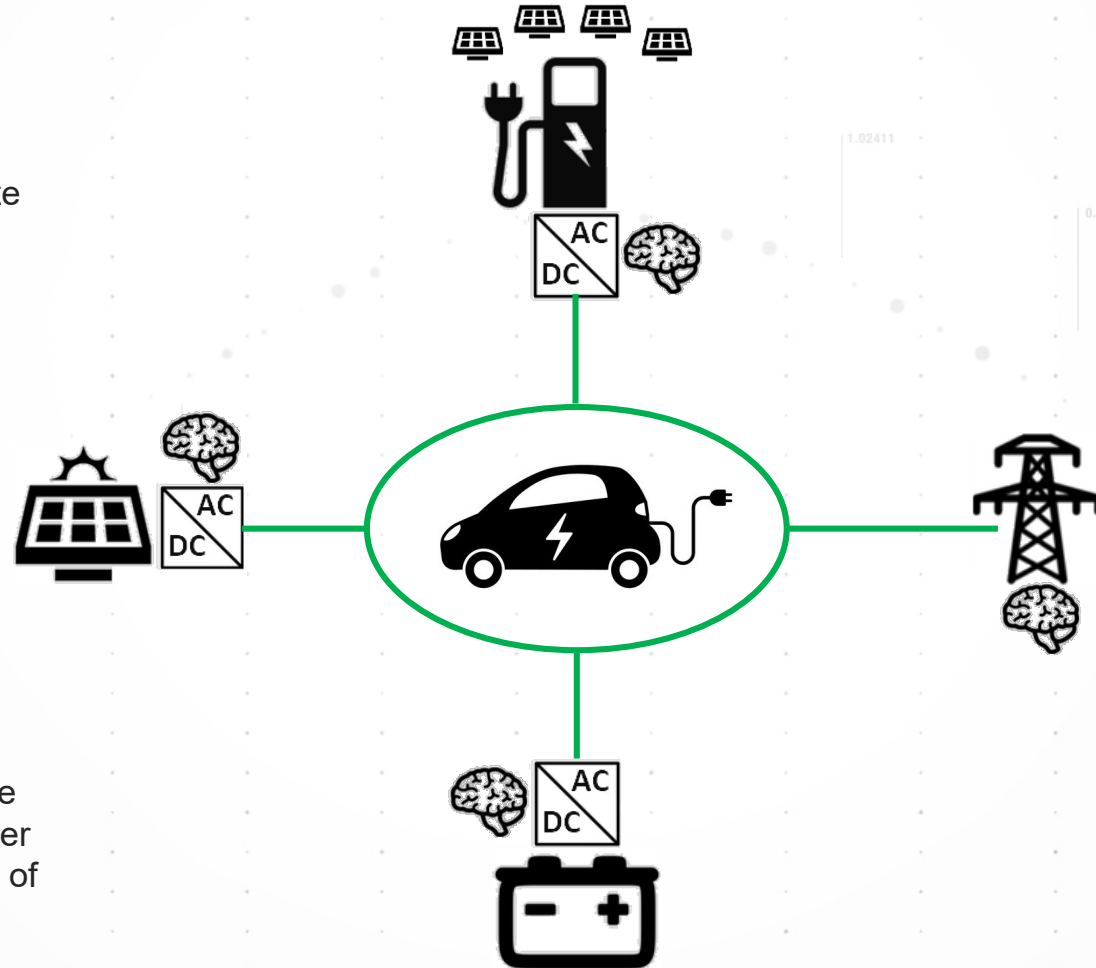
### DECARBONIZATION

Regional policies pushing to accelerate availability of cheap electricity from renewables



### SECTOR COUPLING

Additions of energy storage to balance supply / demand, increase overall power system efficiency and reduce total cost of EV ownership



### DECENTRALIZATION

Distributed energy resources (DER) such as PV help meet EV electricity demand while deferring expensive grid upgrades for charging infrastructure development



### GRID INTEGRATION

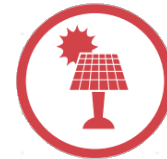
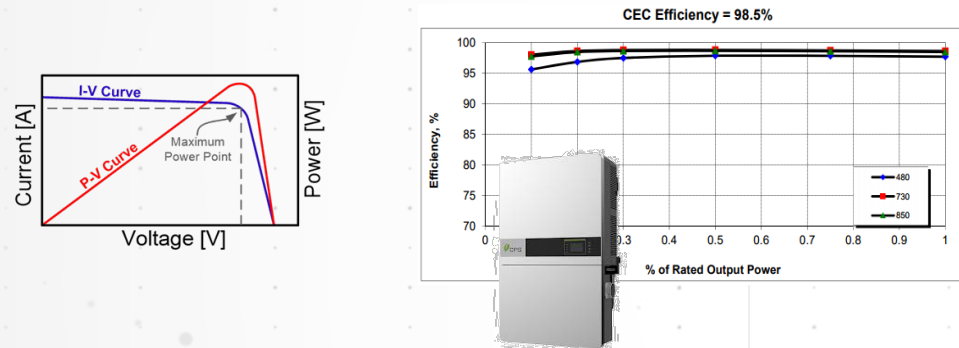
Coordinated interoperability to maintain grid reliability as penetration of variable energy resources increases

# Innovations At The Grid Edge

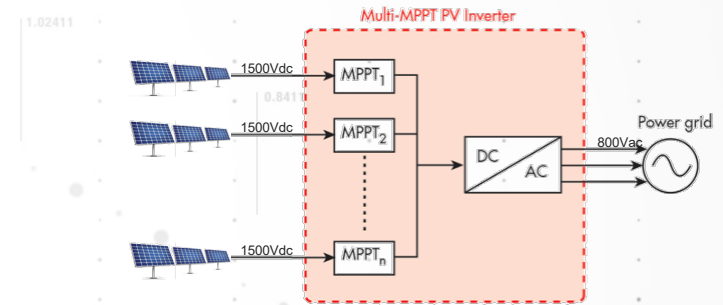
## NEW CHALLENGES FOR DEVELOPERS OF GRID-TIED POWER CONVERSION SYSTEMS



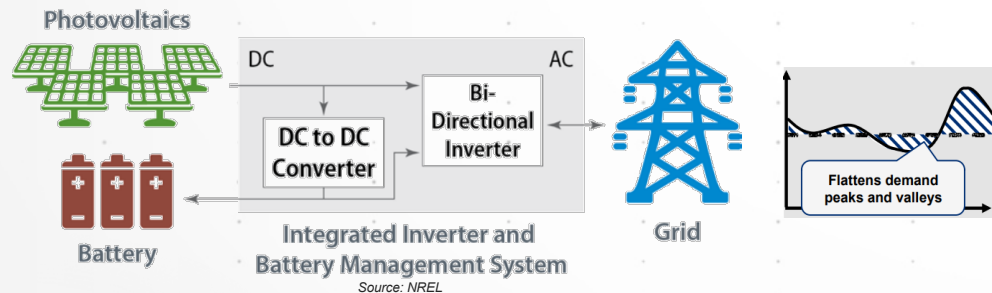
Maximizing efficiency / increasing performance bankability to reduce the total cost of solar



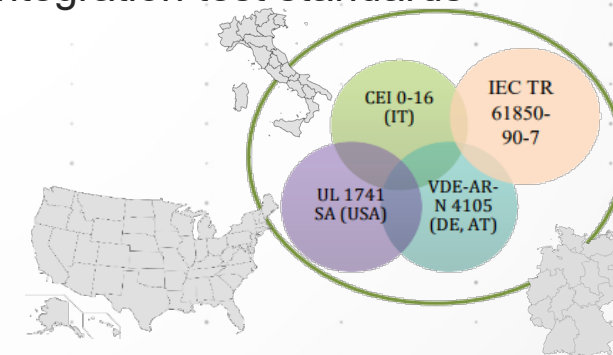
Characterizing performance of new multi-string PV inverters with higher AC+DC voltages and several internal maximum power point trackers



Testing high-voltage energy storage systems and PV+storage inverters with bi-directional power flow



Verifying new smart inverter grid support compliance with regional grid codes / constantly changing grid integration test standards





# Accelerating And Optimizing New Grid-Tied PCS

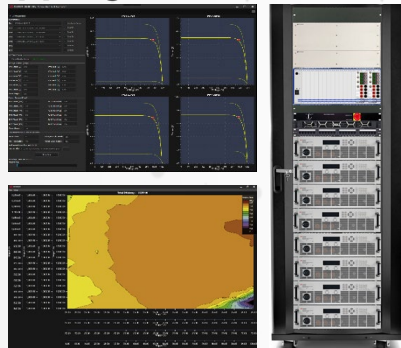
LOWER COST, FASTER TTM, INCREASED PERFORMANCE



## CHALLENGE

Maximizing efficiency and performance bankability

### PV Inverter Efficiency Mapping Characterization



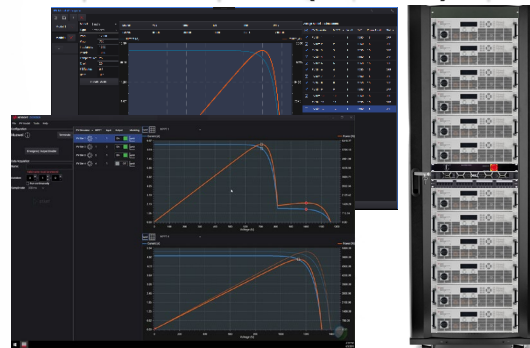
Better / faster efficiency characterization, higher energy yields, increased bankability



## CHALLENGE

Test complexity for multi-string PV inverters

### Distributed Solar Array Simulation (D-SAS)



Reduced complexity, faster testing, more realistic test cases



## CHALLENGE

Bi-directional battery and PV+storage inverter testing

### High-Voltage Regenerative Battery+PV Simulator



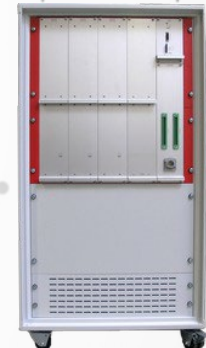
Universal DER simulation, reduced energy consumption / cooling



## CHALLENGE

Verifying smart inverter grid support functions

### High-Voltage 4-Quadrant Regenerative Grid Simulator



Programmable emulation of grid codes / standards, reduced energy consumption / cooling

## BENEFITS

Lower cost  
Faster time-to-market  
Increased performance / reliability

# EV Technology Advancements and Test Challenges



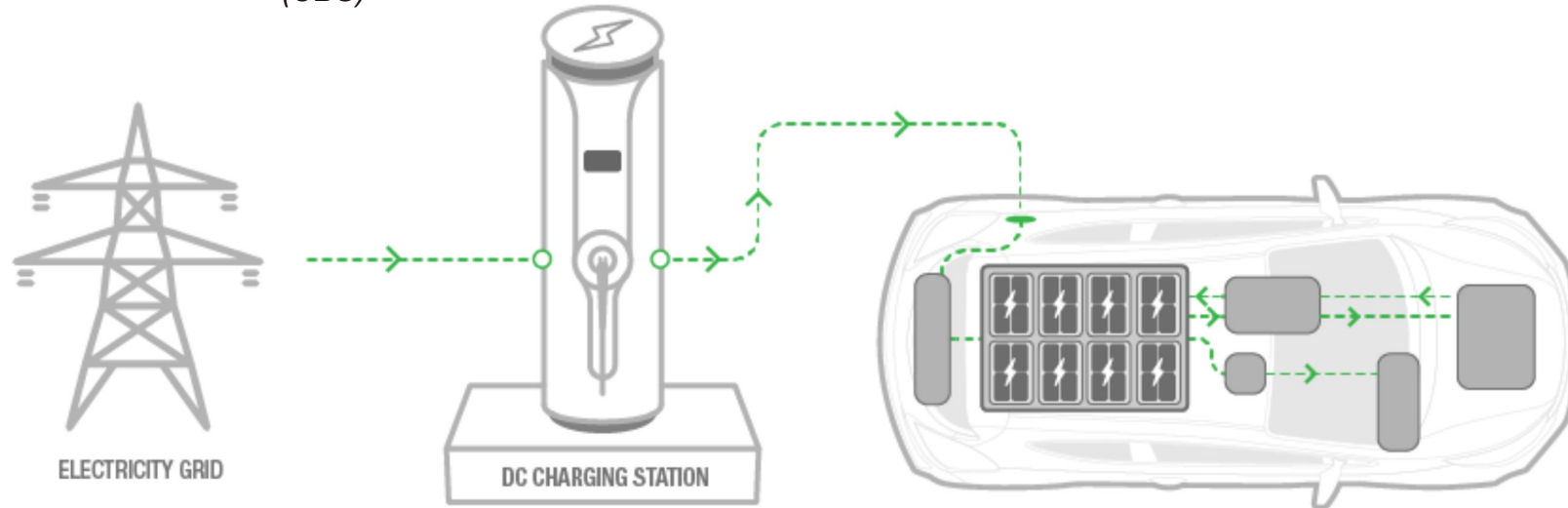
# Electric Vehicles Drive Technology Investments

## INFRASTRUCTURE CHALLENGES: INTEROPERABILITY AND CONFORMANCE

20 Million Charging Stations

Worldwide Expected in 2025

(UBS)



Fast Charging Expectations:

CCS **450 kW**

GB/T **900 kW**

Heavy Duty EVs **1.5 MW**

(CharIN, CHAdeMO Association)

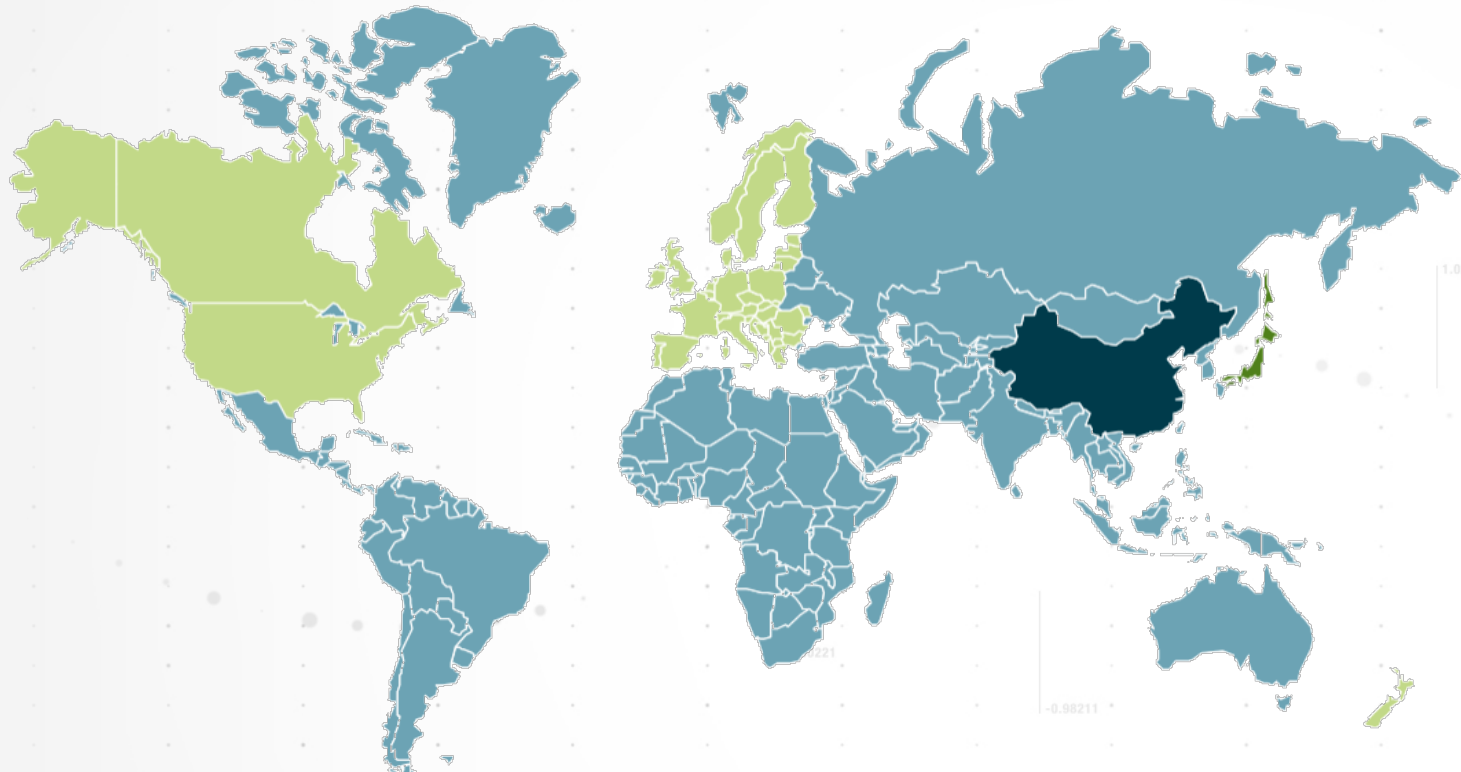
Harmonization of Charging Standards:

Preferable: One worldwide standard

BUT: **Different economical and political interests will stop the harmonization of one worldwide standard**

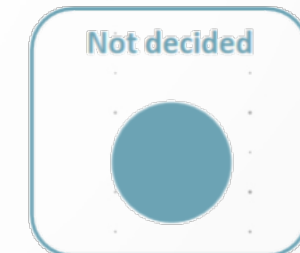


# Different Charging Standards Worldwide



## MARKET CHALLENGE

- OEMs want to sell EVs worldwide
- All the different standards need to be fulfilled

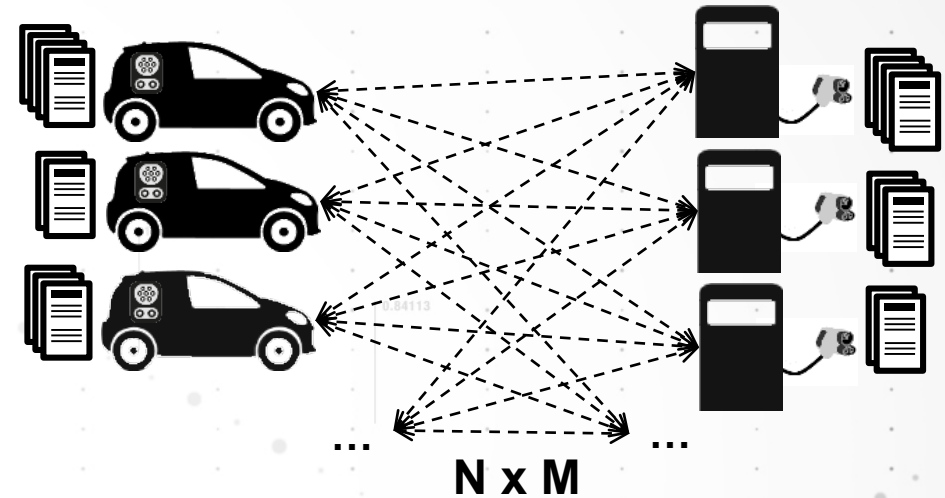


Source: CharIN

# Keysight Enables Automated Interoperability Testing

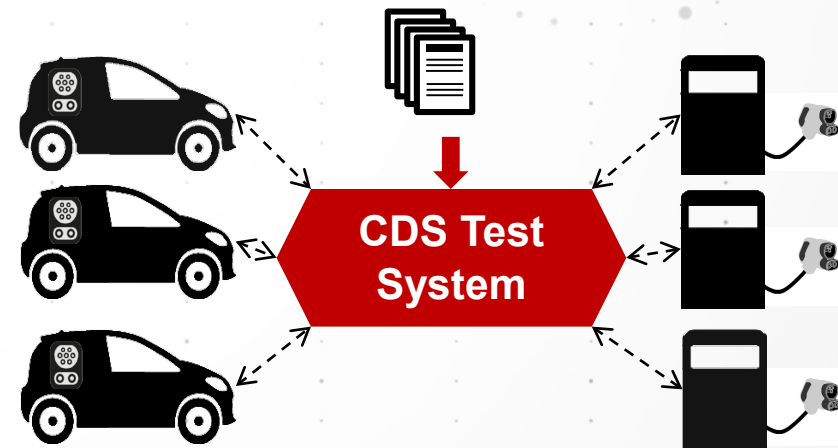
## MANUAL TESTING

- Implementation vs. Implementation (good case only)
- Not feasible for growing market



## AUTOMATED TESTING

- Test cases vs. Implementation (good AND error cases)
- Scalable for growing market

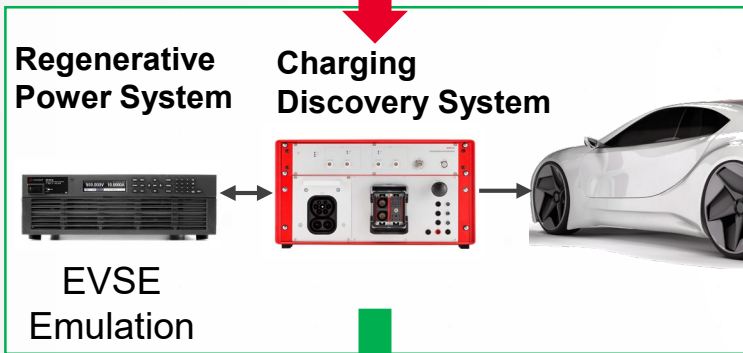


# Keysight Enables Effective Charging Interface Testing

## EV Test

### CHALLENGE

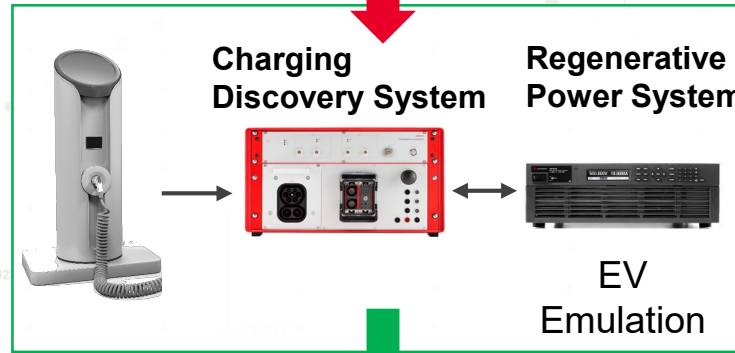
EVSE needs to be emulated according to all worldwide standards and grids



## EVSE Test

### CHALLENGE

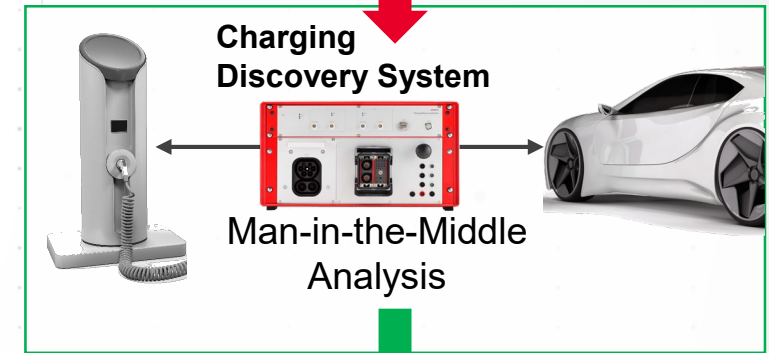
Different EVs need to be emulated with different worldwide standards



## Man-in-the-Middle Test

### CHALLENGE

EV and EVSE need to be interoperable according to the same, worldwide standards



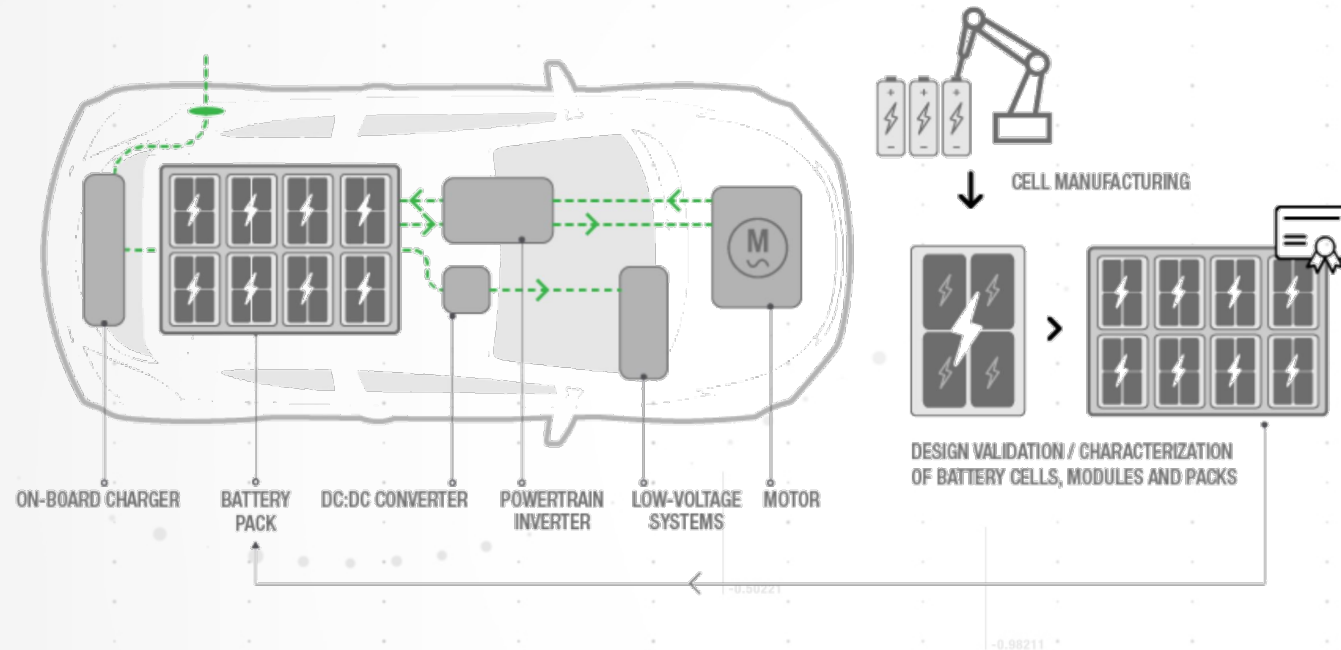
## BENEFITS

- Fully integrated test solution allowing automation of all conformance test cases
  - Easy to use, state-of-the-art Software
- Ensures faster time to market



# Electric Vehicles Drive Technology Investments

CELL/BATTERY DESIGN VALIDATION: PERFORMANCE, RELIABILITY, AND FAST TTM



- 75% Reduction in Battery Cost
- 75% Increase in Battery Capacity
- 35% Reduction in Battery Size and Weight by 2022 (NREL)

- Reduced Vehicle Platform Longevity
- Increase in Regulations
- Consumer Preferences are becoming more Fractionalized
- = Shorter Product Development Cycles (Center for Automotive Research)

# Comprehensive Battery Test Solutions Are Needed

## MARKET CHALLENGE

- Bring more EV models to market quickly,
- Reduce costs and extend the range of the EV



Need to create a lab that allows:

- Cell chemistry research and development
- Validation and functional tests of battery cells, modules and packs incl. Battery Management System (BMS)

**AND is cost effective!**

# Challenges In Battery Testing

Task Management

Testing Capacities

Resource Management

Big Data Management

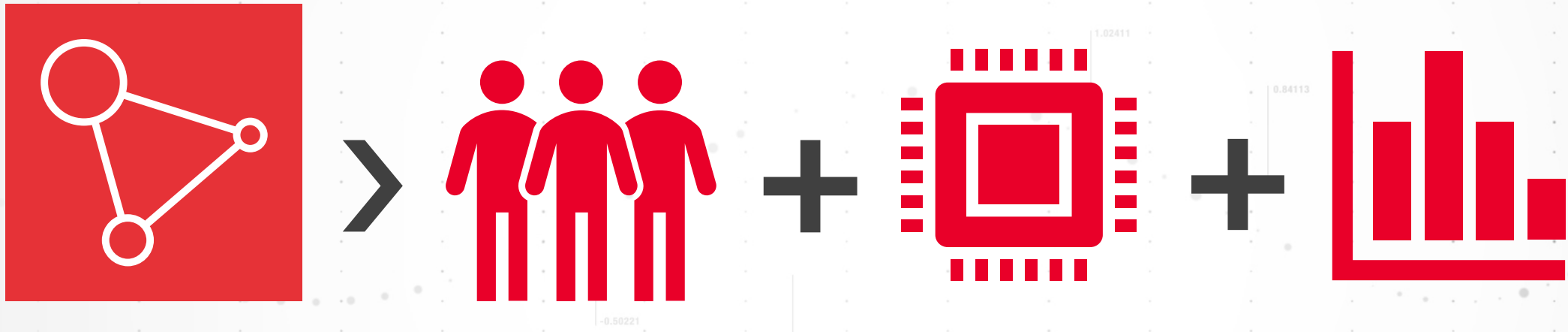
Test Efficiency

Increased Test Automation



# Challenges In Design Validation Workflow Management

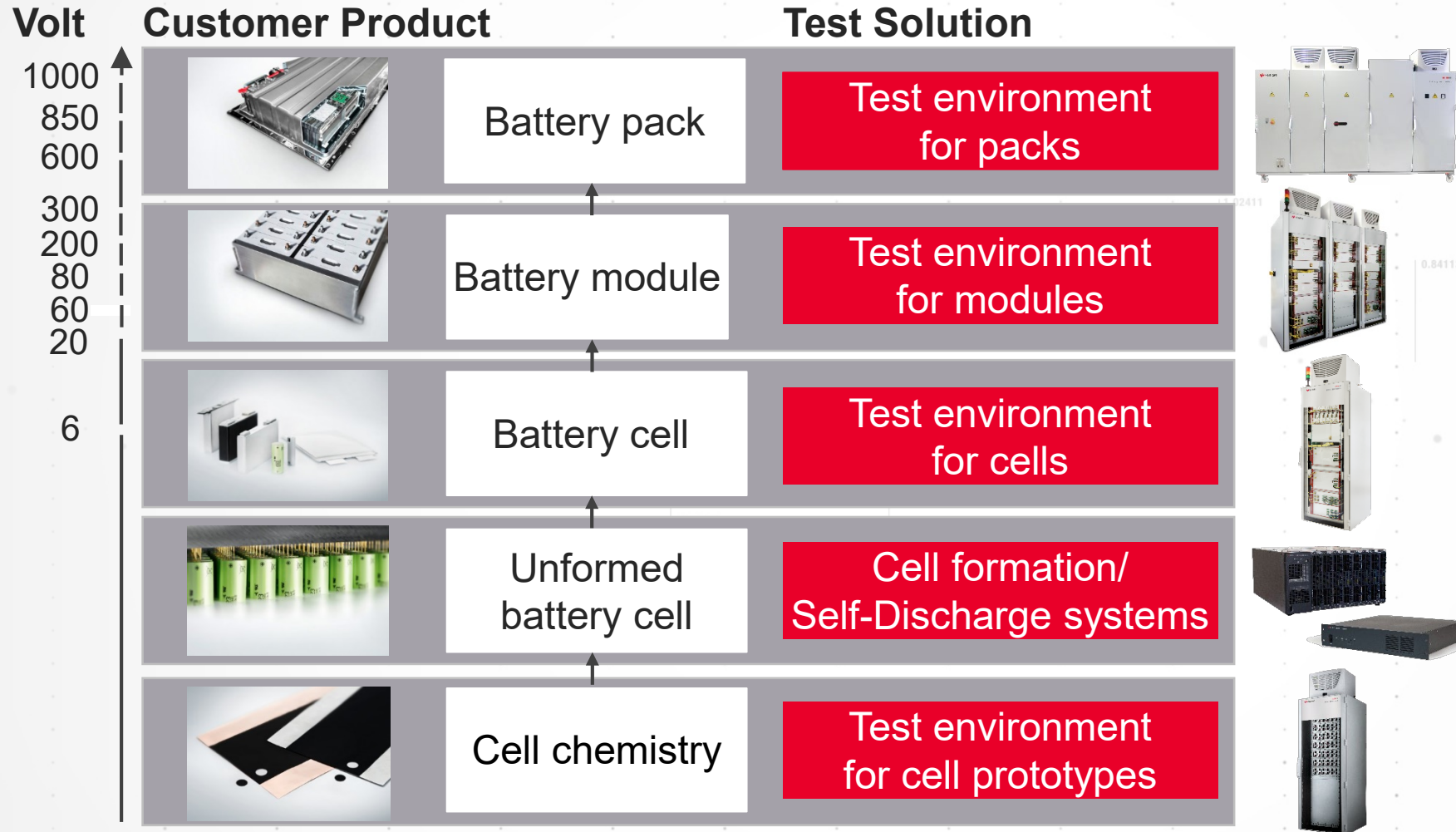
A large lab has many challenges. In general, it will require the management of **people**, **hardware** and **information**.



## BENEFITS

- Workflow management and effective handling of all resources (Lab Operations for Automotive Battery Test)
  - Ensures high utilization of the laboratory
- Comprehensive testing with one state-of-the-art battery test operating software (ESD)
  - Ensures high quality cells and batteries

# Battery Test Solutions From Cell Chemistry To Packs



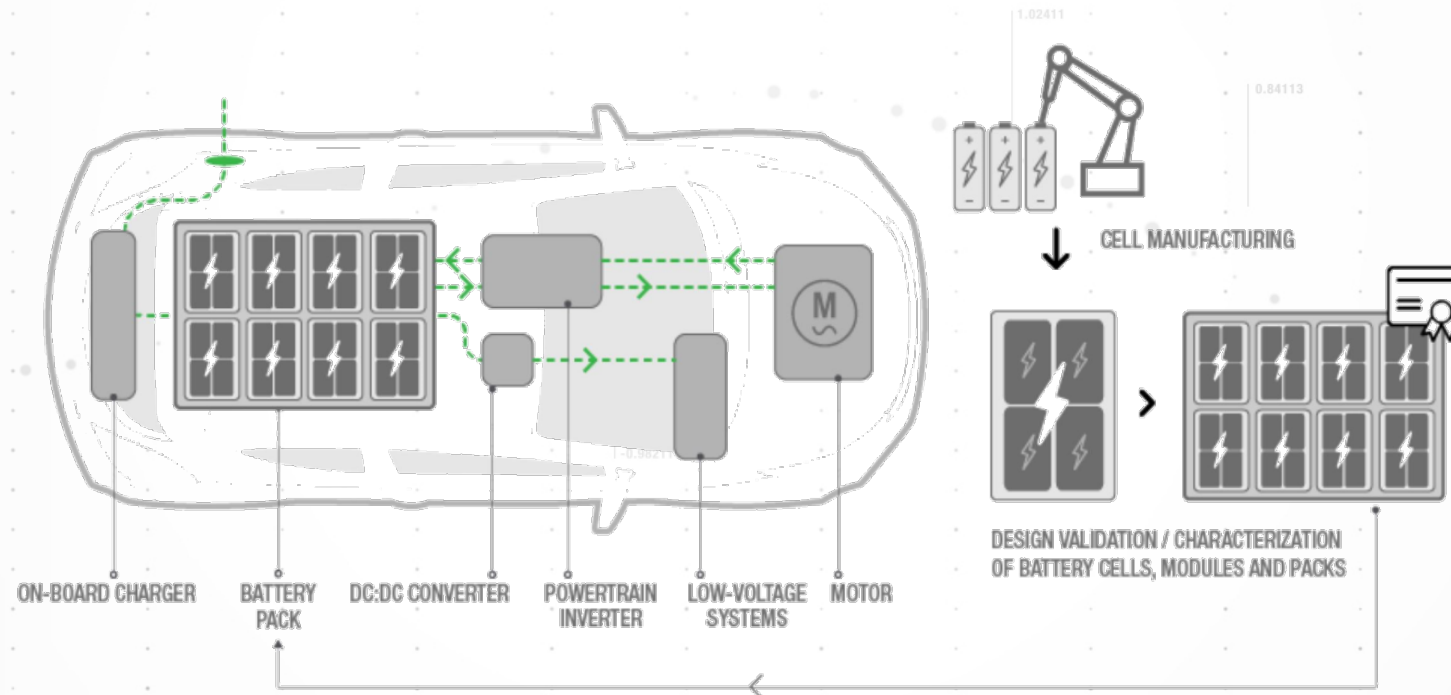
## BENEFITS

- Entire process chain of battery test can be covered
- One operating software for all applications

# Electric Vehicles Drive Technology Investments

CELL MANUFACTURING: CELL COST AND CELL AVAILABILITY ARE CRITICAL

Annual **demand for cell** predicted to **increase**  
from **120 GWh** in 2017 to **1000 GWh** in 2030



**\$70/KWh** Lithium-ion **battery pack prices** by 2030



# Cells Are Critical To EV Adoption

OEMS INVESTING \$300B TO BRING EV TO MAINSTREAM



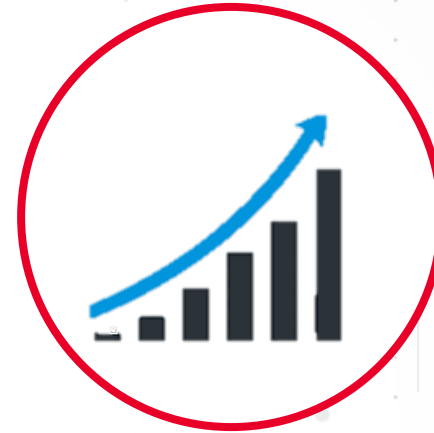
## EV User Experience must be similar to ICE

- Cost too high  
**Must reduce cell cost**
- Range too low  
**Must improve cells**
- Charge time too long  
**Must improve cells, converters, chargers**



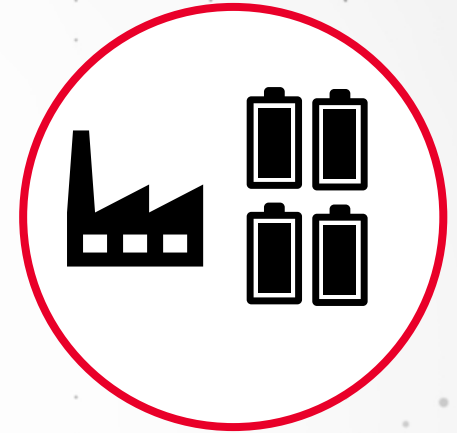
## Cost of cells must come down

- ICE: \$ 80/kWh equivalent
- EV: \$150/kWh ← *Too high*
- 2018 Cell Manufacturers:
  - Revenue= \$32B
  - Profit = 0%



## Supply of cells must meet demand

- EV demand explodes
- 2017: 120 GWh
- 2030: 1000 GWh
- > 30% CAGR
- Need more Gigafactories



## Supply of cells must be assured

- OEMs want cell factories near EV factories
- New entrants to cell mfg
- Example: Europe to add 70 GWh by 2025

**New materials - Better cells - Lower mfg cost - New factories - Right location**

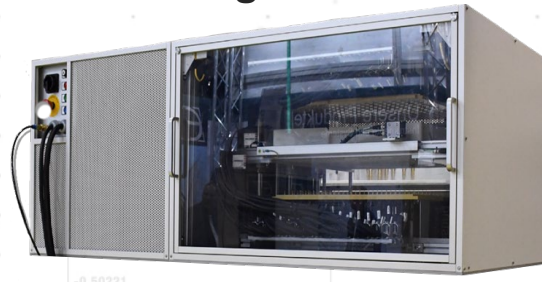
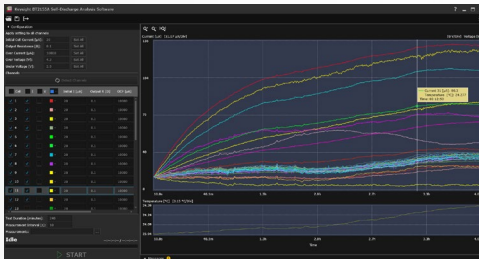
# Accelerating Critical Improvements In Cell Manufacturing

LOWER CELL COST, INCREASE MFG CAPACITY



**CHALLENGE**  
Decrease Cell Cost

**Cell Formation & Finishing**



Reduce formation/finishing time (22% mfg cost) from days to hours  
Reduce power consumption (5% mfg cost) via regeneration  
Reduce \$M's of WIP  
Industry 4.0 Technologies – Lower Opex

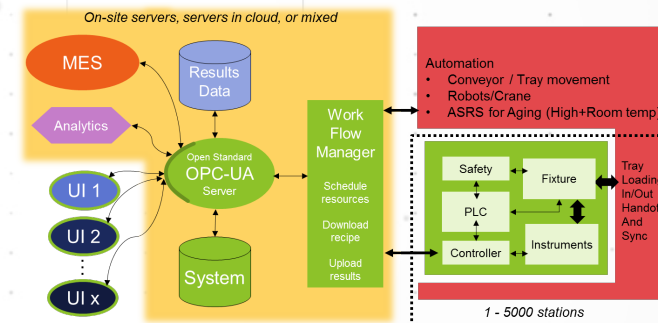
**BENEFITS**

- Lower cell mfg cost
- Reduced WIP Inventory
- Improved ROA



**CHALLENGE**  
Adequate Cell Mfg Capacity

**Factories of the Future**



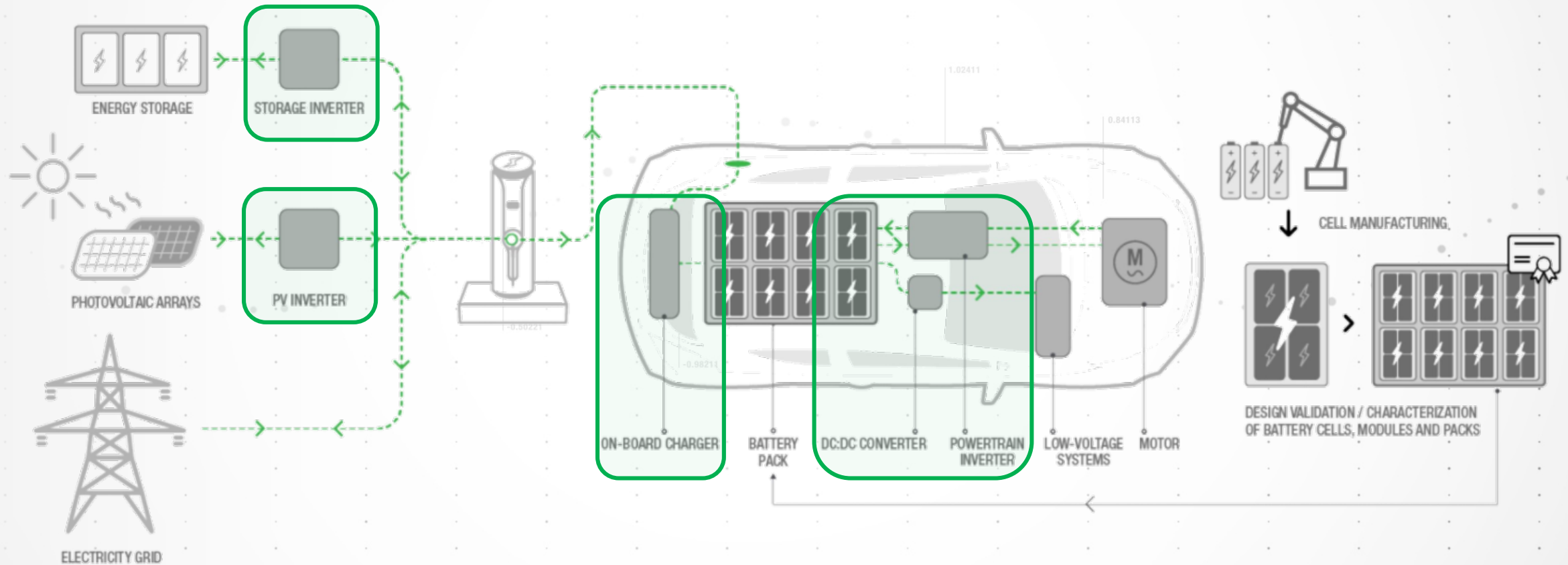
Many new suppliers – Requires scalable Mfg Test:  
R&D/Pilot lines/GFs – Stations to Fully Automated Mfg  
Mass volumes requires Big Data Mgt

**BENEFITS**

- Integrated Formation/Finishing/FA for Better Mfg Productivity
- Improved Process Insight & Control

# The Electrification Of The Vehicle

WIDE BANDGAP DEVICES - HIGHER EFFICIENCY, LIGHTER WEIGHT, LOWER COST

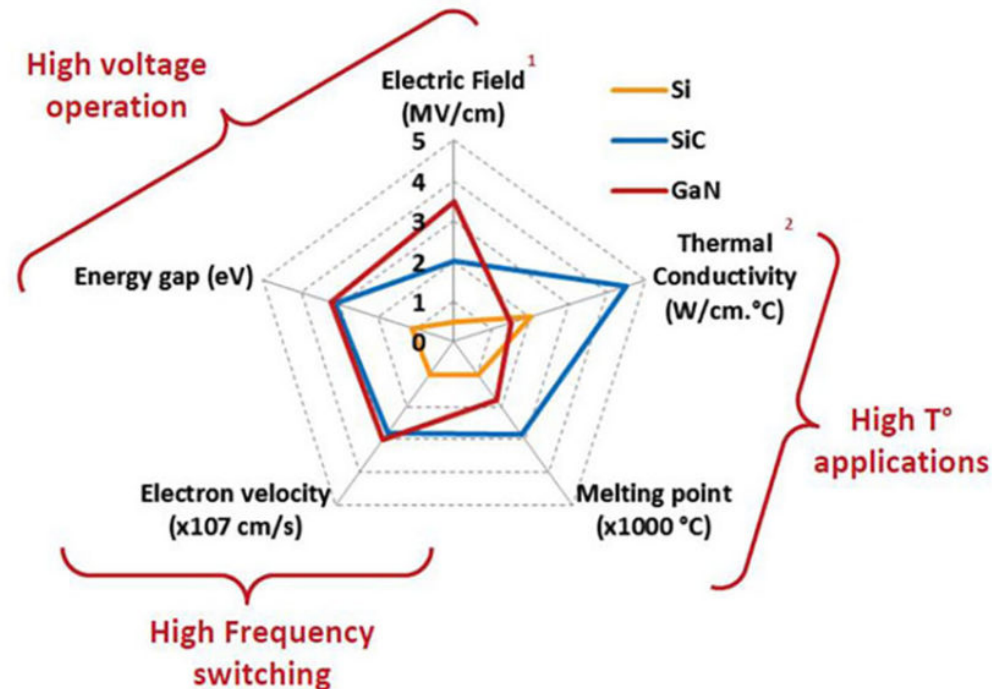


# Market Needs Drive New Power Semiconductor Technology

## WIDE BANDGAP DEVICES (WBG) – SILICON CARBIDE (SiC) & GALLIUM NITRIDE (GaN)

### Gallium Nitride (GaN) advantages over Si

- Very fast switching frequency
- Compactness and weight reduction
- 3X higher bandgap of Si
- Reduction of conduction and switching loss
- Low  $R_{DS(on)}$



### Silicon Carbide (SiC) advantages over Si

- High Temperature Operation
- 3X thermal conductivity of Si
- 3X higher bandgap of Si
- 10X higher breakdown field
- Up to 1000X lower  $R_{DS(on)}$  (conductive loss)

### MARKET CHALLENGE

- Lighter Weight Vehicles leads to Extended Vehicle Range
- Reduce Costs



# Barriers To Wide BandGap (WBG)

DISRUPTIVE CHANGE FOR POWER CONVERTER DESIGNERS

WBG Market Challenge: Reliability in mission critical applications



Established Standards  
Committee for WBG devices  
September 2017



JC-70  
Wide Bandgap Power  
Electronic Conversion  
Semiconductors

JC-70.1  
Subcommittee GaN  
Power Electronic  
Conversion  
Semiconductor  
Standards

JC-70.2  
Subcommittee SiC  
Power Electronic  
Conversion  
Semiconductor  
Standards

# Power Semiconductor Characterization Solutions

GAIN INSIGHT INTO YOUR POWER SEMICONDUCTOR CHARACTERISTICS

## Static Characterization



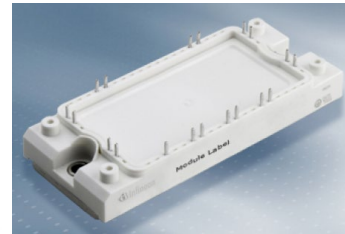
**CHALLENGE**  
Characterizing new, less-reliable IGBT, SiC and GaN power semiconductors

## Dynamic Characterization



### B1505/6A Power Device Analyzer

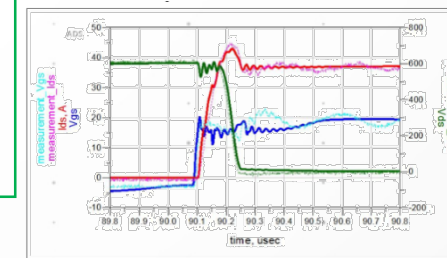
- Wide operation range up to 3 kV/1500 A
- Fully automated fast thermal test from -50°C to +250°C
- Automatic power device (semiconductor and component) datasheet creation
- Auto record function to prevent data loss
- Power Semiconductor characteristics – Ron, BV, Leakage, Vth, Vsat, CV, Qg, etc.



## BENEFITS

Reduce design time with fewer prototypes  
→ Faster TTM & Reduced Cost

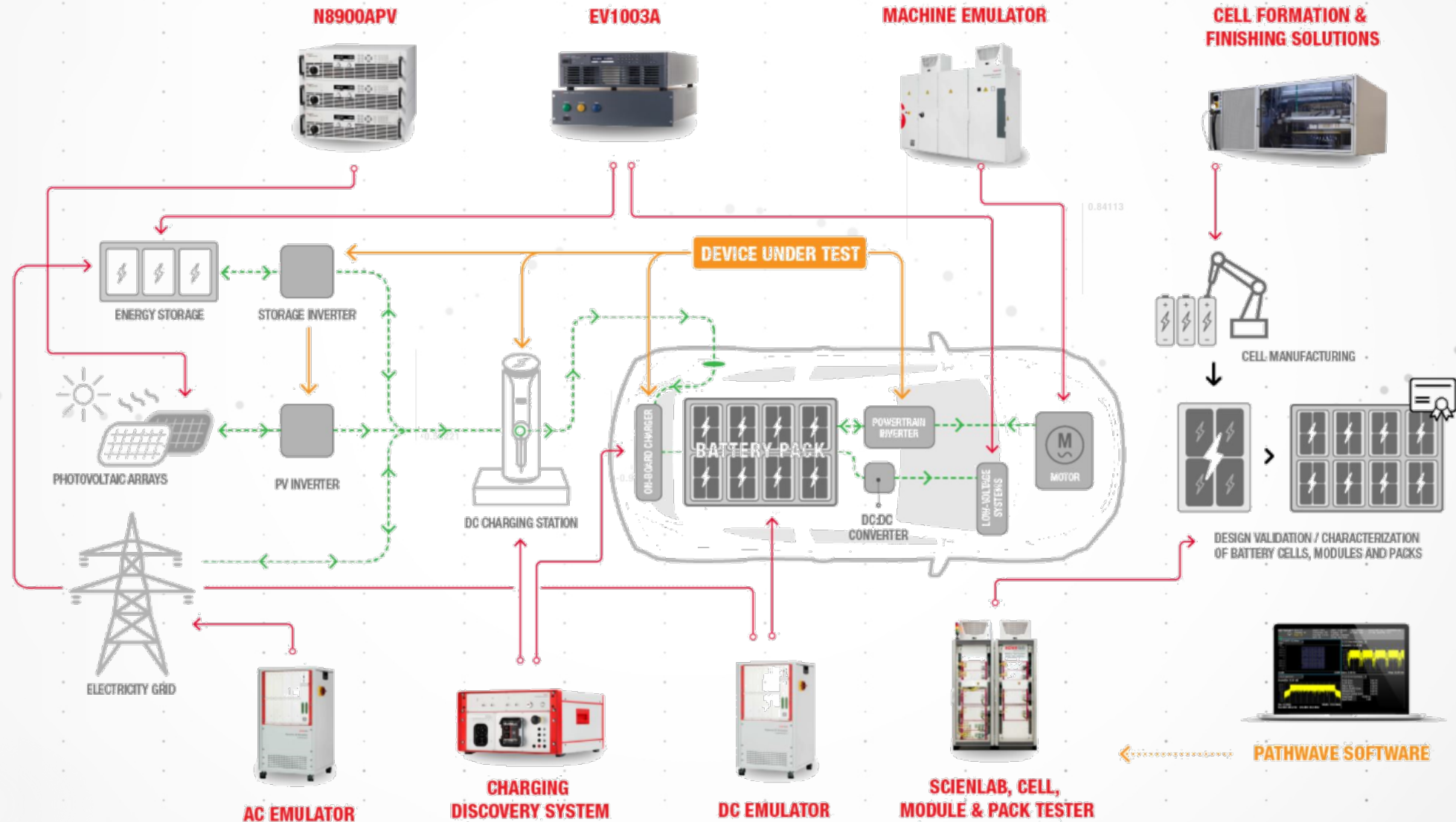
### PD1000A Dynamic Power Device Analyzer



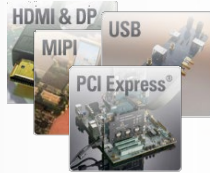
- Double Pulse Test
- Short Circuit Test
- Avalanche Test
- Safe Operating Area (SOA)

# The Electrification Of The Vehicle

## KEYSIGHT SOLUTIONS



# Our Engagement Model Is Partnership



## Workflow

### Maximum Contribution

Help customers optimize workflow processes with Keysight tools. Become part of automation flow

## Solutions

### Higher Value

Complete end-to-end answers to a customer problem  
Software , Fixturing, HW, Expertise

## Applications

### One Supplier

Multiple Keysight products based on fit to specific customer applications. One Stop Shopping Value

## Products

### Single Product

Single products based on best-in-class attributes.





# Summary

- Fundamental disruptive innovations in automotive will create a new mobility ecosystem
- It is our chance to create together a connected and better world
- Let's partner to master the technological challenges and bring your innovations to market first

# Automotive & Energy Resources

FIND THE LATEST AND GREATEST FROM INDUSTRY EXPERTS

## Automotive & Energy Solutions

Realize Your Vision Of Mobility

[Keysight.com/find/automotive](https://www.keysight.com/find/automotive)



## E-Mobility

[Keysight.com/find/e-mobility](https://www.keysight.com/find/e-mobility)

## Autonomous Driving

[Keysight.com/find/autonomous-driving](https://www.keysight.com/find/autonomous-driving)

## Connected Car

[Keysight.com/find/connected-car](https://www.keysight.com/find/connected-car)





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