



## **Electric Vehicle Charging Infrastructure – Challenges & Opportunities**

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**Electrification Coalition Panel**

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# GT Center for Distributed Energy

Creating holistic solutions in electrical energy that can be rapidly adopted and scaled



## Platform Initiatives

### Grid Asset Augmentation

7.2 kV 50 kVA Hybrid Transformer    13 kV 1 MVA Modular Transformer

- 13 kV/50 kVA FUT
- 13 kV 1 MW Power Router
- 67 MVA Modular LPT
- Improving Grid Resiliency
- Smart Wires
- Meshed Grid VVC

### Energy Access in Emerging Markets

'Exponential' Tech  
Self Organizing Nano Grid  
Pay-Go Smart Meter  
Low Cost DA for Grids  
Ad-Hoc Bottom-Up Grids  
Empower a Billion Lives




Emerging Technology: D-Light    Top 10 Emerging Markets  
Source: Global Intelligence Alliance

### Next Generation Grid Power Electronics

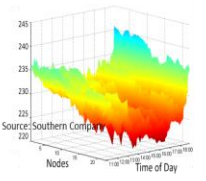
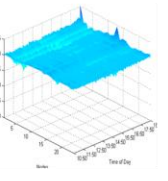



4 kV MVSI for Large PV Farms    7.2 kV 50 kVA SST

- 5 kV DC Grid Building Block
- 7.2 kV 50 kVA Grid Connected SST
- 4 kV MVSI for Large PV Farms
- Triports for PV/Storage/Grid
- MVSI with Integrated Storage
- Microgrid-Grid Interface Device

### Decentralized Grid Control Techniques & Markets

- Grid Edge Volt VAR Control
- Collaborative Control
- High PV Integration
- DER Micro grid Impact
- Self-Pricing Island Grids
- Virtual Power Plants

Feeder Voltage w/o and with GE Control    Feeder Voltage w/ Grid Edge Control

### Next Generation Industrial Power Electronics







100 kVA EV Drive System    200 kVA Isolated Drives    2 MVA Industrial SIVOM

- Industrial CVR Energy Efficiency
- 100 kVA EV Drive System
- 25-500 kVA Isolated Drives
- Energy Hub – DC Fast Charging
- Programmable Load/Source
- Data Center Power Sources

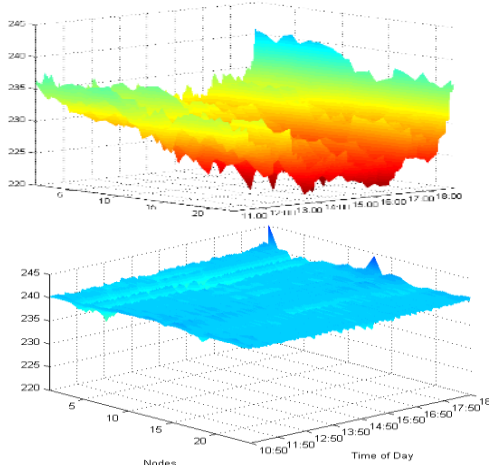
### Global Asset Monitoring Management & Analytics (GAMMA)

- Low-Cost Communications
- Cyber-Security
- Data Management
- AMI Data Analytics
- Global Sensor Networks
- Cloud Based GAMMA System

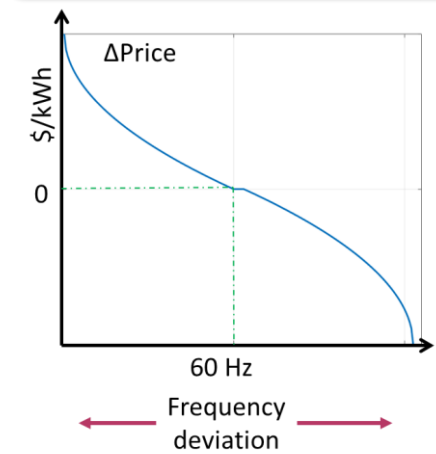
GAMMA Platform    Gamma kernel

WORLD ECONOMIC FORUM  
**TOP 3 TRANSMISSION GRID INNOVATIONS**  
2010-2020  
"Accelerating the Energy Transition"



**COLLABORATIVE CONTROL**  
Varentec

**TRANSMISSION POWER FLOW CONTROL**  
Smart Wires



**AUTONOMOUS MICROGRIDS**  
Transactive/Physical Grid

**SOLID STATE TRANSFORMER (S4T)**

**Primary Drivers**  
Digitalization    Decentralization    Decarbonization

# Major Energy Disruption Underway

## PV & Wind Farms

- PV and wind represent fast global growth – **(120+160) GW/yr**
- 1100 GW storage by 2030, lower cost and better dispatchability
- Utility scale PV/wind plus storage already much lower cost than fossil



PV + storage  
\$32/MWHR



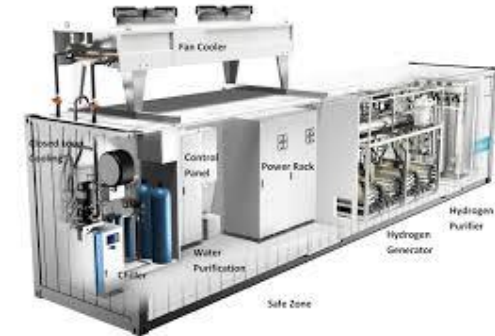
Wind + storage  
\$24/MWHR

## Energy Storage & Hydrogen

- Fast growth for modular battery energy storage – **1100 GW by 2030**
- Hydro to pumped hydro conversion offers central storage
- Clean fuels – hydrogen, ammonia offer long duration energy storage



Storage  
\$100/kWHR



## Transportation Electrification

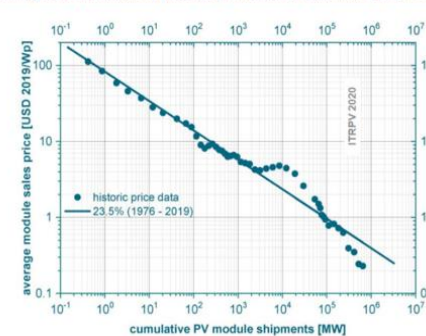
- 125 million EVs by 2040, buses, trucks, semis – all going electric
- Fast charging at 100 kW to 1 MW will stress the grid (peak 1000 GW)
- Significant coordination with grid edge resources will be needed



## Why is the Disruption Occurring?

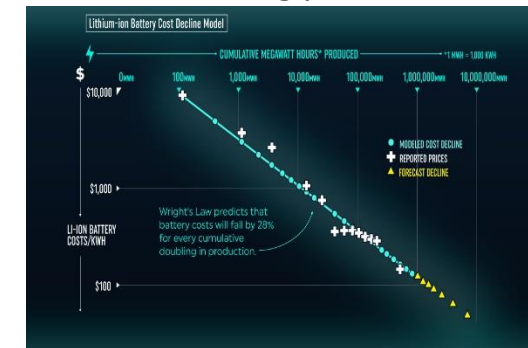
- 21<sup>st</sup> century technologies with steep & sustained learning rates
- Forward leaning policies and incentives applied near break-even
- Fast and dramatic market expansion with decreasing price

Learning curve for module price as a function of cumulative shipments



**PV Cost**  
\$/MWhr  
2000 - \$850  
2022 - \$22

**Battery Cost**  
\$/kWhr  
2000 - \$1500  
2022 - \$100



All these disruptive elements exchange energy with the grid and are growing at an unbelievable pace – but outside utility control

# Rapid Growth of Transportation Electrification

Electrification → Hi-Performance AND Low-Cost

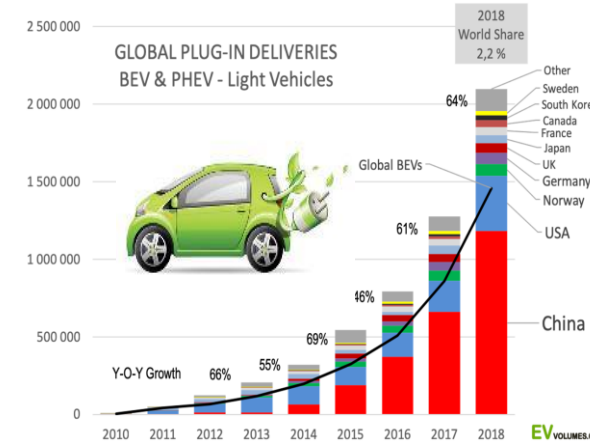
Electrification of transportation proceeding at rapid pace – 60% YoY growth – BNEF mid-estimate ~ 125M EVs by 2040

Low cost of manufacturing/ownership for EVs, buses, trucks and semis – suggest that this will be difficult to stop

Issue of equitable access to EVs & charging infrastructure also needs to be addressed for broad deployment to occur

Rapid growth of electrified transportation will stress a grid already under transformation – integrated approach is critical

- Without adequate cost-effective charging infrastructure, broad EV adoption will fail - economics, not range anxiety is key issue
- Related Issue: What happens if we build charging infrastructure for 125M EVs, and they don't come for many years?



**Finding 5.8\*:** .... peak load for large numbers of EVs with fast charging could be a very large fraction of peak U.S. generation.

# Scaling EVs and Impact

## Charging Requirements and Issues

Type	Requirement	Charging Issues
Level 1	120 volt AC 1.5 kW 4-6 mi/hour	Only opportunity or emergency charging
Level 2	240 volt AC 6-10 kW 25 – 40 mi/hour 6-10 hrs full charge	Require home/office garage 240 volt 30-50A service \$1.5K-6K first cost
Level 3	DC Fast Charging 50-250 kW 150-1000 mi/hour 10-20 min charge time	Charging station needed Visibility to availability Critical to ensure scaling \$100-200K per port
Fleet	DC Fast Charging 50-250 kW	Depot charging for Van/Bus Overhead access for buses
eSemis	DC Fast Charging 250 kW - 1.5 MW 100-750 mi/hour	Truck stops or service areas Complex electrical systems Challenging business model

Automotive companies are familiar with issues of design, supply chain and manufacturing – ensuring ubiquitous equitable charging infrastructure poses a new challenge that can derail progress

- By 2040, 125M EVs will consume ~125 TWHrs/yr, or 3% of US electricity generation – no issue over 20 years
- 125M EVs with Level 2 charging at 6 kW is 750GW peak load – coordinated charging will reduce this peak
- 10M EVs (8% of 2040 estimate) charging at 100 kW = 1000 GW, equals current US generation, worse with fast growth in e-semis

- 10 port DCFC station - 2.5 MW, low duty cycle, high demand charge
- 50 trucks need 50-75 MW, 6000 truck stops = 300 GW of new load

Over the next 10 years, most fast charging stations will be poorly utilized and will be challenged by grid access & business model

**Cost-effectively powering fast-charging infrastructure is critical for success of transportation electrification**

**Bloomberg:** Pure play DCFC operators cannot be commercially sustainable..

# Intersection of Transportation & the Grid

- Utility sector is regulated and risk-averse with long planning cycles, change happening outside their control
- Centrally controlled bulk system → decentralized DER dominant system – how this will be controlled?
- Everyone is thinking in their own silos and moving fast, while assuming their needs at the ‘edge’ will be met – by somebody else!
- Complex system with strong interdependencies with adjacent areas – need flexible adaptive solutions
- Need to holistically address problems of sustainability, reliability, resiliency, affordability and life cycle cost

## Requires Holistic System Level Thinking

- Viable business models for ubiquitous charging are a big challenge
- Overbuild of grid-edge generation and DERs for resiliency and grid services offer unique opportunity to serve transportation needs

## Distribution System Issues - Examples

- Multiple L2 chargers on one xfmr can reduce life from 30+ years to 3 years – no visibility to stressed devices
- Cannot coordinate with distributed DERs in real-time, capacity at desired locations may not be there

## Bulk System Issues - Examples

- 50-75 MW truck-stop or warehouse will need new substation and sub-transmission – 10+ year cycle
- Peak/average demand for DCFC results in high stress on grid, worse with high DER, significant asset overbuild

## Business Model Issues - Examples

- Poor capacity factor and high peak demand result in high cost of hardware, energy and grid infrastructure
- Need to establish charging infra in low-density corridors & communities, can stall wide growth of EVs

# Holistic Approach Needed

- Future grid needs tremendous new capability at the grid-edge, including microgrids and DERs for resiliency, energy storage for reducing grid stress & to serve new loads including data centers, transportation & green hydrogen
- This new infrastructure is being built in isolation of other needs (e.g., EVs) – integration of this functionality is key

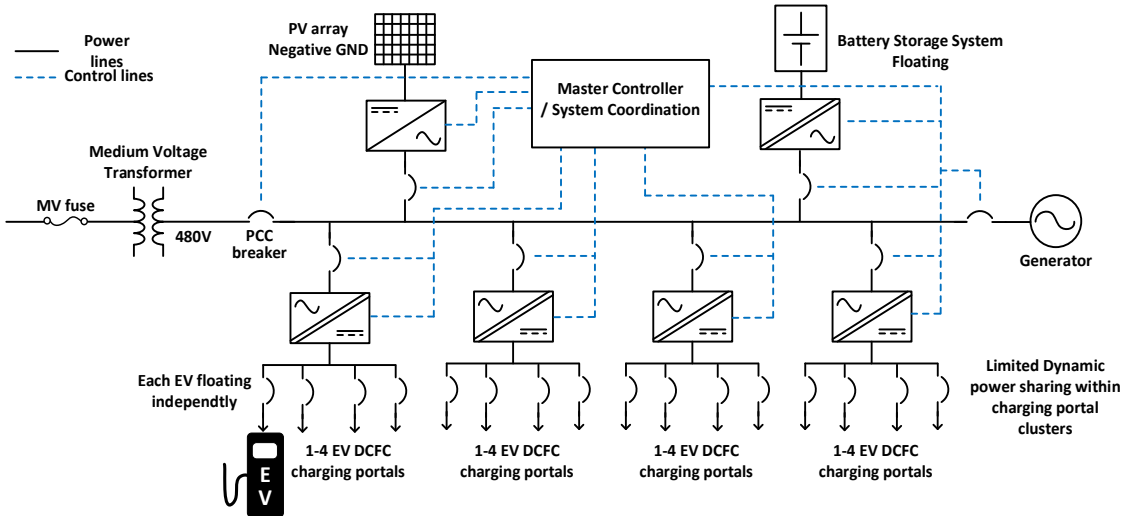
### Possible Grid Support Needs

Coordination of EVs and the grid can provide significant benefits:

- Virtual power plant
- Virtual storage and inertia
- Volt/VAR support
- Increased DER penetration
- Frequency & ACE regulation
- Microgrid for resiliency
- Demand response
- Black-start support, etc.



Typical system providing PV, storage and charging



# NEVI Formula Funding...*funding to create infrastructure is here!*

- Limits NEVI Formula funding to use on projects that are directly related to the charging of a vehicle and only for EV charging infrastructure that is open to the public or to authorized commercial motor vehicle operators from more than one company. [twelfth proviso]
- Directs the Secretary of Transportation, in coordination with the Secretary of Energy, to develop guidance for States and localities to strategically deploy electric vehicle charging infrastructure, which must consider:
  - the distance between publicly available electric vehicle charging infrastructure;
  - connections to the electric grid, including electric distribution upgrades; vehicle-to-grid integration, including smart charge management or other protocols that can minimize impacts to the grid; alignment with electric distribution interconnection processes, and plans for the use of renewable energy sources to power charging and energy storage;
  - the proximity of existing off-highway travel centers, fuel retailers, and small businesses to electric vehicle charging infrastructure acquired or funded with NEVI Formula funding;
  - the need for publicly available electric vehicle charging infrastructure in rural corridors and underserved or disadvantaged communities;
  - the long-term operation and maintenance of publicly available electric vehicle charging infrastructure to avoid stranded assets and protect the investment of public funds in that infrastructure;
  - existing private, national, State, local, Tribal, and territorial government electric vehicle charging infrastructure programs and incentives;
  - fostering enhanced, coordinated, public-private or private investment in electric vehicle charging infrastructure;
  - meeting current and anticipated market demands for electric vehicle charging infrastructure, including with regard to power levels and charging speed, and minimizing the time to charge current and anticipated vehicles; and
  - any other factors, as determined by the Secretary of Transportation. [fourteenth and fifteenth provisos]

- There is rapid global growth in electrification of transportation – driven by lower cost to build and operate vehicles, and by their higher performance
- Availability of ubiquitous fast-charging infrastructure is a critical enabler for wide scale deployment – but cost may not be recoverable, especially in the early years
- Rapid disruptive change in the highly regulated utility sector will compound the difficulty of ensuring that charging is available where and when it is needed
- Holistically solving sustainability, reliability & resiliency issues at the grid edge provides a unique opportunity to create a new flexible electricity infrastructure

The energy system is on the cusp of fundamental transformation, many elements of which are not under industry control.

EV manufacturer representative's comment to: **What happens when an irresistible force** (e.g., EV mfr) **meets an immovable object** (e.g., utility) – **We Go Around It!! We Don't Want to Run EVs with Coal!!**