WIRELESS CHARGING FOR THE OFF ROAD INDUSTRY
1. Building Electric Vehicles since 1932
2. Until recently this industry was the largest Electric vehicle manufacturer in the world with over 300,000 vehicles produced globally.
3. Lead Acid Batteries have been the mainstay of our Industry but with Low voltages (24, 36, 48, 72, 80) From 10kWh to 128kWh
   a) Require high Maintenance
   b) Require dedicated ventilated charging areas.
   c) Limited to a max 0.3C charge rate.
   d) Opportunity and Break Charging cant keep up with Energy Demand
      a) Battery Swapping – Special equipment needed to handle up to 5000 lb batteries
      b) Truck Swapping - Adds to the customer cost of acquisition and operation
   e) Battery Overheating occurs beyond a 2 shift operation.
   f) Opportunity and Break charging have increased connector maintenance.
The Changing Technology Marketplace

1. There is a greater demand for Electric Materials Handling Equipment, in part because of Federal and State Clean air mandates, and also a customer desire for Fossil Fuel free operation.

2. The adaption of new Energy Storage technology e.g. Li-Ion has allowed for
   a) Faster charge rates
   b) Longer battery life,
   c) Zero maintenance.
   d) Zero emissions

3. Larger Electric vehicles with Batteries up to 60 kWh at 400 volts are already being produced.

4. Prototyping of 700 volt /400kWh batteries for 2020 Big truck applications has started.

5. Faster/ Higher Charge Rates require
   a) Larger cables
   b) More expensive connectors - $2500,
   c) Connectors still a Maintenance Issue because of the increased utilization of Opportunity and Break charging with added Connects/Disconnects
Enter Wireless Charging

The Industry roadmap – Focus on the Commuter
Plugging and Unplugging every time one goes to refill is an inconvenience and there a
multiplicity of connector standards based on the type and rate of Power Transfer.

The wireless charging industry goal is.
1. To provide standardized stationary wireless charging in all locations currently served by
current plug in chargers
2. Typically 3.7 kW to 7 kW for the home
   a) Power source limited –
   b) Standardized Height an issue.
3. Target is ultimately 150 kW to 350 kW
Today's Hi Power Wireless applications

Wireless charging is already being adopted for Public Transit both in the US and Europe. by positioning primary coils at bus stops – > 130kW Power charger Despite the high cost of equipment, private operators are making it pay over operating diesel powered buses.
The Ultimate goal is to Charge on the Go

Everyone Else

Truck Recharging

Car Pool
Alternatives to Inductive Charging

- Capacitive wireless charging could be a disruptive technology for the current inductive solutions. *University of Colorado*

  - High-frequency capacitive energy transfer

  - Distributed plates designed for field cancellation using near-field phased array field focusing concept

  - Fixed frequency operation within an ISM band
The Challenges of Road Based Dynamic Charging

- Road based Dynamic Wireless charging faces significant infrastructure costs ($2.4 million/mile) as well as its susceptibility to road repair and natural disasters.

- Fortunately most Industrial vehicle installations don’t face this challenge.
Wired vs Wireless – The Business Case for Materials Handling

- In volume Hi Power Charger costs are the same
- Primary station installation with side mount secondary costs the same as for a wired charger.
- Floor mount adds some additional installation cost $500 to $1000

- **Eliminating the connect/ disconnect step in the charging process plus connector maintenance saves over $4000 / vehicle / year for multi-shift operation.**
Materials Handling Roadmap Issues

- Electric Forklift operations will double in the next 5 years. **Can the wireless charging Industry handle this increase?**

- Wireless Primary in floor/on floor mounting can be expensive and inflexible and has height issues for much of our current product. – **Pursuing side mount solution**

- Even side mount Wireless charging will require auto height adjustment of the primary inductor for different truck sizes. **Added Expense but easier installation and lower cost than floor mount.**

- Per CA mandate all chargers must be > 90% efficient. – Requires precise X, Y, Z alignment between primary and secondary. **Autonomous trucks can consistently handle this but it is a challenge for Manual operation**

- Utilities are not well prepared to manage the increased Power demands that could be represented by multiple forklifts, all charging at a 25 Kw rate in one location at the same time.
The Grid Impact from our Industry

- A Company A in an Industrial Park has 20 forklifts all equipped with 25kWh batteries.
- These forklifts will all be charged at a 1C charge rate during break periods.
- 20 trucks x 25 kW = 0.5 Mw of peak power demand 4 times a day.
- In the same Industrial Park there are 4 more companies with the same equipment, all on the same break schedule.
- Now the demand has risen to 2.5 Mw.

Note that many of our customer fleets exceed a 100 vehicles.
Dynamic wireless charging could work well for Forklift applications with the following advantages.

- Smaller Battery packs = Lower Cost of Acquisition.
- Non stop operation – Automation.
- Lower peak grid demand

Capacitive power transfer to the carriage could be a better solution than inductive.

- Faster Power transfer
- Smaller footprint
- Greater adaptability to distance between Electrodes
- Lower cost installation

Potential problems for dynamic wireless charging

- Floor Mounting will probably be required.
- Adapting to vehicle height differences.
Participants in this technology development

- Universities Research Institutes
  - Utah State University
  - Colorado State University
  - University of Auckland
  - University of Cambridge
  - Lund University Sweden
  - North Carolina State University
  - Purdue University
  - Virginia Tech
  - International Transportation Innovation Center (ITC) (Clemson University spinoff)
  - US Department of Energy Advanced Research Projects (DOE)
  - National Renewable Energy Lab (NREL)
  - Idaho National Labs
  - Oak Ridge National Labs
  - Electric Power Research Institute

- Standards and Regulatory Bodies
  - SAE J 2954 Wireless Transfer Task Force in conjunction with J2836/6, J2847/6, J2931/6
  - UL 2750
  - US DOE
  - UDOT

- Utilities
  - Rocky Mountain Power

- Private Industry:
  - Toyota, Witricity, EPCOS (TDK)
  - Autonomous Solutions
  - Greenlots (charging station apps)
  - Alstom, AECOM, Wasatch Collaboratory
  - WAVE Tech
  - Momentum Dynamics
  - Delta Energy Systems
  - Qualcomm
Utah State University Wireless Charging Test Center