Research Needs & Opportunities: NREL
Agricultural Perspective – March 2022
Darren Almond – John Deere Power Systems
CUSTOMER DECISIONS
MORE FACTORS FOR CUSTOMERS TO CONSIDER

ECONOMIC FACTORS
- Productivity
- Lowest Cost of Operation
- Uptime

SUSTAINABILITY FACTORS
- Consumer
- Financial Partners
- Regulatory
Regulations have increased 2x since 2015.
77% of consumers say it is important that brands offer sustainable products

The Harris Poll, Feb 2020
5X investments in Environmental, Social and Governance (ESG) funds
Global Challenges

- Population Growth
- Climate Trends
- Labor Shortage

Feeding 9.7B people in 2050 equates to a 50% increase in demand.
Larger farms comprise growing share of US crop production...

- Farms with $1M or more of cash income comprised nearly half (49%) of US farm income in 2015
- In 1991, farms with over $1M income contributed 31% of total farm income*
- Farms tasked with managing more land in the same planting/harvesting windows

* Constant currency value (2015 dollars)

Source: USDA ERS

Note: GCFI = Gross cash farm income. GCFI is expressed in constant 2015 dollars using the Producer Price Index.

Source: USDA ERS
US farms have become significantly more productive since 1990…

- Combined corn, soybean and wheat production has increased 50% since 1990
- Farm diesel use is essentially unchanged over same timeframe
- Ag equipment and powertrain advancements have helped farms plant, spray and harvest significantly more grain—without requiring more fuel

Source: USDA, EIA
Farming requires extensive ground and plant engagement...

• Up to ten field passes required for a complete corn crop cycle
• Involves up to six unique machine types
• Some operations involve high loads over long time intervals
  • Tillage
  • Harvesting
• Many considerations required when designing and integrating powertrain systems for different Ag machine types
Relative to trucks, large agriculture equipment demands more power and more energy

• Fuel consumption of 9R tractor and Class 8 truck provides visibility to relative energy consumption
  • Ag equipment = heavy load/high resistance
  • On-highway truck = lighter engine loads
• Relative fuel consumption based on two comparable engines
  • Tractor engine: 13.5L rated at 470hp
  • Truck engine: 15L rated at 450hp
• Tractor uses ~3X more energy per hour in field

*Assumes 65mph speed and 8 mpg average fuel mileage
Source of tractor fuel consumption data: Nebraska Tractor Test
Global Greenhouse Emissions: Agriculture Contribution

Contribution by Sector

- Other Energy: 10%
- Industry: 21%
- Transportation: 14%
- Land Use: 24%
- Electricity & Heat: 25%
- Building: 6%

<10% Ag CO₂e generated by Ag vehicle usage

McKinsey & Company, April 2020
Opportunities for Further Productivity Gains

Biotech, land management and ag equipment advancements unlocking higher yields…

- Average US corn yield (per acre) has increased 45% since 1990
- However, top corn producers have realized greater gains over the same interval
- Gap suggests potential for further gains in average crop yields

Corn: US Average Yield and Top Yield Trend

Source: USDA, National Corn Growers’ Association
RESEARCH Opportunities

- Electrified components
- Battery electric vehicles
- Hybrid electric vehicles
BATTERY PERFORMANCE
DRIVEN BY FIVE ATTRIBUTES

Cell Sourcing
Ability to get access to the best available source on the market.

Cell Density
Ability to position cells in a pack in order to have the maximum energy in each volume.

Ability to maintain the temperature of all cells in the pack to their optimum temperature to drive the power density & durability.

Battery Management Systems
Manage the interaction of the cells within the battery to drive safety, performance and efficiency.

Way to integrate the electric source with the usage of the vehicle both mechanically & logically.

SUPPLY
PACKAGE
THERMAL MANAGEMENT
CONTROL
VEHICLE INTEGRATION

Energy Industry
Ag OEM Mfg
# Battery Performance

Driven by Five Attributes

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<thead>
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<th></th>
<th>Cost</th>
<th>Range</th>
<th>Life</th>
<th>Power</th>
<th>Safety</th>
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CHARGING SOLUTIONS
## ALTERNATIVE FUELS

**GREET: Greenhouse gases, Regulated Emissions, and Energy use in Transportation**

Access to Model: [https://greet.es.anl.gov/greet_1_series](https://greet.es.anl.gov/greet_1_series)

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<tr>
<th>Energy Source</th>
<th>CO₂e g/MJ</th>
<th>GHG Factor</th>
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<tr>
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Research Focus Opportunities

Maximize Productivity & Precision

Electric & Alternative Fuel Solutions

Match Infrastructure to Energy Needs