Removing the Truck from the Carbon Equation

Deep Dive Nikola Two Prototype
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AGENDA

- Nikola Overview & Timeline
- Nikola Two Fuel Cell Vehicle – Alpha Prototypes
  - Patented Technology
  - Hydrogen Storage & Fuel Cell
  - Development & Validation Testing
- Nikola Tre BEV and FCEV Preview
- HD Hydrogen Fueling Stations
  - HD H2 Fueling & Communications Development
- US DOE Project: Nikola Novel HD Fuel Cell MEA
- Conclusion
FC VEHICLES + H2 INFRASTRUCTURE
PARALLEL DEVELOPMENT WITH PARTNERS

**FUEL CELL TRUCKS**
- Long Range, Heavy Duty Class 8 / 40-ton Commercial Vehicle
- High Torque & Power Output
- Zero Tailpipe Emissions and Very Low WTW

**HD H2 STATIONS**
- < 20 min Fast Fueling (in development with NEL)
- 8T On-Site Hydrogen Generation from Grid with Supplemented Renewable Energy
- 10T Onsite Storage
- Heavy Duty & Light Duty Fueling
**NORTH AMERICA**

**FCEV**

- **Status:**
  - Alpha Prototypes developed 2018, debut April 2019
  - Dyno and closed course testing (Michigan and Arizona)
  - Public demonstration at Nikola World and beer delivery at Anheuser Busch Sustainability event
  - Bosch Fuel Cell System used in Prototype

**EUROPE & NORTH AMERICA**

**BEV & FCEV**

- **Status:**
  - Developed with CNHi, based on Iveco S-Way
  - BEV (720kWh) Prototypes are being built in Germany, SOP (Ulm) in Q4 2021
  - FCEV Prototypes will be built in 2021, SOP in 2023
  - Bosch Fuel Cell System
NIKOLA HIGH LEVEL MILESTONE PLAN

- **4Q2020**
  - Complete Tre BEV prototypes
- **1Q2021**
  - Substantial completion of JV manufacturing building modifications in Ulm
- **2Q2021**
  - Break ground on first commercial hydrogen station
- **3Q2021**
  - Ulm facility assembly line complete for start of Tre BEV production
- **4Q2021**
  - Complete Phase I of Coolidge, AZ manufacturing facility
  - Begin testing FCEV truck prototypes
- **2022**
  - Begin Tre BEV production in Ulm
  - Begin U.S. Tre BEV production in Coolidge facility
- **2023**
  - Complete Coolidge facility

- **Manufacturing**
- **Tre BEV**
- **FCEV Truck**
- **Hydrogen Station**
NIKOLA TWO FCEV
ALPHA Prototype

POWER ELECTRONICS / DISTRIBUTION UNIT
Distributes energy to axles and vehicle
- Energy Flow & Conversion

DUAL STACK FUEL CELL
Generates Electricity
- 240 kW Fuel Cell (Gross)
- Heavy-Duty Application
- Custom Build

INDEPENDENT SUSPENSION
Independent Control
- Stability
- Improved ride

HYDROGEN TANKS
Hydrogen Storage
- 61 kg

E-AXLES / ELECTRIC MOTORS
Power the Drive Axles
- Motor and transmission in on compact unit
- Dual-motor commercial-vehicle eAxle
- 2 motors (per axle)
- Torque vectoring capable

BATTERIES
Handle Dynamic Load Conditions (Acceleration, Regenerative Braking)
- 250 kWh, 710 Volt capable battery pack
NIKOLA TWO SYSTEM INTEGRATION PATENTS

SUSPENSION, ELECTRIC AXLE AND GEARBOX

FIG. 1

EP3705321A1- Vehicle Rear Suspension

FIG. 11

10589788/ 20200239076- Vehicle Frame Arrangement
NIKOLA TWO SYSTEM INTEGRATION PATENTS
HYDROGEN STORAGE INTEGRATION

FIG. 2

FIG. 5

10589788/ 20200239076 - Vehicle Frame Arrangement
NIKOLA TWO
HYDROGEN STORAGE
ALPHA PROTOTYPE SYSTEM

- Nine 70MPa Type IV Hydrogen Tanks, 61kg Hydrogen Storage
- Light-duty valving from production FCEVs
- Partially validated GTR #13 Test/CSA with 20,000 hydraulic fueling cycles, Valves Design Validation Tested.
- Light-duty Refueling with Nikola-specific SAE J2799/ J2601 Communication to Station
- Integrated Fire Shield between Battery System and HSS (Patent Pending)
- Six H2 Detectors mounted throughout vehicle
NIKOLA TWO
ALPHA FUEL CELL SYSTEM
BOSCH-POWERCELL TWINBOX

- System power 240kW total
  - 2x 120kW Stack Gross
  - 2x 100kW System Net
- Based on PowerCell S3 Stack
- Alpha/Beta level Balance of Plant components
- Shock, Vibration Resistant
- Series suppliers for Stack (Freudenberg, Umicore, DANA, etc.)

*Images from PowerCell website
FUEL CELL STACK EXTERNAL TESTING
POWERCELL, SWEDEN

- Fuel Cell Stack Testing (120kW) FAT & DV Testing on Greenlight FC Test Stand
- Polarization RH-Stoichiometry-Pressure Sensitivity/ Dynamic Drive Cycle
- Initial Accelerated Stress Test (AST) Evaluation
FUEL CELL SYSTEM EXTERNAL TESTING

SYSTEM TEST STAND WITH INSTRUMENTATION

- Two Single Stack Fuel Cell System Testing for FAT and Basic Function Test
- Functional Safety HV/H2 Safety (Shutoff) Testing including DCDC Converter
- FCCU Calibration Testing (Operation/ Diagnostics)
VEHICLE SAFETY
CRASH MODELING AND SIMULATION

- **Crash modeling:** Conducted crash models to simulate frontal and lateral impacts to identify safety issues and optimize design.

- **Simulations from validated Crash:** Provided critical safety characteristics such as crash displacements, setting of sensors, isolation of HV bus.
NIKOLA TRE BEV
BASED ON IVECO S-WAY CHASSIS

- BEV Prototypes being built in Ulm, Germany
- 720kWh battery storage / 350kW charging
- 480 kW (640 hp) continuous power output at nominal voltage
- Dual motor gearbox integrated into solid axle
NIKOLA TRE
FUEL-CELL TRUCK

SHARED PLATFORM WITH
BEV VARIANT

* Image courtesy of Bosch
NIKOLA’S H2 STATION AT PHOENIX HEADQUARTERS:

HD/LD DEVELOPMENT H2 FUELING STATION WITH 1000KG STORAGE AND DISPENSING CAPABILITIES
HYDROGEN FAST FUELING DEVELOPMENT TARGETS

70 MPa
HIGH FLOW

<20 MIN
HD FUELING

60-80 kg
8T/DAY H2 STATION CONCEPT: 70 MPA HEAVY DUTY & LIGHT DUTY

- Zero Emission Power Generation
- Conversion of Electricity to Hydrogen via Electrolysis
- Onsite Hydrogen Storage Supply
- Fast 70 MPA Fueling Station
- Fast 70 MPA Hydrogen Dispenser
- Hydrogen Fuel Cell Vehicles

LD Fast Charging
LD Hydrogen Fueling
HD Hydrogen Fueling
HD FUELING EQUIPMENT DEVELOPMENT
NIKOLA CO-FOUNDED INDUSTRY GROUP

Project is fully funded by the partners and HD hardware prototypes will be tested in 2021. Nikola Chairing both ISO 17268 Standard for H2 Nozzles & ISO 19880-7 Gaseous H2 Fueling protocols.

- HD H70HF Fueling Nozzle
- Receptacle
- Hose
- Breakaway
DURABLE MEAS FOR HD FCE TRUCKS

DOE PROJECT I

- The goal of this project is to
  - Reduce/eliminate crack formation during deposition/operation \(\rightarrow\) **improve durability**
  - Improve catalyst utilization \(\rightarrow\) **Use less PGM**
  - More effectively orient ionomer, reducing SO\(_3\) poisoning \(\rightarrow\) **better mass transport and ORR activity**
  - Accurately control pore-size distribution \(\rightarrow\) **better water management and mass transport**

- Technology Improvement Targets:
  - At high RH: Reduction in flooding from “macro” pores
  - At low RH: Improvement in ionic conductivity from water condensation in primary pores

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**Northeastern (Prof. Mukerjee):** Dual IBAD technique to produce durable catalyst powders

**Georgia Tech. (Prof. Xia):** Synthesize supported durable cuboctahedral PtCo catalyst

**Nikola:** Novel durable CL/MEA structure (Nikola IP), to form layered structures of catalyst powders and ionomer

**CMU (Prof. Litster):** Create CL transport models and recommend MEA formulation/optimization based on feedback from X-ray computed tomography and pFIB-SEM imaging

Reference 2020 US DOE AMR Publication

ADVANCED MEMBRANE FOR HD TRUCKS
DOE PROJECT II

FY ’20 DOE ADVANCED MEMBRANE PROJECT:

- Objectives:
  - MEA based on reinforced PFSA membrane that meets performance/durability targets at $\geq 95^\circ C$
  - Reduce radical scavenger mobility
  - Prevent ionomer radical attack
  - Develop & validate HD-specific membrane AST in conjunction with DOE FC-PAD

- Partner:
  - Chemours
    - New membrane chemistry and architecture with an immobilized radical scavenger
    - High(er) Temp. Stability – develop ionomer/reinforcement architecture
    - Optimizing membrane thickness for reduced gas crossover

OVERALL MEA DEVELOPMENT AT NIKOLA:

- Design and Develop MEAs optimized for
  - High efficiency
  - Cost
  - Durability under HD Drive Cycles

- Develop Accelerated Stress Tests (ASTs) specific to HD truck operating conditions
  - Predict fuel cell stack failure modes
  - Develop mitigation strategies
    - Materials
    - Appropriate control strategies

Reference: US DOE HT Membrane Workshop Presentation (Sept. 2020)
# PATENT APPLICATION FAMILIES

## EMBODYING NIKOLA’S HYDROGEN-RELATED INTELLECTUAL PROPERTY

<table>
<thead>
<tr>
<th>PATENT TITLE</th>
<th>STATUS OF U.S. APPLICATION*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Frame Arrangement</td>
<td>Issued – 10,589,788</td>
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<td>High Volume, Fast H2 Fueling of a Heavy-Duty Vehicle</td>
<td>Not Yet Published</td>
</tr>
<tr>
<td>H2 Fueling with Bi-Directional Communication</td>
<td>Issued – 10,800,281</td>
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<tr>
<td>Cooling System for Fuel Cell Stacks</td>
<td>Not Yet Published</td>
</tr>
<tr>
<td>Method of Operating a Fuel Cell System for a Motor Vehicle</td>
<td>Not Yet Published</td>
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<tr>
<td>Pressurized Vessel Heat Shield and Thermal Pressure Relief System</td>
<td>Not Yet Published</td>
</tr>
<tr>
<td>Catalyst Layers of Membrane-Electrode Assemblies and Methods of Making Same</td>
<td>Not Yet Published</td>
</tr>
<tr>
<td>Systems, Methods, and Devices for Cation-Associating Fuel Cell Components</td>
<td>Not Yet Published</td>
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</tbody>
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*These patent applications are directed to intellectual property developed jointly by Nikola and its partners, as well as intellectual property developed solely by Nikola.*

*This only denotes the status of U.S. applications. Status of related applications in other jurisdictions may differ.*
CONCLUSION

- Nikola Two is a running Fuel Cell Electric Prototype and in operation since 2019.
- Nikola owns IP related to vehicle integration, H2 storage & fueling, FC & system control, electric axle, suspension, and more.
- Nikola Tre BEV Truck 2021, FCEV Truck 2023, developed together with Iveco and based on S-Way chassis and cab.
- Nikola Co-Developing 70MPa HD Fueling and evaluating Fueling Hardware (nozzles, etc.) with industry group.
- Nikola H2 stations will be available to both lease customers and public for Heavy Duty and Light Duty fueling.
- Nikola working on DOE funded MEA development projects to meet durability requirements for HD (next generation fuel cell).