Vehicle Electrification Technological Change

Electric Vehicle (EV) advances, power demand and risk

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Topics

- Historical background
- Electric Vehicle (EV) technological advances
- Electric power terminology
- EV auto manufacturers expanded production
- Data/Studies
  - National Renewable Energy Lab
  - ISO New England
- Risks
  - Grid shortfall
  - EV technology supply chain - Rare earth magnets/lithium batteries

Vermont circa 1900

- Most cities have electricity
- Rural electrification is years in the future
- Personal transport is horse drawn
- Very few cars- 80% are steam or electric

Newport Vermont Circa 1920-1940

Newport, Vt 1920's

Almost all cars are powered by gasoline internal combustion engines

Newport, Vt 1940's

US Motor Vehicle Ownership 1900 to 1940/EV 2011 to 2019

- 1900 – 8,000 motor vehicles
- 1910 – 468,500 including 10,123 trucks
- 1920 – 9,239,161 including 1,107,639 trucks
- 1930 – 26,749,853 including 3,674,593 trucks
- 1940 – 32,453,233 including 4,886,262 trucks and 101,145 buses
- 2011 – 17,731 EV
- 2015 – 113,773 EV
- 2019 – 1,180,000 (+) EV

Technology Advancement

- Technology moves in fits and starts
- Sudden technological breakthroughs can lead to significant disruptive economic shifts
- Electric vehicle batteries are breaking previous chemistry constraints
- Manufacturers are investing billions in EV manufacturing infrastructure and supply chains
- EV technological adoption may come faster than the grid is prepared to support
- We need to ask different questions and look at vehicle electrification from a new perspective

Battery and Power Terminology

- Ampere-hours battery capacity is the discharge current a battery can release over time –typical starting batteries are rated at 12 volts and 48 amp hours; The Tesla Model 3 extended range battery is rated at 350 volts and 230 amp hours.
- Watt-hours (Wh) Measure of specific power a battery can deliver over time
- Kilowatt hour (KWh)- eg.100 watt/hr used in defining EV battery specific power
- Kilowatt hours/mile KWh/mile is the term that determines how much battery power is required to move a EV vehicle one mile replacing miles per gallon metric used with Internal Combustion Engine (ICE) vehicles.
- Megawatt (MW)- 1 million watts is the standard power industry term to describe power generating facility rating
- Megawatt hour (MWh) A unit for measuring electric power or the rate at which energy is produced or consumed; equal to 1,000 kilowatts of electricity used for one hour, or 1,000 kilowatt-hours.
- Gigawatt hours (GWh)- 1 billion watt/hours a less common term used by ISO New England to describe monthly supply of electricity to the grid
- Terawatt hours (TWh)- 1 trillion watts/hr only used by National Renewable Energy Lab (NREL) to describe annual power required nationally to electrify various economic sectors

Automaker Electric Vehicle Investments and production

- Automakers plan $*300 billion* investments in EV's over ten years– 45% ($135B) in China and $82B Europe
- Nearly half of the current EV vehicles are in China
- A complete range of all vehicle classes have been announced - cars, SUV's, pickups, buses, delivery trucks and class 8 semi trucks
- An estimated 100 million EV's will be produced globally by the year 2025 and 250 million by 2030
- This highly competitive market is already driving to ever larger battery capacity vehicles in all classes

Electric Vehicle Technology Advances

- 2011 Chevy Volt - all electric range 35 miles with a 16 KWh battery 1.4L gasoline engine
- 2016 Chevy Volt - all electric range 53 miles with a 18.4 KWh battery and 1.4L gasoline engine
- 2018 Nissan Leaf - all electric range 151 miles with 40 KWh battery
- 2020 Chevy Bolt - all electric range 259 miles with 66 KWh battery
- 2020 Tesla Model 3 - all electric range 325 miles with 75 KWh battery pack
- 2021 Rivian Automotive RT1 pickup/RS1 SUV– all electric range large w/180 KWh battery 400 miles
- 2021 Ford EV F150 – 200+ KWh battery?

Medium and heavy trucks

- Daimler eCascadia Freightliner tractor trailer and box truck tests use 300 KWh to 550 KWh batteries with a range of 250 miles
- Tesla describes its class 8 semi truck as having 300-500 mile range requiring a 600-1,100 KWh battery
- Innolith battery technology claims 1000 KWh for its pre-production battery giving a 600 mile car range

Daimler-Freightliner Electric Trucks

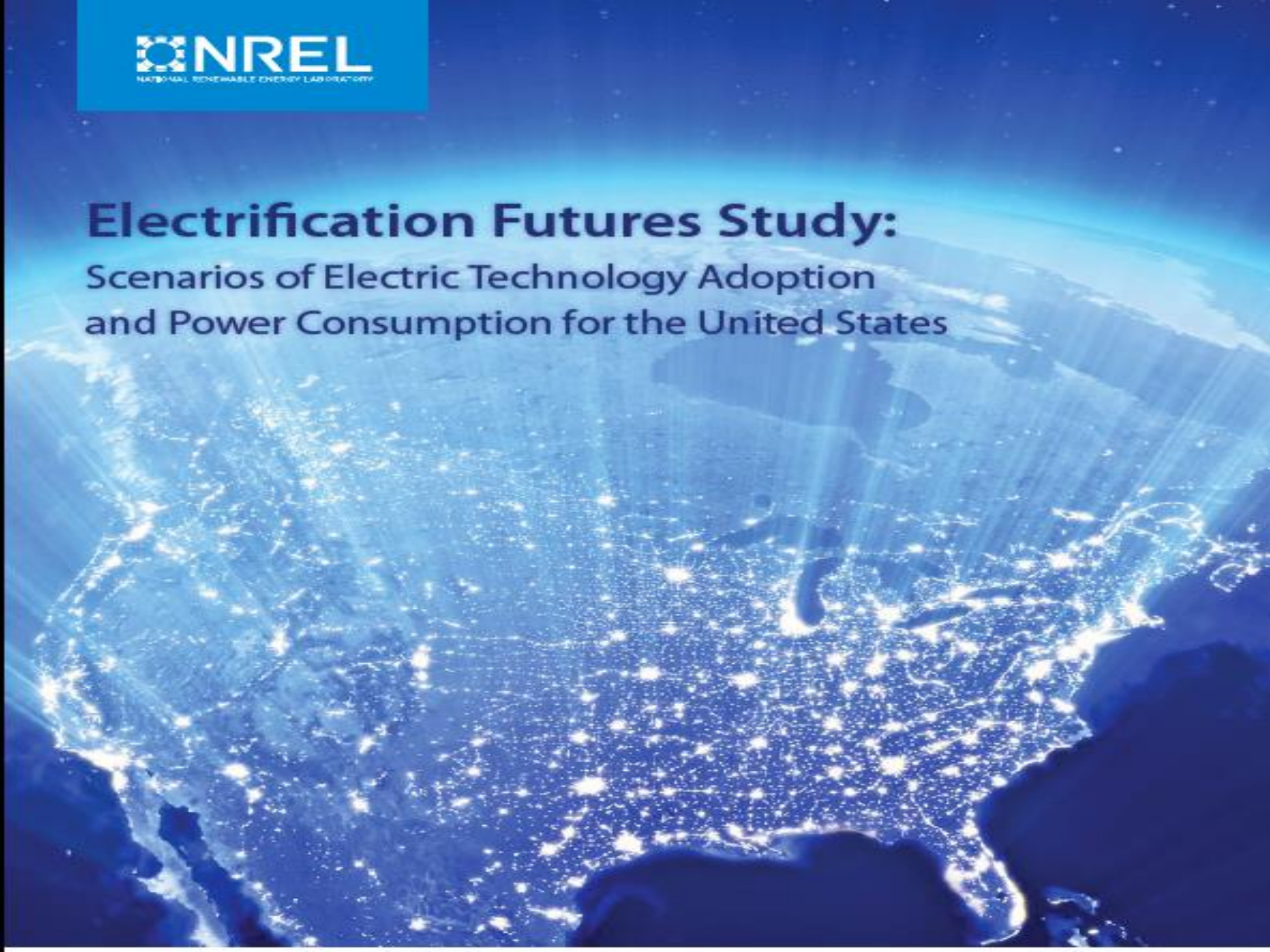
Next Generation Electric Vehicle Technology is Here

- Current EV technology will become obsolete quickly
- The next generation leap-ahead EV technology is going into production
- This is a potentially disruptive technology
- The power requirements for these vehicles may require up to 50% more power than currently produced nationally.
- We need to start planning for significant EV power demand and infrastructure implementation.
- Emissions will drop as a result of this technology if the infrastructure is there to support it.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Electrification Futures Study:

Scenarios of Electric Technology Adoption and Power Consumption for the United States



National Renewable Energy Lab Transportation Electrification Studies

- The NREL Electrifications Futures Study released June 2018 analyzed residential, commercial, industrial and transportation sector electrification
- Estimated annual power demand for three scenarios between 2020-2050
- Transportation electrification created the largest power demand – building/industrial electrification required only 360 TWh/yr increase
- Baseline scenario demand 4,722 TWh/yr assuming a gradual introduction of electric vehicles and other sector electrification
- Mid-range 5,520 - 5,871 TWh/yr – in between baseline and high scenarios
- High – 6,280 - 6,846 TWh/yr based on significant transportation electrification most LDV's, med/hvy trucks - only 10,000 of 983,232 buses
- The EIA estimates that national annual power supply available in 2020 as 4,126 TWhr and that the power supply in 2050 will be 5,429 TWhr
- EIA Annual Energy Outlook (AEO 2020) estimates https://www.nrel.gov/docs/fy18osti/71500.pdf

DECEMBER 20, 2019

Draft 2020 Transportation Electrification Forecast

Load Forecast Committee

Jon Black

MANAGER, LOAD FORECASTING

ISO New England Draft Transportation Electrification Study Dec 2019

- ISO New England draft vehicle electrification study released 20 December 2019 analyzed northeast states transportation electrification
- Covered 2019-2029 time frame and light duty vehicles (LDV) only
- Estimated an increase from 41,349 BEV/PHEV out of 12,452,628 LDV's in 2018 to 515,683 EV's in 2029
- Estimates Vermont EV share to grow from 2,926 to 36,492
- Estimated the annual power demand for EV's by 2029 as only .4 GWhr out of 160 GWhr monthly supply

https://iso-ne.com/static-assets/documents/2019/09/p3_transp_electrification_update.pdf

Vermont’s Energy profile

- Nationally Vermont produces 40% of its electricity but only 20% of its total energy needs
- Vermont produces 2.18TWh electricity but consumes 5.53 TWh annually
- The annual power required for complete transportation sector electrification is 3.77 TWh.

Key Electric Vehicle Raw Materials

- Massive EV manufacturing increases and demand for large battery packs may outstrip short-term lithium supplies slowing near-term EV production.
- Significant near-term supply constraint for EV mass production is the supply of rare earth element (REE) permanent magnets used in 93% EV vehicle motors.
- China dominates the REE market supplying 80% of the US's refined rare earth materials and is electrifying their transportation sector at a fast rate.
- China is electrifying it’s transportation sector much more quickly than the rest of the globe and its demand for permanent magnets will consume much of Chinese REE production.
- The REE’s are critical for all military forces, and the Defense Department has announced plans to stockpile the same REE's used in commercial electronics and EV permanent magnets.
- The third effect is to impose an increasingly large environmental damage burden on areas of the world previously untouched by extractive mining and toxic minerals refining.

Transportation Electrification Risks

- Transforming the transportation sector from its current multi-modal portable and storable energy supply. Nationally there typically exists 2-3 weeks on-hand hydrocarbon fuel supplies.
- Interruptions and shortages occur but supplies are routinely moved as needed.
- Transportation electrification depends on a single, non-portable/storable supply modality (grid transmission lines) subject to interruption over a wide area.
- Battery electric storage is decades in the future. The entire future national battery electric storage projects planned for 2023 would provide enough power for 1/6th of ISO New England's hourly generation for one hour.

Transportation Electrification Risks

- 1998 Northeast Ice Storms destroyed a large swath of the grid including 1,000 transmission towers and 13,000 utility poles. Over 4 million customers were left in the dark for days to weeks across parts of New York, Vermont, Maine, and southern Canada and 44 people died mostly from hypothermia.
- 2003 Northeast Blackout caused by a software bug left 50 million people without power for hours to days.
- 2011 Southwest Blackout caused by a technician switching error left 2.7 million customers without power for hours.
- 2012 Midwest derecho blackout across the Midwest and mid-Atlantic left 4.2 million people without power for hours or days
- 2012 Hurricane Sandy affected primarily New York and New Jersey with damage to both generating facilities and the grid. Outages affected 8.35 million customers for days to weeks.

January 2018 Northeast Cold Snap

- New England was gripped by cold weather between December 25, 2017 and January 8, 2018
  - Monthly HDD of 1,212 is 20.6% higher than January 2017
  - Peak load of 20,599 MW was 5.1% higher than January 2017
  - Frigid cold drove up demand for natural gas which was consumed faster than it could be delivered
  - Gas pressure dropped in the lines feeding the natural gas power plants
  - Natural gas and fuel oil price inversion led to fuel oil being in economic merit and subsequently base loaded. As natural gas prices rose, the entire season's oil supply rapidly depleted. Coal use also increased over normal use
- Sea/river ice affected ship and barge deliveries to fuel oil terminals located in NH, ME and on the Hudson River
- Trucking transport of fuel oil was the primary refueling constraint
- Massachusetts Governor Baker signed hours-of-service waivers to provide fuel deliveries for residential and commercial customers, and power plants
- To increase situational awareness, the ISO initiated semi-weekly then daily fuel surveys of oil-fired generation
- 37 natural gas issues were reported for the period, primarily Operational Flow Orders (OFOs) on Algonquin, Iroquois, and Tennessee Gas Pipelines; 2 in-region force majeure declared ISO-NE requested two conference calls with the Northeast Gas Association's - Gas Supply Task Force
- ISO-NE was in daily communications with interstate pipeline operators

Mitigate Risk

- Establish a deliberate plan to electrify Vermont's transportation and buildings consistent w/grid supply
- Identify and resolve utility and grid constraints up front.
- Identify risks and accept that electrification will not happen overnight
- The New England grid cannot currently support 12 million EV cars, SUV's, pickups, buses and semi's
- Review long-term power supply contracts
- Build additional power generation
- Increase DCFC charging station power output

Questions

Vermont Transportation Emissions Reduction Factors 2025-2030

H.688 required 2025 Greenhouse Gas reductions = 110 million fewer E10 equivalent gallons/yr

EV mass production begins 2022

2030 global EV sales estimates 21 – 44 million w/50% China

EV medium truck/bus battery packs 4X power density of of a Tesla Model 3's @75 KWh

Pickup/SUV EV battery packs will be 3X the power density of a Tesla Model 3's @75 KWh

EV semi truck battery power density are 7-14X of a Tesla Model 3's @75 KWh

One Class 8 semi will use the electricity equivalent to that required for 12.8 average American homes – there are 2.752 million registered US semi-trailers

The EIA and ISO New England's EV power demand forecast based on 2030 low end estimate

The NREL estimated annual power required for transportation sector electrification as 6,786 TWh vs 4,126 TWh today; ISO New England supplies 123.3 TWh annually