The Electrified Mobility Innovation Engine – an Innovation Ecosystem for the U.S. Mobility Industry

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The Ohio State University

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CENTER FOR AUTOMOTIVE RESEARCH

Center for Automotive Research

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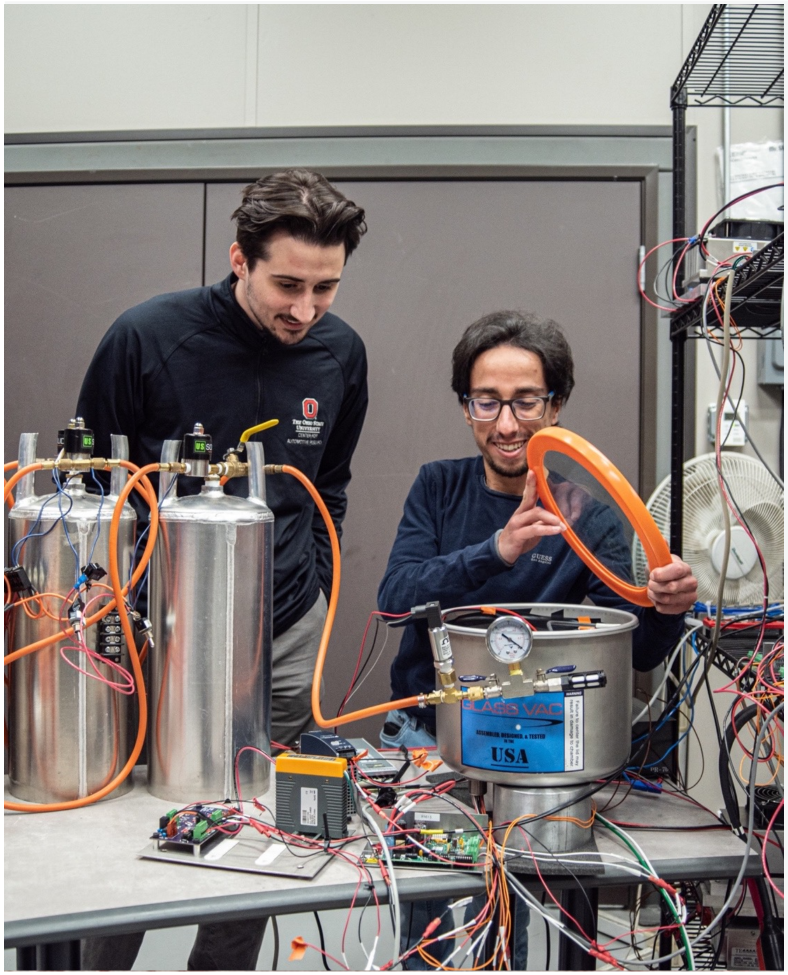


Our Mission

To provide world-class **education** for the next generation of automotive industry leaders, through on-campus learning and continuous professional development;

To serve as a catalyst for **innovation** in automotive technology through collaborative, interdisciplinary research;

To support **economic development**, regionally and nationally.

$18M/year in research expenditures
Supporting >100 graduate students, >300 undergraduate students.

Research Areas of Expertise

Propulsion Systems and Control

Contemporary Engines and Turbochargers
Thermofluids - Acoustics

IC Engine and Powertrain
Modeling - Control Diagnostics

Thermal and Energy Management

Vehicle Emissions

Control Systems

Electrification

Energy Storage
Materials and Cell Development – Material Synthesis and Characterization/Pouch Cell Fabrication

Hybrid and Electric Powertrain
Modeling - Control Diagnostics - xlL tools- Demonstration Vehicles

EV Charging and Grid Interaction

Electric Machine Design

Autonomous And Connected Vehicles

Automated Driving

Advanced Driver Assistance Systems

Test Cases for Automated Vehicles

Driver-in-the-Loop Simulation

Vehicle Connectivity

V2V and V2X Communications

Safety and Security

Cybersecurity

Functional Safety

Pedestrian and Occupant Safety

System Fault Diagnosis

Smart Mobility

Transportation in Smart Cities

Data Platforms and Telematics

Mobility as a Service

Sustainability

Methods of Engagement

BUSINESS UNITS

- CONTINUING EDUCATION
- SPONSORED RESEARCH
- MEMBERSHIP CONSORTIUM
- ENGINEERING SERVICES

EXPERIENTIAL LEARNING

- OUTREACH AND ENGAGEMENT
- STUDENT PROJECTS

Continuing Education

In 2022 delivered continuing education programs for **>1,000** engineers at

HONDA, GM, STELLANTIS, SCHAEFFLER, CATERPILLAR

Educating engineers around the world

- India
- China
- Brazil
- Italy
- France

Led **20** short courses on topics related to:

Electrification
Topics include alternative fuels, electrical storage systems, power electronics for automotive applications and Matlab for data analysis as well as lightweight design and SIL-HIL techniques for automotive control development.

Energy
Topics include battery composition and safety, electrical storage systems and power electronics.

Powertrain
Topics include internal combustion and diesel engines as well as automotive HVAC.

2022 Federal and Industry Research Partners

Over **$5.5M** in new awards **90** active projects Engaging **89** different investigators

UChicago Argonne, LLC
United States Department of Transportation
United States Department of Energy
PACCAR
TRC next
Ohio Department of Higher Education
NSF
ORAU Oak Ridge Associated Universities
State of Ohio Department of Transportation
NEXCERIS where energy meets environment
LG
NASA
infinity LABS
HYUNDAI
HONDA Honda R&D Americas
Hyper Tech Research, Inc.
Georgia Tech
Carnegie Mellon University
gm
Ford
Federal Transit Administration
STELLANTIS
Cummins
arpa·e
EPS Electric Power Systems

A little history

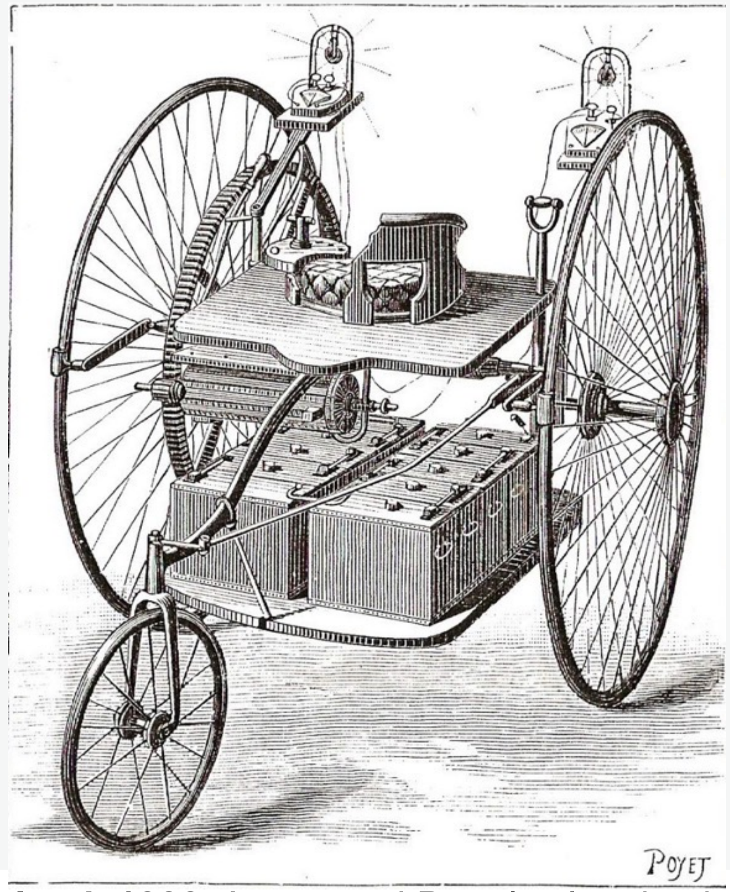
Electric cars are not a new idea

Prof. Bill Knight , 1914. The Ohio State University Archives

THE FIRST TWO ELECTRIC VEHICLES

France, 1881: M. Gustave Trouvé's tricycle

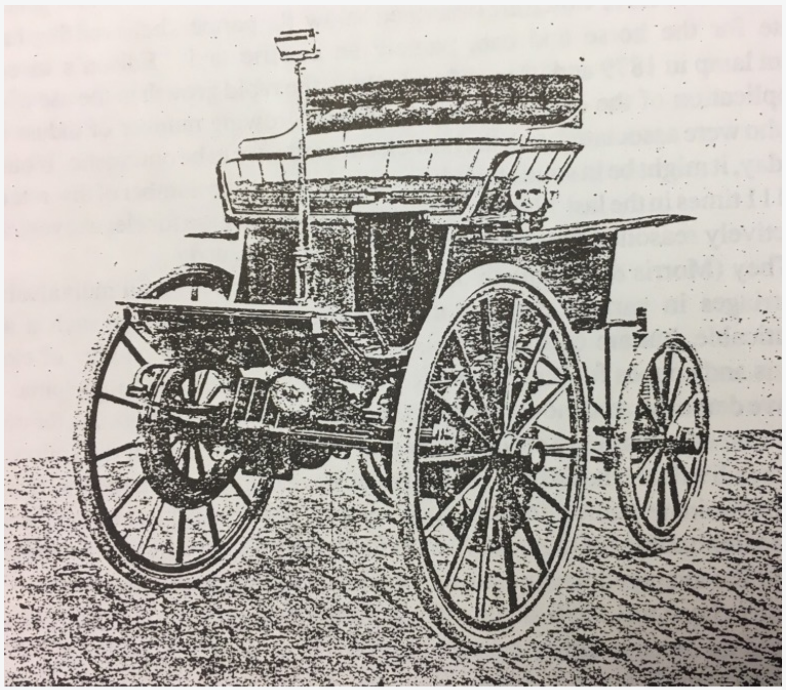
Ernest H. Wakefield, History of the Electric Automobile, SAE International, 1994, ISBN 1-56091-299-5



England, 1882: Ayrton and Perry's electric tricycle

FIRST COMMERCIAL PRODUCTS

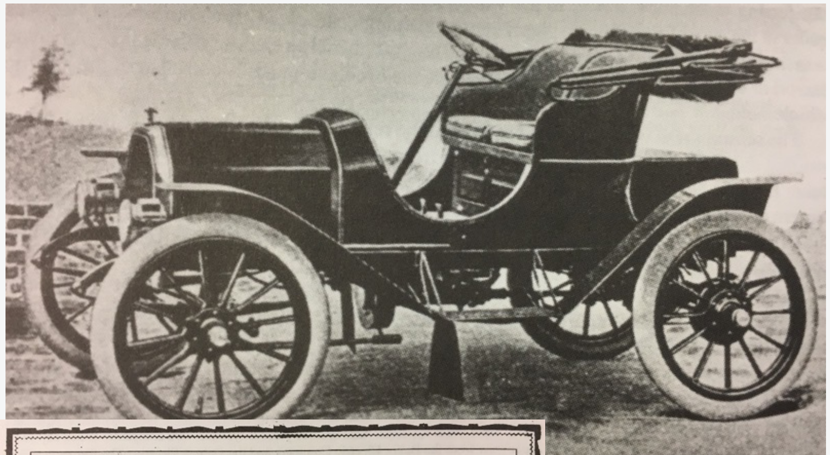
Morris and Salom's Electrobats, 1897: Maximum speed of 20 mph
Energy carried approximately 5 kWh



Ernest H. Wakefield, History of the Electric Automobile, SAE International, 1994, ISBN 1-56091-299-5

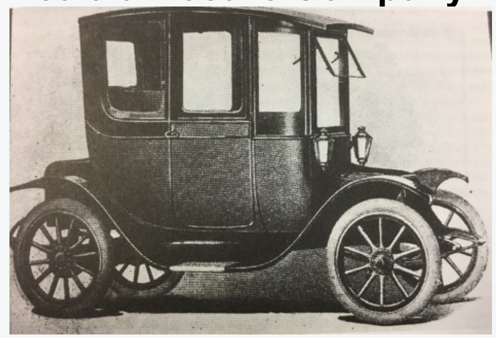
New York City Electric Taxis, 1896: fleet of 13 operating in Manhattan, by the Electric Carriage & Wagon Company of Philadelphia

TWO LONG LIVED ELECTRIC VEHICLE COMPANIES

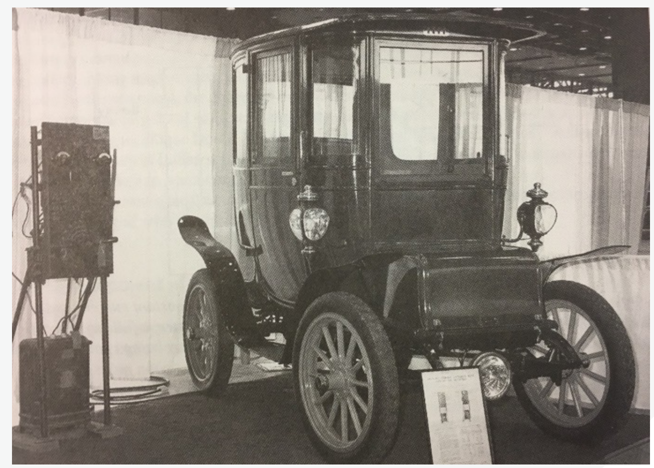


Baker Electric Company:
Baker 1910 Phaeton

Detroit Electric Company: 1908 Standard Electrique



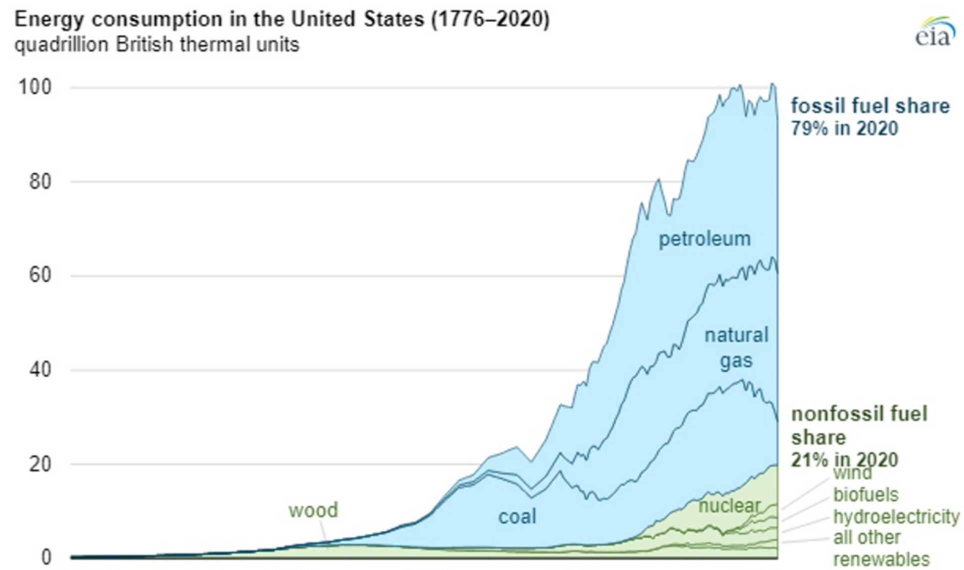
1912 class electric vehicle



Ernest H. Wakefield, History of the Electric Automobile, SAE International, 1994, ISBN 1-56091-299-5

SOME COLUMBUS HISTORY

Some thoughts on energy



UNITED STATES' ENERGY USE IN 2011

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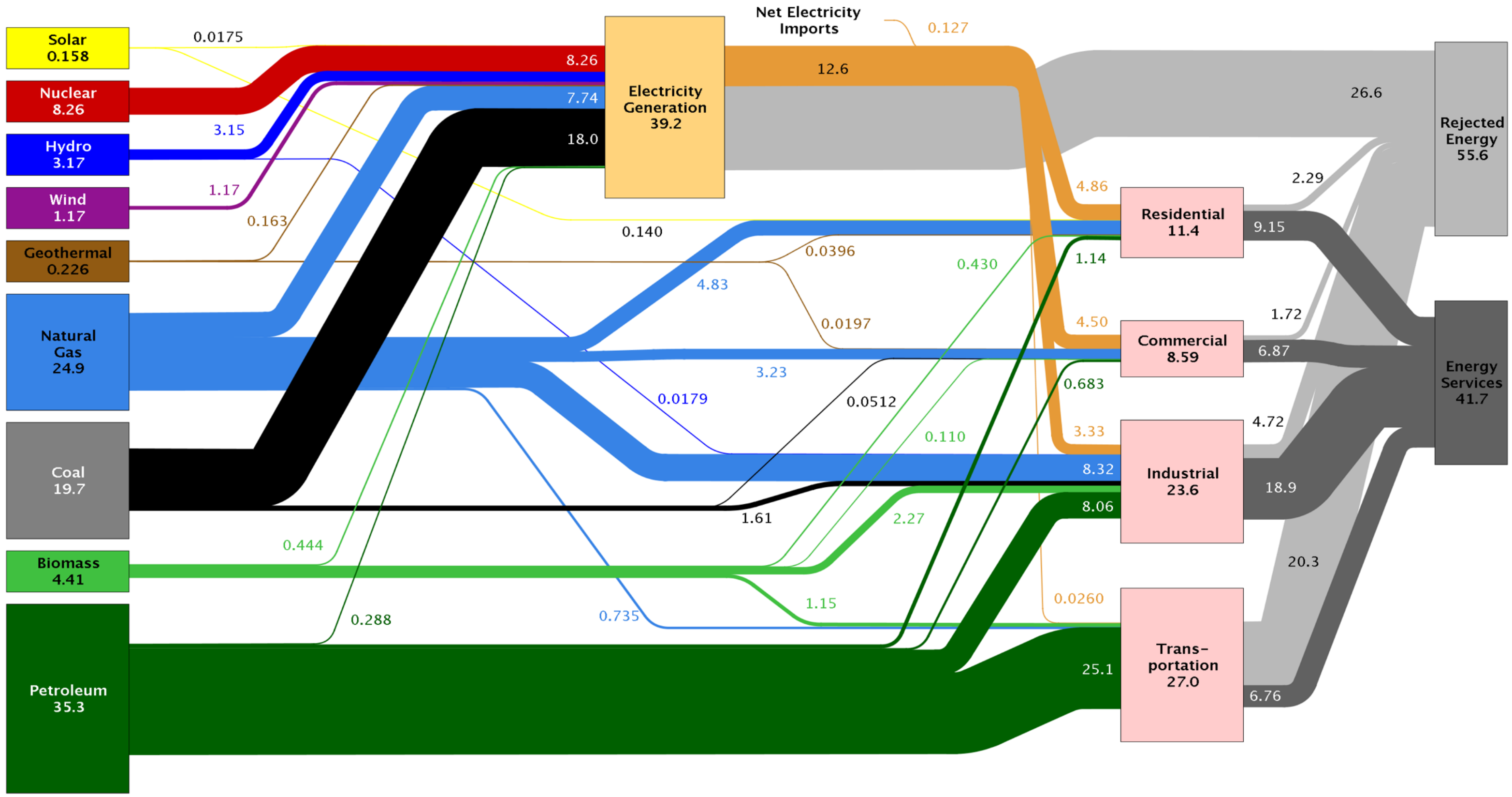
Lawrence Livermore National Laboratory

Estimated U.S. Energy Use in 2011: ~97.3 Quads



Source: LLNL 2012. Data is based on DOE/EIA-0384(2011), October, 2012. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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10 YEARS LATER…

UNITED STATES' ENERGY USE IN 2021

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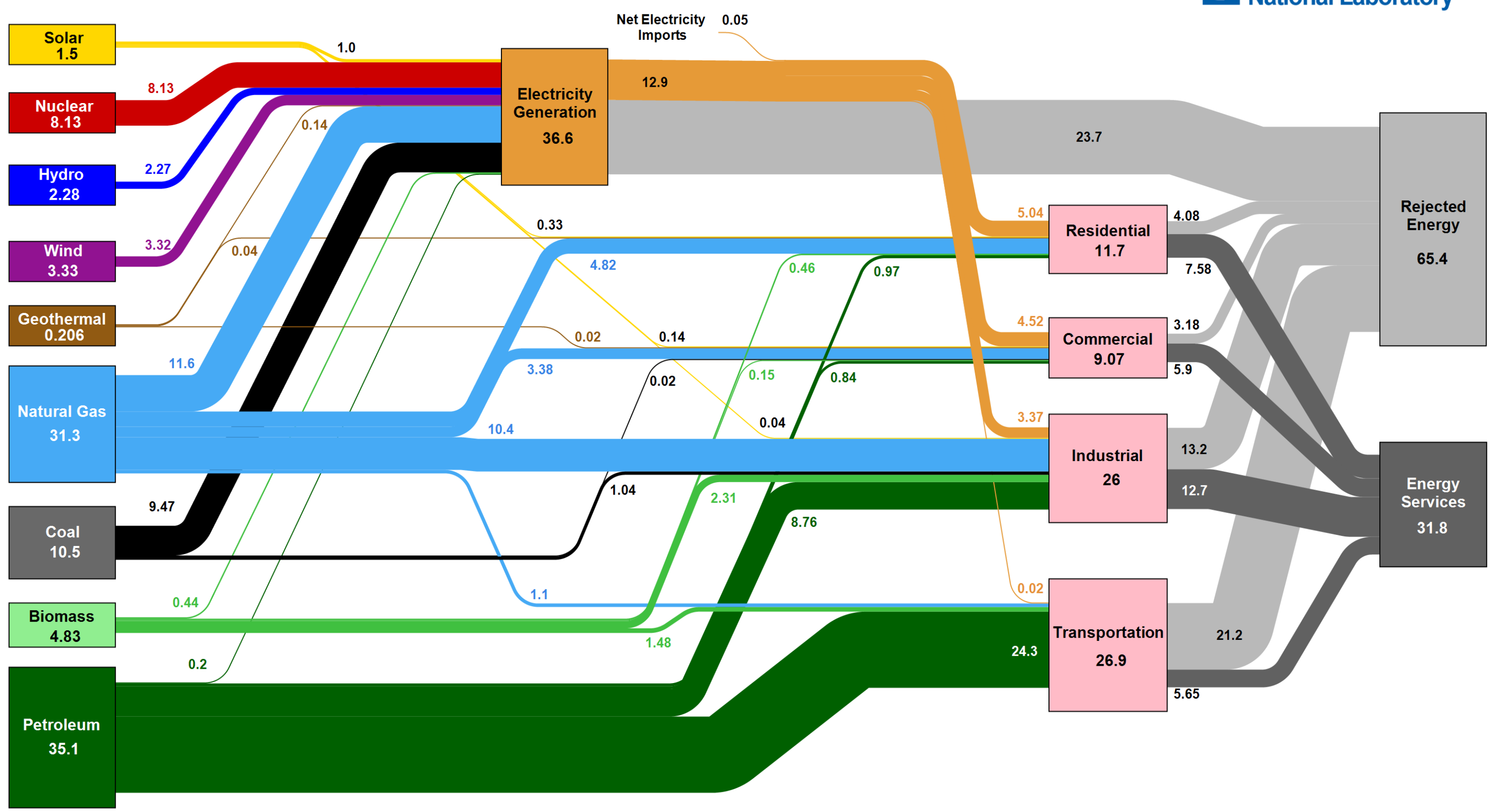
Estimated U.S. Energy Consumption in 2021: 97.3 Quads

Lawrence Livermore National Laboratory



Source: LLNL March, 2022. Data is based on DOE/EIA MER (2021). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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HORSE AND CARRIAGE?

Powered by sustainable biofuels, net zero carbon (well, almost…)

Tailpipe emissions are not quite zero!

1892, horse and buggy behind University Hall, The Ohio State University Archives

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EMIE:
Where We've Been
Where We're Going

Core Team Workshop

March 14, 2023

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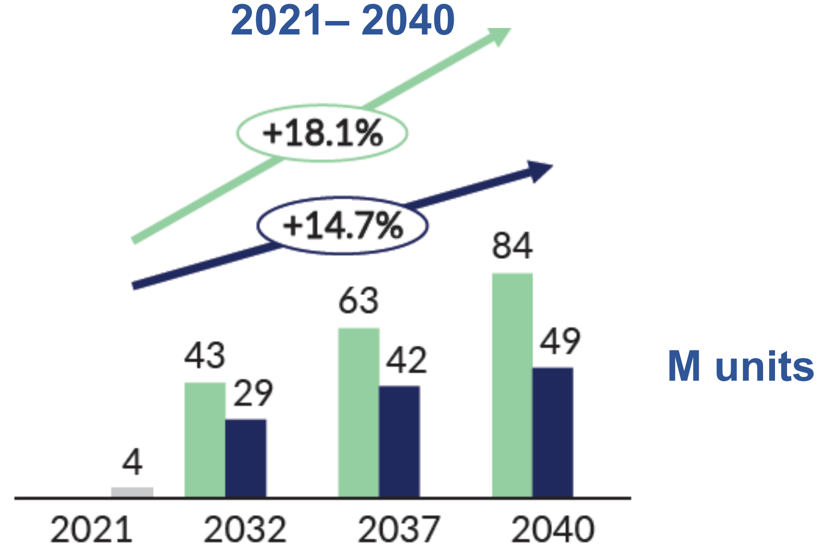
The Context

EV adoption needs to explode to meet climate goals…

Battery EV Growth Scenarios 2021– 2040



Scenario aligned with a +1.5^{o}C warming with little or no overshoot. BEV share reaches 65% of annual sales by 2040.

2022 – 2040 Powertrain Outlook, KGP Powertrain Intelligence, Derby, UK (2022).

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Purdue University
The University of Tennessee Knoxville

…but a number of critical barriers stand in the way

- Customer acceptance based on cost and range
- Model availability
- Fueling and energy
- Resource/material availability
- Workforce alignment

2022 – 2040 Powertrain Outlook, KGP Powertrain Intelligence, Derby, UK (2022).

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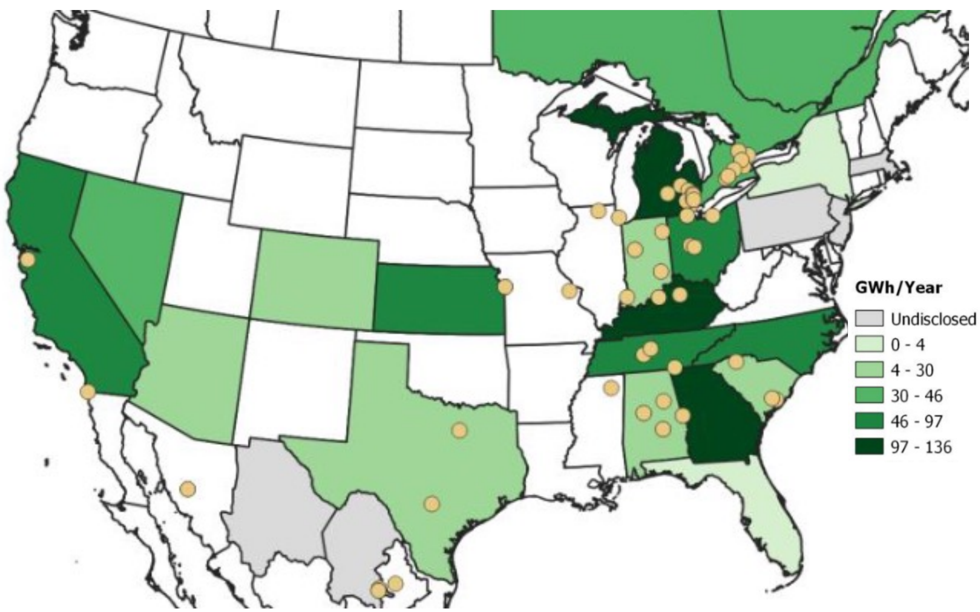
The I-75 corridor is the heart of the US mobility sector

Planned battery plant capacity by 2030 (GWh/yr) overlaid by EV assembly locations (dots).



Over 500,000 automotive manufacturing jobs in the five-state region

More than 4,000 firms tied to legacy component and system production

EMIE. Accelerating the transition to Electrified Mobility through technology, manufacturing, and workforce

What EMIE is:

- Independent, non-profit network linking business, academia, government
- Intellectual property holding subsidiary
- Allied venture studio model fund

What EMIE will do:

- Deploy public and private funds to pull forward use-inspired R&D
- Fund education and training programs for workforce development
- Streamline paths into the marketplace for knowledge, products and processes
- Create new businesses

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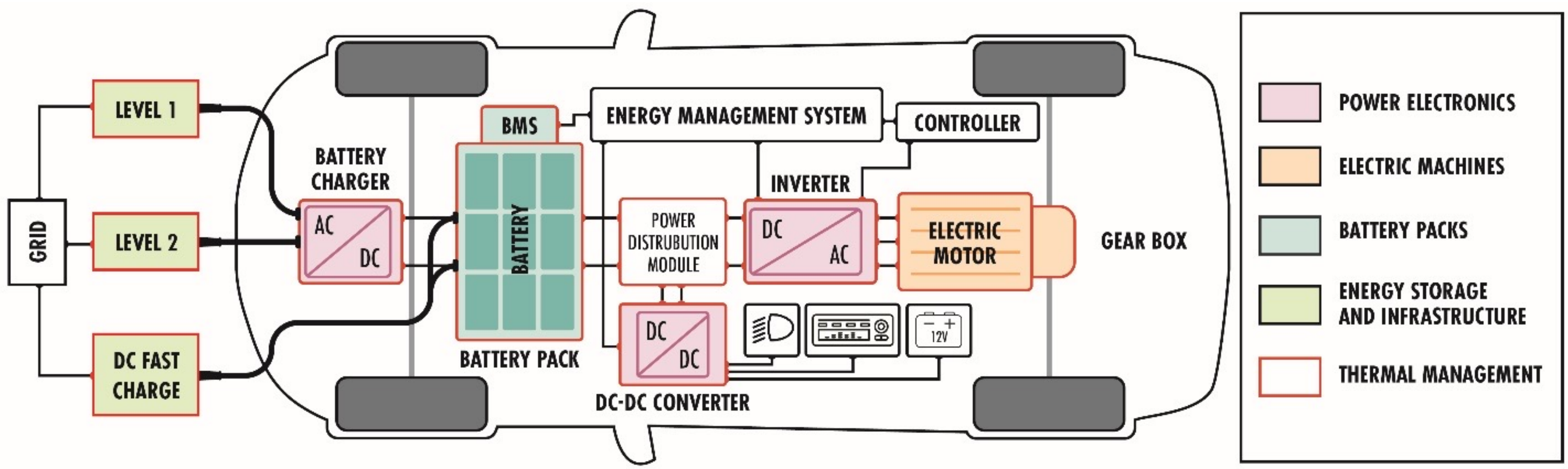
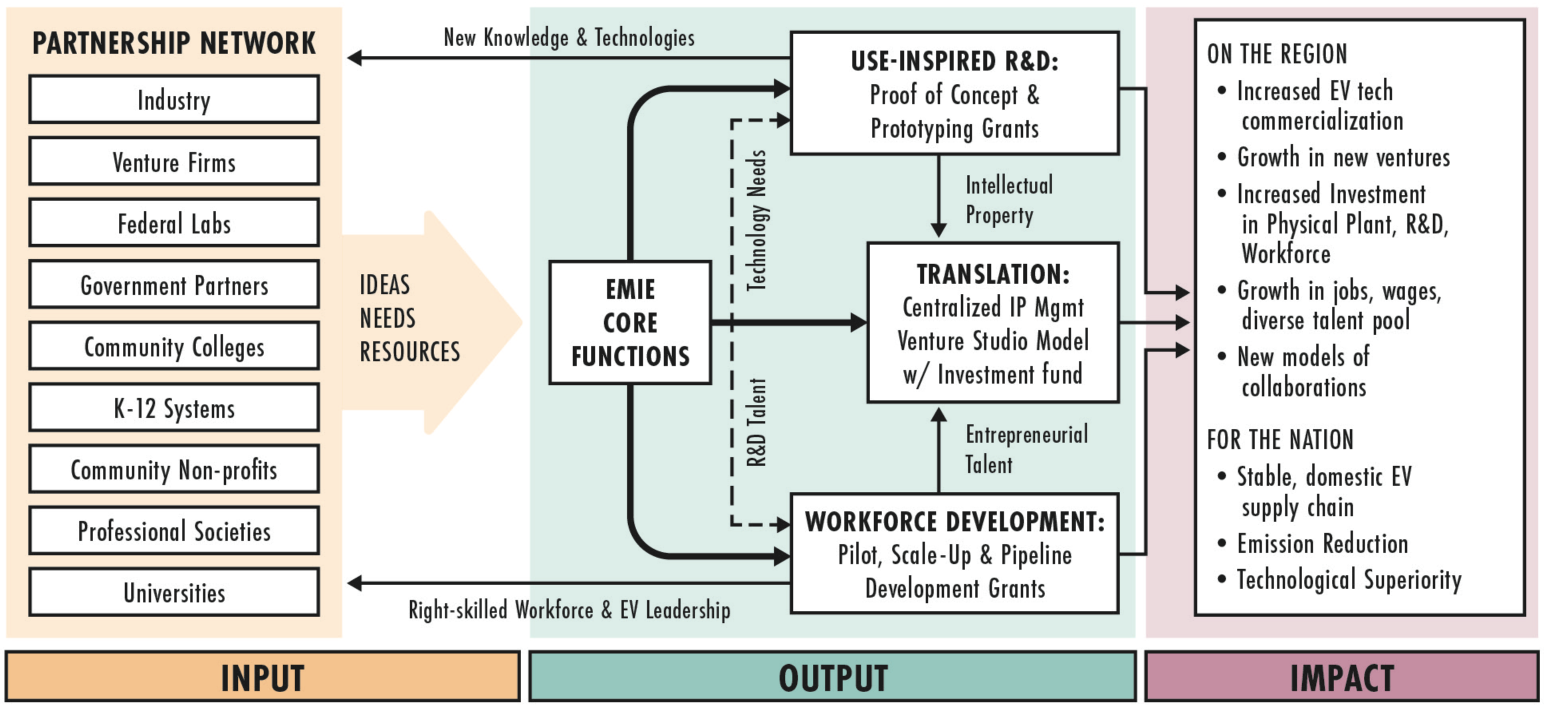
EMIE focuses on **transformative technologies** in the on-board component-to-system design and optimization for integration into vehicle- and grid-level systems...

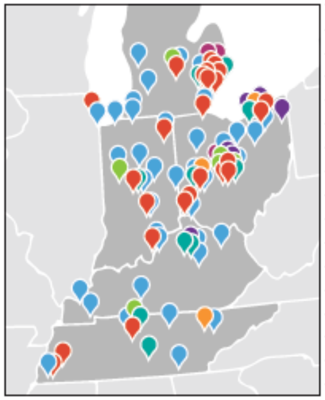


…and the workers, companies, policy environment, and innovation infrastructure needed to get this tech into use

EMIE will stand as a nonprofit industry/government/academic partnership network.



The emerging EMIE partnership network



INDUSTRY
Aerospace
Boeing
Raytheon Technologies
Batteries
LG Energy Solution
XS Power Batteries
Commercial Vehicles
Allison Transmission
Cummins
Kenworth
PACCAR
Workhorse
Energy & Infrastructure
LG&E and KU
RevCharger
Logistics
FedEx
Materials
Nexceris
PowderMet
Safire Technology Group, Inc.
Passenger Vehicle OEM
Ford
General Motors (GM)
Honda
Hyundai
Volkswagen
Supplier
Borg Warner
Dana
Eaton
Gentherm
Robert Bosch
Schaeffler
Stoneridge
ZF

UNIVERSITY
Masters Universities
Morehead State University
Murray State University
R1 Universities - State Leads
Michigan State University
Ohio State University
Purdue University
University of Kentucky
University of Tennessee Knoxville
R1 Universities
Tennessee State University
University of Louisville
University of Memphis
University of Michigan
University of Notre Dame
Vanderbilt University
R2 Universities
University of Akron
University of Toledo
R3 Universities
Northern Kentucky University
Western Kentucky University (WKU)

COMMUNITY & TECHNICAL COLLEGE
Bluegrass
Columbus State Community College
Ivy Tech
Kentucky Community & Technical College System
Lorain County Community College
Macomb Community College
Motlow State Community College
Sinclair

INNOVATION SECTOR
Bluegrass Angels
BRITE Energy Innovators
Innovation fund America
Kentucky Science and Technology Corporation
LaunchBlue
Ohio Innovation fund
Porter Wright
Rev1

FFRDC
Air Force Research Laboratory (AFRL)
NASA Glenn Research Center
National Institute of Standards and Technology (NIST)
National Renewable Energy Laboratory (NREL)
Oak Ridge National Laboratory

TRADE / PROFESSIONAL SOCIETY
Institute of Electrical and Electronics Engineers (IEEE)
Ohio Manufacturers Association
SME
Socitey of Automotive Engineers (SAE)

STATE INITIATIVE / AGENCY
Clean Fuels East Tennessee
DriveOhio
Indiana Department of Transportation
Jobs Ohio
LEAP (Lansing Economic Area Partnership)
Michigan Economic Development Corporation
TN Department of Economic and Community Development

- Community and Technical College
- Trade/Professional Societies
- Innovation Sector
- FFRDC
- Industry
- University
- State Initiative/Agency

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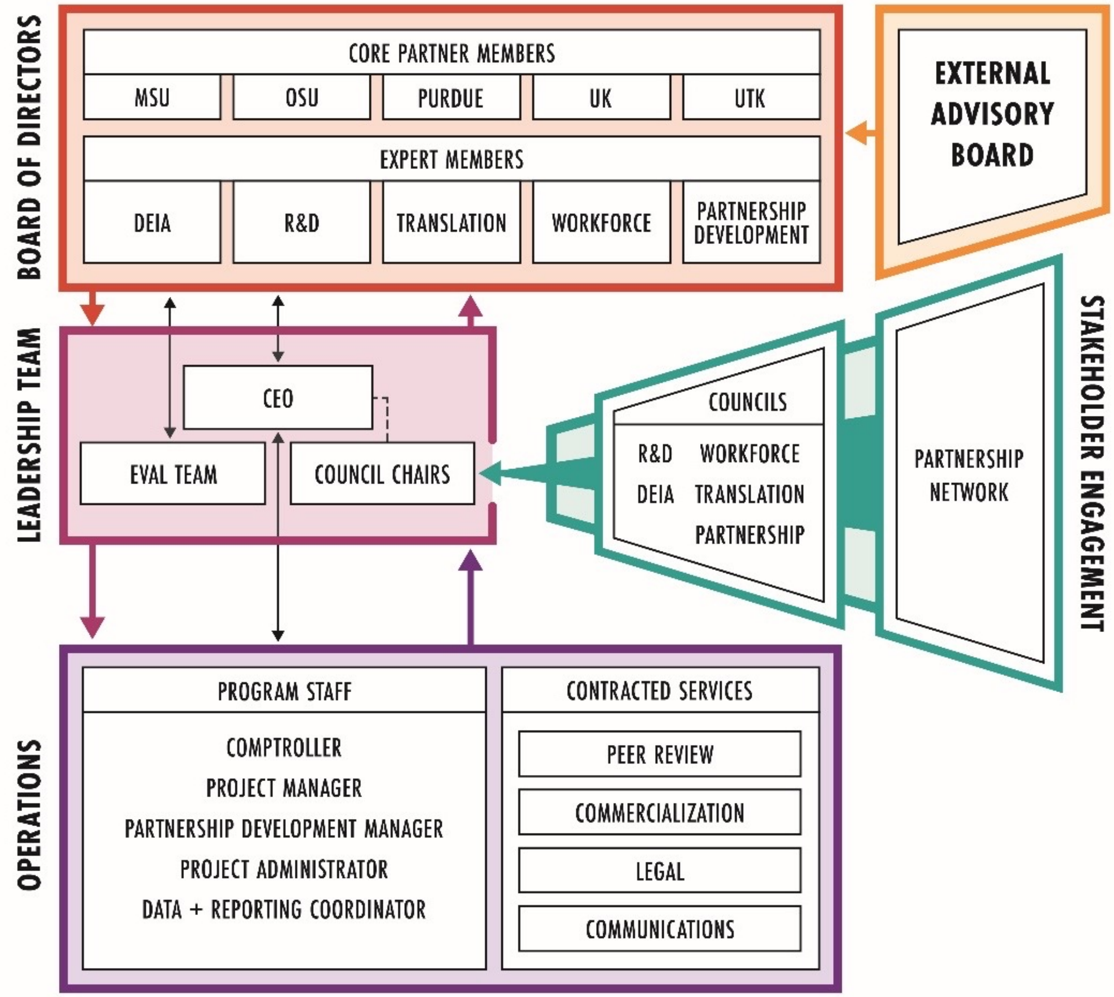
Inclusive, shared regional governance balanced with lean operations



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NSF Engines is the first opportunity to start building a regional resource

- Up to $160M/10 yrs
- The charge: use innovation to drive inclusive economic development

Use-inspired research and development

Translation of innovation results to society

Workforce development to grow and sustain regional innovation

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