

# Beyond Batteries: Direct Electrification of the Transportation Sector

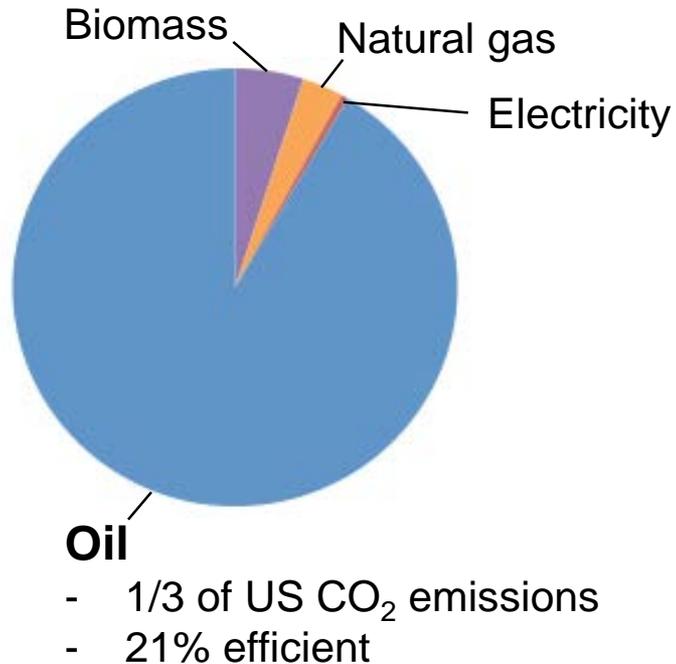
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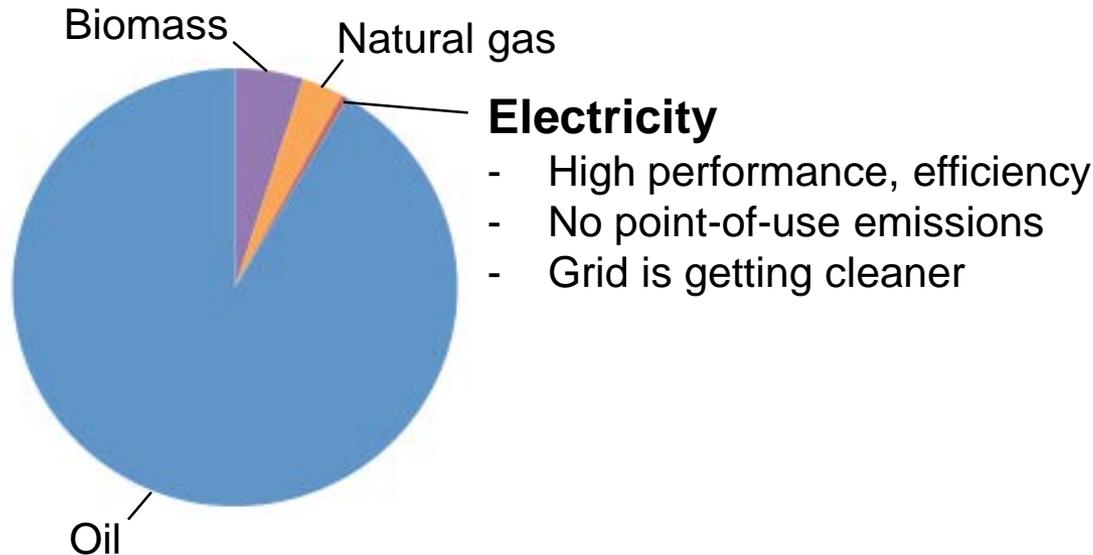
# Direct electrification of transportation

## US transportation energy use



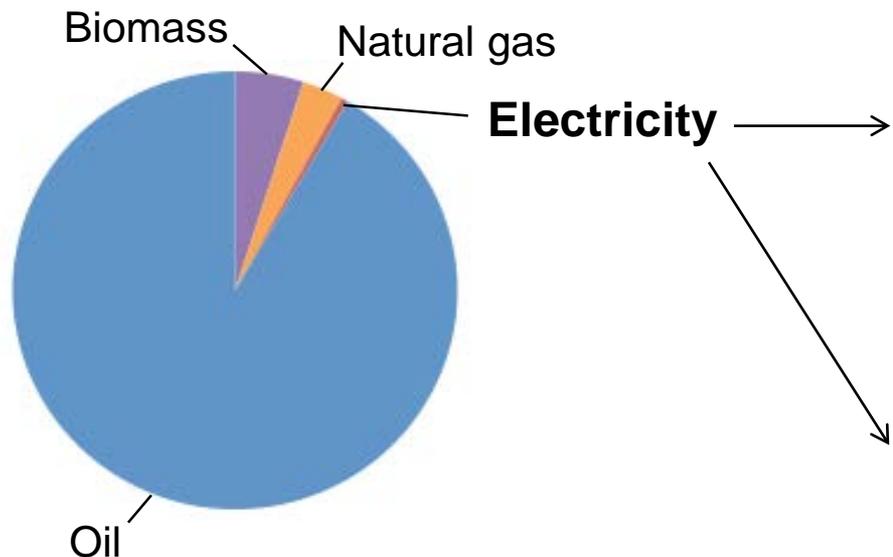
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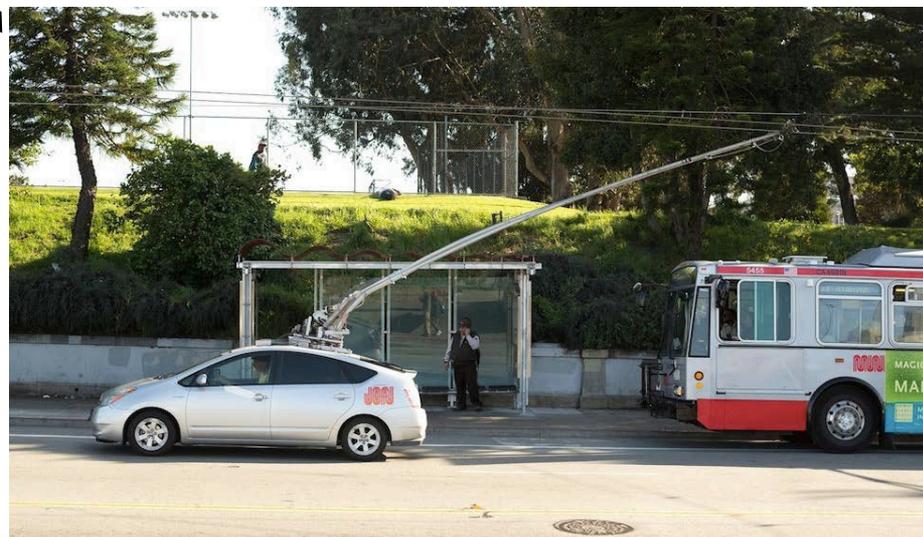


# Direct electrification of transportation

## US transportation energy use



## Direct electrification: new paradigms



# Battery electrification is best for small vehicles

## Battery electrification has arrived

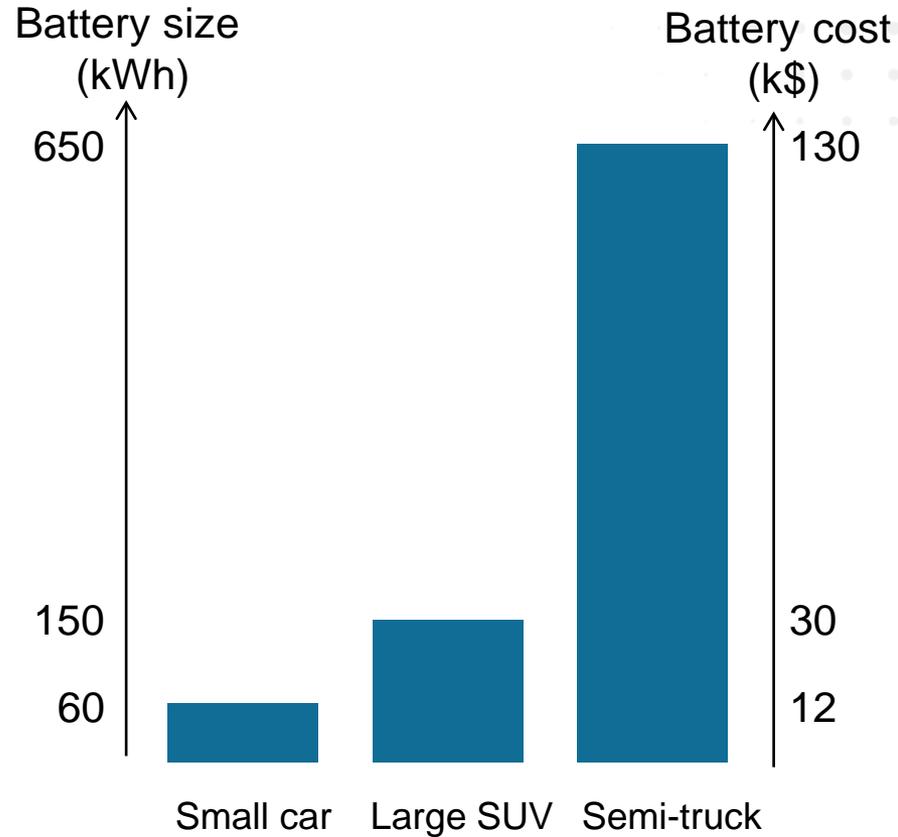
Tesla Model S: 70 kWh, \$62.5k after tax break



Chevy Bolt: 60 kWh, \$30k after tax break

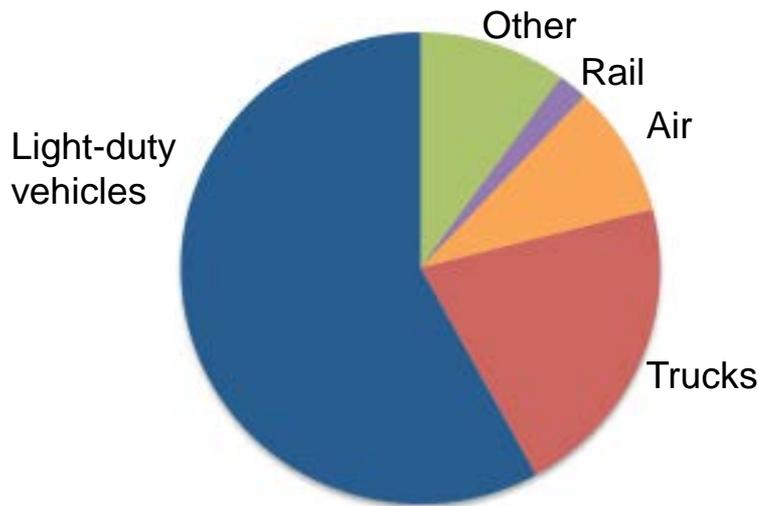


For 250 mile range

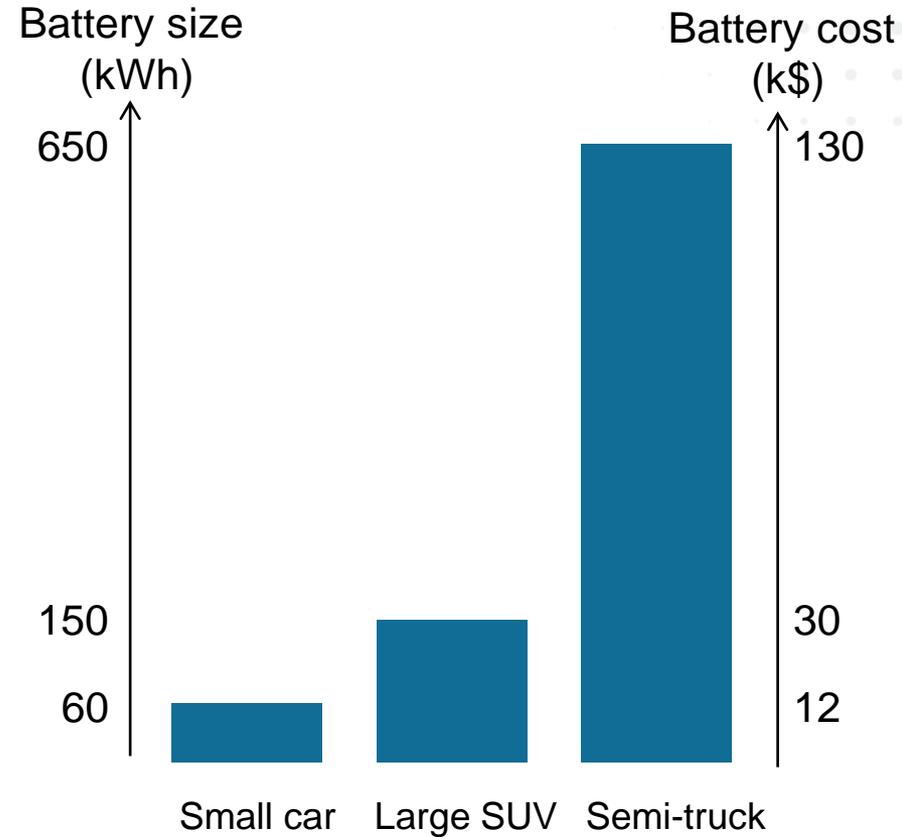


# Battery electrification is best for small vehicles

Transportation energy use by vehicle type

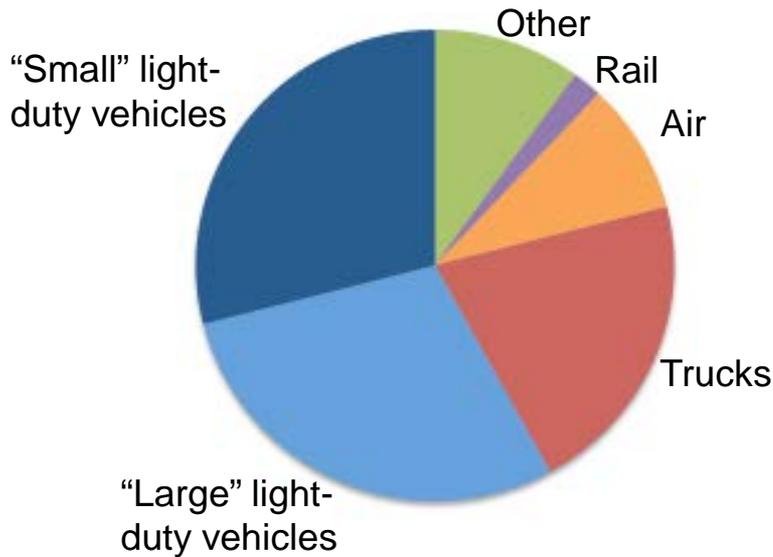


For 250 mile range



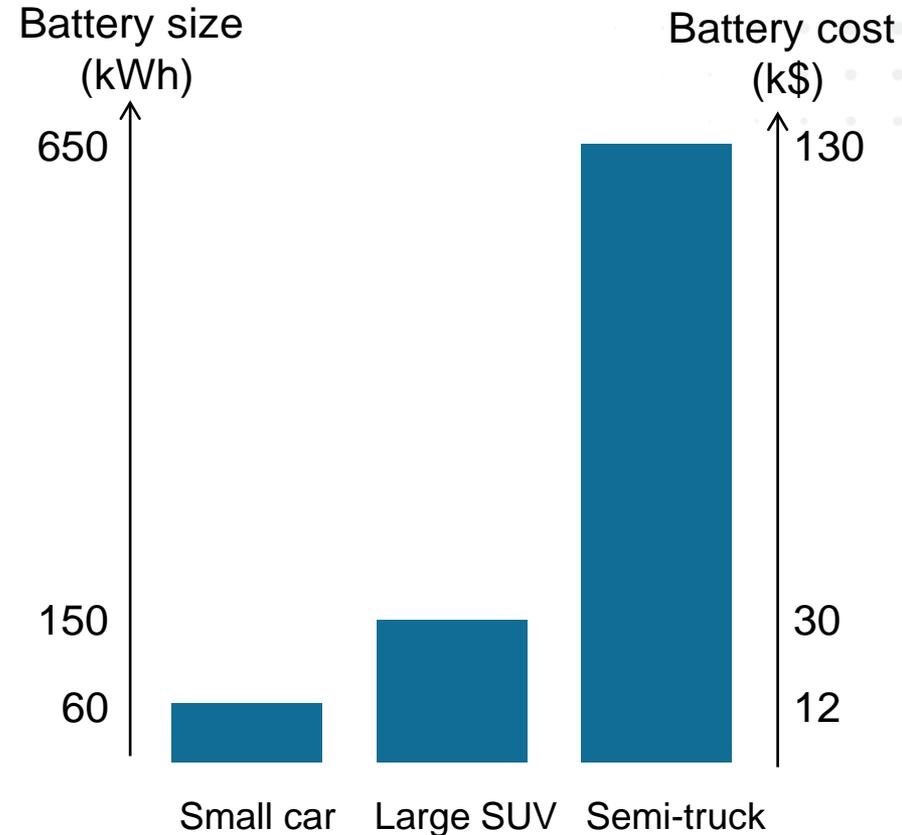
# Battery electrification is best for small vehicles

Transportation energy use by vehicle type



**>50% of transportation energy use is not suited for battery electrification**

For 250 mile range



# Large vehicles have history of direct electric

San Francisco street car



DC Metro



San Francisco electric bus



# There *are* reasons for low penetration

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- ▶ INFRASTRUCTURE: the dreaded 14-letter word.
  - Wire/track costs of 2-5 million \$/mile and up.
  - Fixed routes.
  - Overhead lines and on-ground tracks limit access.
- ▶ High vehicle costs due to low production volumes.
- ▶ **Question: can ARPA-E solve technical challenges and help enable new paradigms?**

# Paradigm change: grid-diesel hybrids

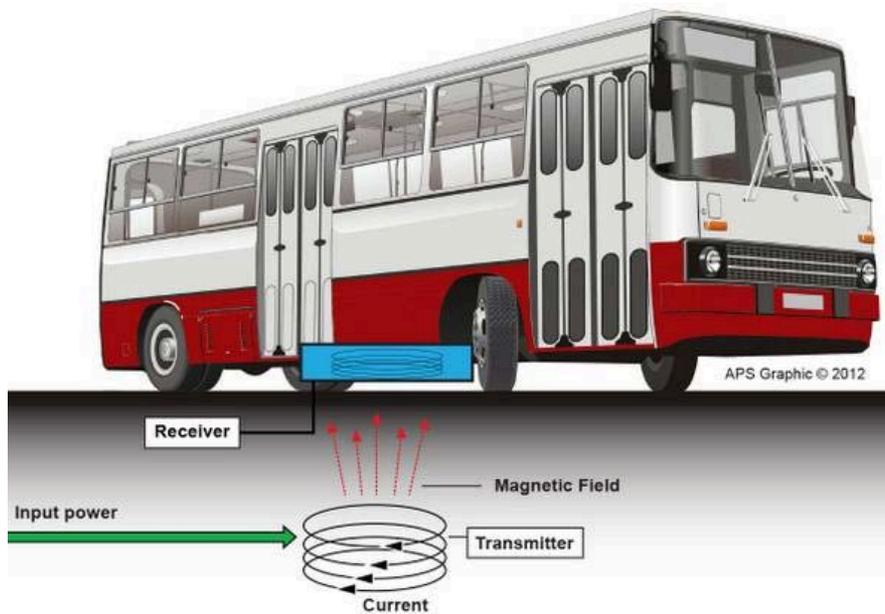
- ▶ Siemens eHighway system

- Flexible routes: retain vehicle diesel powertrain, automatic hook-up.
- Leverage existing vehicle platforms.
- Technical challenges: powertrain optimization, vehicle automation.



# Paradigm change: wireless power transfer

- ▶ Wireless power transfer enables safe ground-level transfer
  - Expand access to a range of vehicles types.
  - Add-on receiver technology can leverage existing vehicles.
  - Technical challenges: cost, efficiency, high-speed operation.



Wireless-powered bus in South Korea



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A creative approach in San Francisco!



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Wireless receiver?

Wireless-powered bus in South Korea

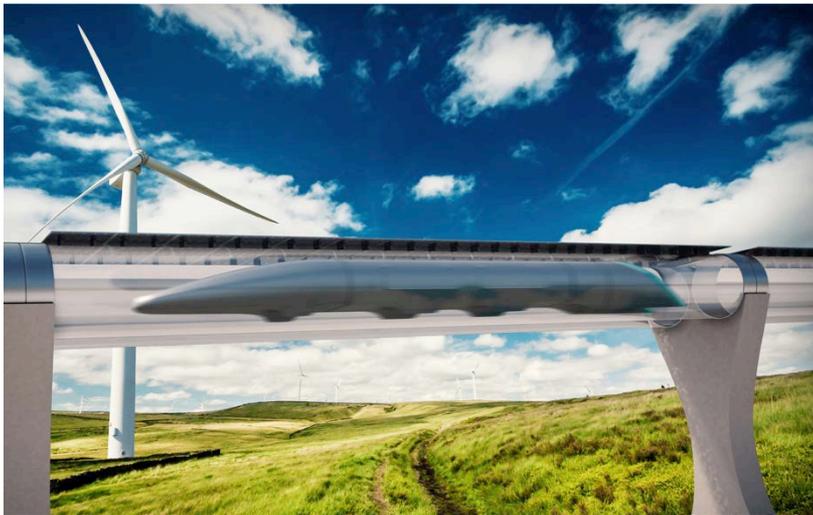


# Paradigm change: new transportation mode

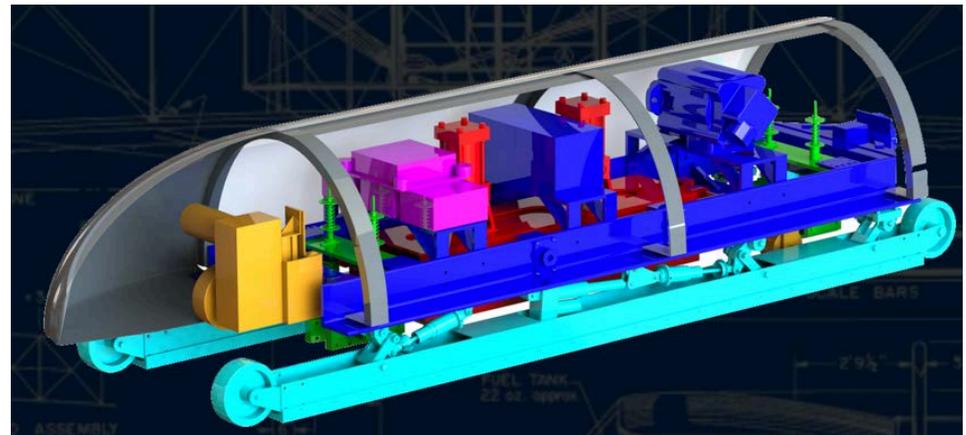
## ▶ Example: Hyperloop

- Vacuum-tube high-speed (>700 mph) system proposed by Elon Musk.
- Path to replace oil used in air travel with electricity.
- Technical challenges: in abundance!

Artistic rendering of Hyperloop



Winner of 2016 SpaceX Design Competition:  
MIT Hyperloop pod



# Problem statement, and next steps

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- ▶ What technical challenges could ARPA-E address that would:
  - Enable cost-effective direct electrification of transportation, especially large vehicles.
  - Further use of existing modes of electric transportation.
  
- ▶ Interested?
  - Come talk to me at the Summit
  - [Paul.Albertus@hq.doe.gov](mailto:Paul.Albertus@hq.doe.gov)