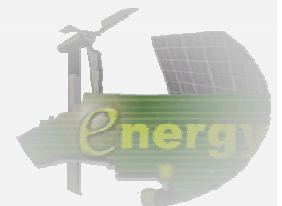




# Market Adoption Factors of 'Hydrail' Technology

Jason Hoyle, Research Analyst  
Appalachian State University Energy Center  
Boone, NC, USA





# Defining hydrail technology

- Technology Innovation
  - Early-market application of fuel cells & hydrogen
  - Complementary to rail technology trends
  - Leverage to overcome energy infrastructure barriers
- Transportation Mode
  - New opportunity for infrastructure expansion
  - Flexibility & diversification of transportation energy
  - Reduced pollution intensity
- Public Goods & Welfare
  - Enable & facilitate hydrogen economy transition
  - Increase value of 'public' goods, e.g. system risks, air quality, affordable mobility





# Product Adoption Chain

- Fuel Cell & Hydrogen Producers
  - Fuel cell modules
  - Electronic balance-of-system suppliers
  - Hydrogen production equipment/refueling/storage
- End-Use Equipment OEMs
  - Engine/Train manufacturers
  - Infrastructure providers
- Final Application Buyers
  - Rail transit companies
  - Governments





# Technology Applications

- Engine power train
  - After market add-on, up-fit existing engine systems
  - Hybrid trend, supplement load
  - Full hydrogen fuel cell engines
- Rail infrastructure
  - Diesel systems, existing
  - Electric systems, existing
  - Planned systems, future
- Ancillary applications
  - Mobile MW-scale generators
  - 'Enable' hydrogen transition





# Microeconomic Factors

- Existing rail systems
  - Diesel-based
    - Break-even is function of fuel price and fuel cell+H2 cost per unit of fuel saved
    - Other value streams: hedge value in total portfolio, carbon and other emissions markets
    - Optimized use: idling emission reductions, demand cycles
  - Electric-based
    - Cost of expanding grid vs. fuel cell add-on, i.e. system productivity
    - Hedge against grid stress, nature risks – storm, drought, etc.
    - Lower marginal cost for rail line extensions to lower-density population areas





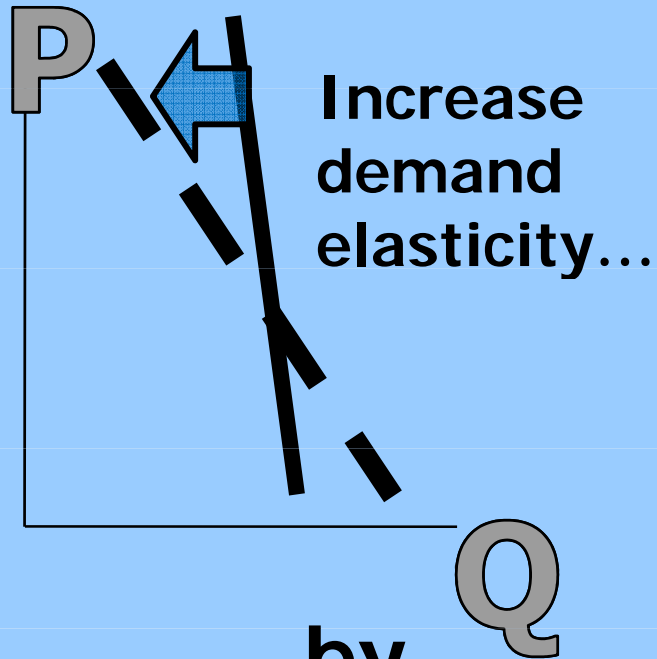
# Macroeconomic Factors

- Direct value
  - Fuel supply diversity: reduce price/shortage risk, increase flexibility of adaptation to market factors
  - Long-term transportation affordability, support higher capacity growth rates
  - Reduced economic exposure to negative externalities
  - Opportunity to reduce economic trade deficit
- Indirect value
  - Secondary technology roles, i.e. disaster response
  - Facilitate energy-supply transition
  - Reduce income sensitivity to energy prices
  - Influence growth patterns, economic development





# Hydrogen Trains & Charlotte, NC

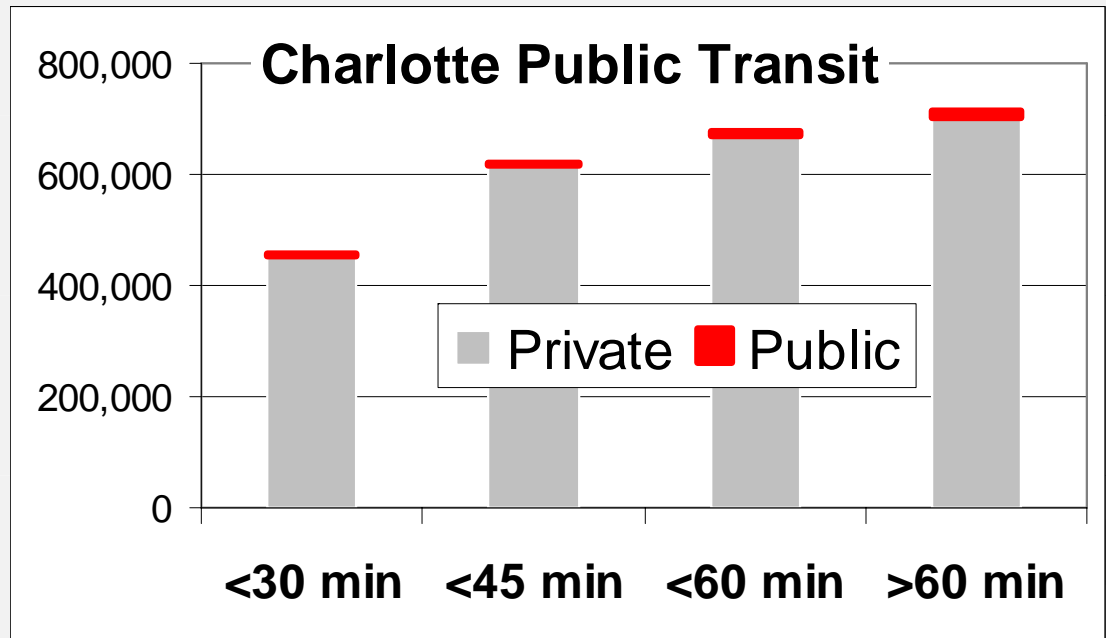


...by  
increasing  
*options*

[www.charlotte.com/109/story/368058.html](http://www.charlotte.com/109/story/368058.html)

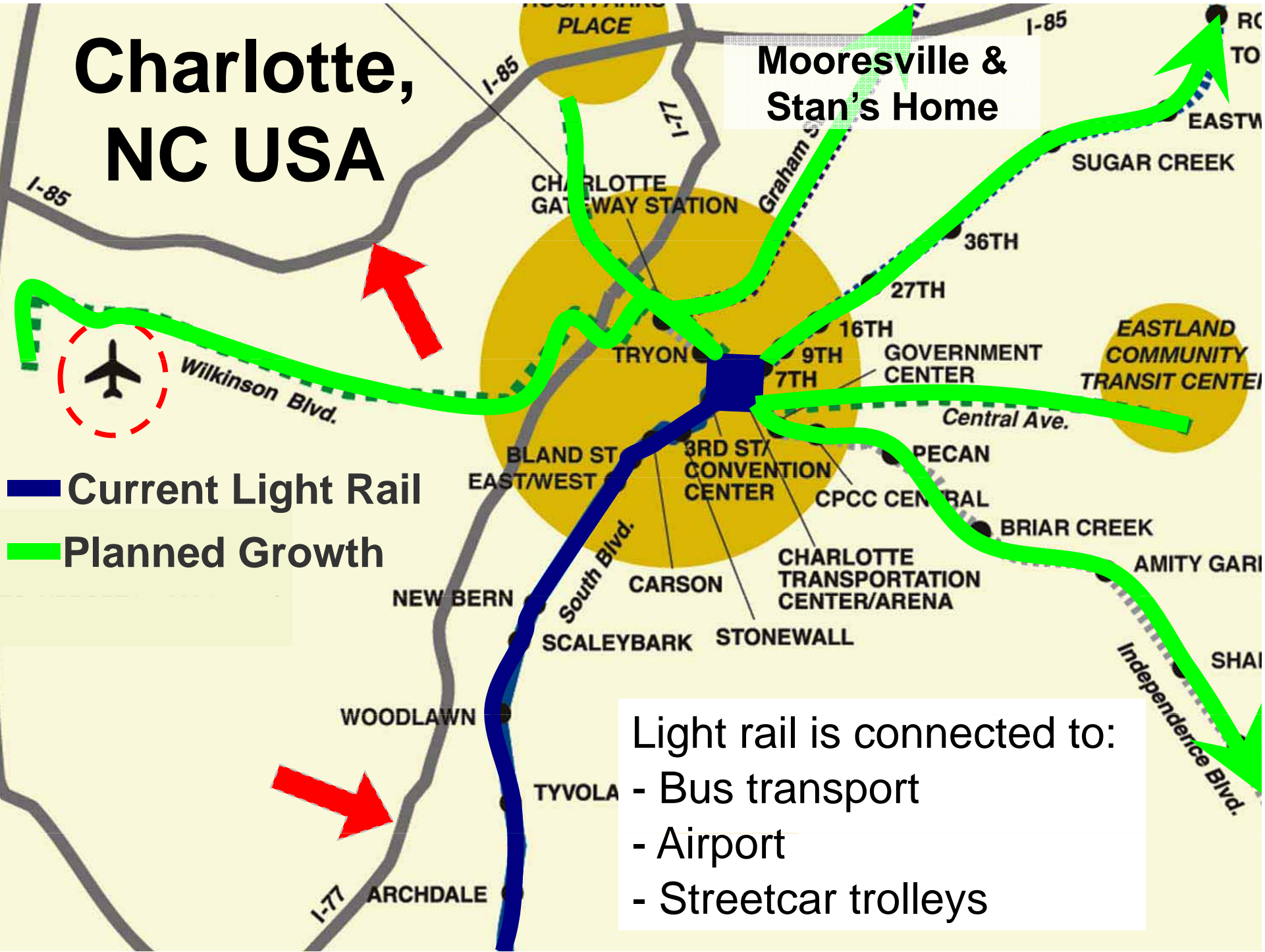
## Local Market Factors:

- Recent light rail success
- Local source of hydrogen
- Local manufacturers
- \$1/gallon  $\Delta$  = \$1 million per day



# Charlotte, NC USA

Mooresville & Stan's Home



- Current Light Rail**
- Planned Growth**

Light rail is connected to:

- Bus transport
- Airport
- Streetcar trolleys



# Flexibility – The Factor

- Local decision context determines value, price
- Use flexibility to maximize value
  - Train engines
  - Infrastructure development
  - Supporting roles
- Fuel Cell ► OEM ► Buyer Application
- Value segments of market
  - Existing: cost savings/price hedge/marginal growth
  - Competing: infrastructure savings/energy transition
  - Emerging: life-cycle costs/growth capacity/equitable

