

Overview of Modeling and Analysis Capabilities at ANL and LLNL

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H2@Scale Review Meeting
Washington D.C.

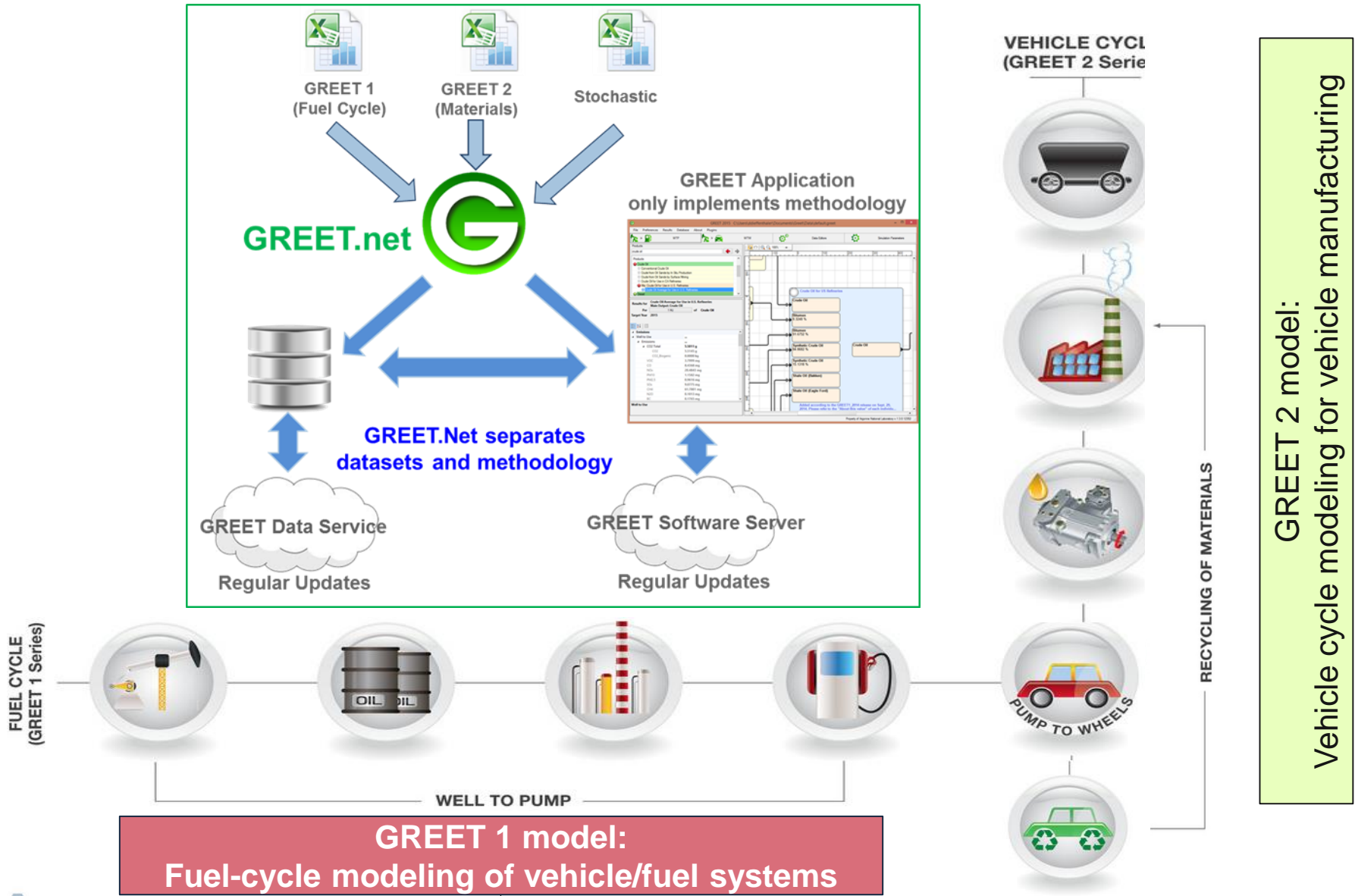
June 9, 2017



***GREET[®] Life Cycle Analysis Model
at
Argonne National Laboratory (ANL)***



The GREET® (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model



**GREET 1 model:
Fuel-cycle modeling of vehicle/fuel systems**

Stochastic Simulation Tool

<https://greet.es.anl.gov/>

GREET outputs include energy use, greenhouse gases, criteria pollutants and water consumption for vehicle and energy systems

□ Energy use

- Total energy: fossil energy and renewable energy
 - Fossil energy: petroleum, natural gas, and coal (they are estimated separately)
 - Renewable energy: biomass, nuclear, hydro-power, wind, and solar energy

□ Greenhouse gases (GHGs)

- CO₂, CH₄, N₂O, and black carbon
- CO₂e of the three (with their global warming potentials)

□ Air pollutants

- VOC, CO, NO_x, PM₁₀, PM_{2.5}, and SO_x
- They are estimated separately for
 - Total (emissions everywhere)
 - Regional, urban (a subset of the total)

□ Water consumption and regional water stress analysis

□ GREET LCA functional units

- Per mile driven
- Per unit of energy (million Btu, MJ, gasoline gallon equivalent)
- Other units (such as per ton-mi for transportation modes)



REET development has been supported by several DOE Offices since 1995

- Vehicle Technology Office (VTO)
- Bioenergy Technology Office (BETO)
- Fuel-Cell Technology Office (FCTO)
- Geothermal Technology Office (GTO)
- Energy Policy and Systems Analysis (EPSA)

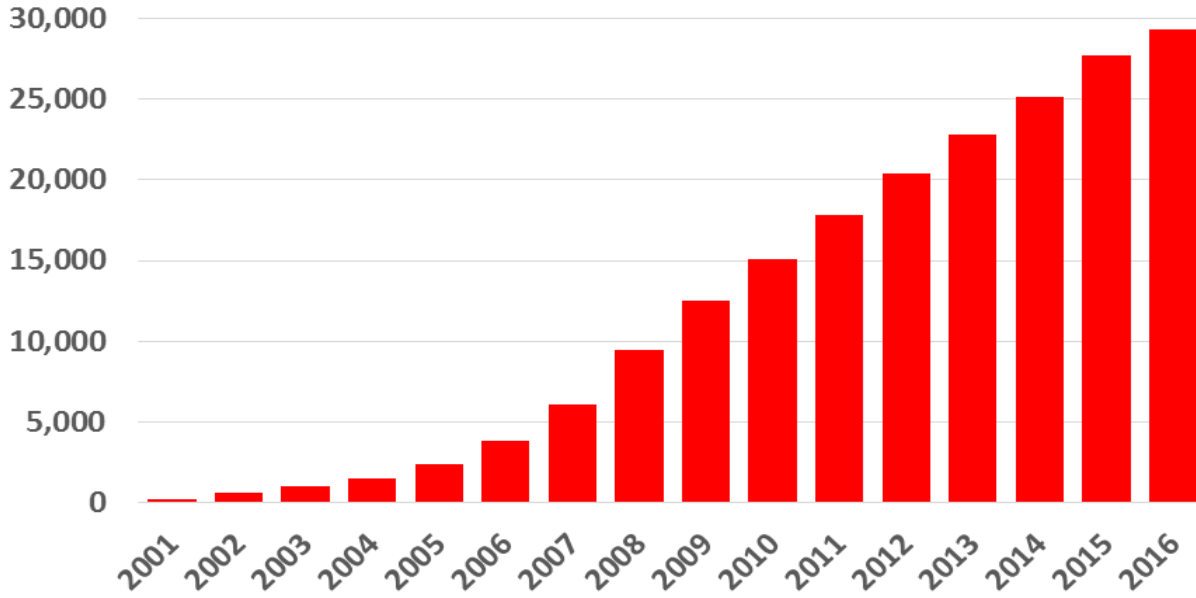
REET has been in public domain and free of charge - Updated annually

Examples of major uses of REET

- US EPA used REET for RFS and vehicle GHG standard developments
- CARB developed CA-REET for its Low-Carbon Fuel Standard compliance
- DOE, USDA, and the Navy use REET for R&D decisions
- DOD DLA-Energy uses REET for alternative fuel purchase requirements
- Auto industry uses it for R&D screening of vehicle/fuel system combinations
- Energy industry (especially new fuel companies) uses it for addressing sustainability of R&D investments
- Universities use REET for education on technology sustainability of various fuels



There are 30,000 registered GREET users globally



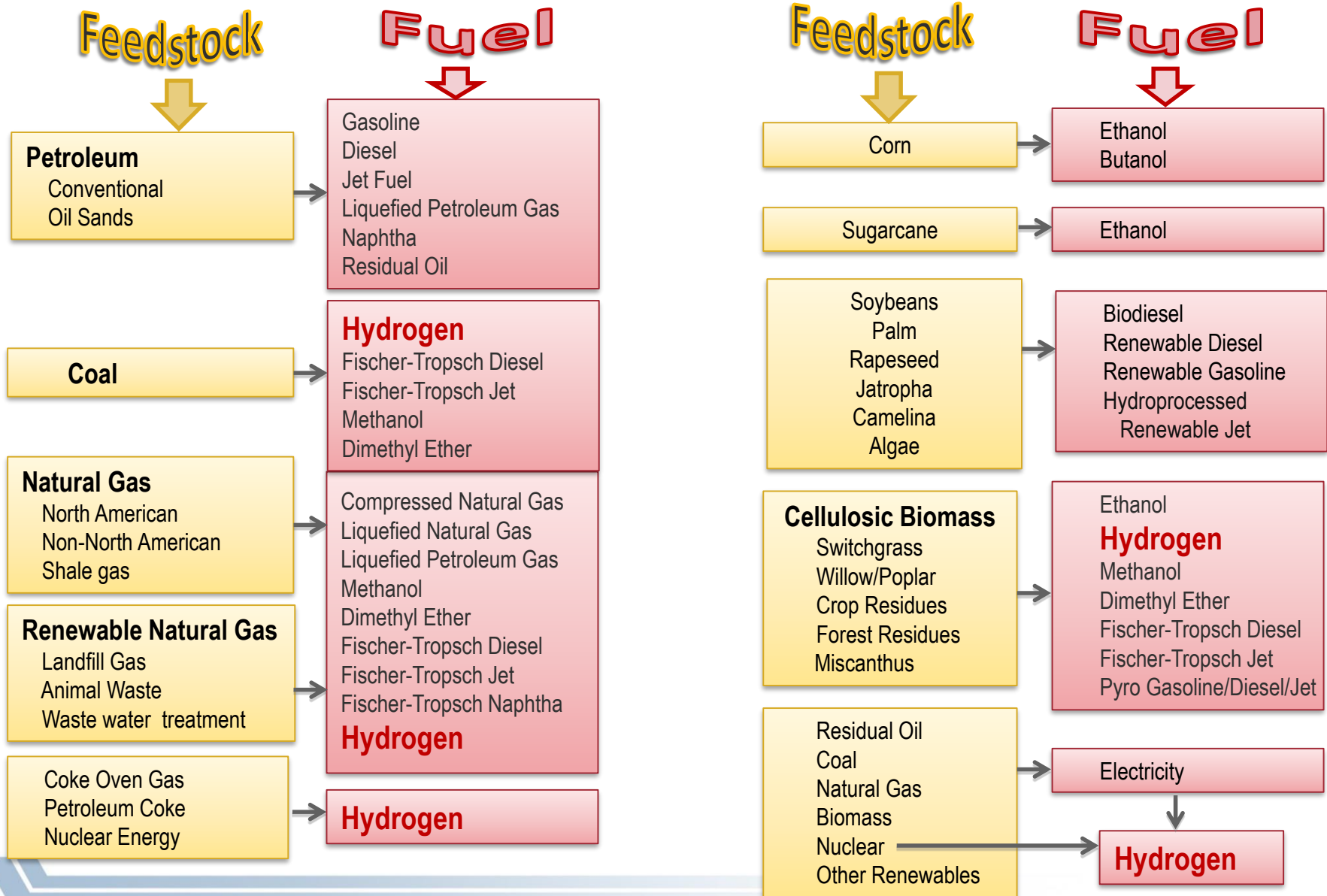
By Region



By Institution

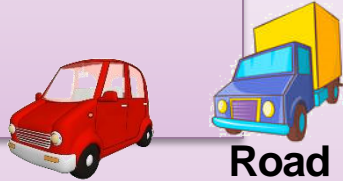


REET includes more than 100 fuel production pathways from various energy feedstock sources



GREET includes all transportation subsectors

- Light-duty vehicles
- Medium-duty vehicles
- Heavy-duty vehicles
- Various powertrains:
Internal Combustion Engines
Electrics
Fuel cells



**Road
transportation**



**Air
transportation**

- Globally, a fast growing sector with GHG reduction pressure
- Interest by DOD, ICAO, FAA, and commercial airlines
- GREET includes
 - ✓ Passenger and freight transportation
 - ✓ Various alternative fuels blended with petroleum jet fuels

**Rail
transportation**



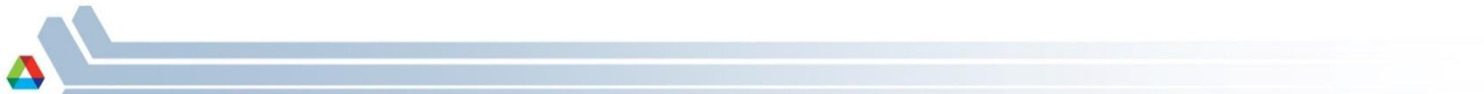
- Interest by FRA, railroad companies
- Potential for CNG/LNG to displace diesel

**Marine
transportation**

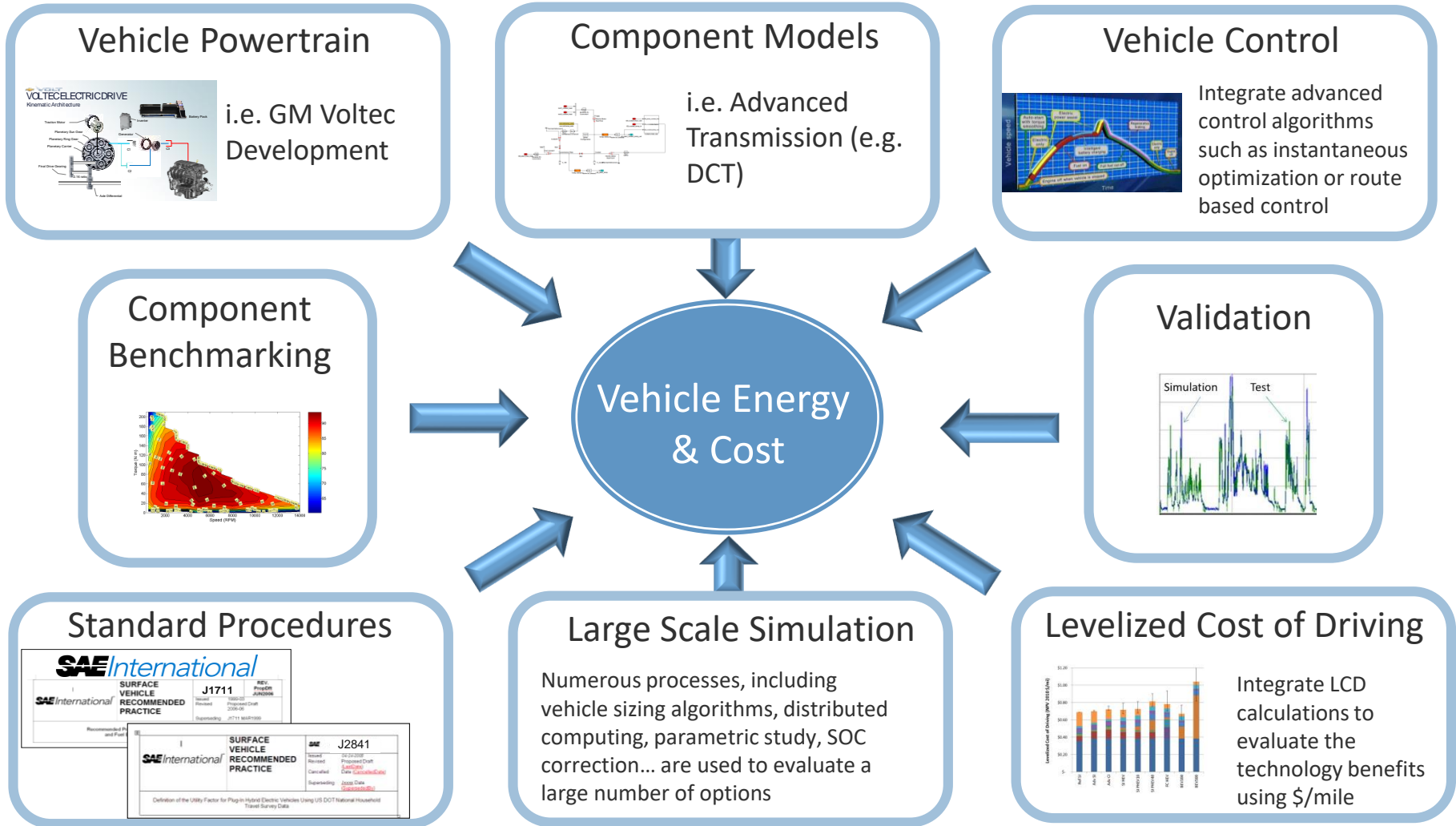


- Desire to control air pollution in ports globally
- Interest by EPA, local governments, IMO
- GREET includes
 - ✓ Ocean and inland water transportation
 - ✓ Baseline diesel and alternative marine fuels

***Vehicle System Simulation Tool
at
Argonne National Laboratory (ANL)***



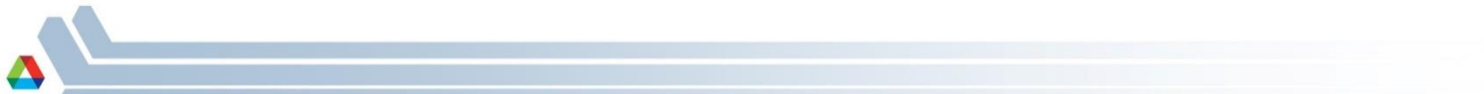
Autonomie Vehicle Energy Consumption and Cost Model



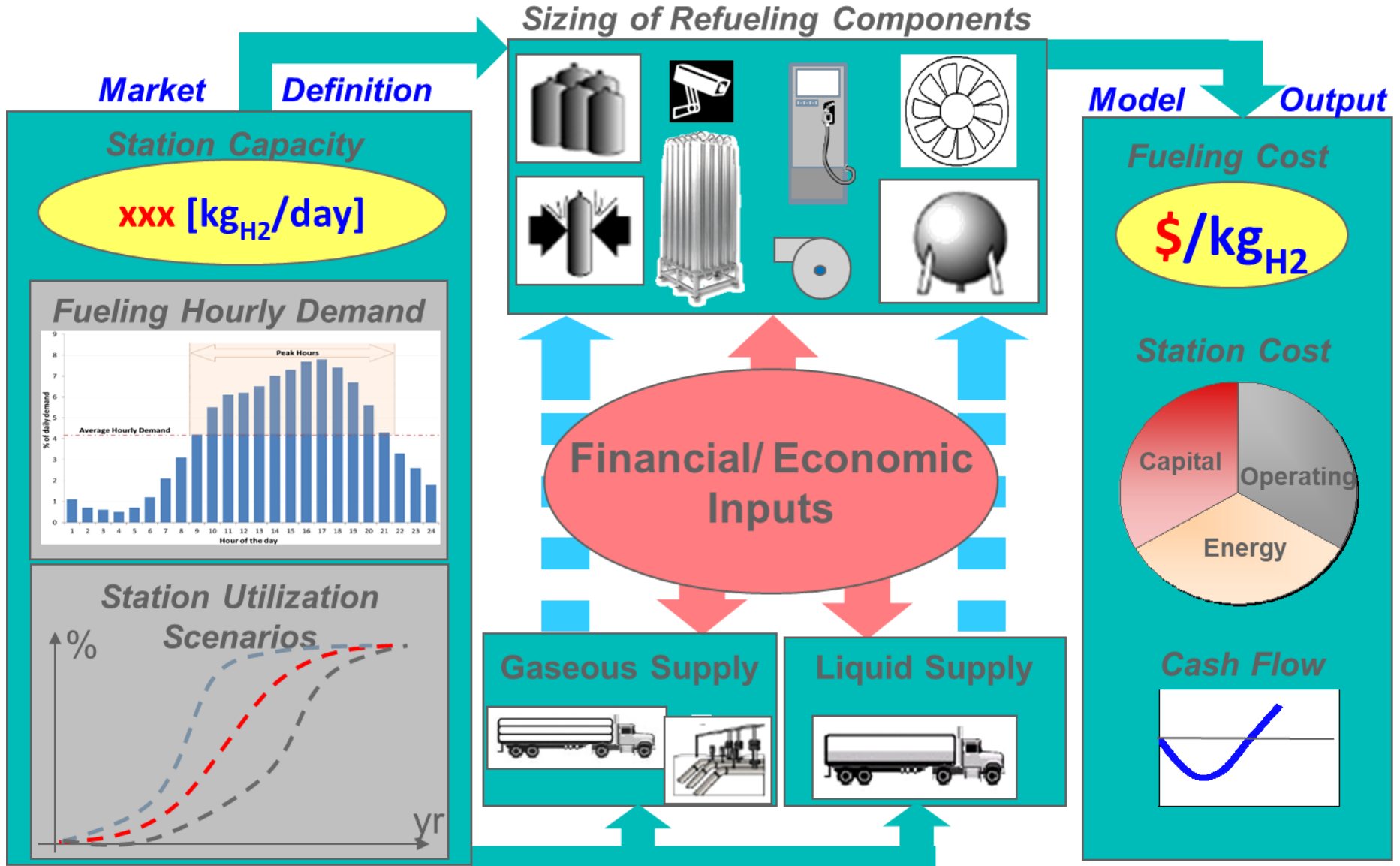
<http://www.autonomie.net/>



***Hydrogen Delivery and Refueling Models
at
Argonne National Laboratory (ANL)***



DOE Tool for HRS modeling (HRSAM)

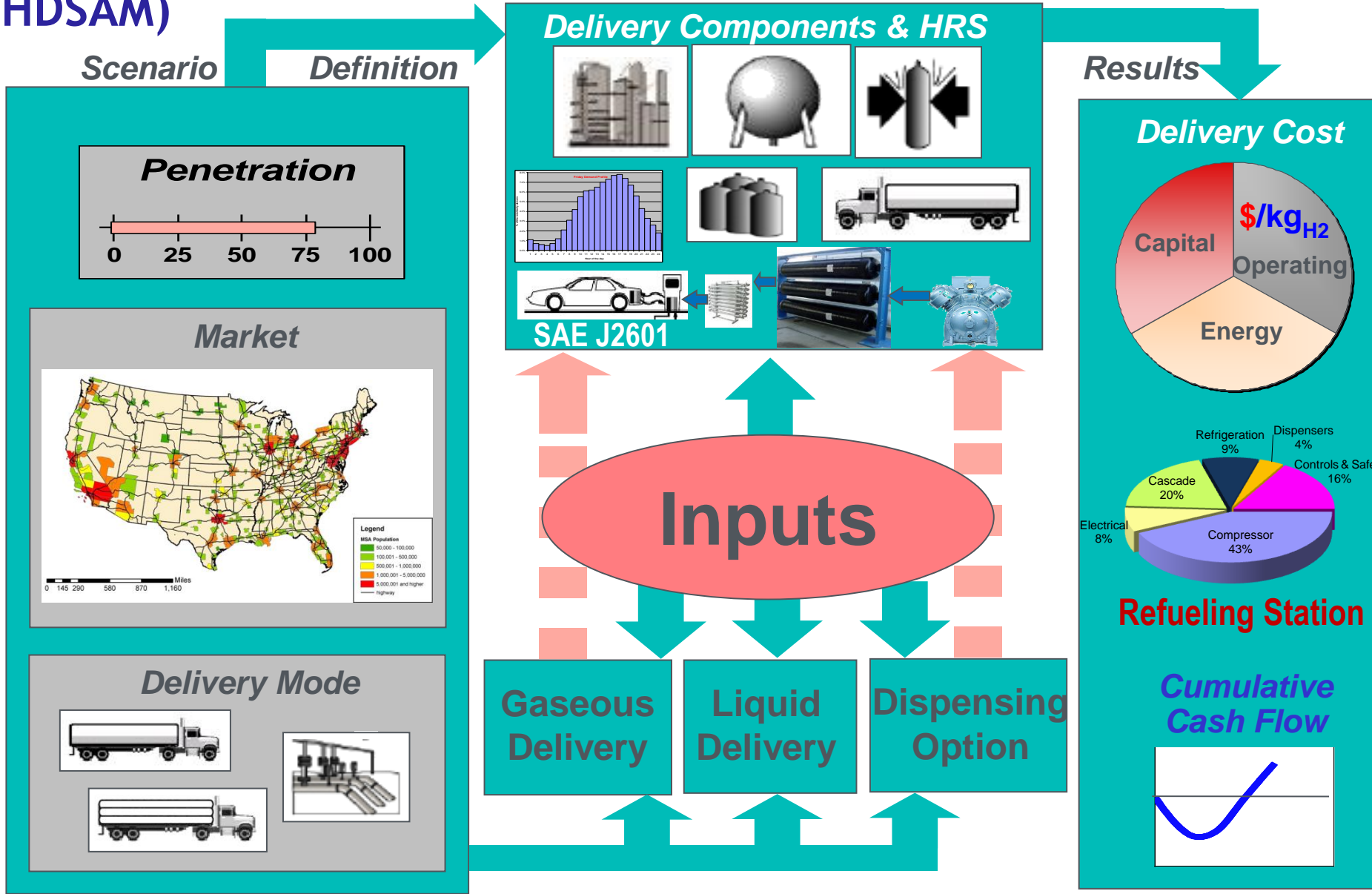


- Developed in Excel and is publicly available for download and use
- Cost data from vendors. Modeling and analysis vetted by experts from industry



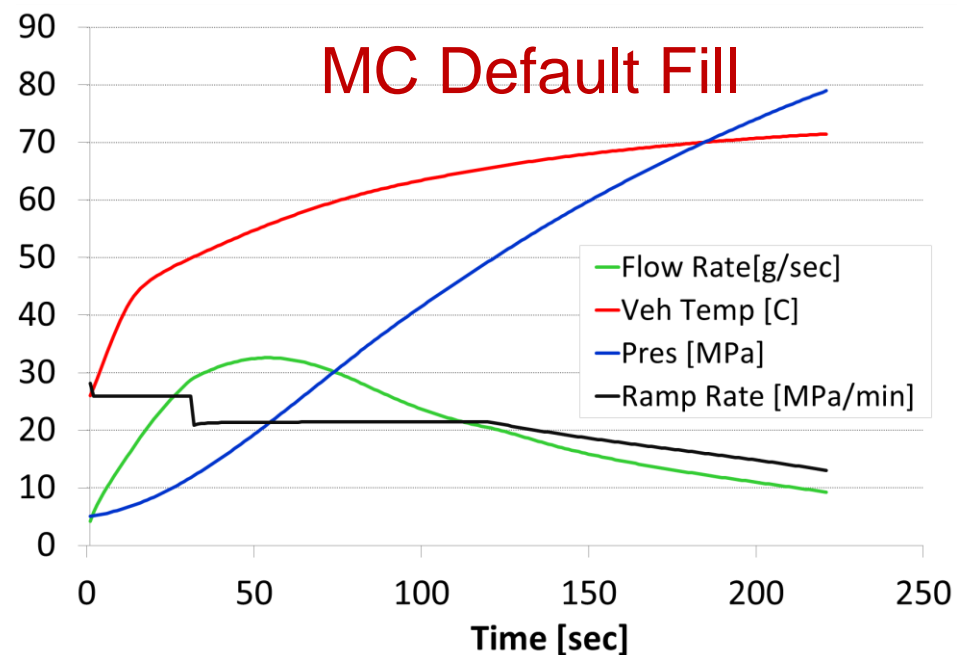
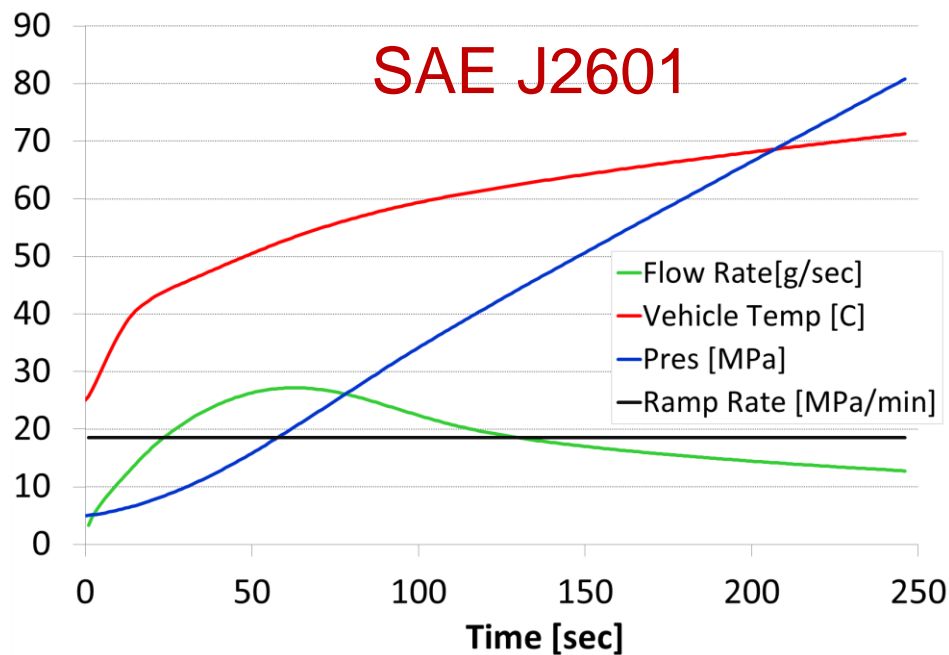
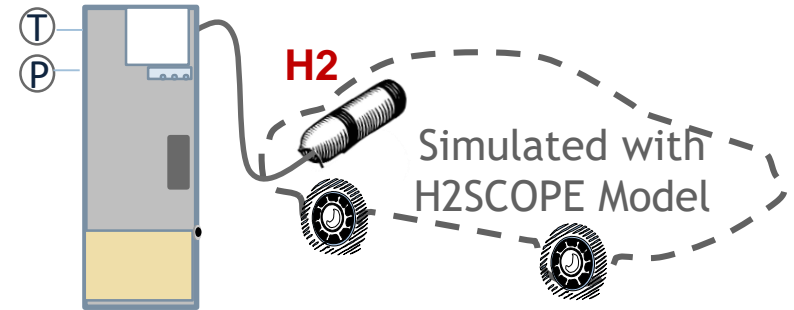
Available at: http://www.hydrogen.energy.gov/h2a_delivery.html

Hydrogen Delivery Scenario Analysis Model (HDSAM)



H₂SCOPE model tracks mass, temperature, and pressure between refueling components and vehicle's tank

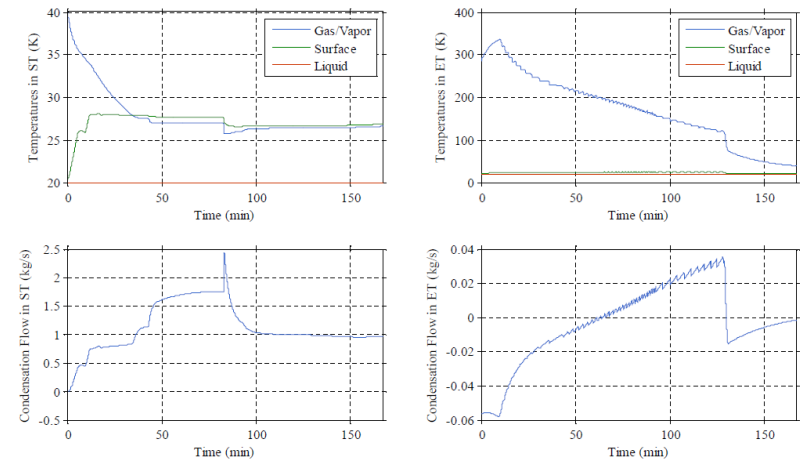
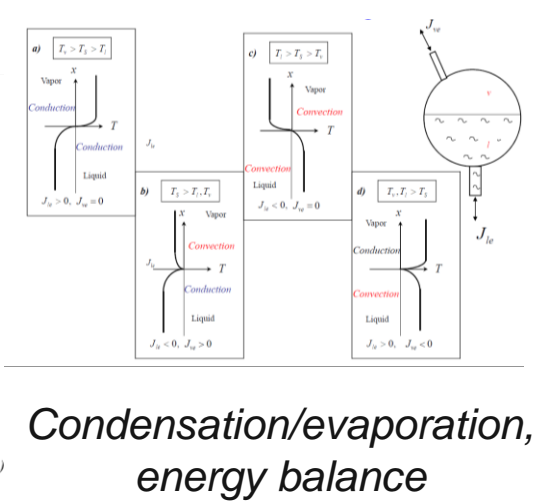
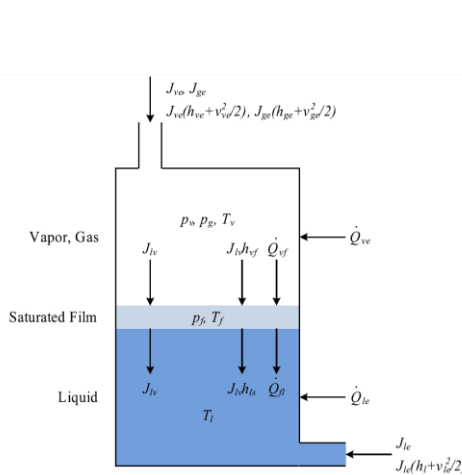
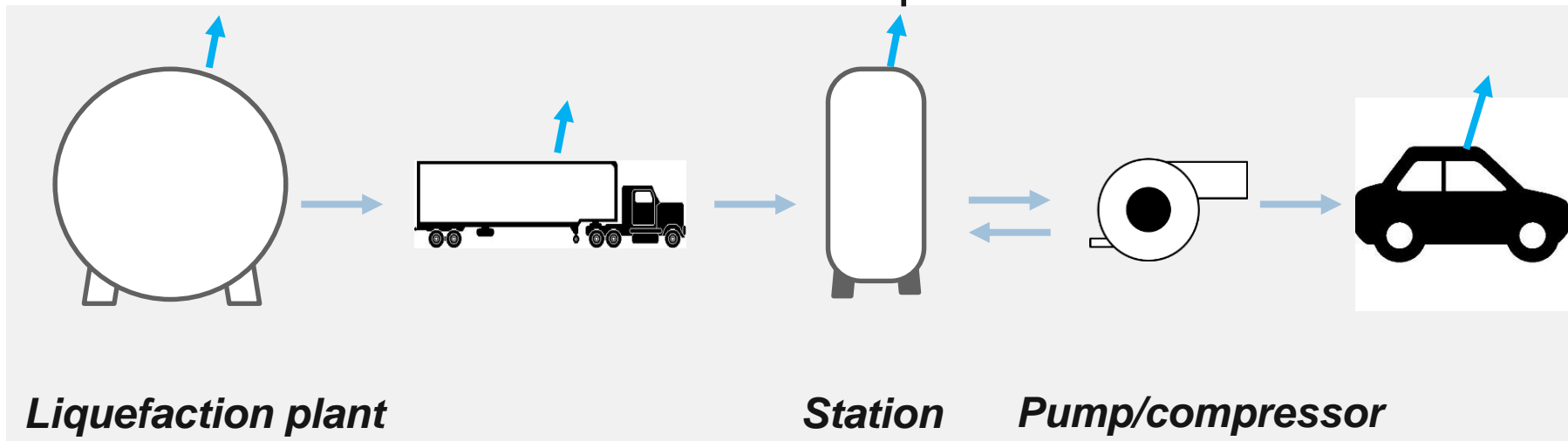
- Solve physical laws (conservation of mass, momentum, energy, EOS, thermodynamics relations)
- Simulate various refueling methods (e.g., SAE J2601, MC Default Fill)



***Hydrogen Thermodynamics Modeling
at
Lawrence Livermore National Laboratory (LLNL)***



Thermodynamic states variations along the H₂ pathway need to be understood in order to improve transfer efficiencies



Heat transfer modes with saturated film



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