NCSU: Smart Grid & H2 Initiatives

Anne Tazewell

NC Solar Center

NC State University

919-513-7831

cleantransportation@ncsu.edu

Smart Grid & Hydrogen Economics Forum
Duke University, Biological Science Bldg, Room 111
August 15,2008

Presentation Topics to Cover

- Who we are, what we do
- NCSC Alternative Fuel Vehicle Garage Fuel Cell Demonstration project
- NCSC's Portable Hydrogen Refueling Station conceptual design project
- NCSU's Advanced Transportation Energy Center

NC Solar Center

- Part of the College of Engineering at NC State University,
- grant /contract/state appropriated funding
- Created in 1988 & serves as clearinghouse for information, training, technical assistance deployment, demonstration and applied research
- Example programs: solar, wind, biomass, sustainable building, combined heat and power, and ***clean transportation***

NORTH CAROLINA
SOLAR CENTER
NC State University

Clean Fuel Advanced Technology

Three year project focused on improving air quality in 24 NC counties that don't meet national air quality standards:

- **$1.4 M Funding for transportation related emission reduction projects**

~ 2006 ,2007 & 2008 call for projects has resulted in 30 awards featuring biodiesel, ethanol(E85) & CNG infrastructure projects, AFVs, Truck Stop Electrification, heavy duty hybrid eclectic vehicles (including PHEV) & diesel retrofits

~ Collectively all 30 projects will reduce over 2.77M kgs of regulated (CO, NOx, HC , PM) and unregulated emissions (CO2) annually

STATE OF NORTH CAROLINA · DEPARTMENT OF TRANSPORTATION

NORTH CAROLINA
DIVISION OF AIR QUALITY
Department of Environment and Natural Resources

State Energy Office
ENERGY
www.energync.net 1-800-662-7131
N.C. Department of Administration "Ensuring a sustainable energy future"

Alternative Fuel Vehicle Garage Fuel Cell Demonstration

Demonstrates the ability to integrate several commercially available renewable energy components into a complete, zero-emissions source to sink system. System includes:

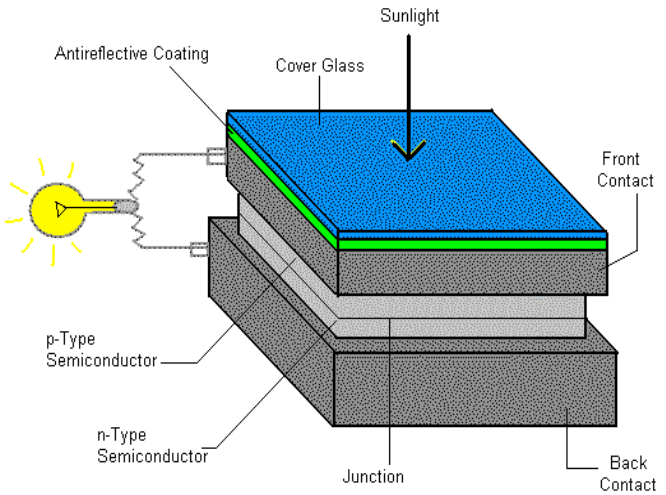
- Photovoltaics (PV);
- On-site hydrogen generation and storage; and
- The use of a fuel cell to provide supplemental electricity to the Solar Center's Alternative Fuel Vehicle Garage (AFVG).

Photovoltaics

Photovoltaics on the roof of the AFVG provide electricity for the hydrogen production process.

When sunlight, in the form of photons, is absorbed by the PV cells' two thin layers of semi-conducting silicon, the solar energy knocks electrons loose from their atoms. This difference in the number of electrons produces a small electric field between the two layers. The electrons then flow through metal conductors on the top and bottom of the semiconductor creating a current of electricity.

NCSC's AFVG



PV Diagram

Hydrogen Generation

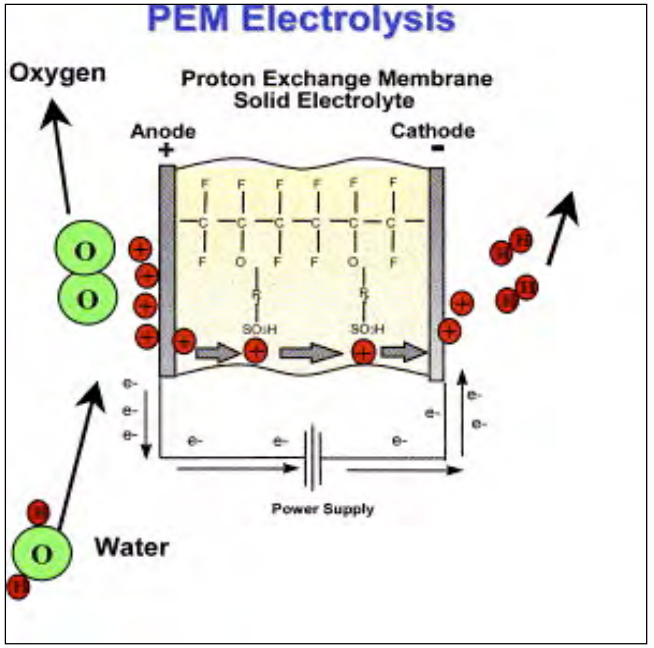
•The Hogen RE hydrogen generator produces hydrogen from water and electricity by means of Proton Exchange Membrane (PEM) electrolysis.

•PEM electrolysis produces 99.999+% pure hydrogen gas.

•Photovoltaics provide electricity for the generator.

•Hydrogen is then fed to a fuel cell which produces electricity.

•Because the electricity is provided by a renewable source, the sun, the energy cost will be essentially zero after the initial payback period for installing the PV system. This lowers the cost of hydrogen production, making it a viable energy source.



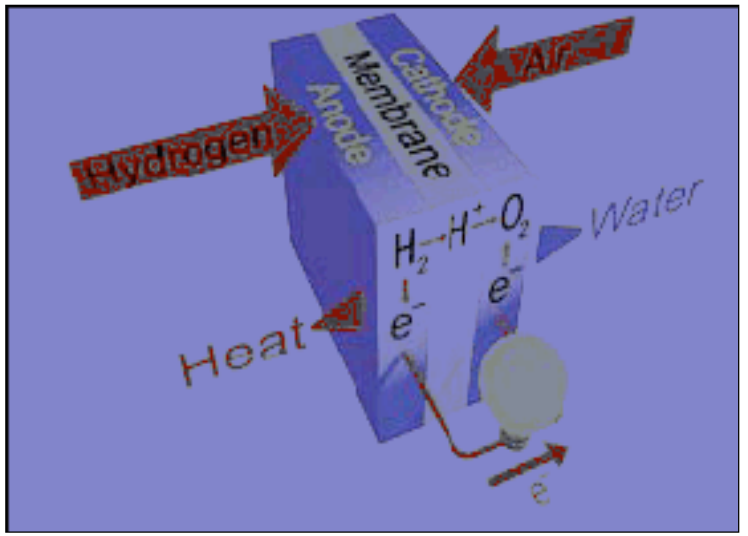
PEM Electrolysis Diagram

PEM Fuel Cell

Fuel cells convert the chemical energy in hydrogen directly into electricity from a combined electrical charge and chemical reaction.

When hydrogen is supplied, a chemical reaction between hydrogen and air produces electricity, pure water and some heat. The electrical power available is proportional to the rate of fuel flowing into the fuel cell, limited by the physical size of the fuel cell.

This process is similar to electricity production by a battery, except the fuel cell only produces electricity while fuel is being supplied to it. The AFVG demonstration system uses hydrogen as its fuel, as do most fuel cells used today.

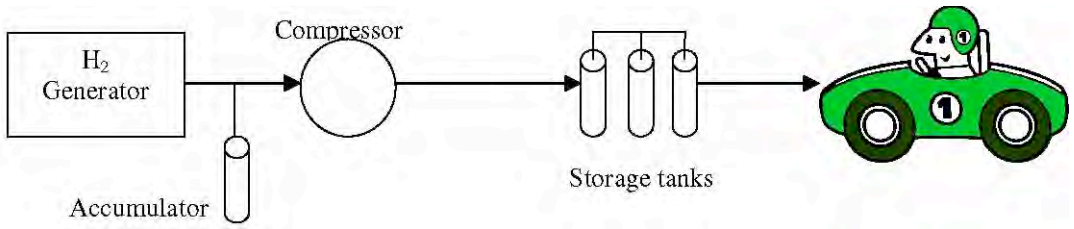


PEM Fuel Cell

Portable Hydrogen Refueling Station Project

The project was a collaboration between the NC Solar Center and the Advanced Vehicle Research Center to develop a conceptual design that would utilize existing market-ready or near market-ready technologies to create a mobile station capable of providing hydrogen for the fueling of hybrid and hydrogen fueled vehicles.

The NC Solar Center developed the Final Concept Design which includes equipment specifications, safety considerations, identification of vendors and manufacturers, system design drawings and diagrams, load calculations, economic modeling, and connection and construction details.



Portable Hydrogen Refueling Station

- Electricity is produced by the diesel generator and distributed to the Stations equipment through the Service Entrance Panel.

- The hydrogen generator uses the electricity and water to produce hydrogen via electrolysis.

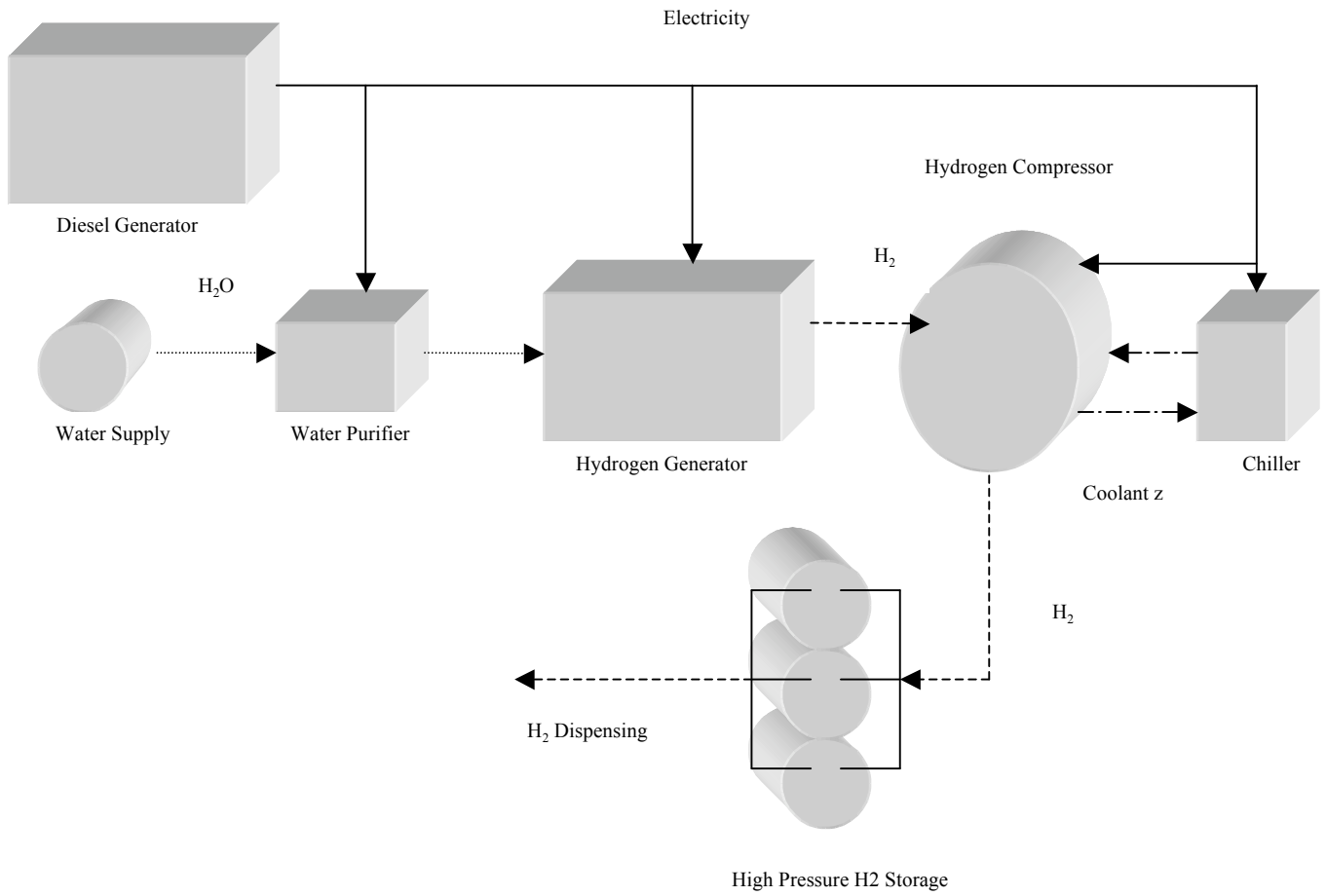
- The hydrogen is sent to the compressor where it is compressed to its working pressure of 6000 psi.

- The chiller pumps coolant to cool the compressor.

- High pressure hydrogen is pumped from the compressor to storage tanks where it is ready to be dispensed when needed.

- The entire station is held on a skid that is loaded onto the back of a truck. Hydrogen storage tanks and dispensing equipment is pulled on a trailer.

Mobile Hydrogen Fueling Station



ATEC Research Thrusts

Demonstration

Distribution System Testbed For Multiple Plug-ins
Vehicle to Grid Interface Testbed
PHEV / PEV Testbed

Enabling Technology

Vehicle to Grid Management
Advanced Power Electronics
Advanced Battery Module
Advanced Motor Drive

Fundamental

Post Silicon Devices
Advanced Storage

ATEC Faculty

Dr. Alex Huang
Professor and Center Director
Power Electronics
Power Devices

Dr. Mesut Baran
Professor
Electric Power System

Dr.Mo-yuen Chow
Professor
Motor Drive
Electric Power System

Dr. Subhashish Bhattacharya
Assistant Professor
Power Electronics
Electric Power Systems

Dr. Srdjan Lukic
Assistant Professor
Power Electronics
Motor Drive

Dr. Xiangwu Zhang
Assistant Professor
Advanced battery

Dr. Wes Henderson
Assistant Professor
Advanced battery

Dr. Peter Fedkiw
Professor
Advanced battery

Dr. Wenye Wang
Assistant Professor
Communication

Dr. Richard Gould
Professor
Thermal and Mechanical

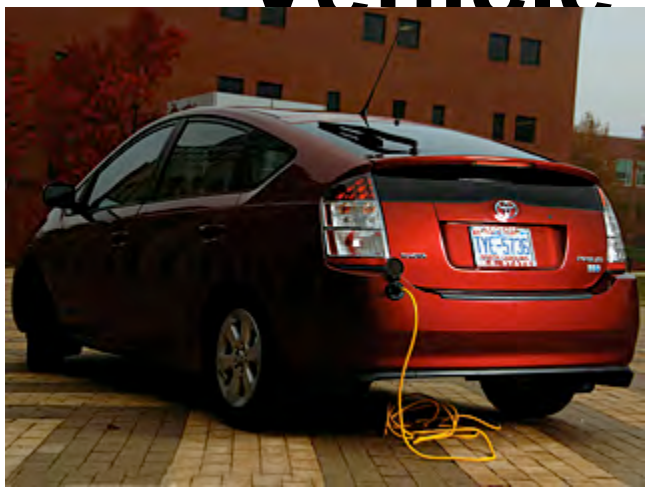
National and Global Energy Crisis

Towards green energy

- According to DOE, offshore wind alone is enough to power entire USA (900,000MW)

must address the transportation energy need

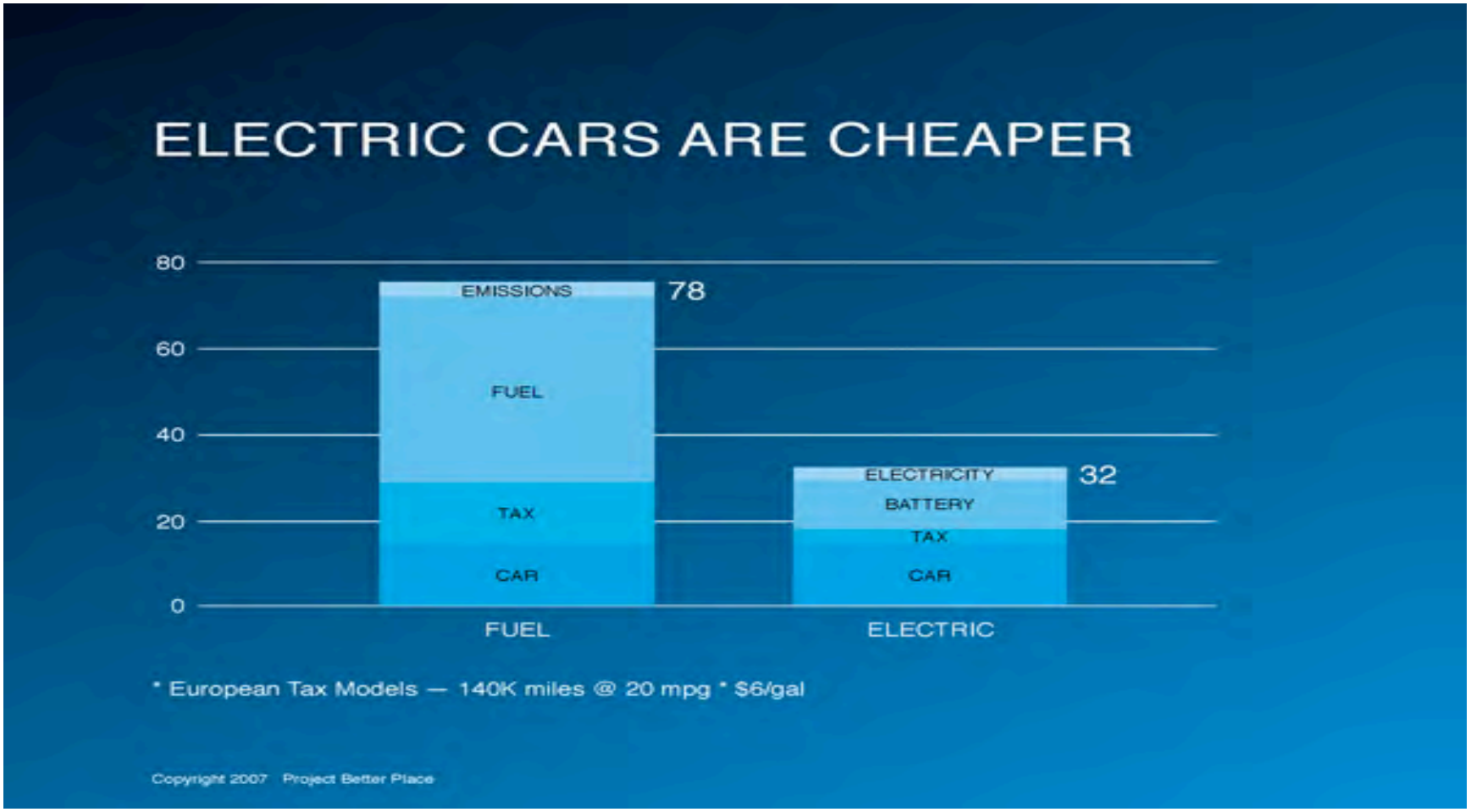
A possible solution: Plug-in Vehicle



- Electricity is generated by renewable energy
- Electricity delivery is one of the best way for energy delivery
- Use green electricity to charge a vehicle

Moving from hybrid to Plug-in hybrid (PHEV) to Plug-in electric vehicle (PEV)

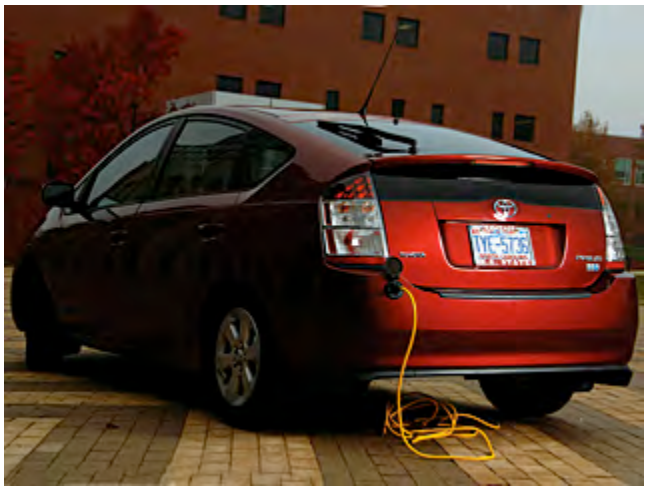
Electric vehicle are also cheaper



Implication: New grid

ATEC research: PHEV/PEV is both a load and a generator

Major challenge 1: V2G Management



- Total US installed generation capacity = ~1,000 GW
- Current US vehicle fleet ~ 200 million vehicles
- By the year 2020, at least ten percent (10 %) of the vehicle fleet will be some form of electric drive vehicle with a storage capacity of at least 30 kWh.
- Vehicles are in use an average of 1 hour per day.

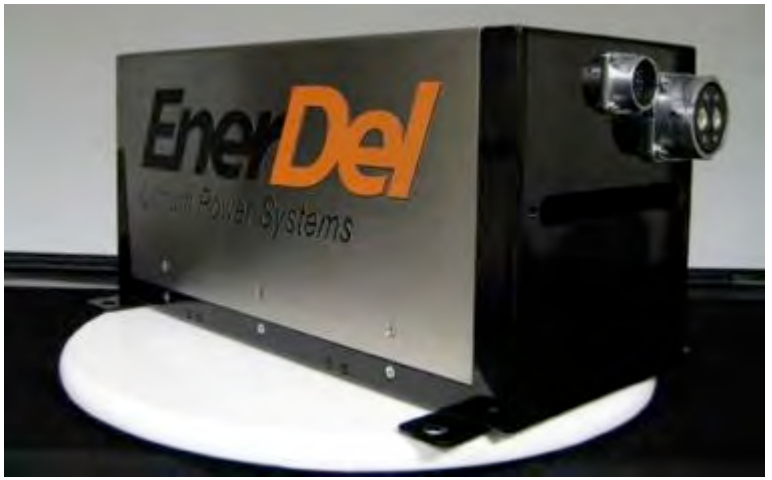
$(10\%) * (200*10^6 \text{ vehicles}) * (30 \text{ kWh}) = 600 \text{ GWh}$

Issues: communication, software & policy (business model)

Major challenge 2: Battery System

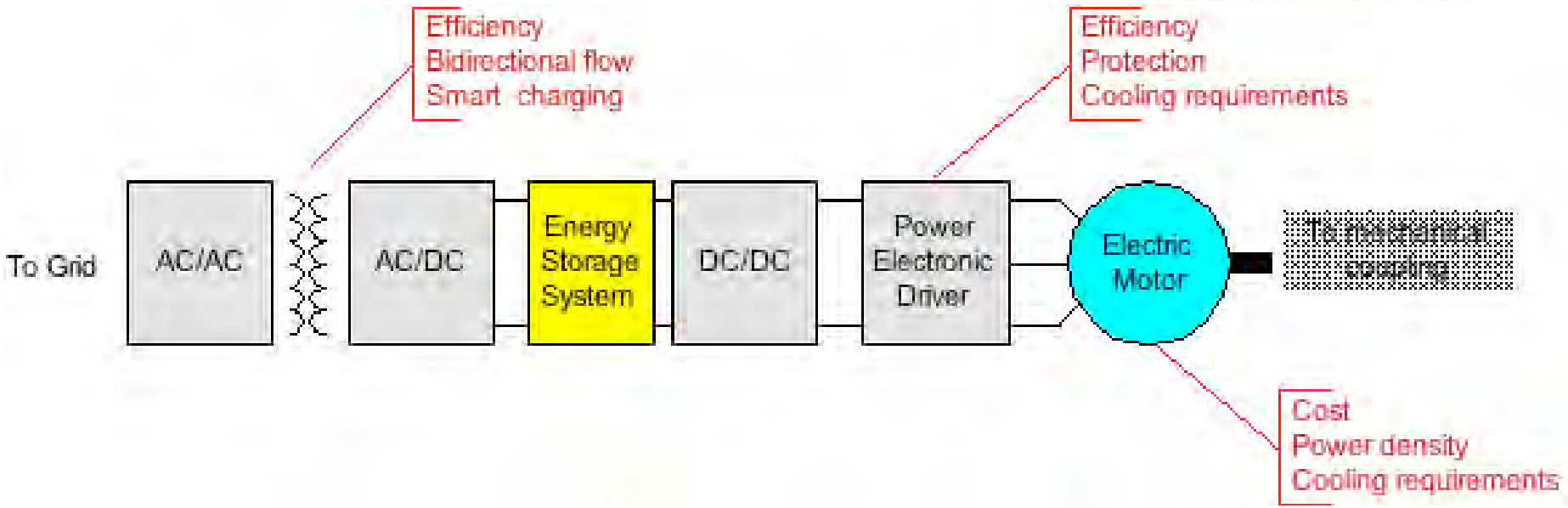
Issues

- Energy and power density
- Cost
- Operating state prediction
- Lifetime prediction
- Cell voltage/charge balance
- Thermal management
- Safety
- Charge time



Major challenge 3: Power Electronics & Motor


COURTESY: GENERAL MOTORS



Let us help you! Partnerships are Important!

- Clean Cities coalitions in Asheville, Triangle & Charlotte and NC Mobile CARE partnership initiative through NC Solar Center work to build public private relations to expand alternative fuel use

- NCSU:
  - Electrical Engineering
  - Material Science
  - Mechanical
  - Chemical
  - Textile
- Advanced Energy and NC Solar Center: involve in the demonstration and outreach program

ATEC
ADVANCED TRANSPORTATION ENERGY CENTER

Triangle
Clean Cities Coalition