U.S.-China
Clean Energy Research Center

Dr. Robert C. Marlay, U.S. Director
U.S.-China Clean Energy Research Center
Office of Policy and International Affairs
U.S. Department of Energy

MIT Club of Washington
Washington, DC
February 4, 2013

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History of U.S. - China S&T Cooperation

- **Period I: S&T Cooperation (1979-1990)**
  - Agreement on High Energy Physics (1979)
  - Protocol on Nuclear Physics and Fusion (1983)
  - Protocol on Fossil Energy R&D (1985)
  - Agreement on CO2 Research under the Fossil Energy Protocol (1987)
  - Reduction in Cooperative Activities (1989), due to IPR Issues

- **Period II: Energy Policy Consultations (1991-2000)**
  - Agreement on Superconducting Super Collider (1992)
  - Two Annexes Added to the Fossil Energy Protocol (1994)
  - MOU on Energy Consultations: Reactor Fuel, RE, and EERE (1995)
  - Three Annexes Added to the EERE Agreement (1996)
  - The 1st Oil & Gas Industry Forum (1998)
  - Agreement on Peaceful Use of Nuclear Technology (PUNT) (1998)
  - Revised Fossil Energy Protocol (2000)

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Background & History of S&T Cooperation

- **Period III: Broadened Relationship (2001-2007)**
  - OGIF, APEC, JCC (PUNT)
  - Statement of Intent on Nuclear Non-Proliferation (2003)
  - Joining the ITER; and the CSLF (2003)
  - Sec. Abraham's Visit to China; MOU on Energy Policy Dialogue (EPD)
  - Megaports Initiative; Reduced Enrichment for Research and Test Reactors; and Gen IV International Forum (2004)
  - DOE China Office Opened; Conduct of 1^{st} EPD (2005)
  - APP; 2^{nd} EPD; and 1^{st} Strategic Economic Dialogue (SED) (2006)
  - GNEP (2007)
  - Ten Year Framework (2008) with objectives to pursue energy efficiency, environmental conservation, new energy, and energy security.

- **Period IV: Seven Joint Clean Energy Initiatives (November 2009)**
  - Seven Joint Clean Energy Initiatives (see next slide)

U.S.-China Clean Energy Initiatives – Period IV

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Seven Joint Clean Energy Initiatives (2009)

- Electric Vehicles Initiative
- Energy Efficiency Action Plan
- Renewable Energy Partnership
- 21st Century Coal
- Shale Gas Resource Initiative
- Energy Cooperation Program
- U.S.-China Clean Energy Research Center

WHY CHINA ?

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Why China and the U.S.?

- China and U.S. S&T Cooperation is Important, Because:
  - United States and China are the world's two largest economies.
  - United States and China are the world's largest producers and consumers of energy, and share many common challenges and common interests.
  - China and the United States together account for 40 percent of annual global emissions of greenhouse gases.
  - Both countries are highly dependant on coal for electricity – about 50% in the U.S. and 80% in China.
  - Significant actions by both nations are critical to combat climate change globally.
  - Both are heavily reliant on foreign sources of oil.
  - Both recognize the vital importance of secure, affordable and clean energy.
  - Both face common challenges of diversifying sources of energy and transforming users of energy.
  - Both see strengthening scientific discovery, as a means to inspire economic competitiveness and quality of life through innovation.
  - Both countries are expanding 21st Century infrastructure, most of which has yet to be built and can be significantly influenced by advanced technology.

The Promise of Combining Strengths

- Each Country Brings S&T Strengths to the Table
- U.S. Strengths:
  - World Class Research Universities, Institutes & National Laboratories
  - Pioneering Businesses, Entrepreneurs, and Technology-Based Private Partners
  - Well-Developed Financial & Legal Infrastructure
  - Excellence in Theoretical Work, Large-Scale Computational Models & Simulations
- China Strengths:
  - Large and Growing Presence in Basic & Applied Research
  - Facility in Experimental Work & Translating Scientific Advances into Prototypes
  - Resources to Carry out Large-Scale Pilot Projects & Demonstrations
  - Expertise in Rapid, Large-Scale Technology Deployment
  - Largest and Fastest Growing Energy Market; Test Bed for New Technologies
- Both Countries Gain from Accelerated Deployment of Clean Technologies

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CERC Protocol

- CERC Protocol Signed, Nov. 2009
- Calls for Joint U.S.-China Clean Energy Research Center (Virtual, not Physical)
- CERC Goals:
  - Spur Innovation of Clean Energy Techs
  - Diversify Sources of Energy Supply
  - Improve Energy Efficiency
  - Accelerate Transition to a Low-Carbon Economy
  - Avoid the Worst Consequences of Climate Change
- Three Areas for Initial Cooperation – Clean Coal; Clean Vehicles; and Efficient Buildings
- Open to Other Areas in the Future

Signing of CERC Protocol Nov. 2009

Steven Chu, U.S. Secretary of Energy
Liu Yandong, PRC State Councilor (S&T, MOST)
Gary Locke, U.S. Secretary of Commerce
Wan Gang, PRC Minister of S&T (MOST)

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New Model for Enhanced S&T Collaboration

Cooperation (Traditional)

- Work Plans Coordinated, but Separate
- Independent Work on Similar Projects
- Interactions Characterized by Research Visits, Personnel and Student Exchanges
- R&D Focuses on Institutional Strengths
- Relationships Collegial
- R&D Results Shared Externally
- Benefits Mainly Academic. Transfer of Knowledge via Technical Papers & Reports
- No guaranteed IP Rights in Other's Territory.   IP Provisions Not Flexible
- Few IP Advantages for R&D Partners

Collaboration (New) *

- Work Plans Developed Jointly
- Work Together on Same Projects
- Research Characterized by Division of Labor Among Participants on Joint Tasks
- R&D Exploits Complementarities
- Relationships Interdependent
- R&D Results Can Arise Jointly
- Benefits are Embedded among Partners and Extended by Interests in Commercialization
- Guarantees a Right to IP in Other's Territory. IP Terms & Conditions May be Negotiated
- Potentially More Attractive IP Platform

* Jointly Funded Research Projects, as Defined by Mutually Agreed-Upon Technology Management Plans

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CERC's Five-Year Funding Plan

Planned CERC Awards (Over 5 Years)

Technology Area	U.S.		China	Total Project Funding
	DOE	Partners	MOST & Partners	
CERC-ACTC	$12.5M	≥ $12.5M	$25.0M	$50.0M
CERC-CVC	$12.5M	≥ $12.5M	$25.0M	$50.0M
CERC-BEE	$12.5M	≥ $12.5M	$25.0M	$50.0M
			Planned	$150.0M

Note: $ = U.S. Dollars
M = Millions

CERC GOVERNANCE

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CERC Governance

Steering Committee

U.S.
Secretary Steven Chu, DOE

China
Minister WAN Gang, MOST
Administrator LIU Tienan, NEA
Vice Minister QIU Baoxing, MOHURD

Secretariat

U.S.
Assistant Secretary David Sandalow, DOE

China
Vice Minister CAO Jianlin, MOST
Members: Deputy Director General MA Linying, MOST
Director General LI Ye, NEA
Deputy Director General HAN Aixing, MOHRUD

Executive Committee for Clean Coal Consortium	Executive Committee for Buildings Consortium	Executive Committee for Clean Vehicles Consortium

MOST: Ministry of Science & Technology; NEA: National Energy Administration; MOHURD: Ministry of Housing and Urban-Rural Development

CERC Directors & Secretariat Support

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U.S.

- U.S. Director, U.S.-China CERC
  - Dr. Robert C. Marlay, DOE
- Director, East Asian Affairs
  - Dr. Casey Delhotal, DOE

China

- China Director, U.S.-China CERC
  - Counselor LIU Zhiming, MOST
- Director, Americas and Oceania
  - WANG Qiang, MOST

Roles and Responsibilities:

- Provide Inter-Governmental Coordination for CERC between the U.S. and China
- Facilitate Intra-Governmental Coordination for CERC within Respective Countries
- Provide Technical and Analytical Support for Steering Committee and Secretariat
- Provide Leadership for CERC Consortia within Respective Countries
- Coordinate Support and Guidance on Diplomatic and Legal Matters

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Leadership of CERC Research Teams

	Coal		Vehicles		Buildings	
U.S.	WVU	Director Dr Jerald J Fletcher	UM	Director Prof Huei PENG	LBNL	Director Dr Nan Zhou
U.S.	LLNL	Tech Pgm. Mgr. Dr Julio Friedmann	UM	Deputy Director Prof Jun NI (Research)	LBNL	Deputy Director Dr YAO Yuan
U.S.	WVU	Collaboration Mgr Dr SUN Quingun	UM	China Liaison Professors PENG & NI	LBNL	Advisor Dr Mark Levine
U.S.	WVU	Operations Manager Sam Taylor	UM	Operations Manager Carrie Morton	LBNL	Operations Manager Brian Heimberg
China	HUST	Director Dr ZHENG Chugang	Tsinghua	Director Dr OUYANG Minggao	MOHURD	Director Dr LIANG Junqiang
China	Huaneng CERI	Chief Engineer Dr XU Shisen	Tsinghua	Deputy Director Dr WANG Hewu	Tsinghua MOHURD	Tech Pgm. Mgr. Dr JIANG Yi
China	Tsinghua	Chief Scientist Dr YAO Qiang	Tsinghua	Deputy Director Dr QIU Xinping	MOHURD	Deputy Director Dr LIU Younong

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Summary of Research Activities

CERC Technical Track	Joint Work Plan Research Areas	Number of Research Activities	Number of Joint Research Activities	Present Extent of Joint Work	Goal for Joint Work
Advanced Coal Technology Consortium	9	38	27	71%	100%
Clean Vehicles Consortium	6	33	18	55%	100%
Building Energy Efficiency	6	17	14	82%	100%
Summary	21	88	59	~ 67%	100%

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Researchers Supported by CERC

	US	China	Total
Advanced Coal Technology Consortium	40	200	240
Clean Vehicles Consortium	127	320	447
Building Energy Efficiency	79	320	399
Total	**246**	**840**	**1,086**

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CERC Partners

Technology Area	U.S.		China		Totals
	Lead	Partners	Lead	Partners	
Advanced Coal Technology Consortium	WVU	10	HUST	16	26
Clean Vehicles Consortium	UM	15	THU	19	34
Building Energy Efficiency	LBNL	15	MOHURD	37	52
Totals		40		72	112

RESEARCH FOCUS & IMPLEMENTATION

1. Advanced Coal Technology
2. Clean Vehicles
3. Building Energy Efficiency
4. Intellectual Property
5. Summary

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ADVANCED COAL TECHNOLOGY

VISION: Advance coal technology to safely, effectively, and efficiently utilize coal resources in both countries, including to capture, store and utilize emissions from coal use.

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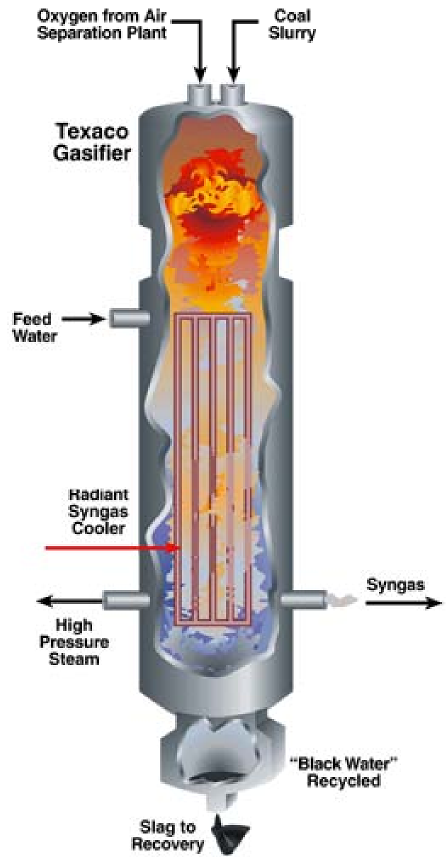
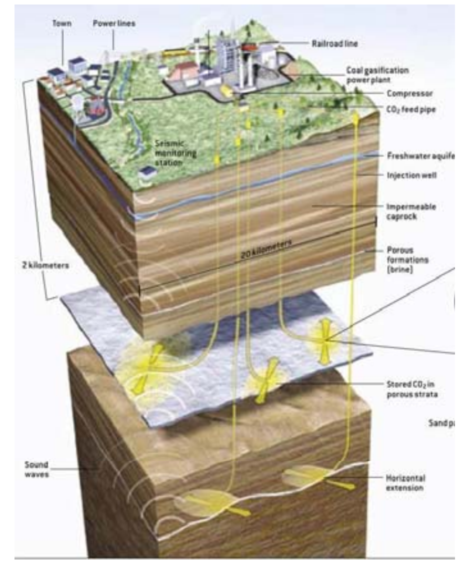
Advanced Coal Technology

Advanced Coal Conversion, Including IGCC with CCS

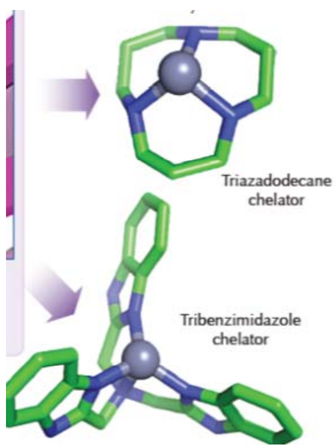


Oxy-Fuel Combustion



CCS Technology & Geologic Storage

CO2 Utilization, Including Micro-Algae for Fuels



Novel CO2 Capture

B&W amine test center, OH

Post-combustion CO2 Capture

Clean Coal Projects Covered in CERC-ACTC (9/38)

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- **Advanced Power Generation**
  – Increase efficiency and availability of existing coal power plants
  – Advanced Ultra Supercritical power generation
  – Upgrade Pulverizing system for Subcritical Power Plant
- **Clean Coal Conversion Technology**
  – Co-generation system combined pyrolysis, gasification, and combustion
  – Chemical Looping Gasification with CO2 Capture
  – Direct SNG production from coal
  – Coal to SNG by Catalytic gasification
  – Gasification properties of Direct Coal Liquefaction residue
  – Measurement\Modeling\Environmental Technologies for Unconventional Coal Gasification
  – Coal/biomass co-conversion process
- **Pre-Combustion CO2 Capture**
  – IGCC with CCS
  – IGCC Knowledge Transfer
- **Post-Combustion CO2 Capture**
  – Post-combustion CO2 capture at Duke Gibson Station
  – Solvent for CO2 Separation from Utility Flue Gas
  – Catalyst to Enhance CO2 Capture Kinetic in the Scrubber
  – Membrane for CO2 Separation from Utility Flue Gas Stream
  – Post CO2 Scrubber Solvent Enrichment
  – Amine Based Capture Modeling
- **Oxy-Combustion Technology Development**
  – Fuel and Emission Characterization
  – Pilot Scale Evaluation
  – Steady-State and Dynamic Process Modeling Simulations
  – Feasibility Study for Large Scale Deployment
- **Evaluation Technology of CO2 Geological Storage Sites**
  – Saline Formations at the Basin Scale
  – Geologic Storage & EOR
  – Geologic Storage & ECBM
  – Simulation and Modeling
- **Carbon Dioxide Utilization with Microalgae**
  – Screening of Algae Strains
  – Growth System Optimization
  – Develop efficient post-processing technologies
  – Techno-Economic Analysis
- **Systems Integration, Simulation and Assessment**
  – Static and Dynamic Modeling of IGCC+CCS
  – Modeling of Post-Combustion Capture Technologies
  – Visualization and Operator Training Tools and Simulations
  – Model. and Sim. of Post-Combustion Plants with CO2 Capture
  – Modeling of coal fired Pre & Post Combustion CO2 Capture
  – Life-Cycle Analysis of Coal to Chemical Systems
- **Communication and Integration**
  – IP Management and Development Support
  – Communication and Integration

Advanced Coal Technology Partners

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U.S.

– **Project Lead**
  - West Virginia University (WVU)
– **Partners:**
  - Babcock & Wilcox (B&W)
  - Duke Energy (Duke)
  - Indiana Geological Survey (IGS)
  - Lawrence Livermore National Lab (LLNL)
  - Los Alamos National Lab (LANL)
  - LP Amina
  - University of Kentucky (UKy)
  - University of Wyoming (UWy)
  - U.S.-China Clean Energy Forum, China Relations Council
  - World Resources Institute (WRI)

China

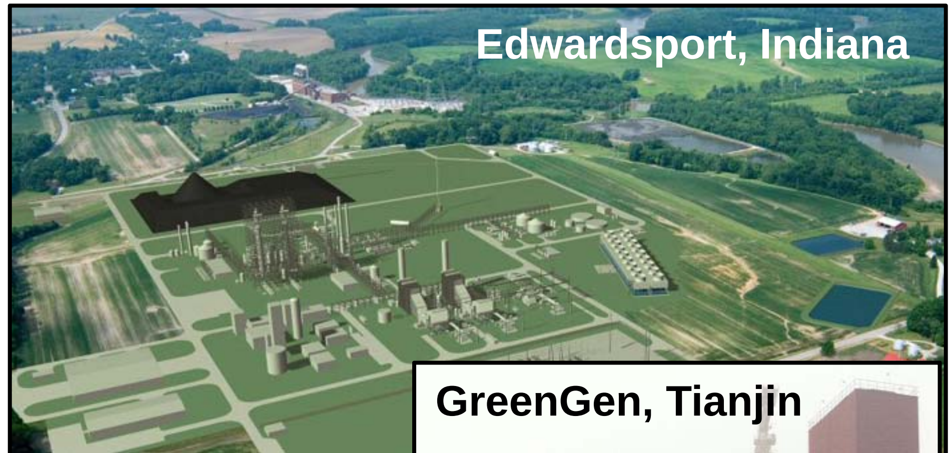
– **Project Lead**
  - Huazhong Univ. of Science and Technology
– **Partners:**
  - Ctr. for Energy & Power, Ch. Acad. of Sciences
  - China Huaneng Group Clean Energy Res. Inst.
  - China Power Engineering Consulting Group Corporation (CPECC)
  - China Power Investment Corporation, Beijing
  - China Univ. of Mining and Technology
  - ENN (XinAo Group)
  - Huaneng Power International, Inc
  - Institute for Rock & Soil Mechanics, Chinese Academy of Science
  - Jinan University, Guangzhou
  - NW Univ. of China
  - Shaanxi Provincial Institute of Energy Resources, Xianyang
  - Shanghai JiaoTong University
  - Shenhua Group
  - Tsinghua University
  - Yanchang Petroleum
  - Zhejiang University, Hangzhou

C-4: Large-Scale Post-Combustion Capture Retrofit

- Duke Energy, Univ. KY, Huaneng-CERI, LLNL
- Joint process model
  - Gibson plant, Unit-3
  - Shidongkou Pilot
- Technical Results:
  - 28% capture penalty, all in
  - $30/ton in China confirmed
  - $61-68/ton Gibson retrofit
  - Additional operational info
- Commercial Results:
  - Huaneng/Duke agreement
  - Huaneng FEED study for 400 MW

C-3: Large-Scale IGCC w/CCS (1 Mt/Y)

- Duke Energy, GE; Huaneng-CERI, NETL, WVU, LLNL; Tsinghua
- Both Plants under construction
- Some engineering data available
- Share operating data (2013-2014)
- Potential to share USTDA project
- Cross-training on simulators



Duke Energy
中国华能集团公司
CHINA HUANENG GROUP

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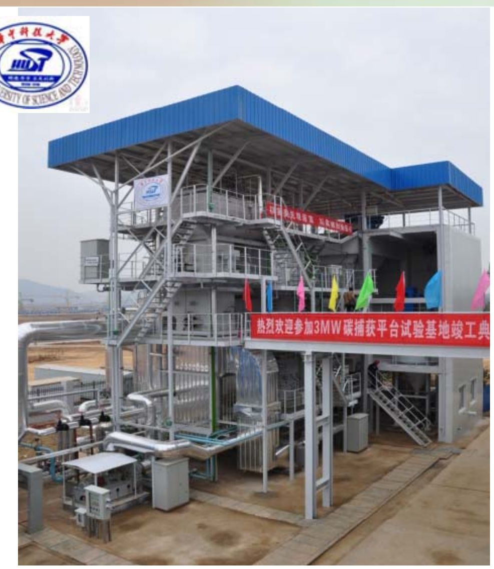
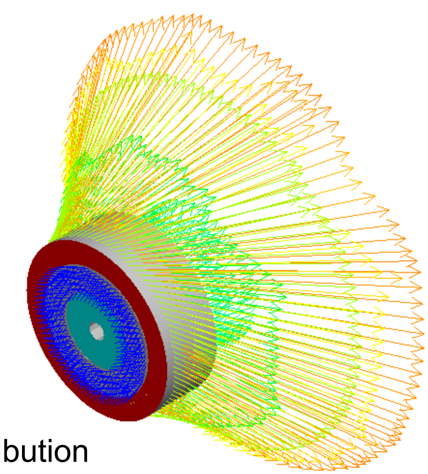
C-5: Oxy-Fired Combustion

- B&W; HUST, WVU, Tsinghua
- Demonstration Plant Feasibility Study
- Coal Combustion Studies: CFD Modeling, Kinetics and Thermodynamics
- Simulation and Validation Exchange (WVU, HUST, B&W)
- Potential Demonstration Identified
- Validation at 3 MW Unit and 1.8 MW Unit
- Next steps
  - 35 MW Retrofit Begun
  - 100 MW Retrofit Assessment
  - 350 MW New-\Build Feasibility



$3MW_{th}$ full chain system (FCS)

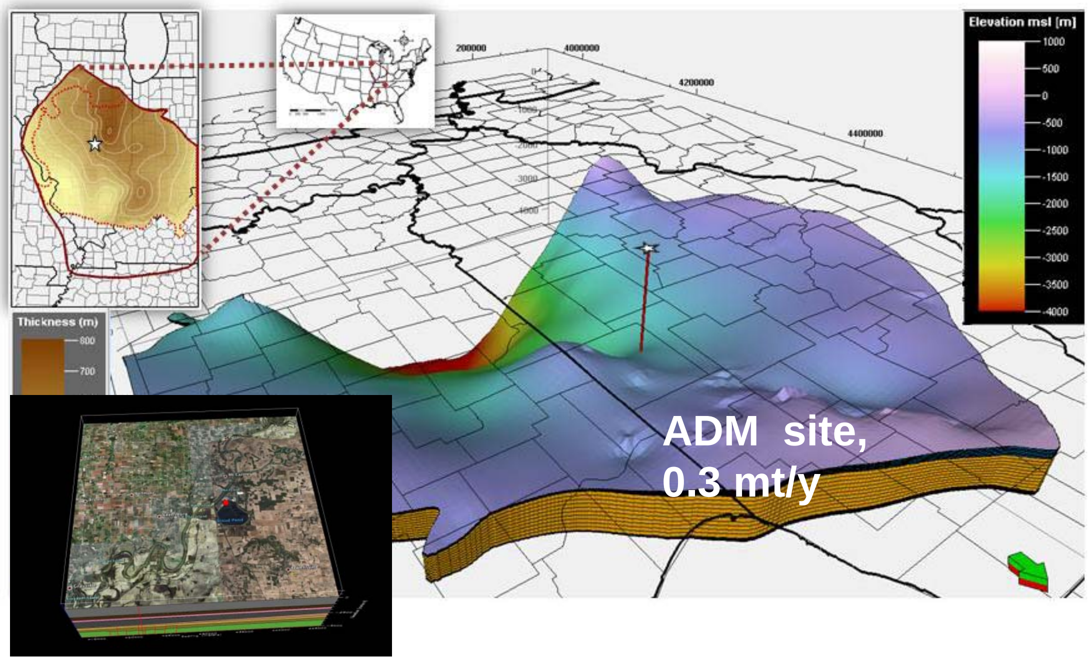


Burner throat velocity distribution
NOTE: This was the breakthrough - sharing the muzzle velocities from the burners

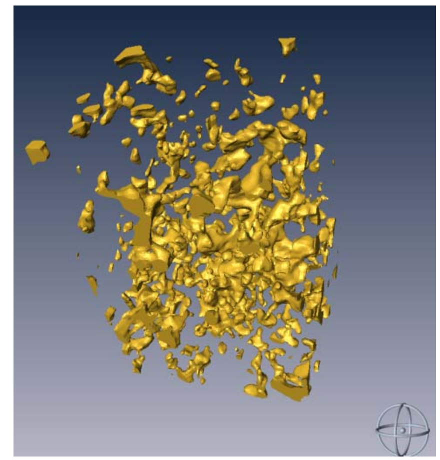
C-6: Important Progress: Sequestration

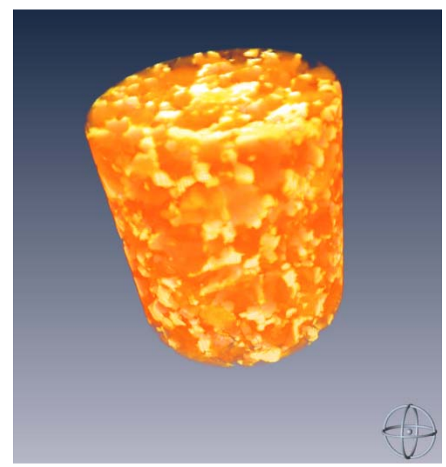
- University of Wyoming, Institute for Rock and Fluid Mechanics
- Evaluation Technology of CO2 Storage Sites - Enhanced Oil Recovery
- Yanchang Oil Field, Ordos Basin

C-6: Important Progress: Sequestration



- WVU, UWy LANL, LLNL, Shenhua Group, IRSM-CAS
- Two major sites: Indiana and Wyoming
- Evaluation Technology of CO2 Storage Sites - Saline Formations





Pore map (top) and rock map (bottom), IRSM+LANL

C-7: CO_2 Utilization via Micro-Algae

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- UKy, Duke Energy, NETL, PNNL, ENN Group, Zhejiang U, Jinan U
- ENN Tested 1,600 Generic Variants
- Selected Top-20 for Further Implementations
- Both UKY and ENN Engineering Designs, are being tested at East Bend Station, KY

ENN microalgae, Lang Fang

UKY bioreactor,

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CLEAN VEHICLES

VISION: Contribute to dramatic improvements in vehicle technologies with potential to reduce the dependence on oil and improve fuel efficiency in both countries.

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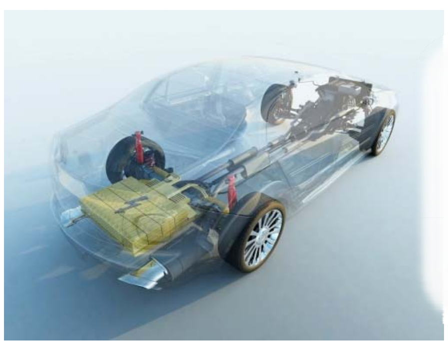
CERC-CVC Thrust Areas

1. Advanced Batteries and Energy Conversion

2. Advanced Biofuels, Clean Combustion and APU



3. Vehicle Electrification

4. Lightweight Structures

5. Vehicle-Grid Integration

6. Energy Systems Analysis, Technology Roadmaps and Policies

Vehicle Projects Covered in CERC-CVC (6/33)

- **Advanced Batteries and Energy Conversion**
  - Characterization of Degradation in Li-Ion Batteries
  - High Energy Density Battery Chemistries
  - Battery Implementation, Safety, Recycling & Standardization
  - Modeling & Control of Li-Ion Batteries
  - In-situ Neutron Profiling of Li-Ion Battery materials
  - Li-ion battery Aging and Internal Degradation Mechanisms
- **Advanced Biofuels, Clean Combustion, and APU**
  - Biofuel Chemistry & Physics
  - Chemical and Physical Models for Novel Fuels
  - In-Cylinder Biofuel Combustion Behavior
  - Power-Train and After-Treatment System Control
  - Development of APU-Oriented Boxer Engine
  - APU High Efficiency and Clean Combustion System
  - Integration and Systematic Control of APU System
  - Energy Conversion (Thermoelectric Generation)
- **Vehicle Electrification**
  - Efficient and High-Power Density Electric Powertrain
  - Control and Optimization of Distributed Vehicle Network
  - Improved Efficiency, Safety, Reliability and NVH Performance
  - Data-Based Techniques for Battery-Health Prediction
- **Advanced Lightweight Materials and Structures**
  - Warm Forming Processes for Al and Mg alloys
  - Bulk Forming Processes of Lightweight Materials
  - Joining in Multi-Material Vehicle Structures
  - Lightweight Body Subsystem and Vehicle Optimization
- **Vehicle Grid Integration**
  - Architecture and Interaction Mechanism of ITS Based V2G
  - Assessment of PEV Impact on the Grid
  - Vehicle-Grid System Modeling for Technology Deployment
  - Control Strategies for Vehicle-Grid Integration
  - Vehicle-Grid System Integration Policies
  - Adaptive Battery Management System On and Off the Grid
- **Systems Analysis, Technology Roadmaps, and Deployment**
  - Energy Efficiency, GHG Targets and Life Cycle Performance
  - Fuel Mix Strategies and Constraints
  - Fuel Economy and GHG Standards and Labels for PEVs
  - CV Technology Roadmap and Policy Recommendations
  - Electricity & material sourcing scenario analyses

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Clean Vehicles Partners

U.S.

– **Project Lead:**
  - University of Michigan (UM)
– **Partners:**
  - Argonne National Laboratory
  - Delphi
  - Denso
  - Eaton
  - Environmental Protection Agency
  - Ford Motor Company (Ford)
  - Honda R&D Americas, Inc.
  - Joint Bio Energy Institute
  - Massachusetts Institute of Technology (MIT)
  - Oak Ridge National Laboratories (ORNL
  - Ohio State University (OSU)
  - PJM
  - Sandia National laboratories, Combustion Research Facility
  - TE Connectivity
  - Toyota Motor Company, Toyota Motor Engineering and Manufacturing North America

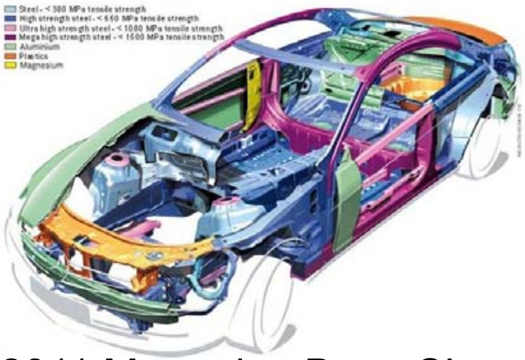
China

– **Project Lead**
  - Tsinghua University
– **Partners:**
  - Beihang University
  - Beijing Institute of Technology
  - Beijing SinoHytec Co., Ltd
  - China Automotive Engineering Research Institute Co., Ltd
  - China Automotive Technology & Research Center
  - China Potevio
  - Chinese Academy of Sciences
  - Geely Group
  - Jing-jin Electric Co., Ltd
  - Microvast
  - North China Electric Power University
  - SAIC Motor
  - Shanghai Jiao Tong University
  - Tianjin Lishen Battery Joint-stock Co., Ltd
  - Tianjin University
  - Tongji University
  - Wanxiang
  - Wuhan University of Technology
  - Yintong Energy

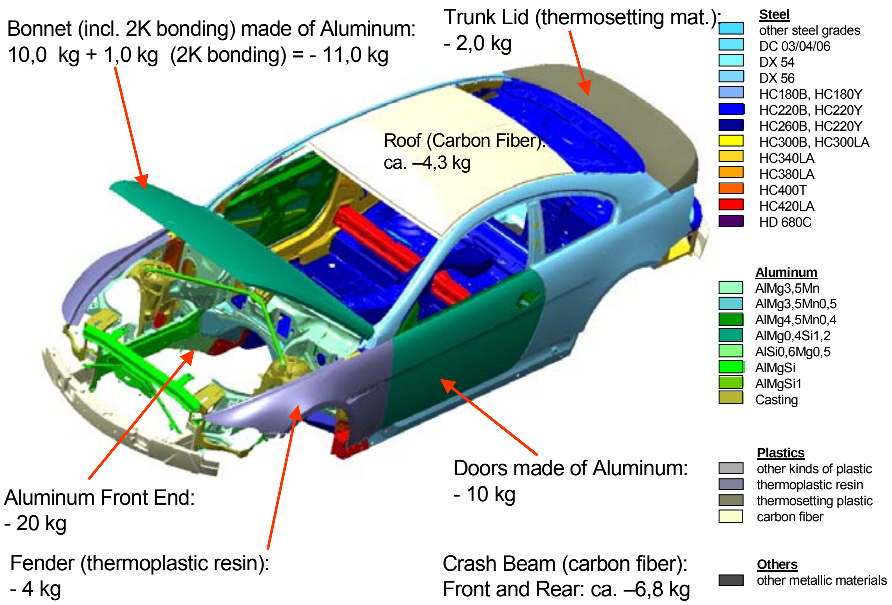
V-4: Trends in Vehicle Body Lightweighting

Typical Multi-material car body

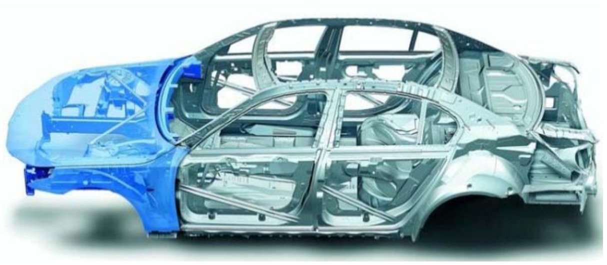
- BMW 5/6/7 (>18%)
- Audi TT/TTS Coupe (68%)
- Audi TT/TTS Roadster (58%)
- Mercedes-Benz CL Class Coupe



2011 Mercedes-Benz CL Class Coupe



BMW 6 (Frond End+Hood+Bodyside)



BMW 5 (Frond end+Hood)

V-4: Lightweight Structures Study of Crash Safety of Small Lightweight EV

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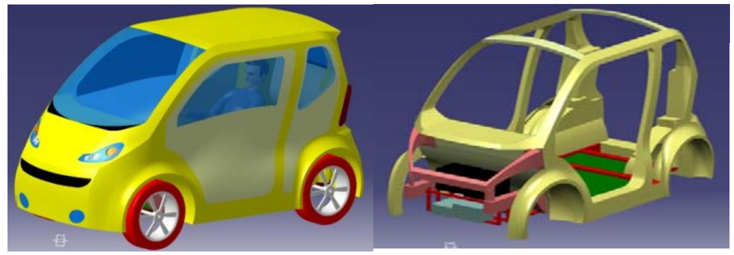
Research Objectives

Study of influence of structural design parameters and applications of lightweight materials for crash safety of small lightweight EV

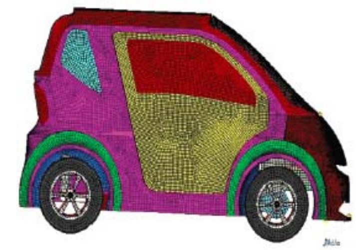
Technical Approach

- Define parameters of a study vehicle
- Build parameterized finite element model for crash analysis
- Crash simulations and analyses
- Material selection for small lightweight EV body
- Deformation and failure modeling methods for lightweight materials and structures and design countermeasures
- Preliminary study of crashworthiness of EV battery

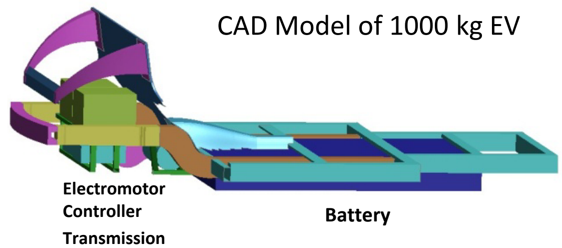
Achievements

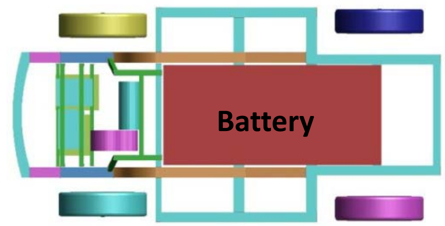


CAD Model of 1000 kg EV



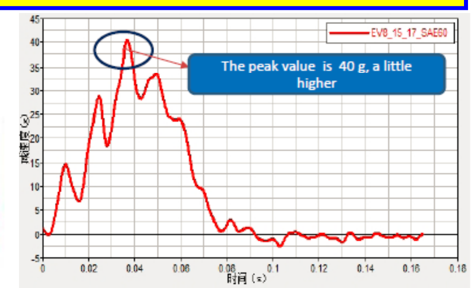
Finite Element Model





Influence of mass distribution of the battery and passengers on crash performance
Influence of using lightweight material on mass reduction and vehicle safety

Load path of crash force



The parameters that influence the crash pulse
– The height of the center of mass
– The thickness and structure of the front rail
– The thickness of the A pillar
– The thickness of the front wheel cover board
– The mass distribution of the battery

V-3: Efficient and high-power density electric powertrain

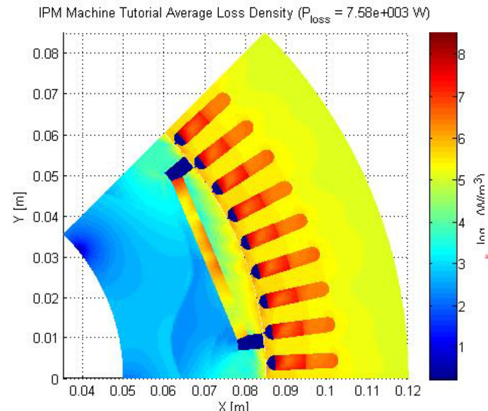
Research Objectives

- Develop innovative and optimized electric machines and drives to achieve electrified powertrain with significantly higher power density and efficiency.

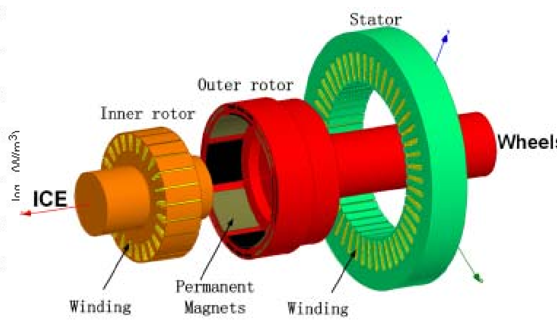
Technical Approach

- Development of computationally-efficient finite element analysis (FEA) tools for the steady-state analysis of electric machines (UM)
- Development of EVTT dual-mechanical port electric machine concept for electric vehicle and hybrid electric vehicle applications. (OSU)
- Modelling of amorphous iron laminations to capture magnetic saturation and high-frequency eddy currents (CAS)
- Design optimized permanent magnet machine using the above magnetics models (CAS)

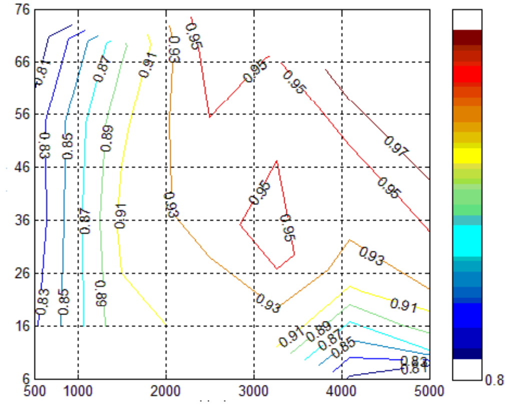
Initial Results



Power losses calculated by computationally-efficient FEA solver

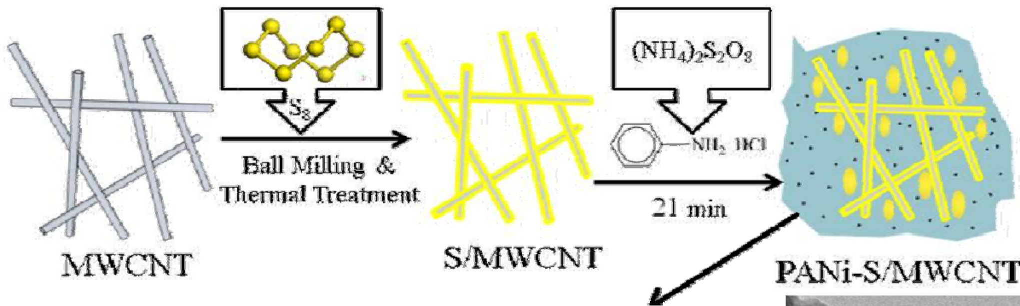


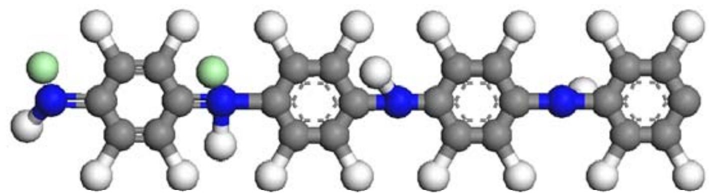
Electrical Variable Traction-Transmission machine and drive.

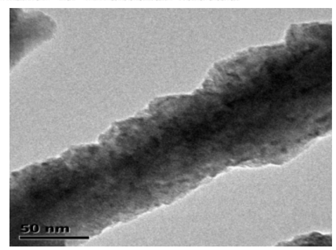


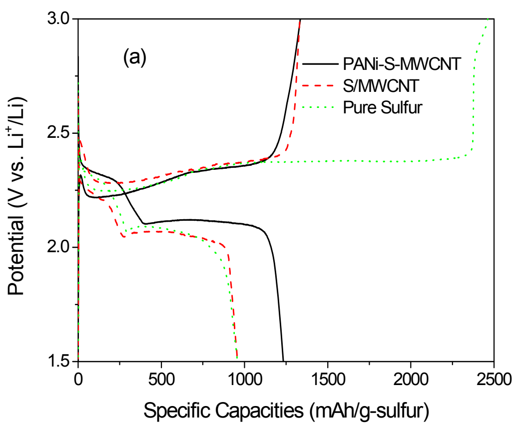
Left: prototype permanent magnet machine with amorphous alloy laminations. Right: efficiency map

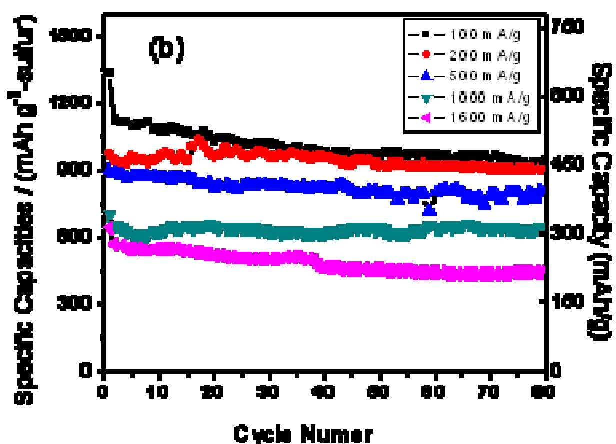
V-1: Composite S/C Material for Li-Sulfur Batteries











J. Phys. Chem. C, 2011, *115* (49),24411

- Polymerization creates a shell which prevents the Sulfur shuttle mechanism.
- **Benefits:** columbic efficiency doubled (~90%), discharge capacity maintained (1334.4 mAh g^{-1}), improved rate performance (634.1 mAh/g at 1C).

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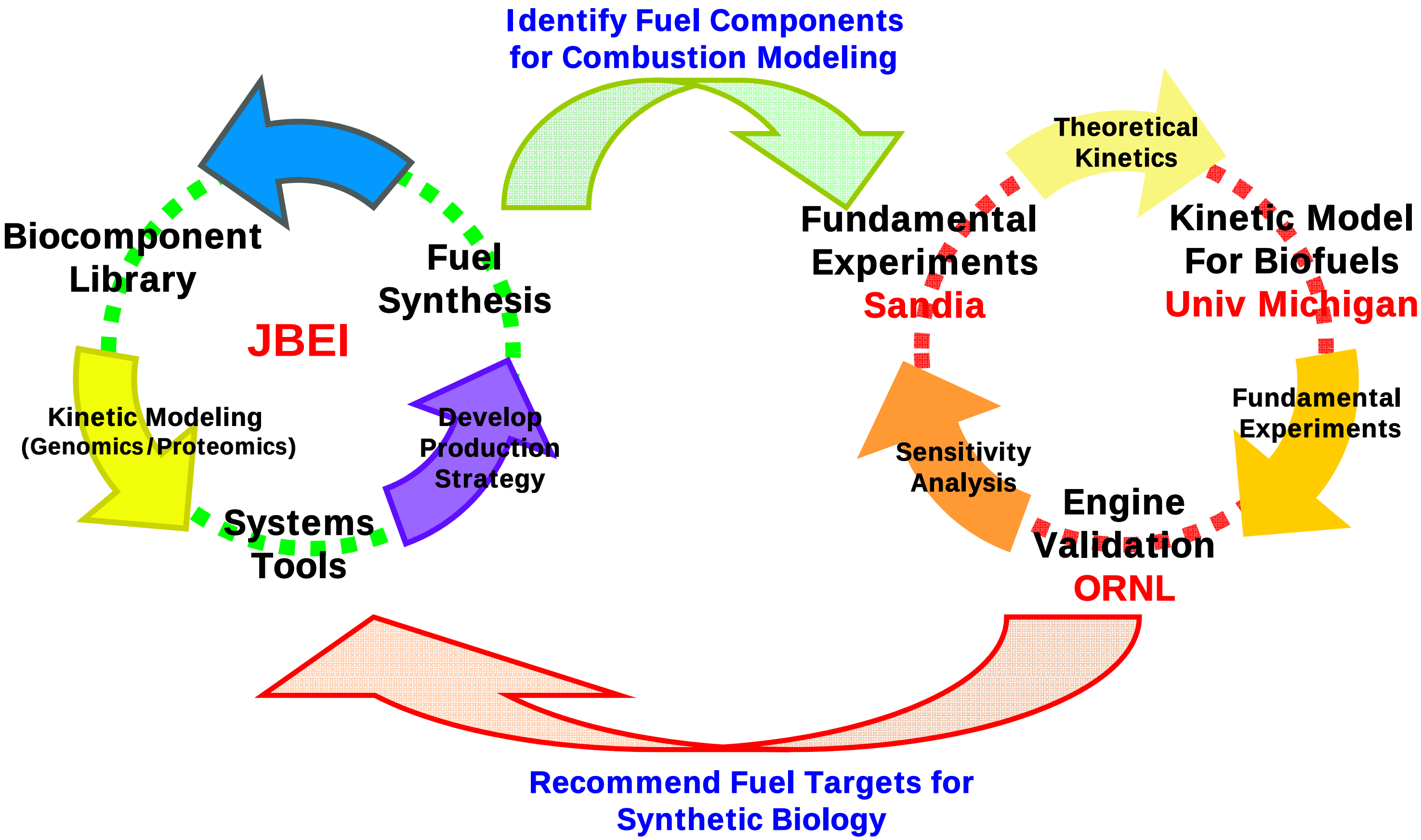
V-2: An Optimal Biofuels Production Process



Research Uniquely Connects Synthetic Biology (JBEI), Combustion Chemistry (UM & Sandia), and Engine Design and Performance (ORNL).

V-5: Driving Pattern in China Mega City for EV Design

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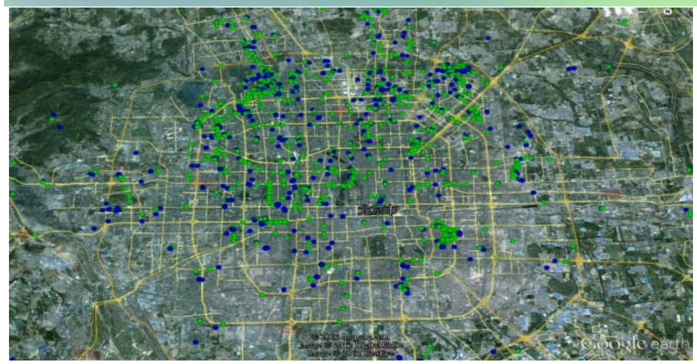
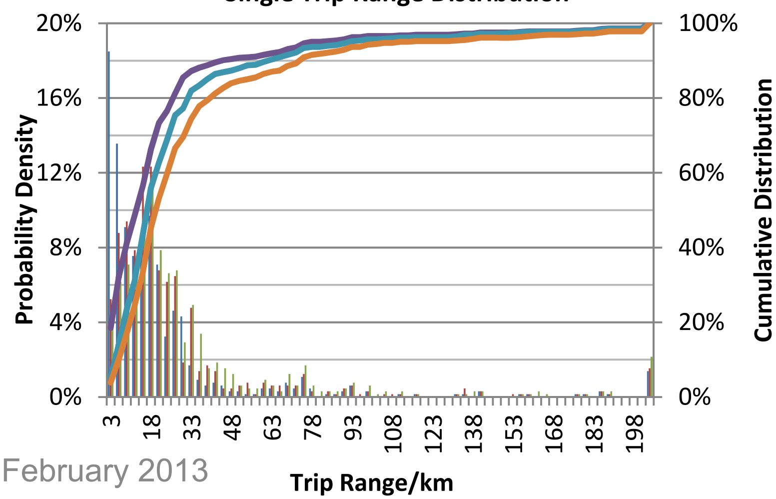


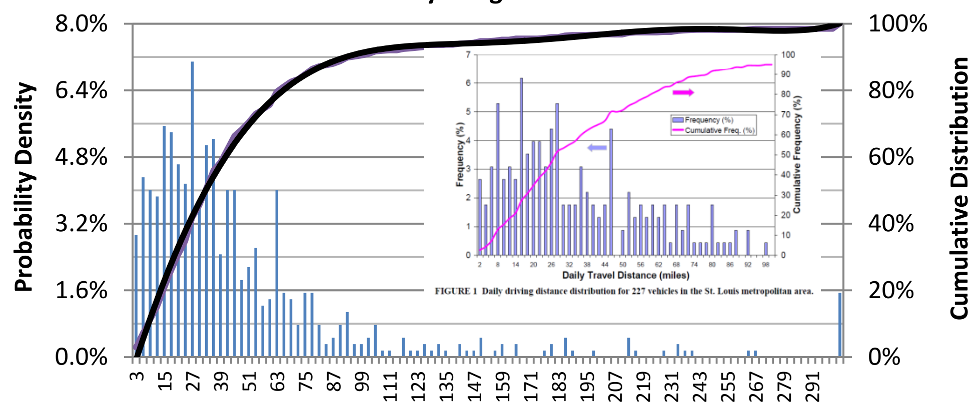
98 household，987 vehicle-days, 4-41days, >2000 trips

	3rd Ring	4th Ring	5th Ring
Origin	26.2%	43.0%	72.8%
Destination	24.6%	43.6%	75.9%

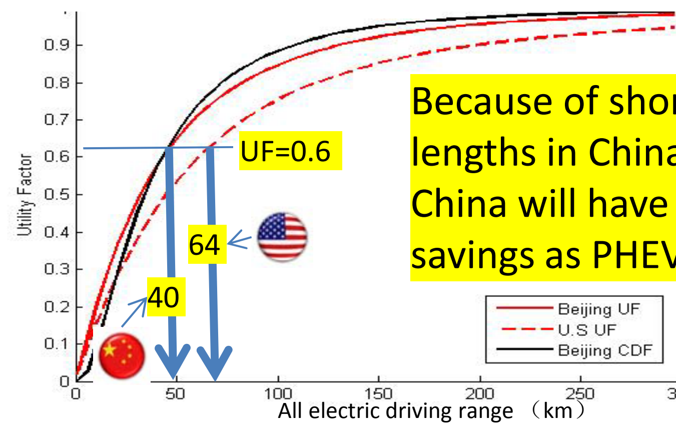
Single Trip Range Distribution



Daily Range Distribution



	Mean (km)	50% (Km)	80% (km)
Beijing survey based on GPS（2012）	**43.1**	33	60
NHTS（US，2009）	**46.8**	-	-



Because of shorter trip lengths in China, PHEV-25 in China will have similar fuel savings as PHEV-40 in the US

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BUILDINGS ENERGY EFFICIENCY

VISION: Build a foundation of knowledge, technologies, human capabilities, and relationships that position the United States and China for a future with very low energy use and highly energy efficient multi-family residential and commercial buildings.

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Strategy to Achieve Cost Effective Very Low Energy Buildings

Building Design

Integrated Design
Protocols and design tools for VLEBs

Behavior
50-70% reduction in energy use

Building Envelope

Roofing technologies / Cool Roof Coatings
Long life high solar reflectance

Insulation
New cost effective air sealing technology

Advanced Window and Shading Technologies
Perimeter energy reduction of 15% - 30%

Building Equipment

Natural Ventilation Design
Optimization of efficiency / comfort

Lighting Controls
New lighting control algorithms

HVAC Systems
Efficiency improvements

Renewable Energy / Distributed Generation Integration

Integration and Operation in Real Time
Optimized technology selection, real time controls

New Heat Pump Design
System energy use reductions >30%

Whole Building

Building technology integration
Optimization and evaluation of energy system and operation

Policy, Market Promotion

Data and Energy Management
Energy use reductions

Policy Analysis and Incentives
New codes & policies

Building Projects Covered in CERC-BEE (6/17)

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- **A. Integrated Building Design & Operation of Very Low Energy, Low Cost Buildings**
  - Methods and tools to achieve integrated design
  - Human behavior
- **B. Building Envelope**
  - Advanced Window and Shading Technologies
  - Liquid Flashing to Air Seal Windows, Doors and Piping Penetrations
  - Cool Roofs & Urban Heat Islands
  - Hybrid ventilation technology and product R&D
- **C. Building Equipment**
  - Dehumidifier devices for hot summer & cold winter regions
  - Advanced Lighting Controls R&D and Policy
  - Popularize evaporative-cooler chiller application in the U.S.
- **D. Renewable Energy Utilization**
  - Building Integrated PV
  - Microgrids for Low Energy Buildings
  - Advanced Ground Source Heat Pump Technology for Very Low Energy Buildings
- **E. Whole Building**
  - Energy System and Technology for Pilots
  - *Construction of pilot building*
  - Commissioning, Operation, Real-time Monitoring and Evaluation of Pilots
- **F. Operation, Management, Market Promotion and Research**
  - Research on Very Low Energy Building Operations and Management Methods
  - Incentive Policies, Demonstration and Market Promotion

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Buildings Energy Efficiency Partners

– **U.S. Project Lead:**
  - Lawrence Berkeley National Laboratory (LBNL)
– **U.S. Partners:**
  - Bentley Systems Inc.
  - C3
  - ClimateMaster
  - Demand Energy
  - DOW Chemical Company
  - Energy Foundation China Sustainable Energy Program
  - Honeywell Corporation
  - ICF International (ICF)
  - Lutron*
  - Massachusetts Institute of Technology (MIT)
  - National Association of State Energy Officials (NASEO)
  - Natural Resources Defense Council (NRDC)
  - Oak Ridge National Laboratory (ORNL)
  - Saint-Gobain
  - UTRC*

– **China Project Lead**
  - Center of Science and Technology of Construction, Ministry of Housing and Urban-Rural Development (MOHURD)

– **China Partners:**
  - Aide Solar
  - Anhui ROBA
  - Beijing University of Civil Engineering and Architecture
  - China Academy of Building Research (CABR)
  - Chinese Society for Urban Studies
  - Chongqing University
  - CISDI Engineering
  - CONVERTERGY
  - East-West Control Group
  - ENN Group
  - Ever Source Technology Development
  - Fullshare Energy
  - Guangdong Provincial Academy of Building Research
  - Huaqing Geothermal
  - Jiangsu DISMY GSHP
  - Lampearl Photoelectric Co., Ltd
  - LANP
  - Lattice Lighting

– **China Partners:**
  - Leye Energy Service
  - LH Technology Co., LTD
  - Liaoning Solar Energy R&D Co., LTD
  - NARI Technology Development
  - National Center for Quality Supervision Test of Building Energy Efficiency
  - Persagy
  - Shanghai Futian Air Conditioning Equipment Co., Ltd
  - Shenzhen Institute of Building Research
  - Singyes Solar
  - SOLATUBE Daylight Technology, CECEP
  - Telchina
  - Tianjin University
  - Tongguang Construction Group
  - Tongji University
  - Tsinghua University
  - Vanke Building Technology
  - Wall Insulation Committee in China Association of Building Energy Efficiency
  - Xinjiang Green Messenger
  - Yingli Energy, Beijing

** Entrance discussions underway*

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Build-Out of New City

- Massive Trends in China Toward Urbanization
- 100 Million New City People in Next Decade
- Building the Equivalent of One NYC Every 3 Years
- MOHURD Plans to Create 90 Pilot Smart Cities, With China Development Bank
- Unprecedented Opportunity for Urban Design, New Technology Demos, and Adoption

B-2: Building Envelope - Cool Roofs -

- LBNL, Dow Chemical, Chongqing Univ.
- Create white roof coatings with superior reflectance and durability for U.S. and China markets
- Demonstrate and Quantify Cool Roof Benefits in China and U.S.
- Establish Chinese Rating Systems, Incentives, and Standards Similar to Those in the U.S.
- New coating product yields IP in 2013 with sales in China and the U.S. by 2016
- Potential Impacts
  - 2Billion m^2 (China,)
  - 1B m^2 (U.S.)
  - 200 TBtu/y Saved
  - 14 $MtCO_2$/y Avoided

High Efficiency Building Envelopes, Including Cool Roofs

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B-5 Whole Building
- Natural Ventilation -

- Institute of Building Research, Shenzhen, China

- Natural Ventilation Open Air Building

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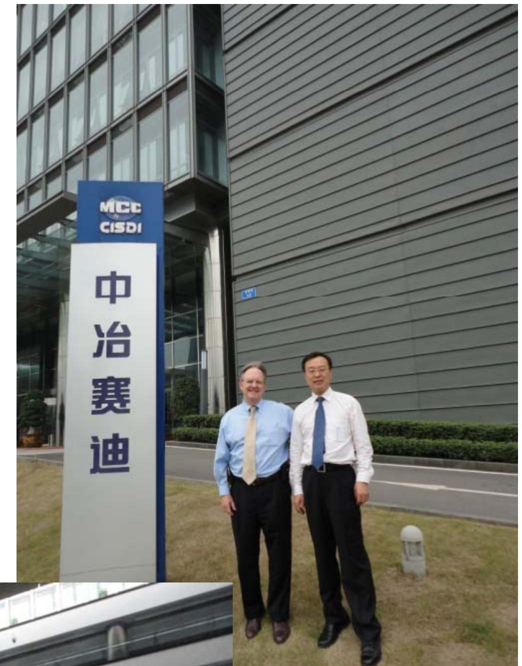
B-2: Building Envelope - Innovative Design -

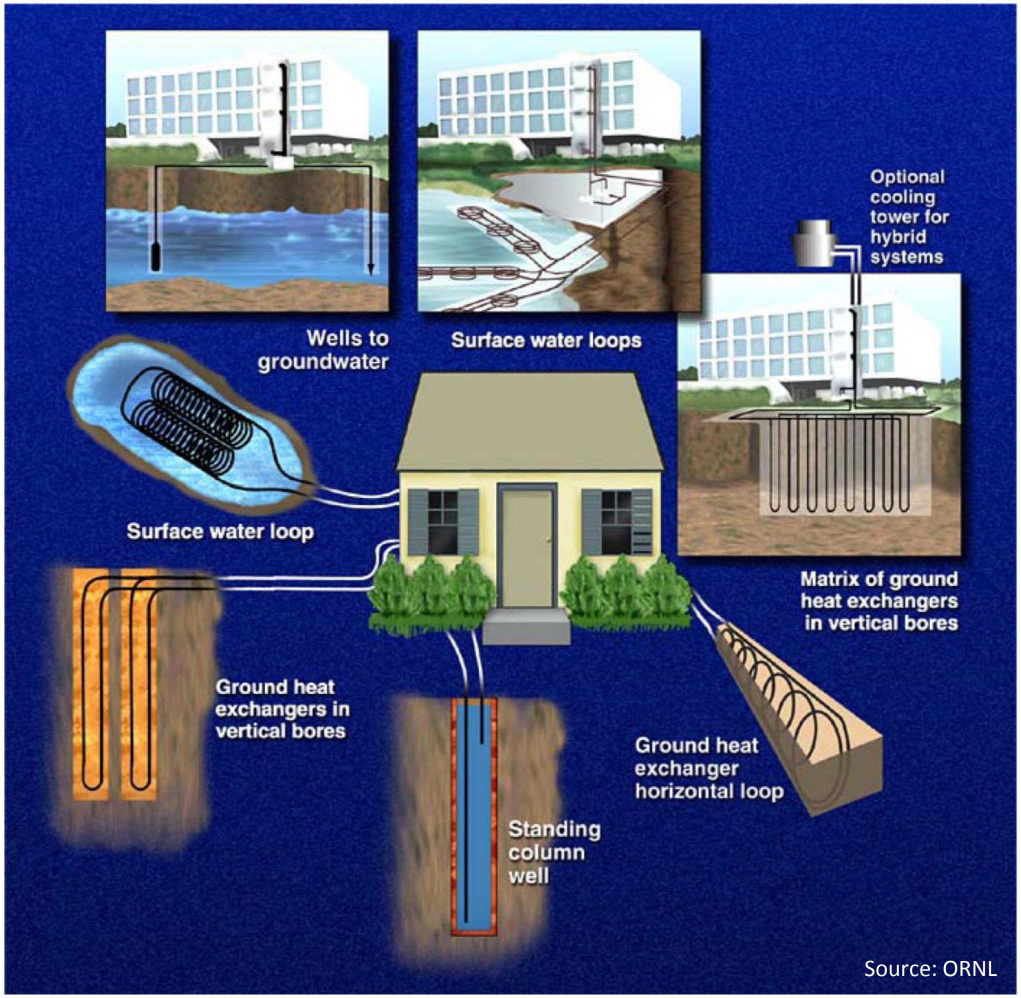
- CISDI Engineering Co, Ltd.
  - Chongqing Iron and Steel Design Institute
- CISDI Steel Building
  - Advanced Window Design
  - 18” Air gap with natural Air Flow.
- Maximum Use of Daylighting



B-4: Renewable Energy Utilization

Ground Source Heat Pumps

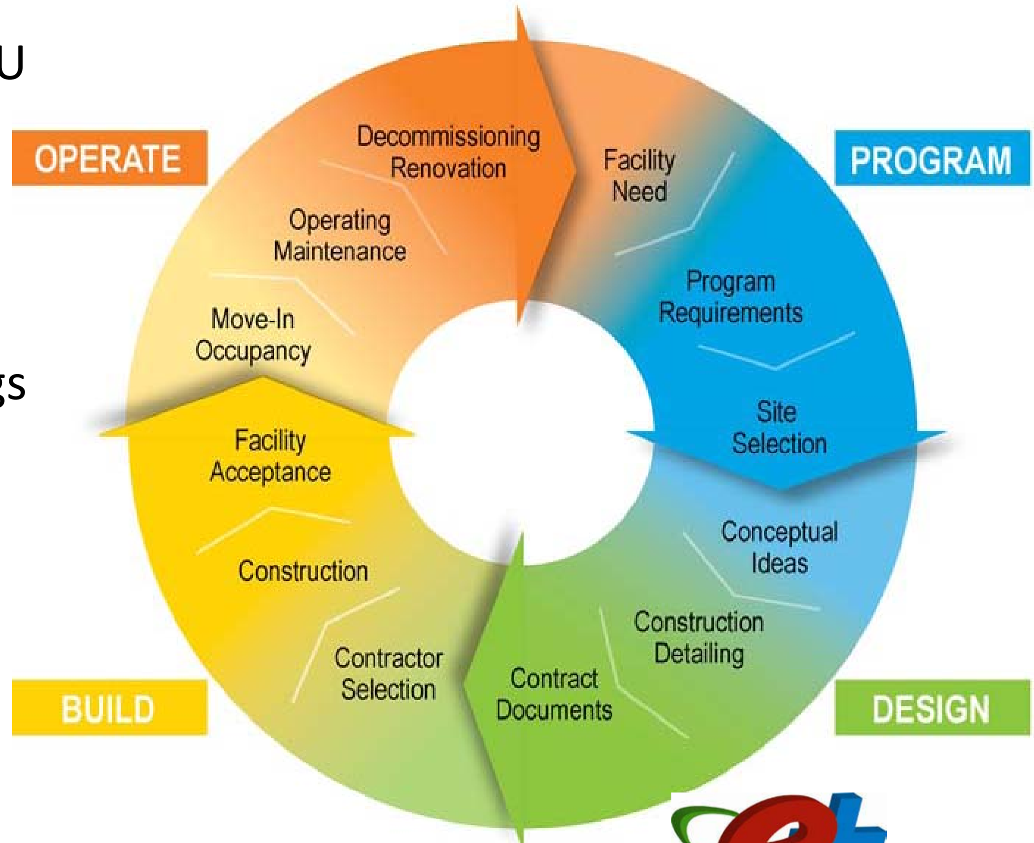
- ORNL, ClimateMaster, Chongqing U, Tianjin U, Tongji U
- Evaluating Emerging GSHP Technologies in both U.S. & China (GHX, Wastewater)
- U.S. & China are participating in GSHP Demonstrations in the Other's Country.
  - China Typically Uses Centralized GSHP Systems
  - U.S. typically Uses Decentralized GSHP Systems



Common GSHP systems

B-1: Integrated Building Design

- LBNL, Bentley Systems, Tsinghua U
- Building Energy Monitoring and Simulation
- Supports the Design and Operation of Low-Energy Buildings in U.S. & China
- Includes Behavior Modeling
- Compare DOE Simulation Tools:
  - Designer's Simulation Toolkit (DeST)
  - EnergyPlus Simulation
- Behavior Largest Variable in Building Efficiency Results



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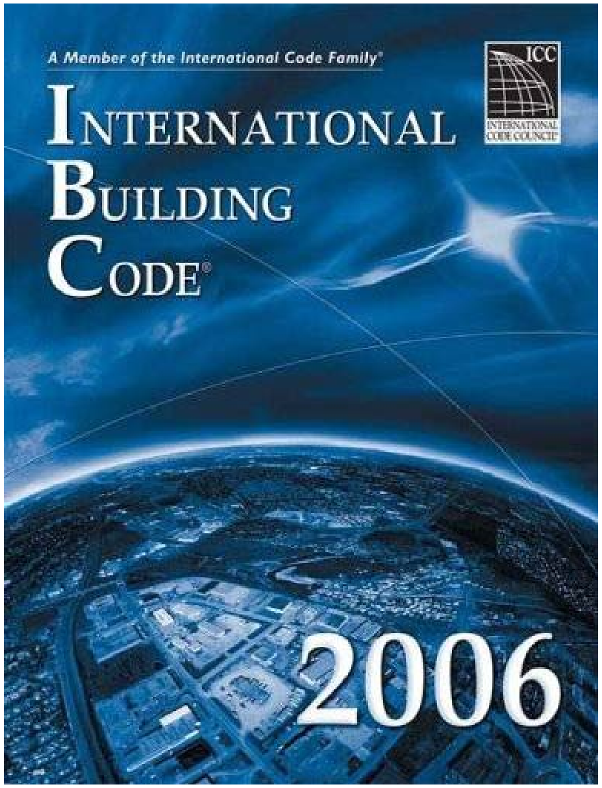
B-6: Operation, Management, Market Promotion and Research

Building Codes & Standards

- LBNL, ClimateMaster, Energy Foundation, MOHURD, Shenzhen IBR
- Comparative Analysis and Research on Efficacy of Policies Related to Building Energy Efficiency in China and the U.S., Considering:
  - National Laws & Regulations
  - Local Conditions
  - Habits of Energy Consumption
- LBNL & IBR Provide Inputs and Updates to Building Codes in China, U.S., and for International Use



INTELLECTUAL PROPERTY

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Intellectual Property

12 March 2012

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Intellectual Property

- Innovative Bi-Lateral Approach to IP Enabled by CERC Protocol & Annex
  - Guarantees of Right to IP Under CERC
  - Strengthens IP Protections
  - Enables Robust Research Agenda
  - Encourages Sharing the Best of IP
  - Supports Fair Resolution of Disputes
- Technology Management Plan (TMP)
  - Endorsed by Both Governments
- Successful IP Conference, Hainan, March 2012
- Follow-Up Conference – Palo Alto, Feb 2013

Two governments sign endorsement letters supporting the jointly agreed upon & signed Technology Management Plans *

Observers:
Secretary of Energy Steven Chu
Minister of Science & Technology WAN Gang
Vice Minister QIU Baoxing , MOHURD
Signatories:
Assistant Secretary David B. Sandalow, DOE
Deputy Director General MA Linying, MOST
Country Directors of CERC:
Dr. Robert C. Marlay (for U.S.)
Counselor LIU Zhiming (for China, Not Shown)

* TMP, regarding the exploitation of intellectual property rights pursuant to paragraph ILB,2,(d) of Annex I- Intellectual Property (hereinafter "IP Annex") of the CERC Protocol, Beijing, September 23, 2011

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Technology Management Plan

- Clearly states the rules of partner engagement under CERC;
- Provides for declaration and protection of background IP;
- Defines “a priori” procedures for allocating and protecting rights to new inventions;
- Provides for non-exclusive licensing of IP under favorable terms;
- Encourages sub-agreements for specific IP and related terms & conditions;
- Supports fair resolution of disputes under international standards;
- Establishes a role for government monitoring and oversight; and
- Encourages compliance with existing agreements.

TECHNOLOGY MANAGEMENT PLAN

(Regarding the exploitation of Intellectual Property Rights)

for the Clean Energy Research Center Clean Vehicles Consortium (CVC)

中美清洁能源研究中心清洁汽车联盟（CVC）

关于知识产权利用的

技术管理计划

I. PREAMBLE

一、前言

1 The Chinese members of the CVC (hereinafter, China CVC) and the United States of America members of the CVC (hereinafter, U.S. CVC) agree to the following Technology Management Plan (TMP) regarding the exploitation of intellectual property rights pursuant to paragraph II.B.2.(d)of Annex I - Intellectual Property (hereinafter "IP Annex") of the Protocol for Cooperation on a Clean Energy Research Center (hereinafter "CERC Protocol"), signed on the 17th day of November, 2009, by the Department of Energy (DOE) of the United States of America, the Ministry of Science and Technology (MOST) and the National Energy Administration (NEA) of the People’s Republic of China, (hereinafter “Signatories to the CERC Protocol”).

1. 清洁汽车联盟中方成员（以下简称“中方 CVC”）和清洁汽车联盟美方成员（以下简称“美方 CVC”）根据美利坚合众国能源局（DOE），中华人民共和国科学技术部（MOST）和国家能源局（NEA）（以下简称“CERC 议定书缔约双方”），于 2009 年 11 月 17 日签署的关于中美清洁能源联合研究中心合作议定书（简称“CERC 议定书”）以及附件 I 知识产权（简称“IP 附件”）第二节第 2 条第 2 款第 4 项就以下技术管理计划（TMP）关于利用知识产权的条款达成共识。

2. This TMP is applicable to all CERC-CVC Cooperative Activities undertaken pursuant to the CERC Protocol and its IP Annex, except as otherwise agreed to by the Signatories to the CERC Protocol or their respective designees in writing.

2. 本计划适用于根据 CERC 议定书以及 IP 附件开展的所有 CERC-CVC 合作活动，但 CERC 议定书缔约双方或其书面指定的各自代表机构另有专门协议除外。

3. This TMP considers the exploitation of intellectual property rights as described in the CERC Protocol and paragraph II.B.2.(b) and (c) of IP Annex. The IP rights of visiting researchers set forth in

1

Available at: http://www.us-china-cerc.org/Intellectual_Property.html

LP Amina -- IP Success Story

IP Success Story:

- LP Amina, Charlotte, NC
- Gemeng* Facility, Shanxi, China
- Large Commercial Demo
- IP Legal Framework Under CERC
  - Enabled Progress
  - Restrained Over-Reaching
  - Animated Action by Ambassador Locke
- Joint Oversight by US & China Encouraged Compliance with TMP

*Gemeng International Energy

Combined Power & Chemicals Production from Coal Using Oxyfiring, Pyrolysis and Gasification. Large Efficiency Gains and Emissions Reductions. LP Amina Calcium-Carbide Furnace.

Summary

- Bilateral S&T Cooperation is Challenging
- Much Progress to Date
- Much Work Remains to Be Done, with Much Benefit to Gain
- In the Near-Term, U.S. and China will Benefit from:
  - Leveraged Research and Important breakthroughs
  - Demo Platforms and Accelerated Technology Deployment
  - Opportunities for Clean Energy Technology Manufacturing, Sales and Installation Domestically and Internationally
- In the Long-Term, U.S. and China will Benefit by:
  - Accruing to Itself and its Peoples the Benefits of Greater Deployment of Clean and Affordable Energy Technology at Scale;
  - Greater Efficiency, Reduced Energy use and costs, and Less Pollution and Mitigated Emissions of Greenhouse Gases; and
  - Expanded Markets for Domestic Businesses and Industries.

CERC LOGO

U.S.–China Clean Energy Research Center

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U.S.: http://www.us-china-cerc.org
China: http://www.cerc.org.cn/