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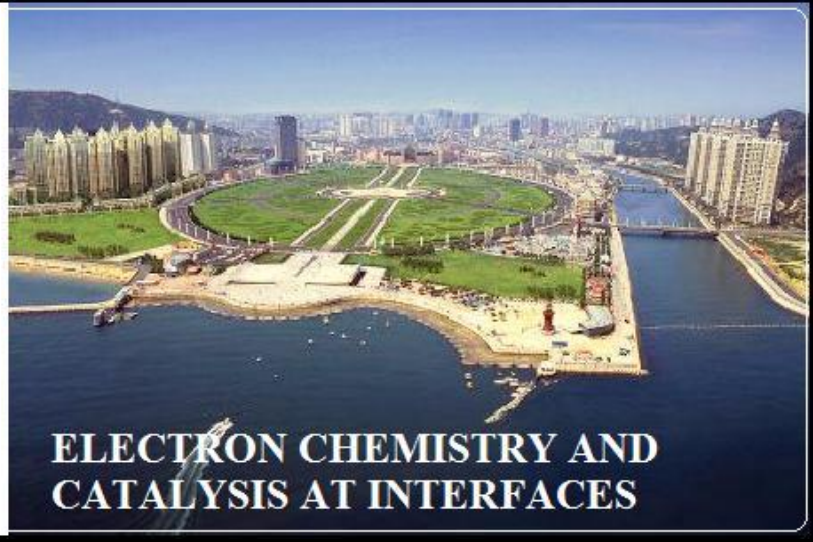


Catalysis for Sustainable Energy Production:
A US-China collaboration

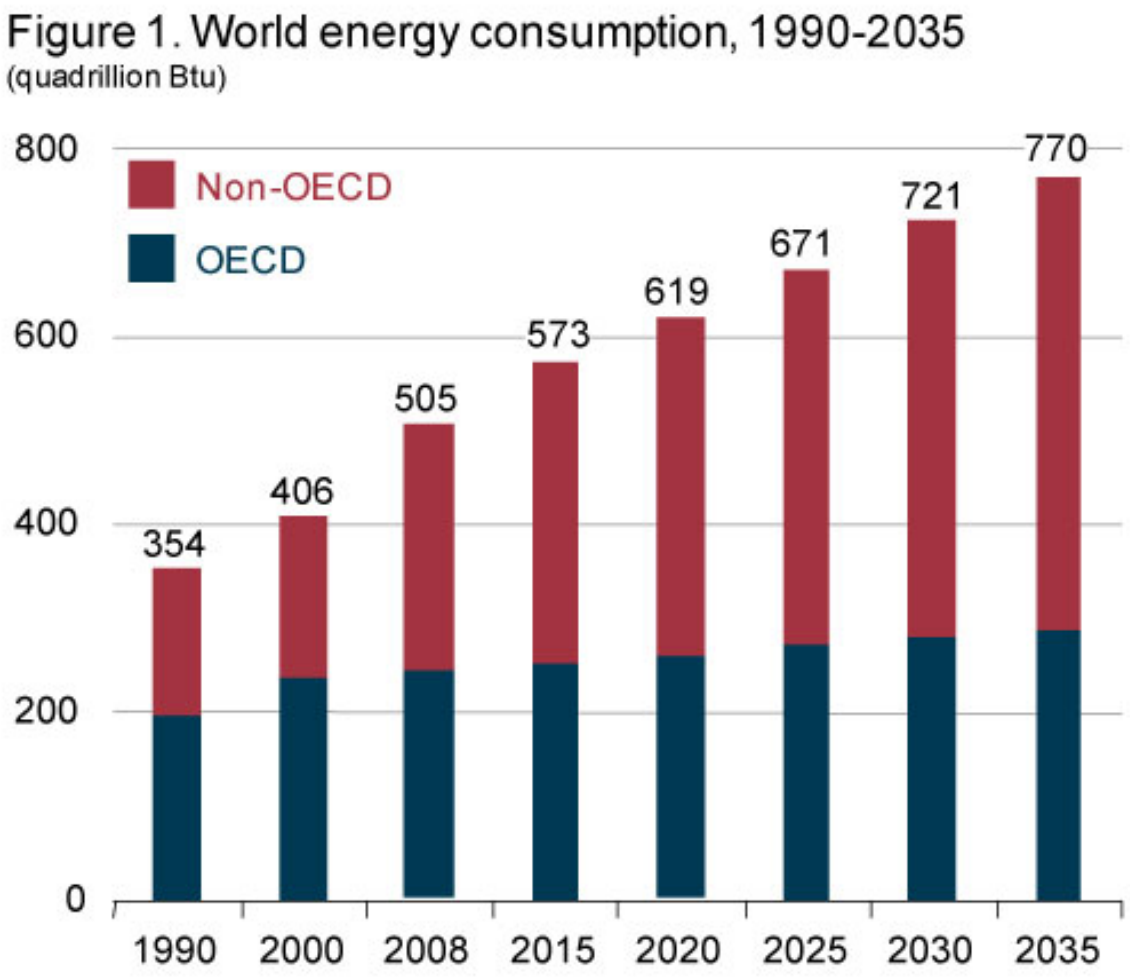
Susannah Scott, UC Santa Barbara

PIRE-ECCI Phase I: 2005 – 2010

PIRE-ECCI Phase II: 2010 - 2015

Santa Barbara – Dalian – Fudan –Tsinghua – Hefei – Suzhou – Xiamen – Zhejiang

Future world energy demand



"The energy problem is ***the*** *single most important problem* that has to be solved by science and technology in the coming decades."

- Steven Chu (2006)

International Energy Outlook 2011, US Energy Information Administration, Report number DOE/EIA-0484(2011)

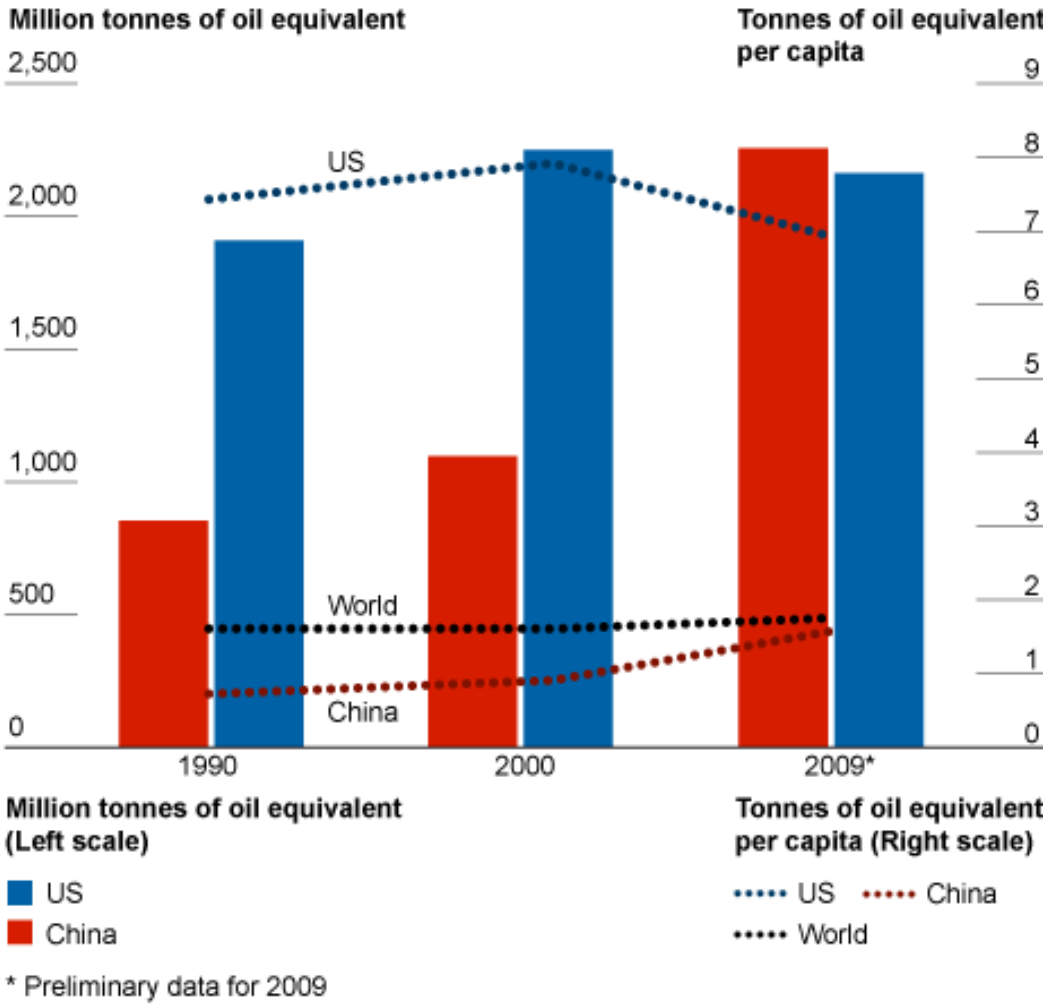
SusChEM

2012 NSF Workshop

Sustainable Chemistry, Chemical Engineering and Materials

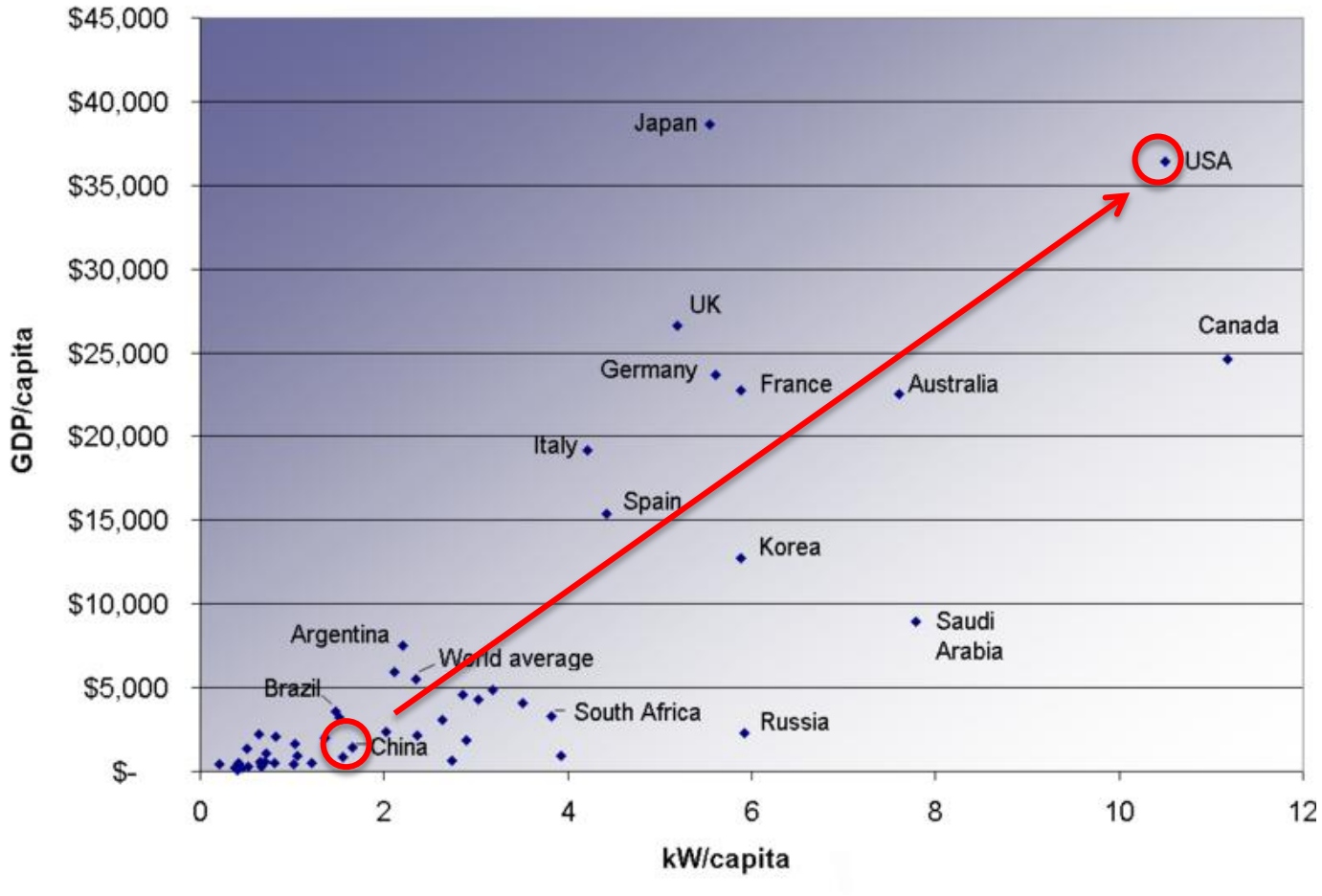
- Manufacture with **renewable** rather than non-renewable feedstocks where possible
- Minimize the use of energy and fresh water through process intensification
- Favor the use of **Earth-abundant** elements over rare elements
- Design products to facilitate **recovery** and **recycling**
- Train researchers to integrate **life-cycle analysis** and **toxicology** considerations into process design
- Equip science and engineering students to recognize opportunities for **innovation** and give them **entrepreneurial** skills to implement them
- Appreciate **global** dimensions and **regional** variations in sustainability perspectives

China as energy consumer



International Energy Outlook 2011, US Energy Information Administration, Report number DOE/EIA-0484(2011)

Energy use ⇔ standard of living



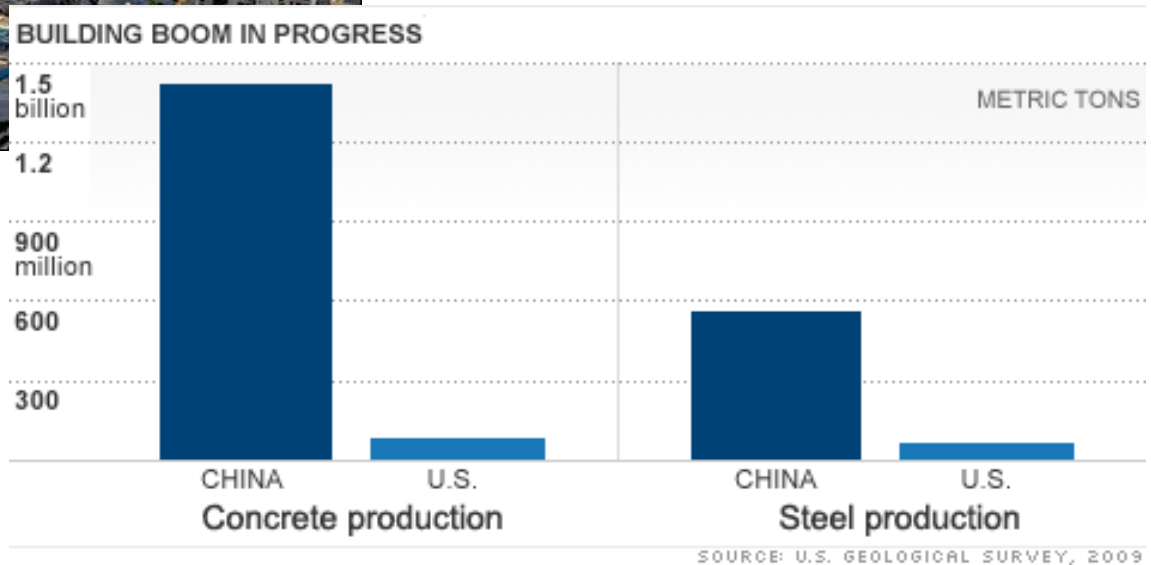
Frank van Mierlo, 2006 Key World Energy Statistics from the International Energy Agency

Building China's infrastructure

Shanghai skyline
Chang W. Lee/The New York Times

Over the next 15 years, China is expected to build the equivalent of New York City -- 10 times over. That's a lot of concrete and steel, and it goes a long way to explaining why the country is using so much energy.

CNNMoney.com - *November 29, 2010*

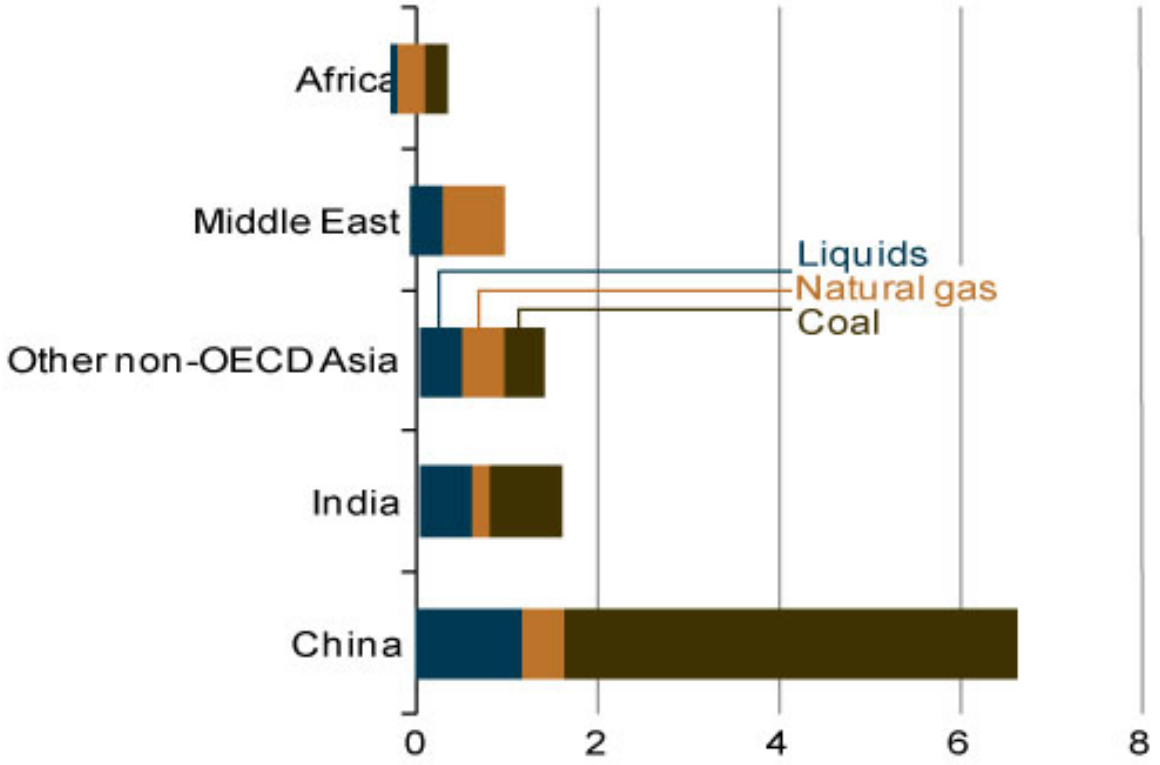


Transportation in China

- Global registrations for cars, trucks and buses surpassed 1 billion in 2010.
- Registrations in China increased by 28 % in a single year.
- Beijing alone adds 1,500 cars to its roads per day.
- The OECD forecasts 2.5 billion vehicles worldwide by 2050.

China as CO_2 producer

Figure 115. Increases in carbon dioxide emissions by fuel type for regions with highest absolute emissions growth, 2008-2035
(billion metric tons)

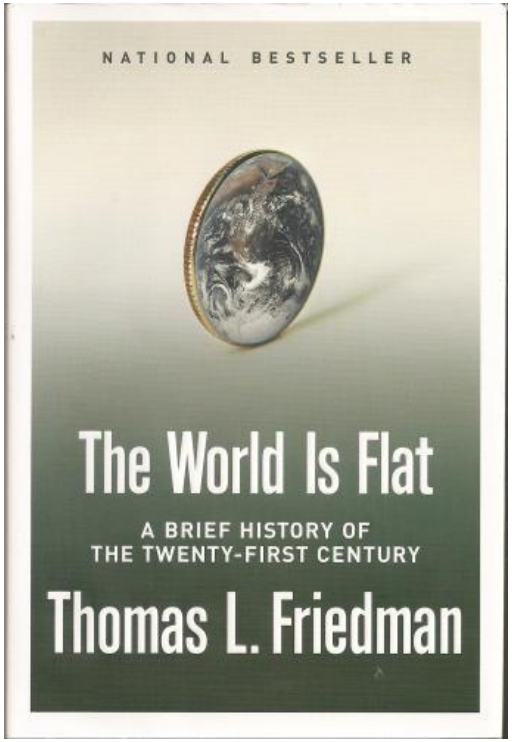


International Energy Outlook 2011, US Energy Information Administration, Report number DOE/EIA-0484(2011)

Energy efficiency

Hey, I'm really glad you switched to long-lasting compact fluorescent light bulbs in your house. But the growth in … Dalian ate all your energy savings for breakfast. I'm glad you bought a hybrid car. But … Dalian devoured that before noon… I'm glad that solar and wind power are "soaring" toward 2 percent of U.S. energy generation, but … Dalian will devour all those gains for dinner.

T. Friedman, *New York Times*, September 19, 2007



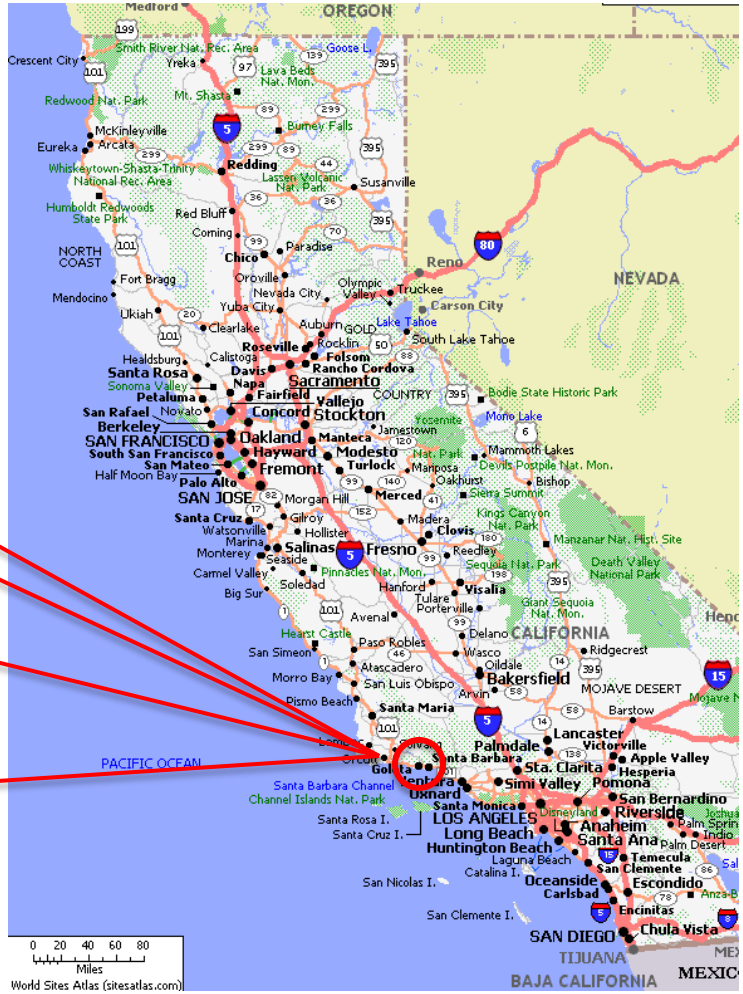
Jevons' Paradox

"It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth."

"Whatever, therefore, conduces to increase the efficiency of coal, and to diminish the cost of its use, directly tends to augment the value of the steam-engine, and to enlarge the field of its operations."

W.S. Jevons, The Coal Question, 1866.

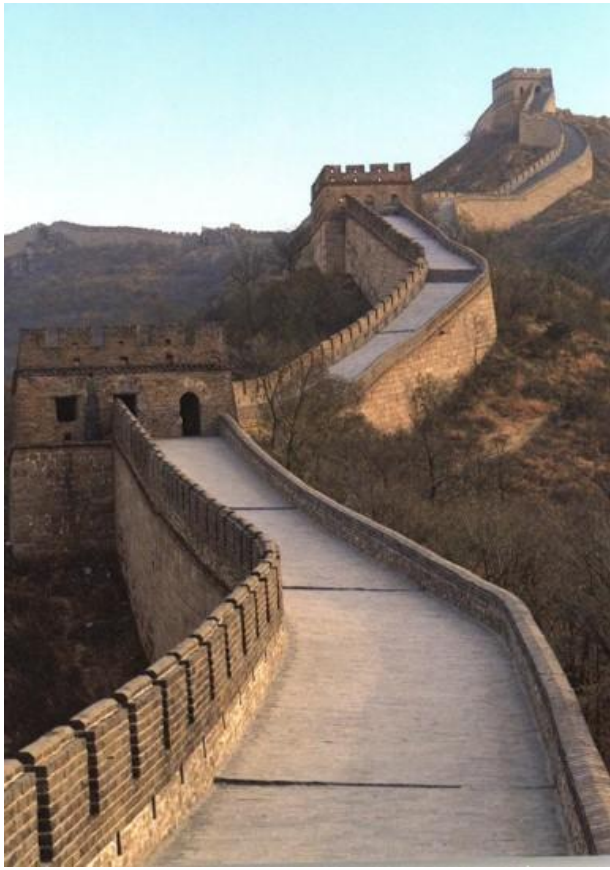
PIRE = International Partnership



Guiding principles

The *purpose* of the PIRE-ECCI is to train Ph.D.'s to conduct interdisciplinary research in the area of catalysis in an international setting. We aim to give graduate students the opportunity to **experience China first-hand** while participating in forefront research.

Our *goal* is to grow a new generation of academic and industrial leaders with **international knowledge**, experience, and personal and professional networks.

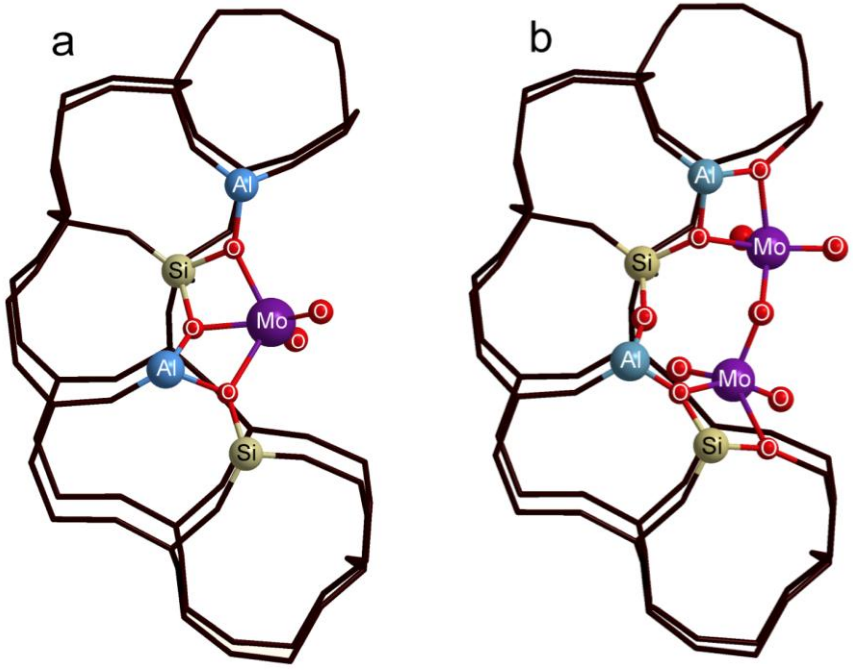


Turning methane into liquid fuels

$6\,CH_4$ (gas) $\rightarrow$ C_6H_6 (liquid) $+\ 6\,H_2$

CH_4 (gas) $+\ N_2O \rightarrow$ CH_3OH (liquid) $+\ N_2$

catalyst: Mo/ZSM-5

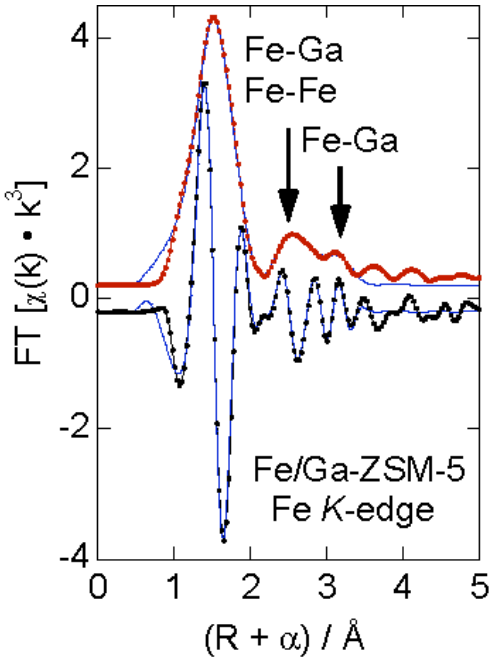


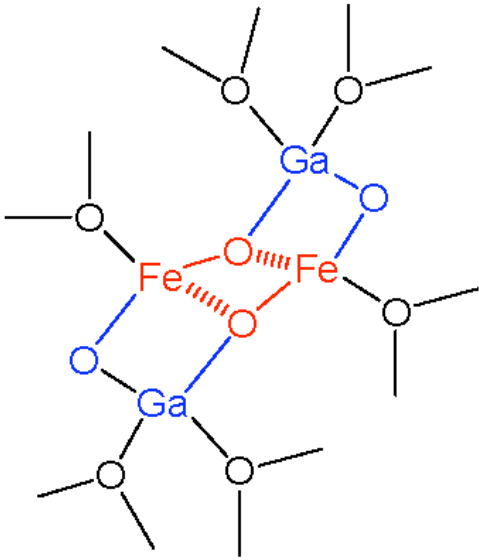
high Mo loading

low Mo loading

"Wavelet transform EXAFS analysis of mono- and dimolybdate model compounds and a Mo/HZSM-5 dehydroaromatization catalyst ", *Phys. Chem. Chem. Phys.***2010,** *12*, 5660

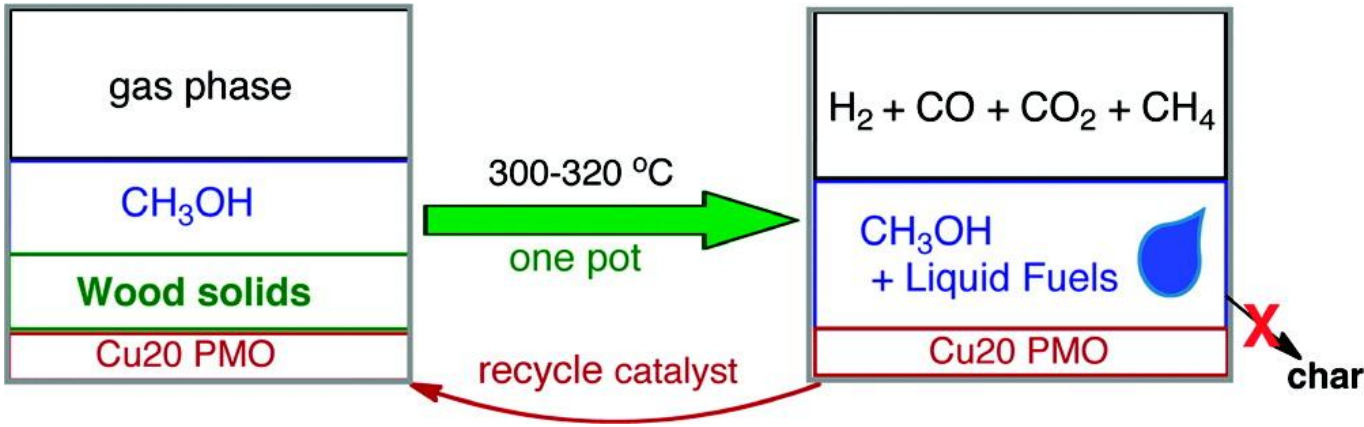
catalyst: Fe/ZSM-5, promoted by Ga

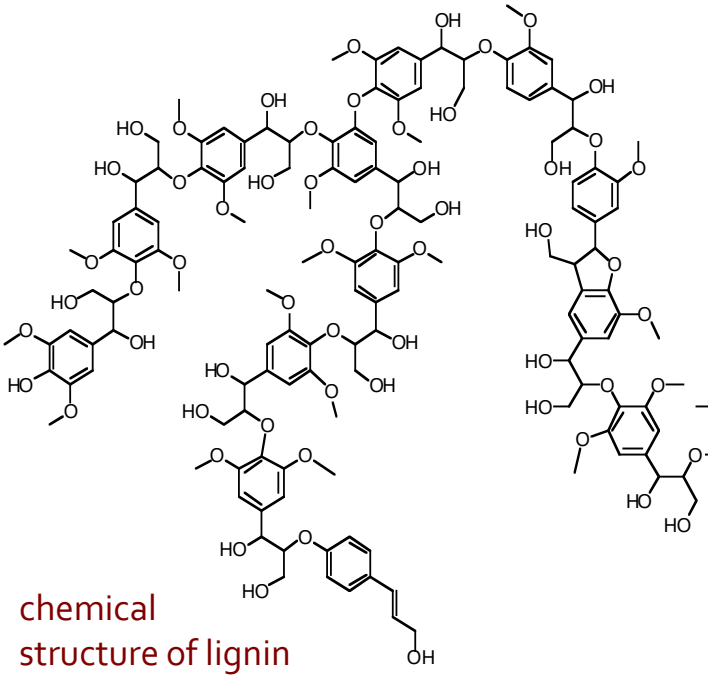




"Spectroscopic Evidence for Extra-Framework Heterometallic Oxo-Clusters in Fe/Ga-ZSM-5 Catalysts", *J. Phys. Chem. Lett.*, **2011,** *2*, 190.

Liquefying lignocellulose

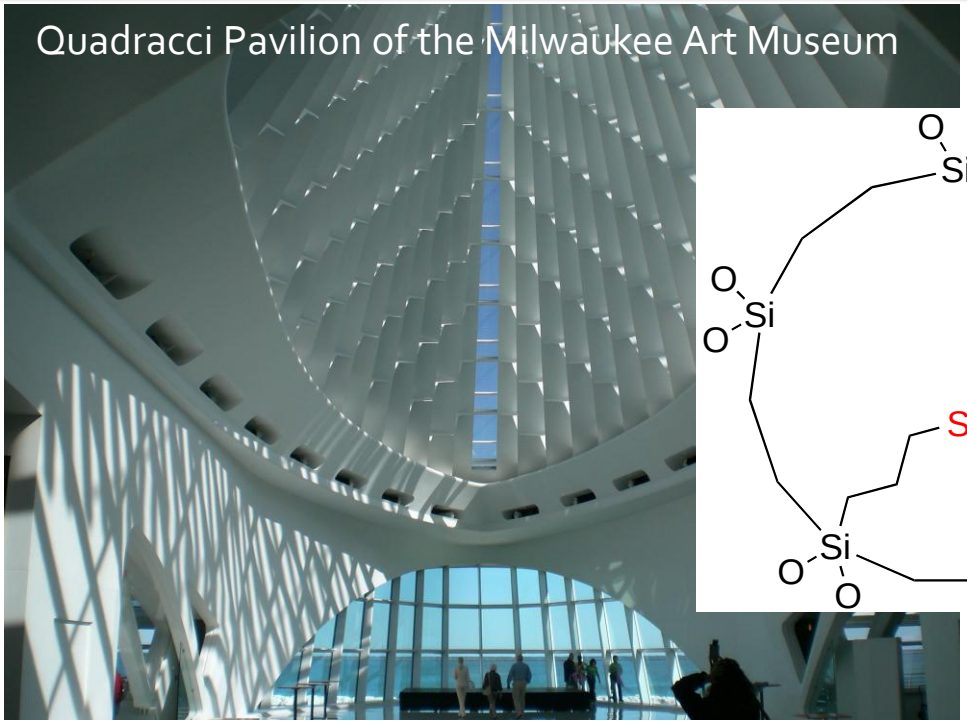


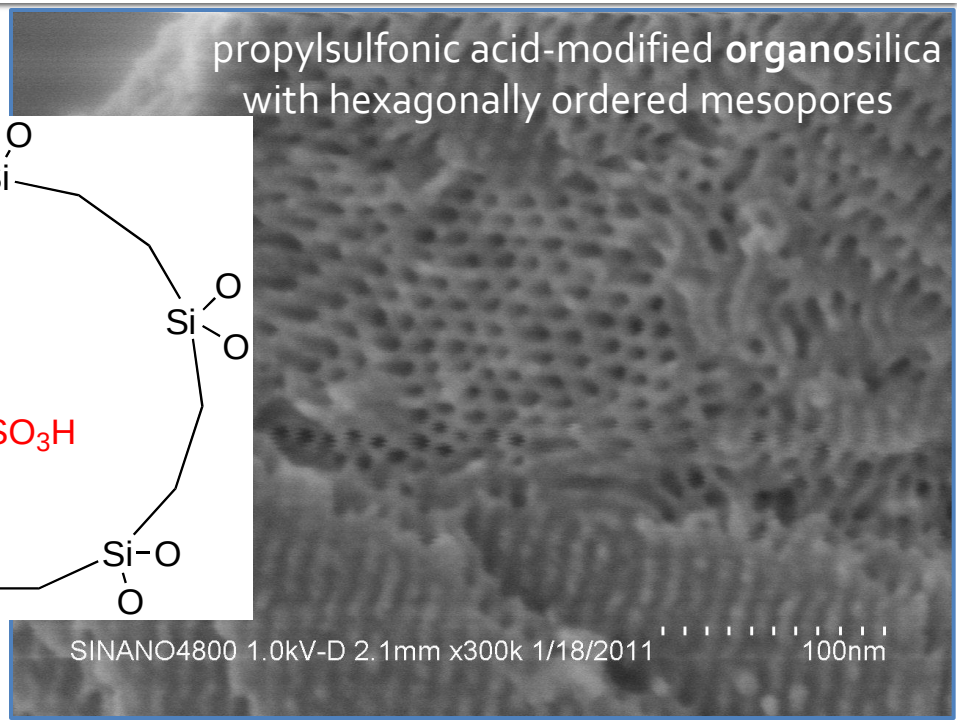


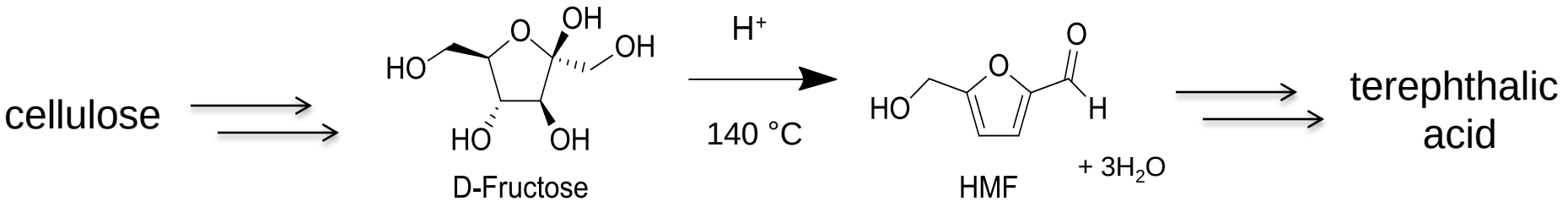
chemical structure of lignin

"One-Pot Catalytic Conversion of Cellulose and of Woody Biomass Solids to Liquid Fuels", *J. Am. Chem. Soc.*, 2011, *133*, 14090.

Dehydrating carbohydrates







"Acid-Functionalized SBA-15-Type Silica Catalysts for Carbohydrate Dehydration", *ACS Catal.* **2011**, *1*, 719.

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science
transcends
borders

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