Geospatial cognition and understanding of Global Energy Systems

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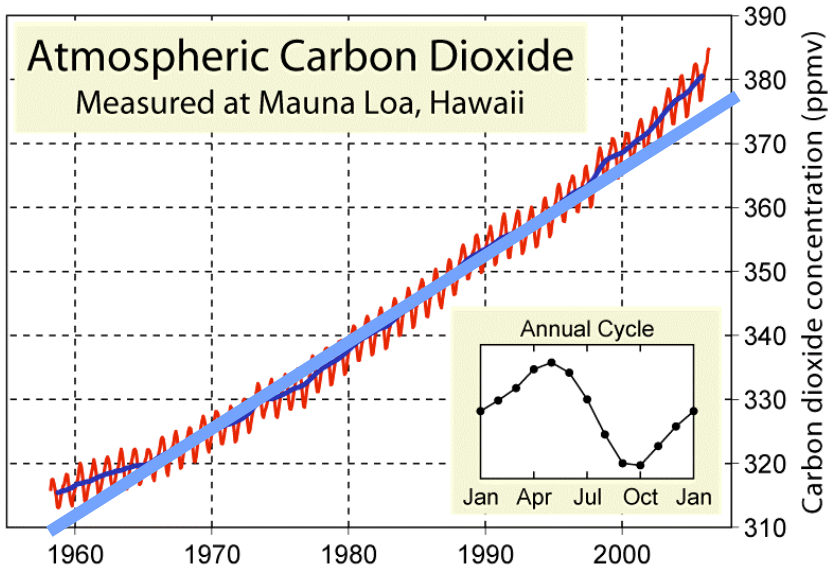
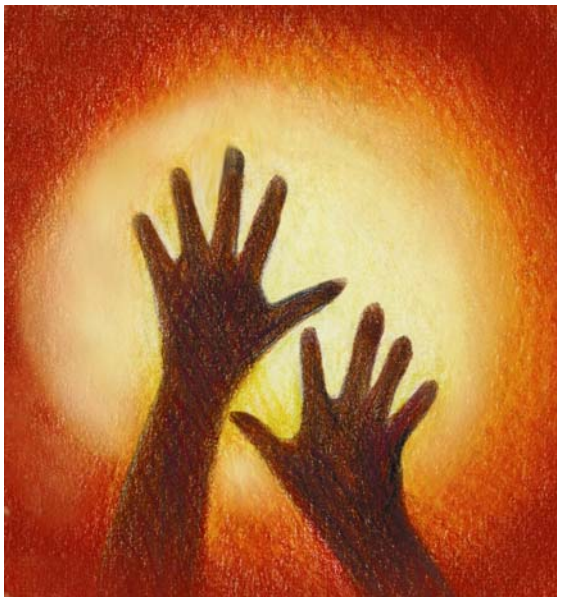
(LA-UR-09-01389)





Thanks to Collaborators and Sponsors

Developers

UNM Students (ECE, CS)

- ✓ Harihar Shankar
- • Ratheesh Prabhu Rajendran
- • Parthiban Jayabal
- ✓ Aswin T. Y. Venkata
- ✓ Saravanan Poosanthiram

LANL

- • David Daniel (CCS)
- • Fernando Gonzalez (STBRL)
- ✓ Rajan Gupta
- • V. Morris (UGS)

Sponsors

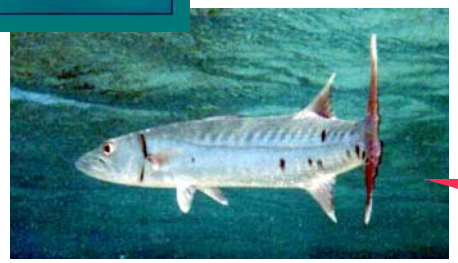
Faculty at UNM (ECE)

- • Chaouki Abdallah
- • Greg Heileman

- • LANL
- • NM Consortium

A macro view of global population

2 billion in 21st century



Health
Education
Energy
Water
Job Skills

1.5B people in Transition

3 billion in 18th century with less than $2 ppp/day

(Additional 2.5B will start here)

The energy-environment-development-climate challenge requires evolving to

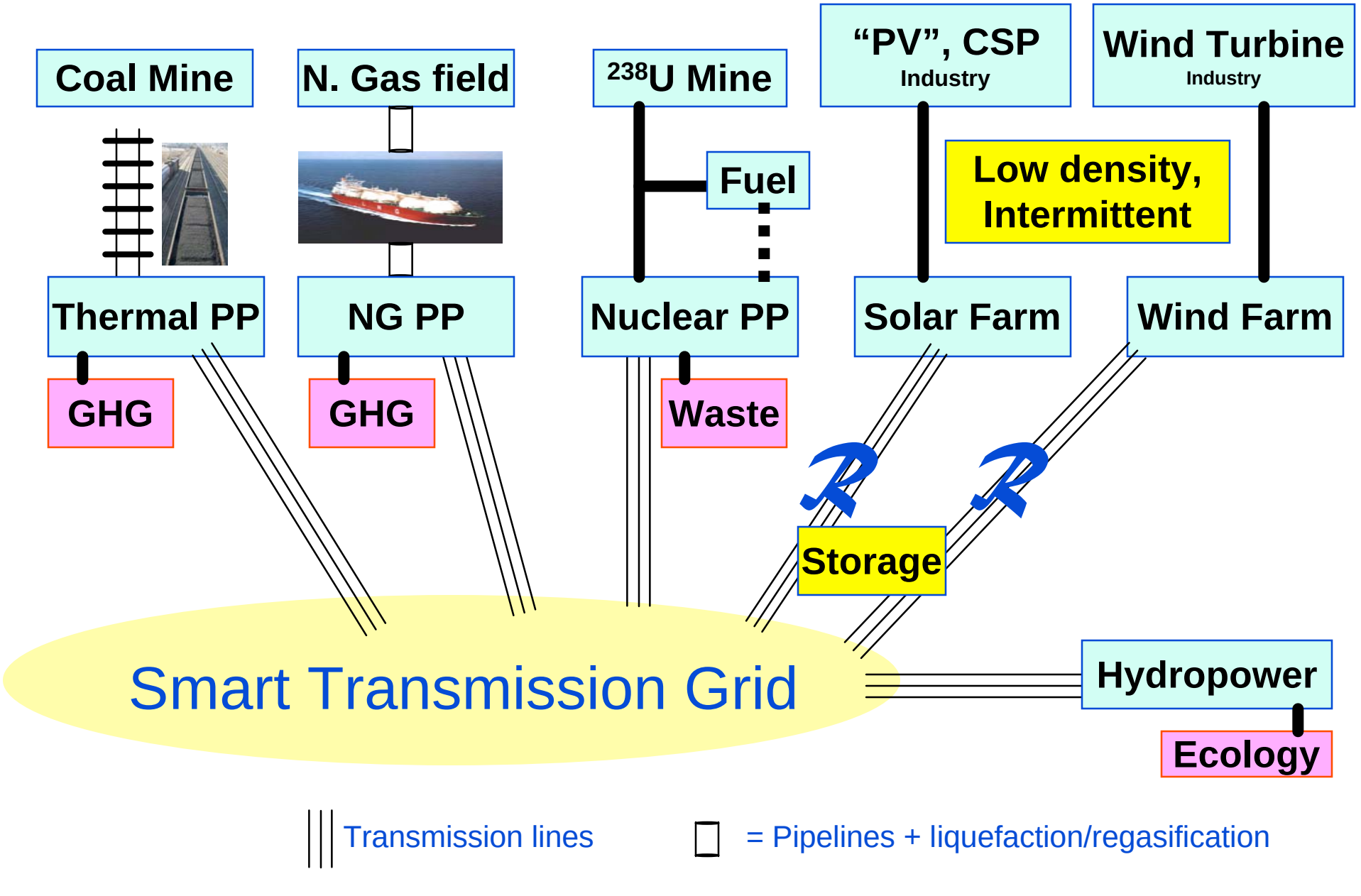
- **Cheap**
- **Copious**
- & **Clean**

} Energy

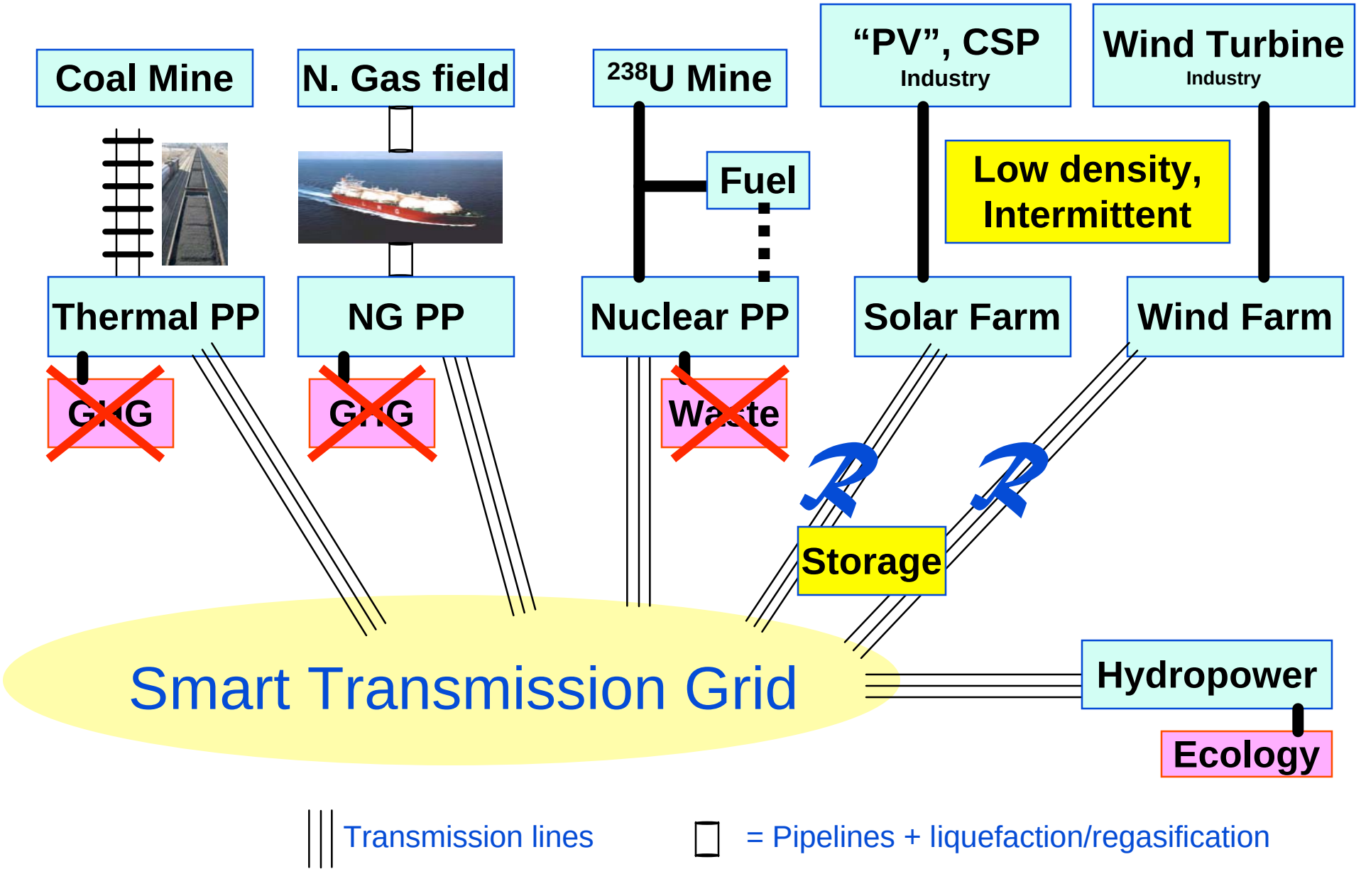
Needs and impacts are global

6.6 (→9) billion people want same opportunities

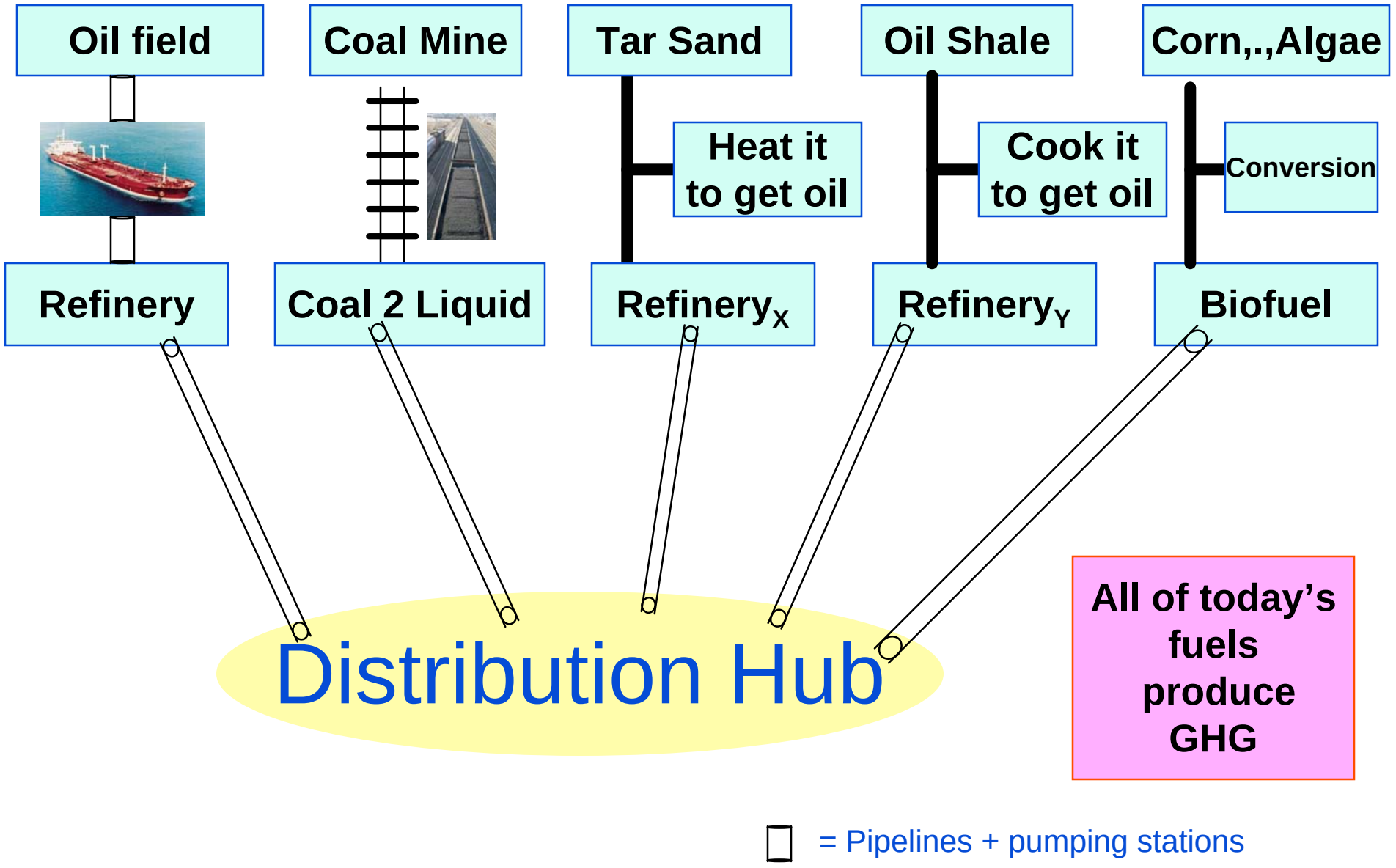
Electric Power System: Lifecycle cost comparison



Electric Power System: Lifecycle cost comparison



Transportation fuels: Lifecycle cost comparison



A global infrastructure (>$25 trillion) provides modern energy/mobility to ~3.5 billion people

Fossil Fuel Industry

- **Oil and gas contracts, rigs, exploration, recovery**
- **Tankers, ports, pipelines**
- **Refineries, LNG facilities**
- **Auto industry**
- **600 (+ 220) million cars (+ trucks) running on gasoline**
- **Service, gasoline stations**
- **Existing coal/gas electricity generation plants**

All alternatives to fossil fuels have a market niche. *World Needs 10 TW_e*

	Today	Potential
• **Nuclear**	**~370 Gw**	**?**
• **Hydro**	**~400 Gw**	**~600 Gw**
• **Wind**	**90 Gw_p /(3-5)**	**+~20%/year**
• **Solar PV**	**5 Gw_p /(3-5)**	**+~30%/year**
• **Geothermal**	**25 GW (e+th)**	
• **Biofuels**	**1.5 Mboe/day**	**?**

But none is large enough today!

Need technological breakthroughs

7 Global Science Grand Challenges: Innovation is key

- **Carbon neutral use of fossil fuel (especially coal)**
- **Economic Solar and Wind ($1/watt$_p$)**
- **Storage and Transmission of electric power**
- **Closed nuclear fuel cycle to enable safe, secure, sustainable nuclear energy**
- **H_2 / fuel produced from non-fossil sources**
  - **From Photochemical and/or thermal splitting of H_2O**
- **Biofuels ⇐ Pest-resistant, self-fertilizing, low water using, easily degradable biomass**
- **Fusion – the ultimate "source"**

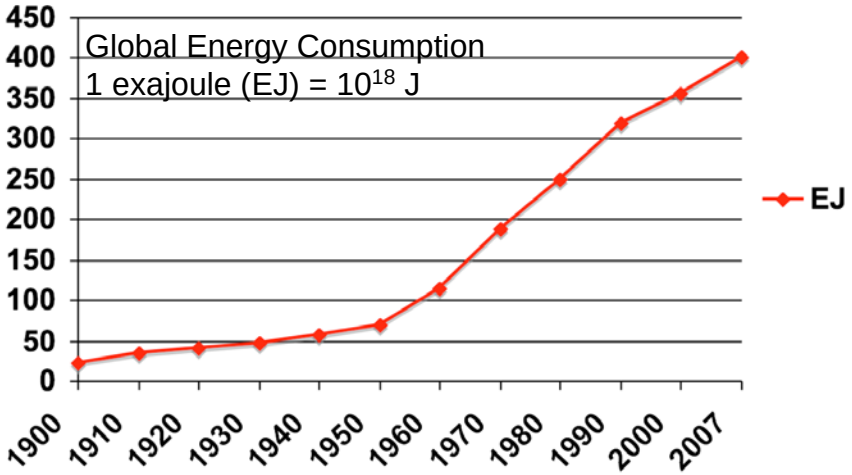
9 faces of the challenge

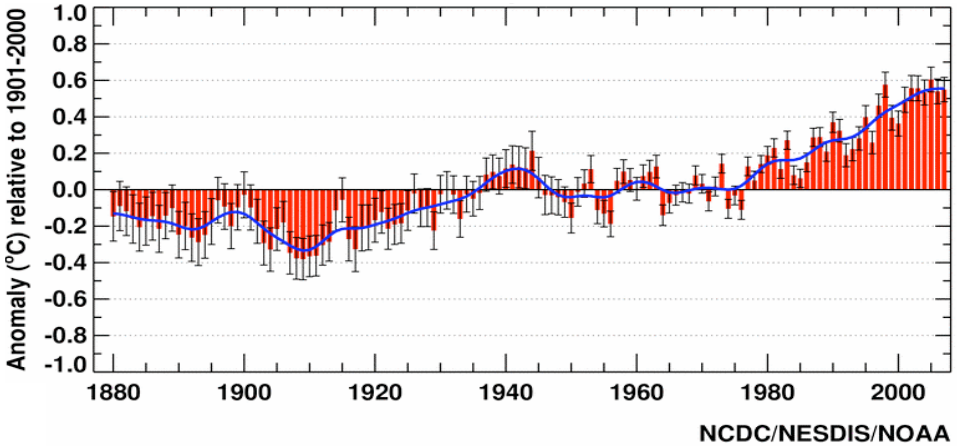
1) **USA, Europe, Japan, China, India, …**
   lack energy security (conventional oil, gas)
2) **Climate Change – an uncontrolled experiment**
3) **Middle East & Russia control oil and gas**
4) **Increasing competition (China, India, …)**
5) **Military solutions too costly ($ and lives)**
6) **The energy infrastructure is huge (>$25 trillion)**
7) **Unconventional fossil fuels: 2-3 ⊗ pollution&CO_2**
8) **Cheap clean energy – an economic opportunity**
   - **Alternatives have a market niche but are small today**

9) Energy efficiency ↔ behavior change

What will drive change?
(>$25 Trillion investment in fossil systems)

- **Markets, resources, policy will need to respond to demand and climate change**
- **They will not change overnight**
- **Yet they are in the middle of change!**





Opportunity to move away from fossil fuels

In industrialized nations, energy systems need replacement over next 20-30 years

In developing countries Coal & Gas plants are being installed for the first time

Business as usual ⇒ Growth in coal and gas fired plants and automobiles for next “20” yrs

Why EU, Japan, are well placed to go Green

No population growth & improved efficiency
⇒ staged replacements in step with technology

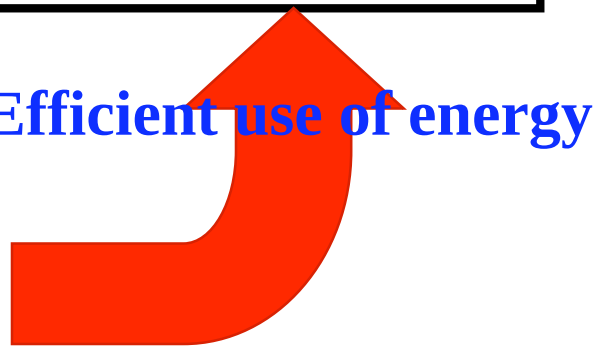
Public transport systems are effective and used by a large fraction of the population

Nuclear Power is an issue!

Until technology provides solution[s]
Need Top Down & Bottom Up Effort

- Evolution of the large infrastructure
- Access versus environmental (climate) challenge
- Policy, regulations, incentives

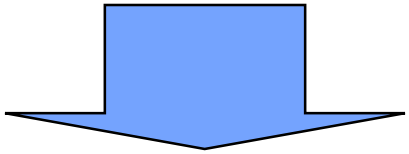
Accelerated transition



- Individual's energy footprint
- Individual decisions
- Distributed generation & Storage
- Cooperative action (smart Grid)

Many issues to understand and analyze

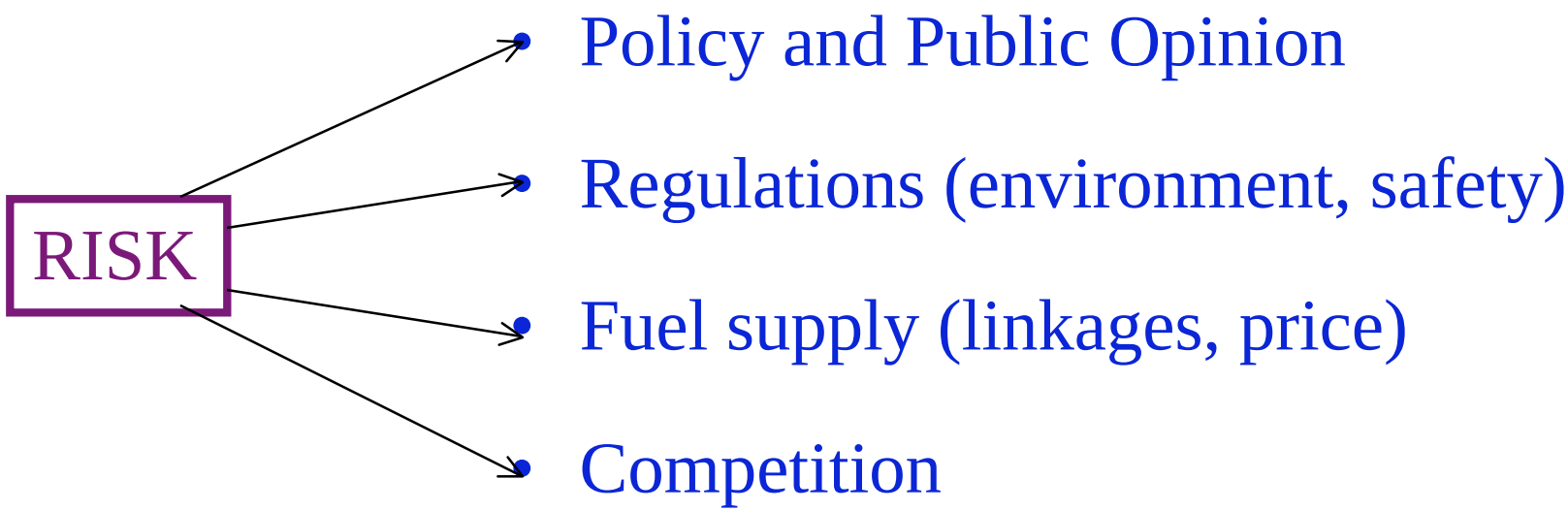
- An open web based framework for time and geo-spatial referenced data: its management, integration, and access
- Facilitate muli-sector research and analysis
- Tool for policy makers
- Education: public, high schools and colleges students



Global Energy Observatory

Understanding Dynamics of Change/Growth

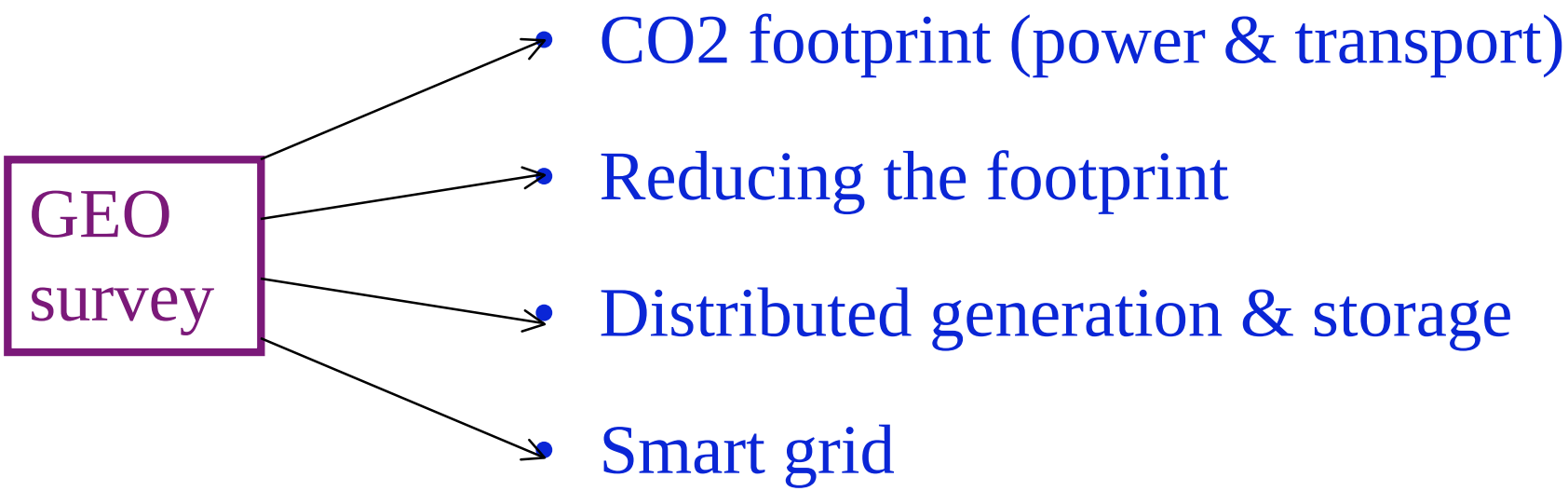
Business World



Example: Nuclear Power in the US

Impact of Policy and Markets

Efficient Use of Energy



Monitoring, Measurement and Validation for Environmental Treaties

- Baseline inventory of emissions
- Technology for control of emissions
- On site measuring and monitoring devices
- Remote Sensing (Satellite Measurements)
- Compliance with Treaties and Regulations

Global Energy Observatory (GEO)

URL of GEO: http://openmodel.newmexicoconsortium.org

Our effort to create an open comprehensive database to enable the proposed analyses by a global community

Global Energy Observatory (GEO)

URL of GEO: http://openmodel.newmexicoconsortium.org

Goal 1: to assemble, annotate, store and analyze the global energy system

Goal 2: understand the dynamics of change in various energy systems

Goal 3: inform educate & influence the transition to affordable carbon neutral energy systems

4 linked databases:

1. Large Power Plants
2. Fuels and Resources
3. Transmission
4. Reduce your CO2 footprint

Integrate Volunteered Information
(Examples of needed IS&T paradigms)

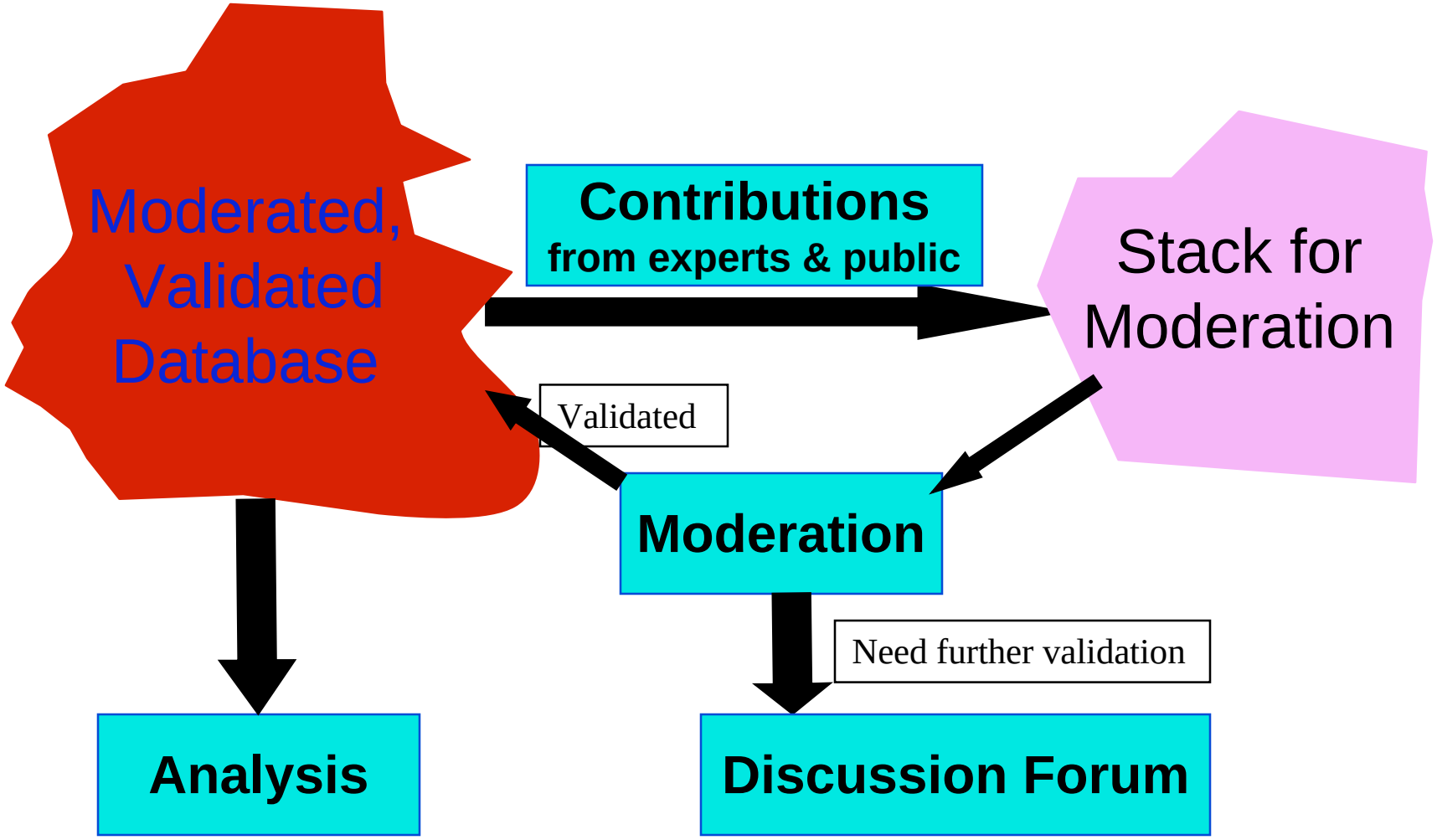
- Harvesting chatter
  - Increase in activity before social or terrorist events
  - Google map of spread of flu (harvesting queries)

- Framework for collecting, managing, *verifying and validating* information through voluntary participation (citizen sensors)
  - Amateur astronomers
  - Christmas bird inventory

- Universally Accessible Formats
  - WWW, Web 2.0

GEO @ openmodel.newmexicoconsortium.org

Framework for harnessing heterogeneous data, contributions, moderation, validation & analysis



Database: Reduce your CO_2 footprint

- Calculate your CO_2 foot print
- Strategies for reducing your CO_2 footprint
- Database of distributed generation & storage
  - Solar PV
  - Wind
  - Heat Pumps
  - Storage (batteries)

Large Infrastructure Databases

Power Plants
(GEOwiki)

* Coal Plants
* Gas Plants
* Geothermal Plants
* Hydroelectric Plants
* Nuclear Plants
* Oil/Diesel Plants
* Solar PV Farms
* Solar Thermal Plants
* Waste Plants
* Wind Farms

Fuels&Resources
(GEOresources)

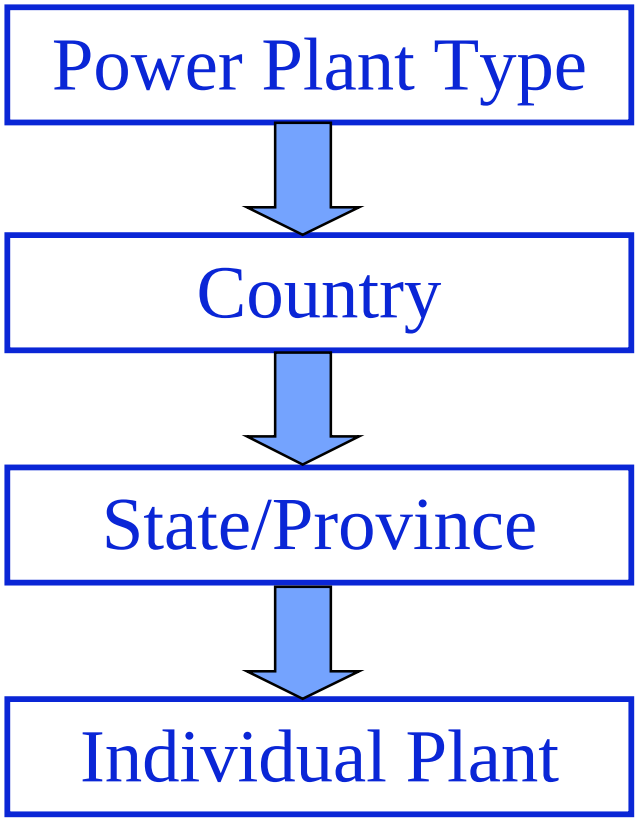
* Gas Fields
* Oil Fields
* Coal Mines
* Uranium Mines
* Crude Oil Refineries
* Solar Potential
* Wind Potential
* Biomass resource

Transmission
(GEOtransmission)

* Gas Pipelines
* Oil Pipelines
* Coal Ports
* LNG ports
* Oil Ports
* Rail Links
* Road Links
* Shipping Lanes
* Electric Transmission Grid

Blue=done, others=under construction

Organization of GEOpower: Large power plants database



Overview of features

- View existing data
- Create a new entry
- Edit and Add data
  - Moderation
  - Discussion Forum
- Download data
- Analyze data
- Create a Linked and Integrated Network of energy systems

View: Visualize existing systems

- Mashup of existing data on Google Maps
  - Visualize systems and inter-relationships
- Overview of the energy systems network
  - Interconnections and interdependencies

Creating new entries

- Formatted Structured Data input via web forms
  - Geo-location
  - Unit description
  - Status of emission control devices and monitoring
  - Linked Infrastructure
  - Performance
  - Emissions and impacts
  - Major upgrades
  - Ownership
  - Comments
  - References

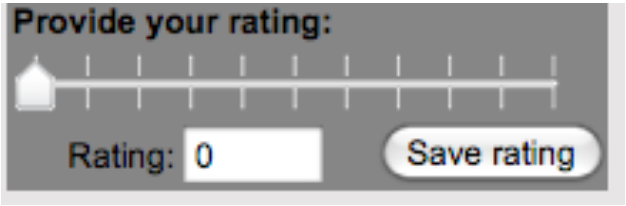
Editing and adding to existing systems

- Enlarging the scientific database
- Visualization and analysis
- Timeline of improvements and enhancements

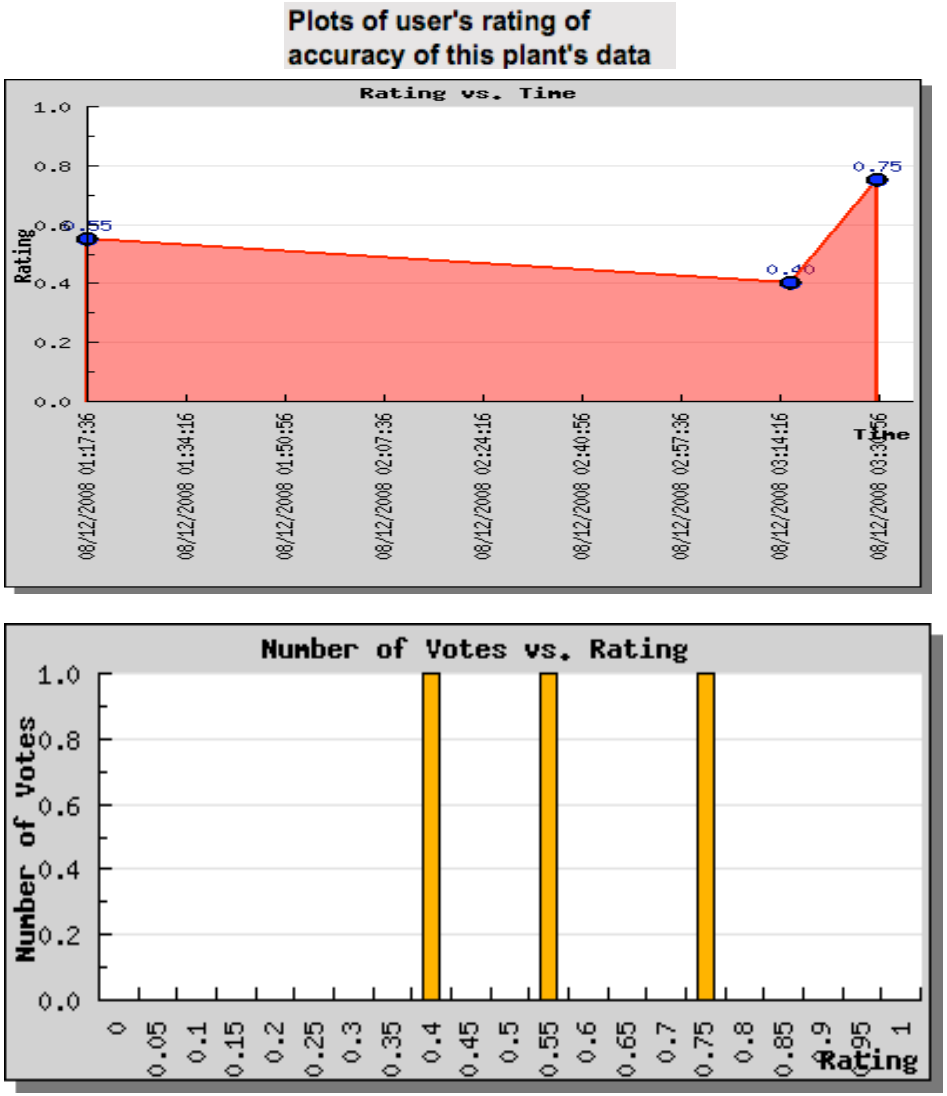
Maintaining Data Integrity

- On view: last moderated version
- Corrections: placed in a viewable stack for moderation
- Moderation: validating and incorporating new data

Ratings of Data

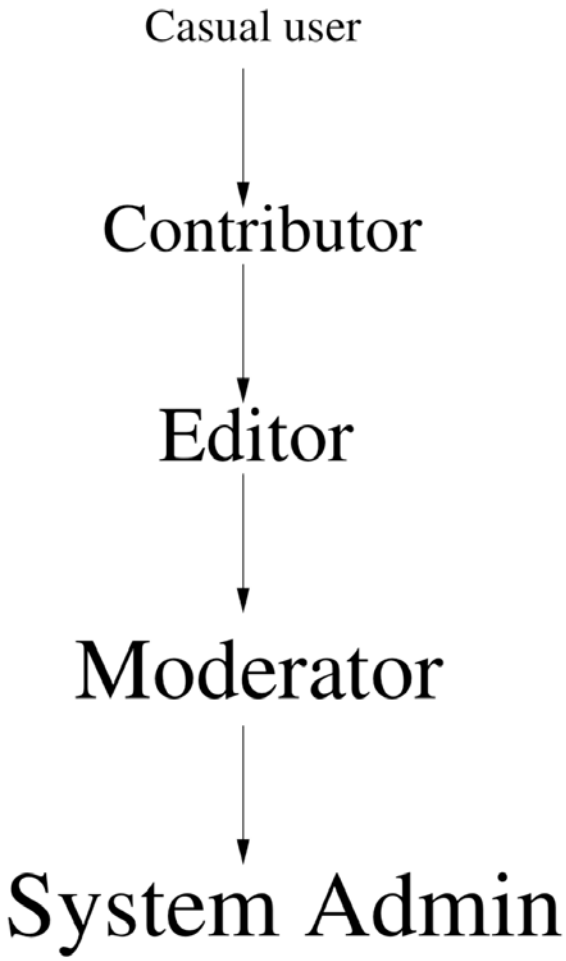


- Evaluating data records
  - Visitors score the accuracy of existing data in a record
  - Previous scores available as a graph showing distribution
  - Time history of previous scores with overlay of dates on which the record was updated with a new moderated version.



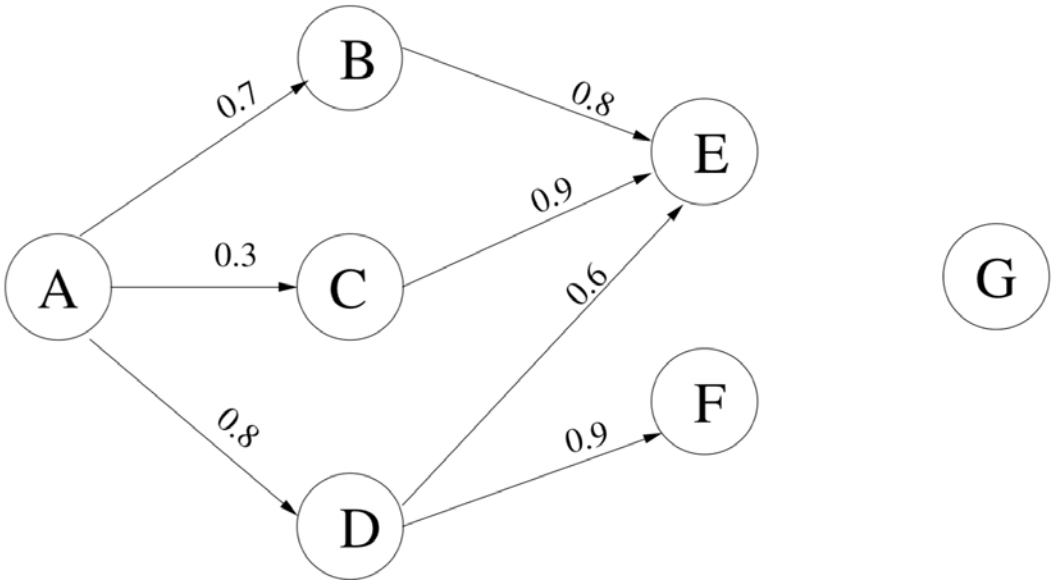
V&V: (based on referee system in journals)

- Editors (subject area experts)
  - Review and verify submissions
  - Create a new version for moderators to accept
  - Enter unverified data into discussion forum
  - Provide “trust rating” of contributors
- Moderators (subject area experts with experience in moderation)
  - Integrate verified data submitted by editors
  - Provide “trust rating” of editors



Trust Network

- Evaluating contributors
  - Moderators rate editors
  - Editors rate contributors for accuracy of input
  - Trust scores organized by subject and geographical area
  - Contributions from users with high trust accepted directly (random checks with probability based on trust scores)
  - Users with score above “0.9” added to the pool of possible editors



$$trust(u) = \frac{\sum_{i \in predecessors} (trust(i) * trust\_edge(i,u))}{\sum_{i \in predecessors} (trust(i))}$$

$$trust(E) = \frac{0.7 * 0.8 + 0.8 * 0.6}{0.7 + 0.8} = 0.69$$

Analysis

- Understand drivers
- Correlate (growth, scaling laws, …) with
  - demographics
  - economic activity
  - land and water use
- Multi-sector network models:
  - Feedbacks, nonlinearities, tipping points
  - Crisis & Bottlenecks
  - Evolution towards Smart / Green grids
- Understand the dynamics of change in energy systems
- Expose and validate options of carbon neutral systems

Modeling

- Exploring scenarios
- Exploring options
- Exploring consequences
- Connecting multiple sectors / networks
- Validation of data
- Providing input to policy

Partnerships and Collaborations

- High Schools, Colleges, Universities, Research Labs
- Academics and Scholars
- Utilities and energy companies
- Special Interest Groups
  - WWF: Influenced moving the East Siberia-Pacific Ocean pipeline further from Lake Baikal
  - Greenpeace
  - Sierra Club
  - Industry
- Informed Public

Education

- *Course EDUC 223B, School of Education*, UC Berkeley. Instructor Prof. Michael Ranney. Exercise and evaluate the prototype system from a reasoning and cognitive perspective.

- *Course SC/NATS 1840.06 on Science, Technology and the Environment,* Physics Department, York University, Canada. Instructor Prof. Carl Wolf. (242 students) Map the Canadian energy system. Develop a plan to meet the growing energy needs of a region.

- *Course 33-115 on Energy and Environmental Issues*, Physics Department, Carnegie-Mellon University. Instructor Prof. John Nagle. Twelve students are using GEO to understand current energy systems of eight regions (Illinois, Texas, Connecticut, Pennsylvania, India, Hong Kong, Taiwan, Mexico, and the UK).

Why OpenModel?

Why not just buy information from "Platts"?

- Easy and free access for casual users
- Many more people can engage and contribute
- Topics, data, information selected by a diverse public and experts and not just by a few experts & what sells
- Rapid and constant updates
- Constant scrutiny and validation of data
- Mashups and analyses contributing to education and policy
- Tracking growth in
  - Distributed Generation and Storage
  - Energy Efficiency
- Smart Grids

GEO ⇔ Platts (Wikipedia ⇔ Britannica)