Global Energy Observatory (GEO): A one-stop site for information on energy systems, infrastructure and emissions

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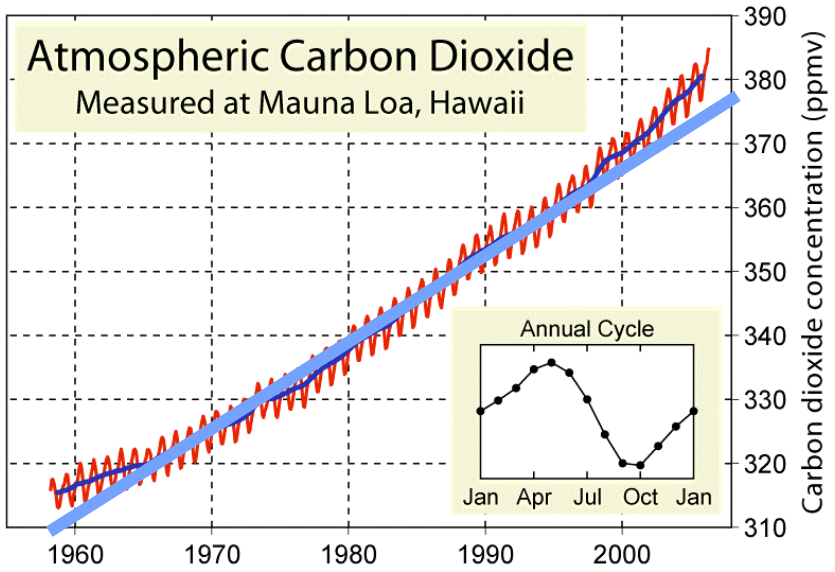

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Thanks to Collaborators and Sponsors

Collaborators

UNM Students (ECE, CS)

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

Sponsors

- LANL
- NM Consortium
- ECE Department at UNM

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

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

} Energy

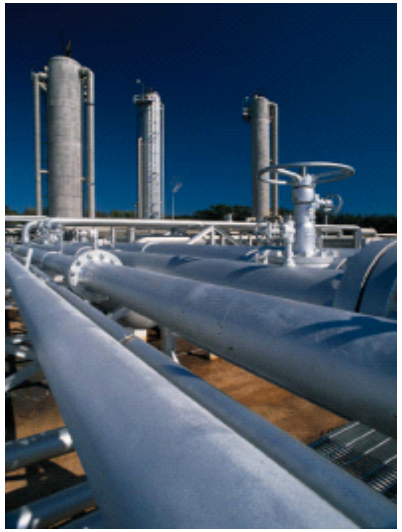
Needs and impacts are global

6.6 (→9) billion people want same opportunities

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

	Today	Potential
• Nuclear	~370 GW	?
• Hydro	~400 GW	~600 Gw
• Wind	90 GW_p (25)	+~20%/year
• Solar PV	5 GW_p (1.25)	+~30%/year
• Geothermal	25 GW (e+th)	
• Biofuels	1.5 Mboe/day	?
• Fossil	~1500 GW	

But none is large enough today to meet
World Requirement of 10 TW_e
Need technological breakthroughs

Energy Systems 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

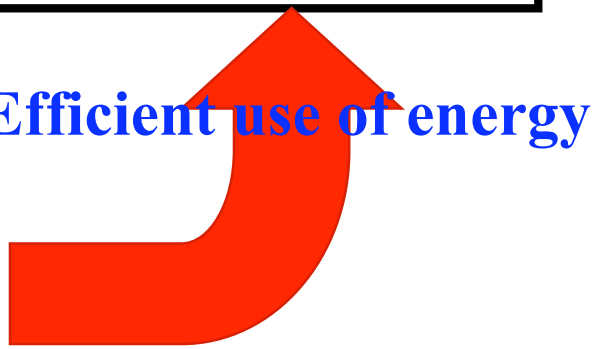
In developing countries Coal & Gas plants are being installed for the first time

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

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)

Global Energy Observatory (GEO)

URL of our open tool: openmodel.newmexicoconsortium.org

An effort to create an open, comprehensive, scientific database to enable analysis of the dynamics of change by a global community

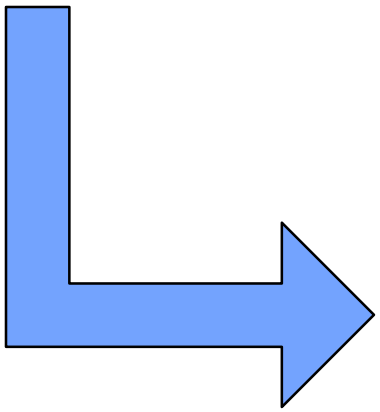
Global Energy Observatory (GEO)

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

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

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. Power Plants
2. Fuels and Resources
3. Energy Transmission
4. Reducing Our CO2 Footprint

Database: Reducing Our CO_2 Footprint

- Calculating and evaluating end-user CO_2 foot print
- Strategies for reducing our CO_2 footprint
- Database of distributed generation & storage
  - Solar PV
  - Wind
  - Heat Pumps
  - Storage (batteries)
- Surveys evaluating awareness of
  - Energy Climate Challenge
  - Smart Grids

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

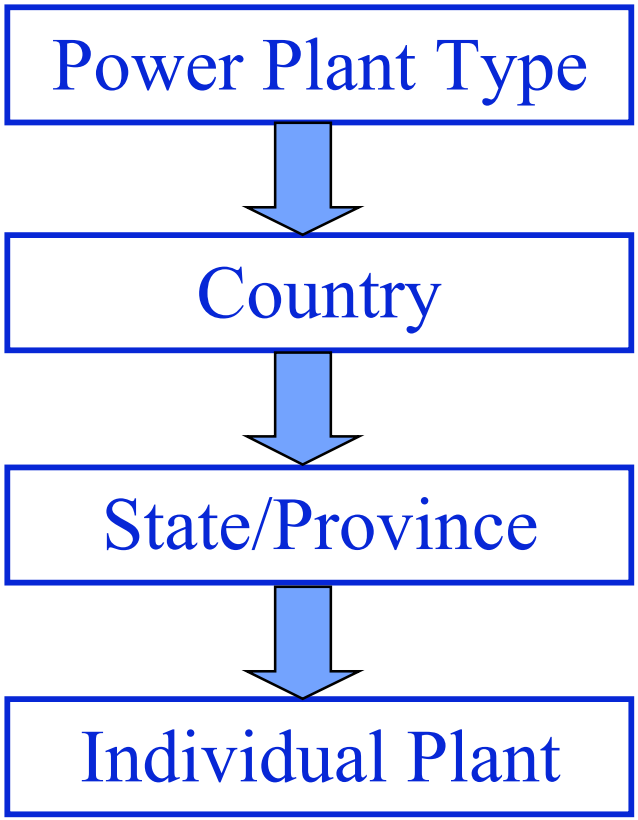
Transmission
(GEOtransmission)

* 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 Data

GEOpower: Power Plants database



What is in the power plant database

- Formatted Structured Data input via web forms
  - Geo-location
  - Direct footprint (disturbed earth)
  - Description of subunits within a plant
  - Status of emission control devices and monitoring
  - Associated Infrastructure
  - Performance tables
  - Emissions
  - History of major upgrades
  - Owners, Operators
  - Comments
  - References

New Mexico Consortium

Google

GLOBAL ENERGY OBSERVATORY

INFORMATION ON GLOBAL ENERGY SYSTEMS & INFRASTRUCTURE

ACCELERATE THE TRANSFORMATION TO A WORLD WITH **CLEAN ENERGY** FOR ALL

Large Power Plants

Fuels and Resources

Energy Transmission

Select and Load Existing Entry for a Large Power Plant to View and Edit Data:

Select Plant Type:

- Coal
- Gas
- Geothermal
- Hydro
- Nuclear
- Oil
- SolarPV
- SolarThermal
- Waste
- Wind

Select the Country:

- Botswana
- Canada
- Hong Kong
- India
- Ireland
- Mexico
- United Kingdom
- United States of America

Select the State:

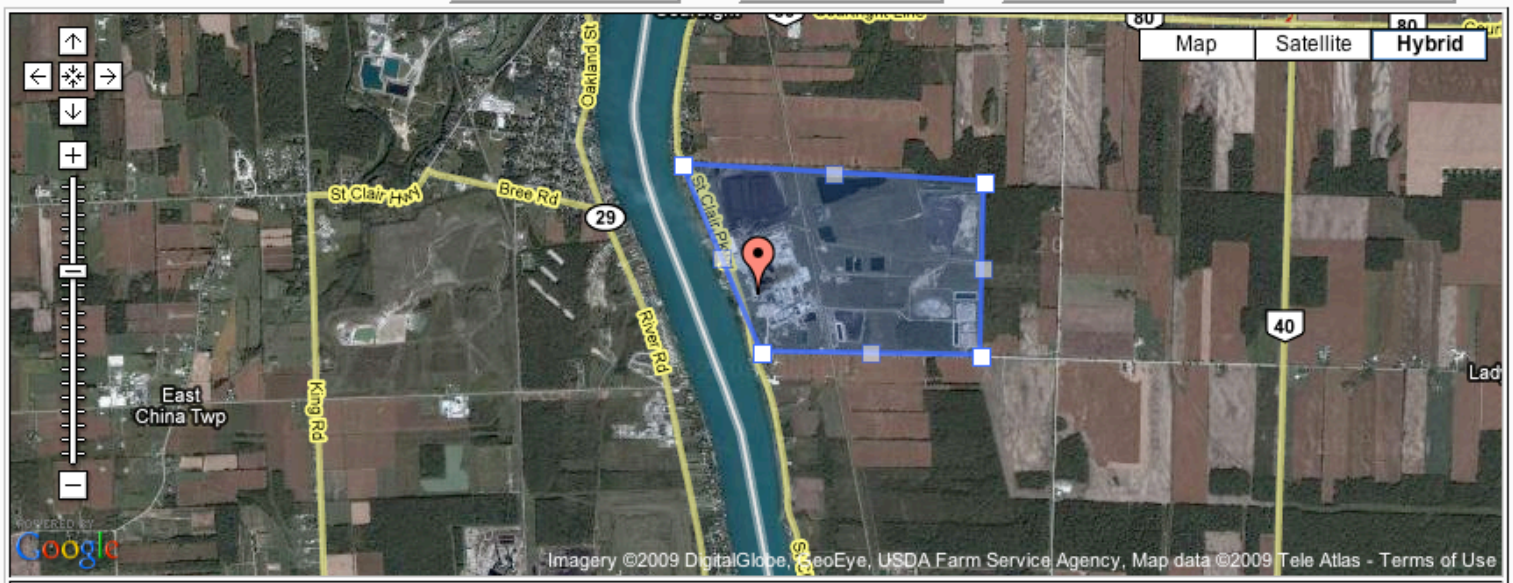
- All
- Alberta
- New Brunswick
- Nova Scotia
- Ontario
- Saskatchewan

Select the Plant:

- Boundary Dam Coal Power Station, Canada
- Atikokan Coal Generating Station, Canada
- Battle River Coal Generating Station, Canada
- Belledune Generating Station, Canada
- Genesee Coal Generating Station, Canada
- Grand Lake Coal Generating Station, Canada
- H.R.Milner Generating Station, Canada
- Lakeview Coal Power Plant, Canada
- Lambton Coal Generating Station, Canada
- Lingan Coal Generating Station, Canada
- Nanticoke Coal Generating Station, Canada

Lambton Coal Generating Station, Canada

Direct Impact Footprint **2.977 km²** Restore Initial Polygon | Polygon Show/Hide | Move Polygon Around Placemark And Update



Width: 850 px Height: 320 px Resize Map

Design Capacity: 2050 MWe
Realized Capacity: 1976 MWe
Primary Fuel: Bituminous Coal
Location (city/state): St. Claire, Ontari, Canada

Unit Description:

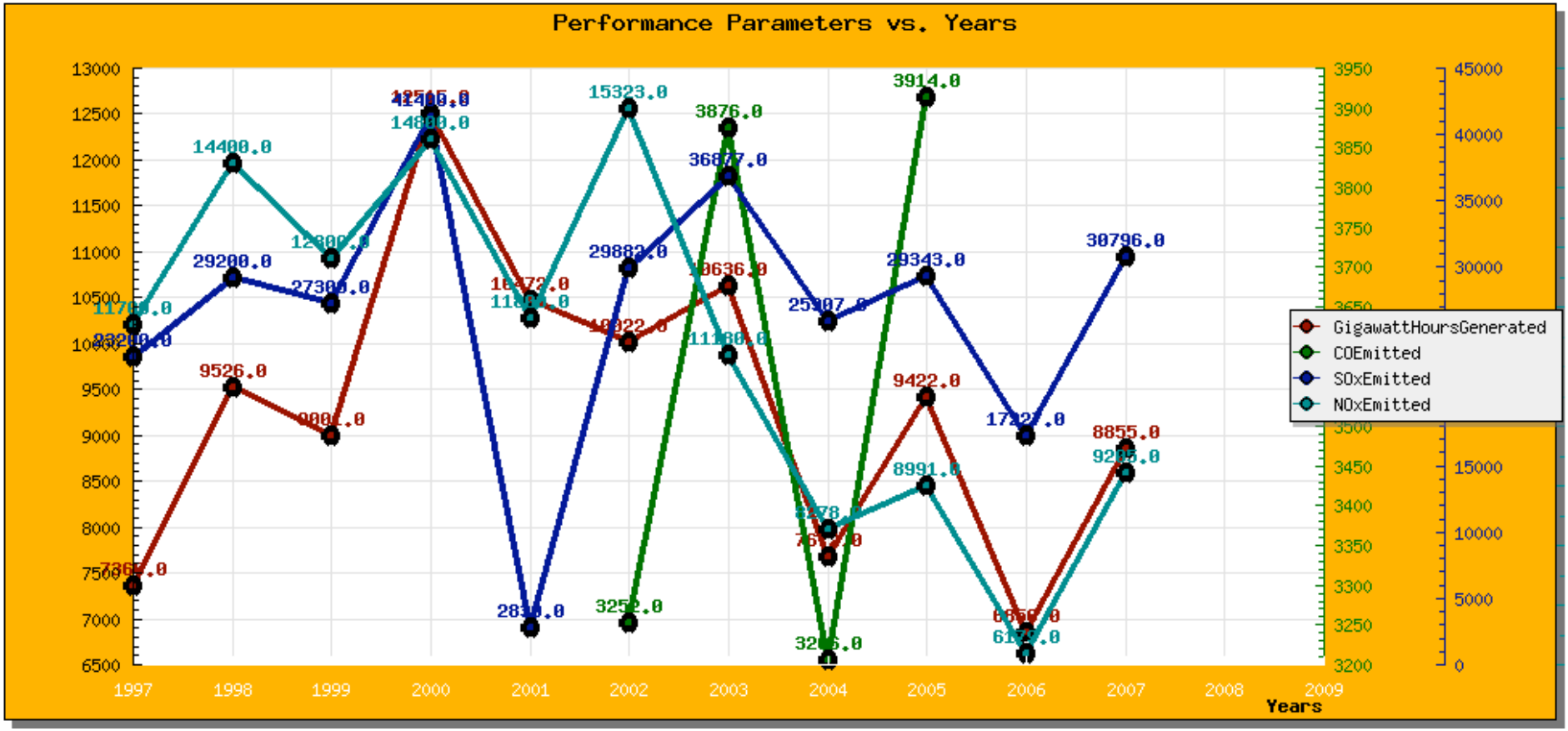
UNITS	Capacity MWe	Date Commissioned (dd-mm-yyyy)	Boiler Manufacturer	Boiler Model	Turbine Manufacturer	Turbine Model	Chimney Height (m)	Date Decommissioned (dd-mm-yyyy)
Unit 1	500	00-00-1969	combustion engineerin		GE			
Unit 2	500	00-00-1969	Combustion Engineerir		GE			
Unit 3	525	00-00-1970	Combustion Engineerir		GE			
Unit 4	525	00-00-1970	Combustion Engineerir		GE			

Choose decade for Performance Statistics: 2000-2009 | Select Fields and plot vs. years

Plot Annual Performance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
☑ Gigawatt Hours Generated	12515	10472	10022	10636	7672	9422	6856	8855		
☐ Plant Load Factor (%)										
☐ Domestic Coal Consumed (Million Tonnes)										
☐ Imported Coal Consumed (Million Tonnes)										
☐ Heat Input (MM Btu)										
☑ CO Emitted (Tonnes)			3252	3876	3206	3914	2364	3395		
☐ CO2 Emitted (Tonnes)	1.08e+07	9.42e+06	8.99e+06							
☐ CO2 Captured (Tonnes)										
☐ CO2 Offset (Tonnes)										
☑ SOx Emitted (Tonnes)	41400	2830	29882	36877	25907	29343	17227	30796		
☐ Methane Emitted (Tonnes)										
☐ N2O Emitted (Tonnes)										
☑ NOx Emitted (Tonnes)	14800	11800	15323	11180	8278	8991	6179	9205		
☐ Mercury Emitted (kgs)	174	164	130	122	46	67	53	107		
☐ Volatile Organics Emitted (Tonnes)			112	119	84	102	75	97		
☐ Particulates Emitted (Tonnes)			3647	3790	2749	3072	2837	3445		
☐ Ash Generated (Tonnes)										
☐ Water Drawn (MM cum)										
☐ Water Used (MM cum)										
☐ Annual Operating Cost										
☐ Annual Fuel Cost										
☐ Annual Maintenance Expenses										
☐ Capital (Upgrade) Investment										
☐ Number Of People Employed							400	390		

Notation:

Plot of Selected Performance Data



Electric Power Grid Connected To:	Ontario power grid
Coal Obtained From:	
Source Of Water:	St. Claire River
Type of SOx First Control Device:	Units 3&4 were overhauled and retrofit with Joy/Bischoff
Type of NOx First Control Device:	Babcock & Wilcox Selective Catalytic Reduction (SCR) re
Type of Mercury Control Device:	
Environmental Issues:	
Capital Cost Of Plant:	in Year (yyyy)

Owners List:

Owner 1: Ontario Power Generation

Add Another Owner | Delete Selected Owner

Type Of Ownership:	Governmant of Ontario
Construction Contractor:	
Operating Company:	Ontario Power Generation

Comments: The station's annual production is about 11000 GWh. At full production uses 640 tonnes of coal per hour

Add Another Comment | Delete Selected Comment

References: http://www.opg.com/power/fossil/lambton.asp

References: http://www.industcards.com/st-coal-canada.htm

References: http://www.opg.com/pdf/sustainable development reports/sustainable development Report 2007.pdf

References: http://www.ec.gc.ca/pdb/npri/npri_prev_dat_e.cfm

Emissions Tracked

- **GHG:** CO_2, CH_4, N_2O
- **Acid Rain:** SOx, Nox
- **CO, NH_3**
- **Mercury (Hg)**
- **Volatile Organic Matter**
- **Particulates, Ash**

Other fields can be added as desired

Overview of features implemented

- View existing data
- Create a new entry
- Edit and Add data
  - Framework for moderation
  - Rating of accuracy
  - Discussion Forum
- Download data (KML for Google Earth)
- Analyze data
- Create a Linked Network of associated energy systems

Editing and adding to existing data

- Organic growth of the scientific database
- Visualization and analysis
- Timeline of improvements and enhancements

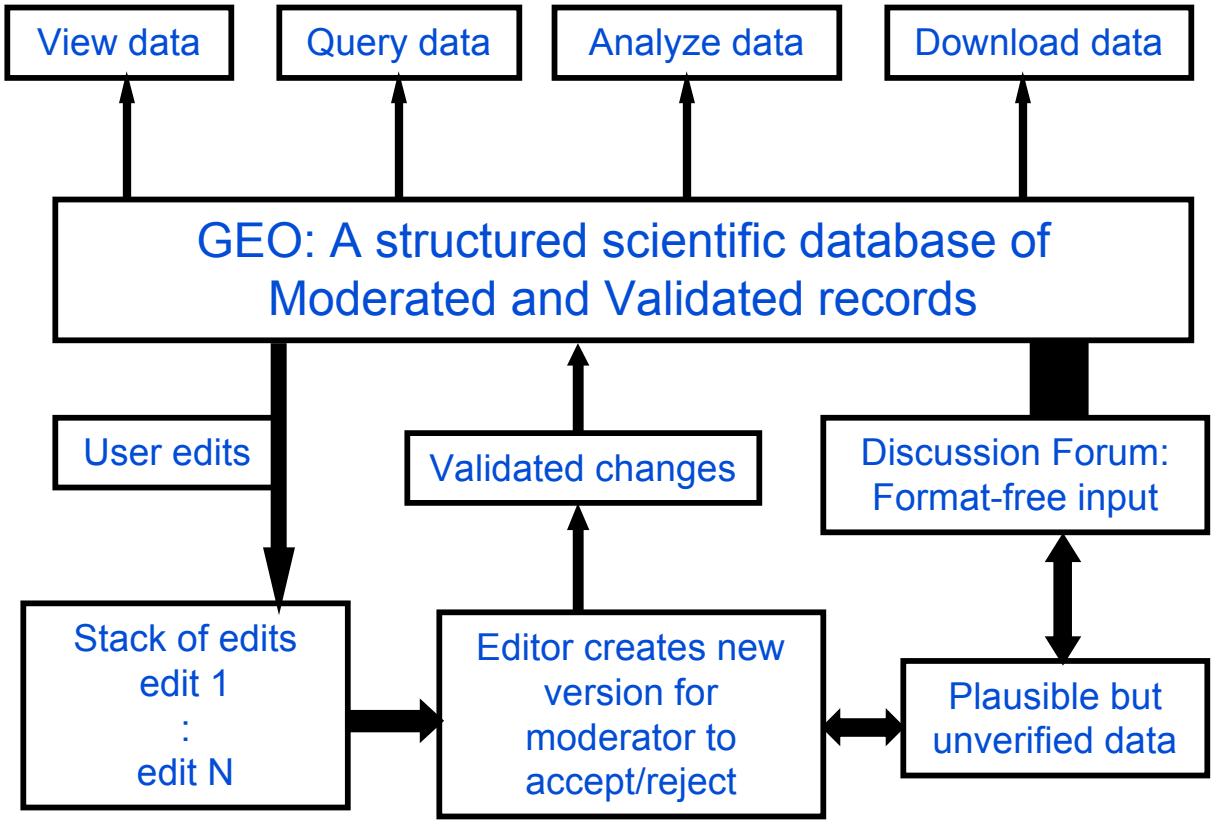
Strategy for Maintaining Data Integrity

- Record on view: Last moderated version
- Corrections: Go into a viewable stack for moderation
- Moderation: * Consolidate corrections and additions
  * Validate this new data
  * Incorporate validated data

GEO @ openmodel.newmexicoconsortium.org

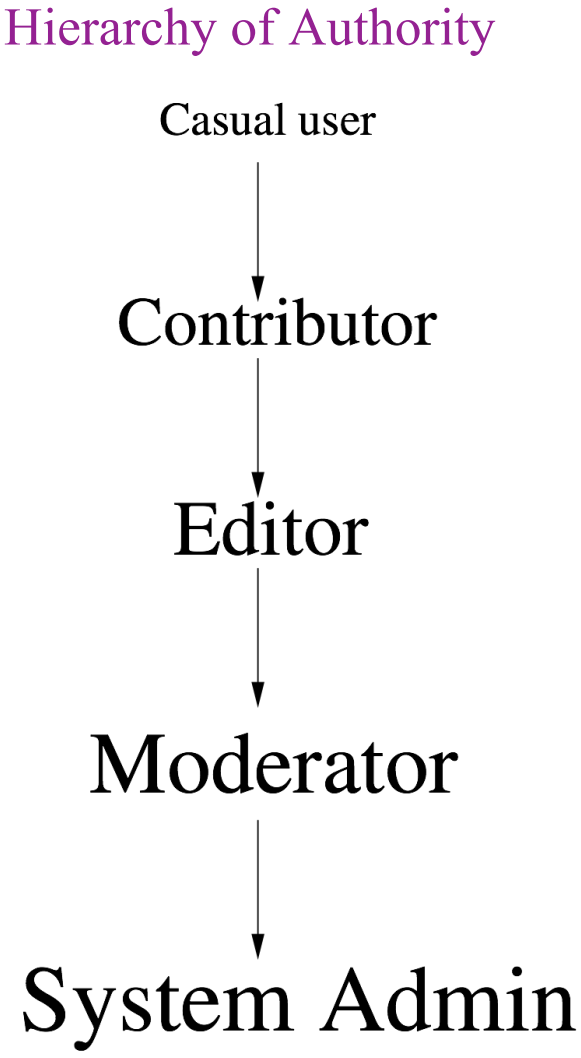
A framework for harnessing heterogeneous data, contributions, moderation, validation & analysis

Flow Chart of the Global Energy Observatory



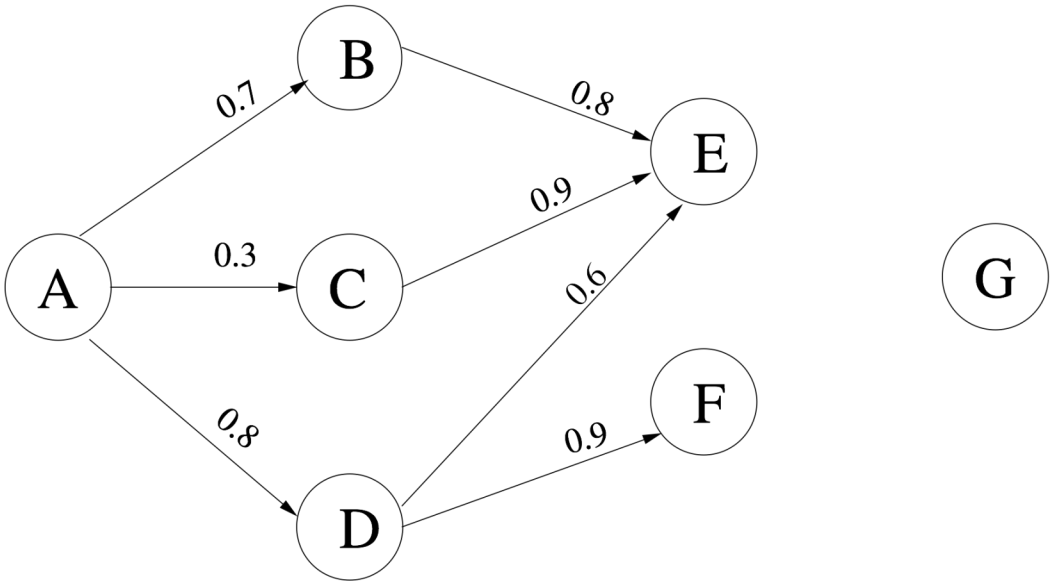
V&V: (based on referee system in journals)

- Editors (subject area experts)
  - Review and verify submissions
  - Create a new version of validated changes 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

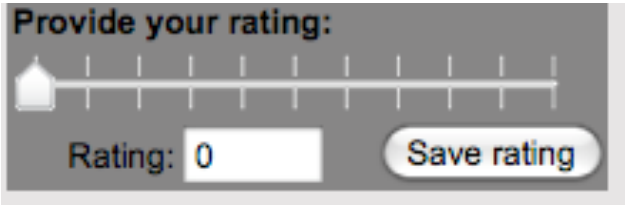
- Evaluating contributors
  - Moderators rate editors
  - Editors rate contributors for accuracy of input
  - Trust scores organized by subject and geographical area
  - Contributions from users with high trust accepted directly (random checks with probability based on trust scores)
  - Users with score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



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

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

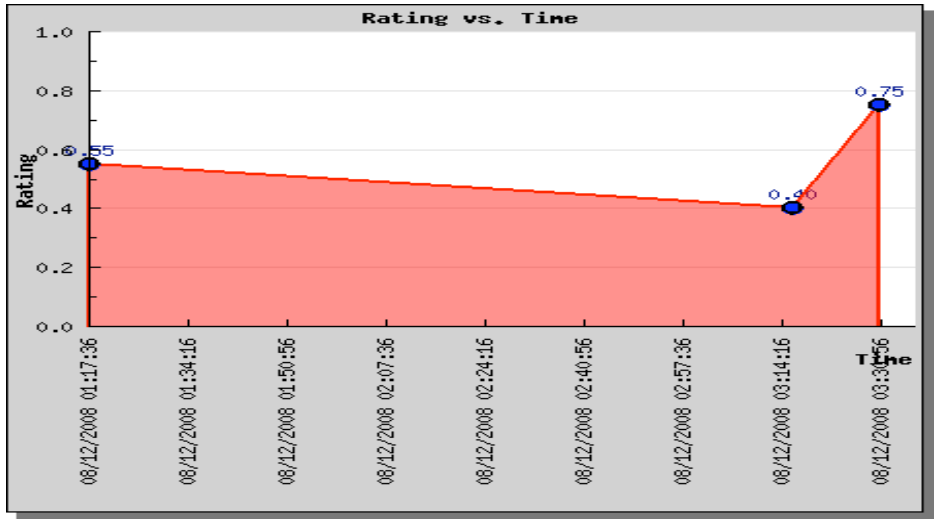
Ratings of Data

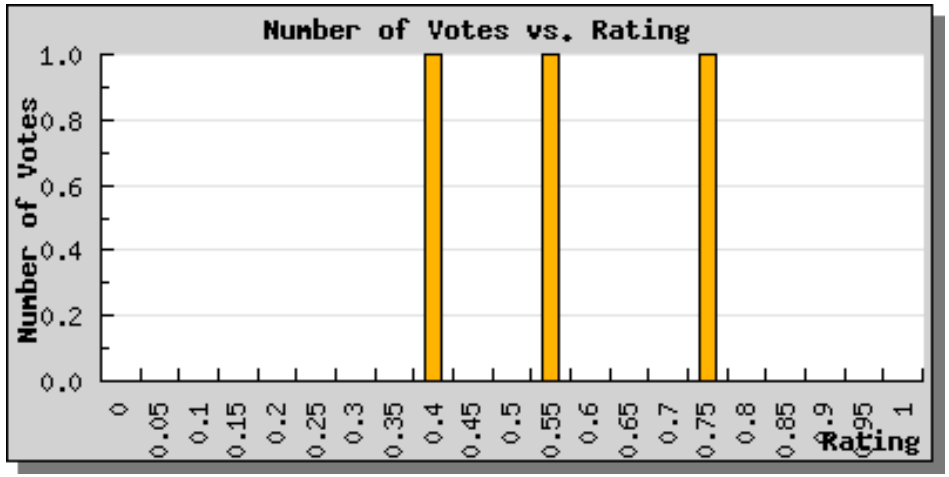


- Evaluating data records
  - Visitors score the accuracy of existing data in a record
  - Previous scores available as a graph showing distribution
  - Time history of previous scores with overlay of dates on which the record was updated with a new moderated version.

Does the user community value this data?

Plots of user's rating of accuracy of this plant's data





Analysis

- Understand drivers
- Correlate (growth, scaling laws, …) with
  - demographics
  - economic activity
  - land and water use
- Multi-sector network models:
  - Feedback loops, 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

Education

An introduction to *real-life* systems and databases

- *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.

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

Extras

Map: Visualize existing systems

- Mashup of existing data on Google Maps
  - Visualize systems and inter-relationships
- Linked network of associated energy systems
  - Highlight interconnections and interdependencies

Strategy for growth

- Provide the framework for collecting, managing, visualizing, analyzing, information through a global participatory collaboration
- Develop tools for automating the verification and validation process
- Use Universally Accessible Formats and Tools
  - WWW, Web 2.0, Google Map/Earth
- Harvest open databases
- Couple the scientific database to analysis

Why OpenModel?

Why not just buy information from "Platts"?

- Easy and free access for casual → expert 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, research, policy, monitoring of environmental treaties
- Tracking growth in
  - Distributed Generation and Storage
  - Energy Efficiency
- Motivating the development of Smart Grids

GEO ⇔ Platts (Wikipedia ⇔ Britannica)

Platts provides valuable business information