Global Energy Observatory: A one-stop site for information on Global Energy Systems

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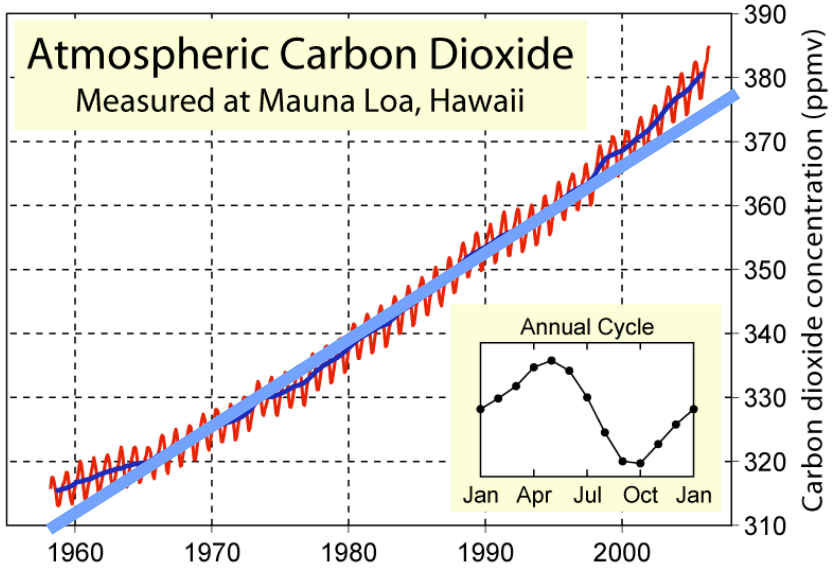

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Thanks and Acknowledgements

Collaborators

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- Ratheesh Prabhu Rajendran
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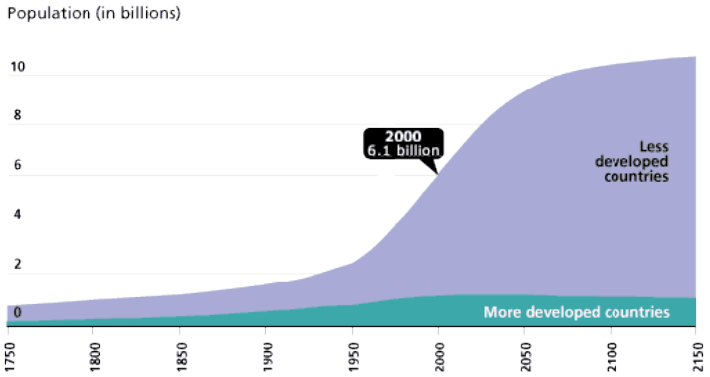
- NM Consortium
- ECE Department at UNM

The 2nd half of the 20th century was phenomenally successful in raising the living standards of ~2 billion people but also generated 3 challenges

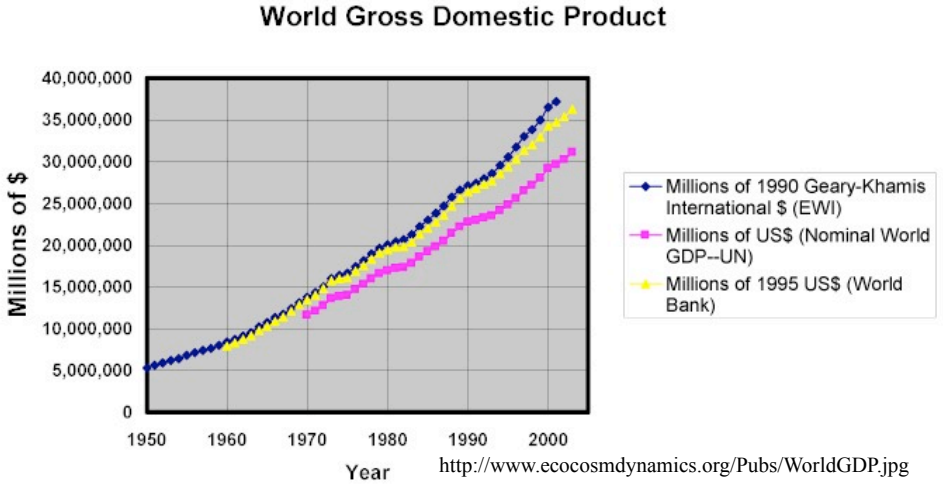
- Dependence on easy to exploit fossil fuels (fastest route to growth)
- A rate of exploitation of resources that is not sustainable under Business-As-Usual (BAU)
- An even larger number of people (2→6.7→10B) wanting the same standard of living

⇒ **Energy-environment-development-climate challenge**

B.A.U ⇒ Growing population and standard of living ⇒ Need more (fossil) energy



http://www.prb.org/images/e-01(world_pop_growth).gif



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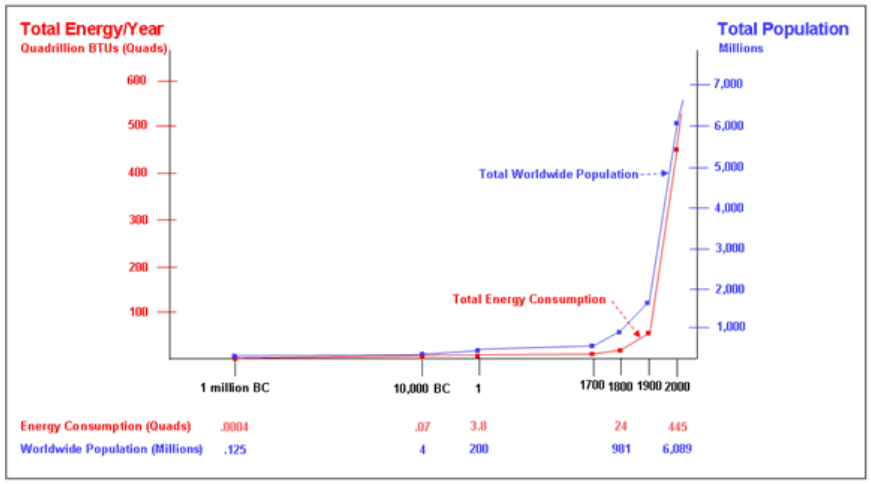
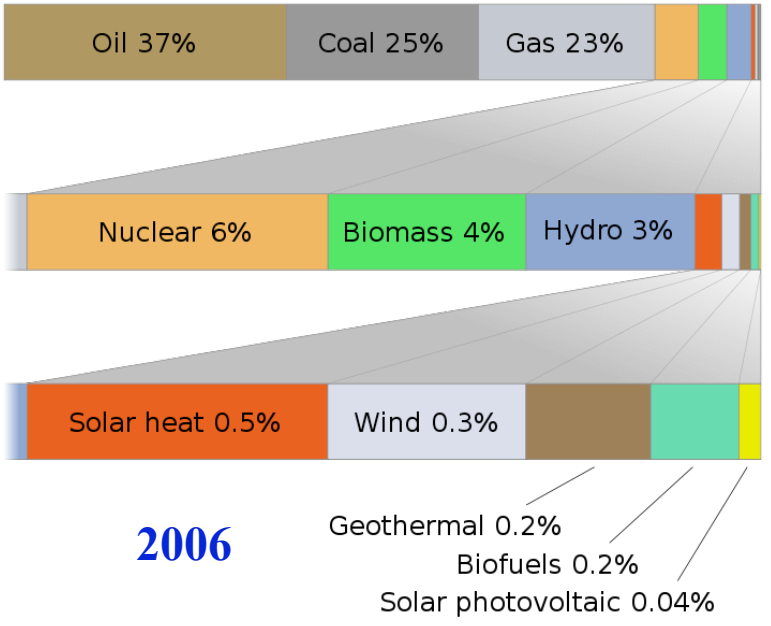
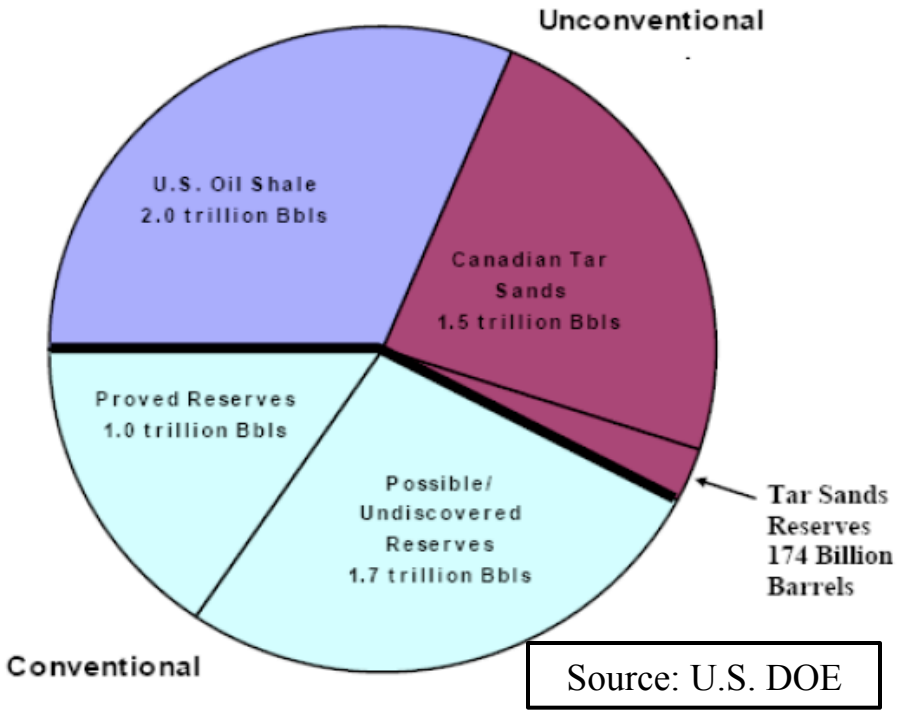


http://www.researchandmarkets.com/research/66d892/germany_solar_pv_m

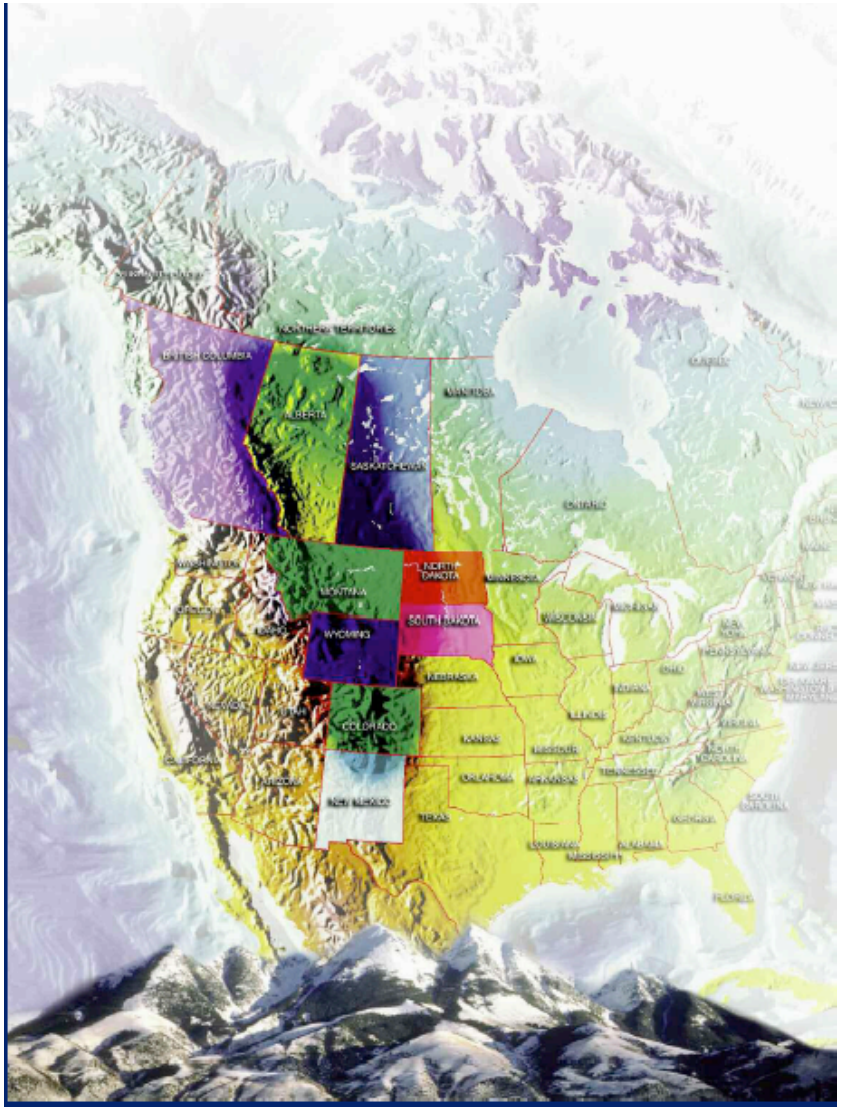


http://www.greenvalhalla.com/wp-content/uploads/2007/11/world_energy_usage.png

Plenty of fungible carbon ⟷ Energy-Climate Challenge



Source: U.S. DOE



The Rocky Mountain Corridor has the largest deposits of unconventional oil.

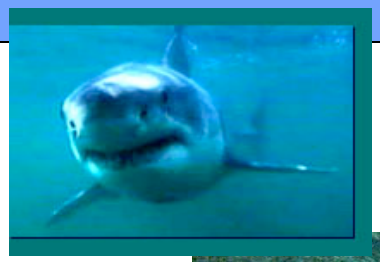
Challenge: Extracting energy without GHG & environmental impact

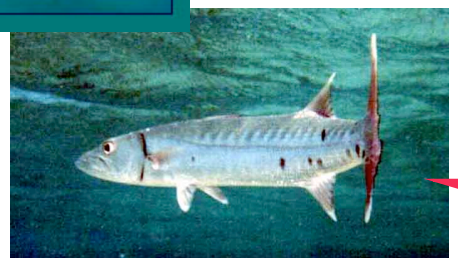
CO_2 is the highest oxidized form of C ⇒ **does not degrade**

A macro view of the global population

2.2 billion live in 21st century

Health Care
Education
Energy
Water
Job Skills





1.5B people in Transition

3 billion live in 18th century

i.e. on less than 2_{ppp}$ /day

(Additional 3.5B will start here)

Energy-environment-development-climate challenge is

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

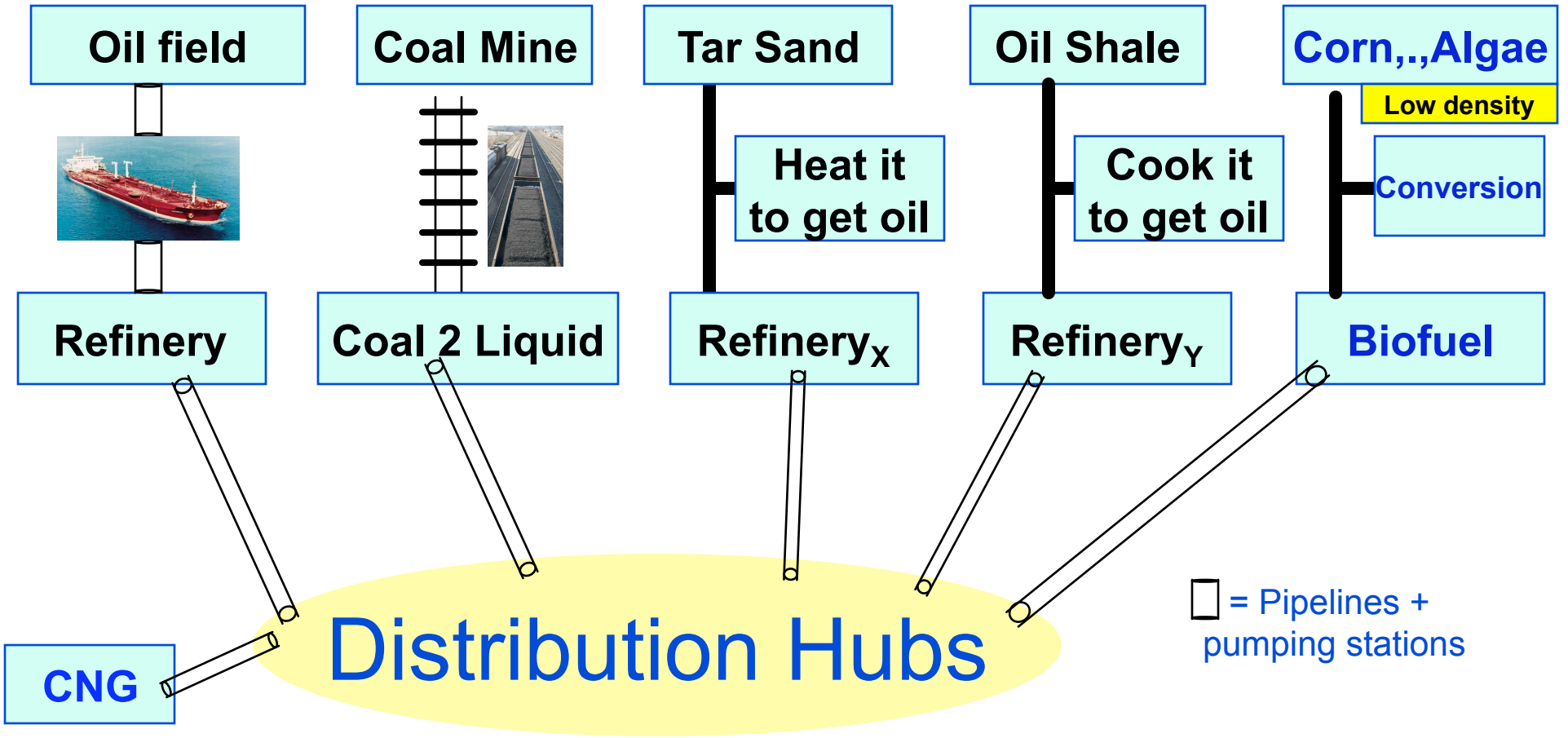
} Energy

Needs and impacts are global

6.7 (→10.2) billion people want same opportunities

Development:	Short Term
Energy Efficiency:	Immediate
Environmental Impacts:	Medium Term
Climate Impacts:	Long Term

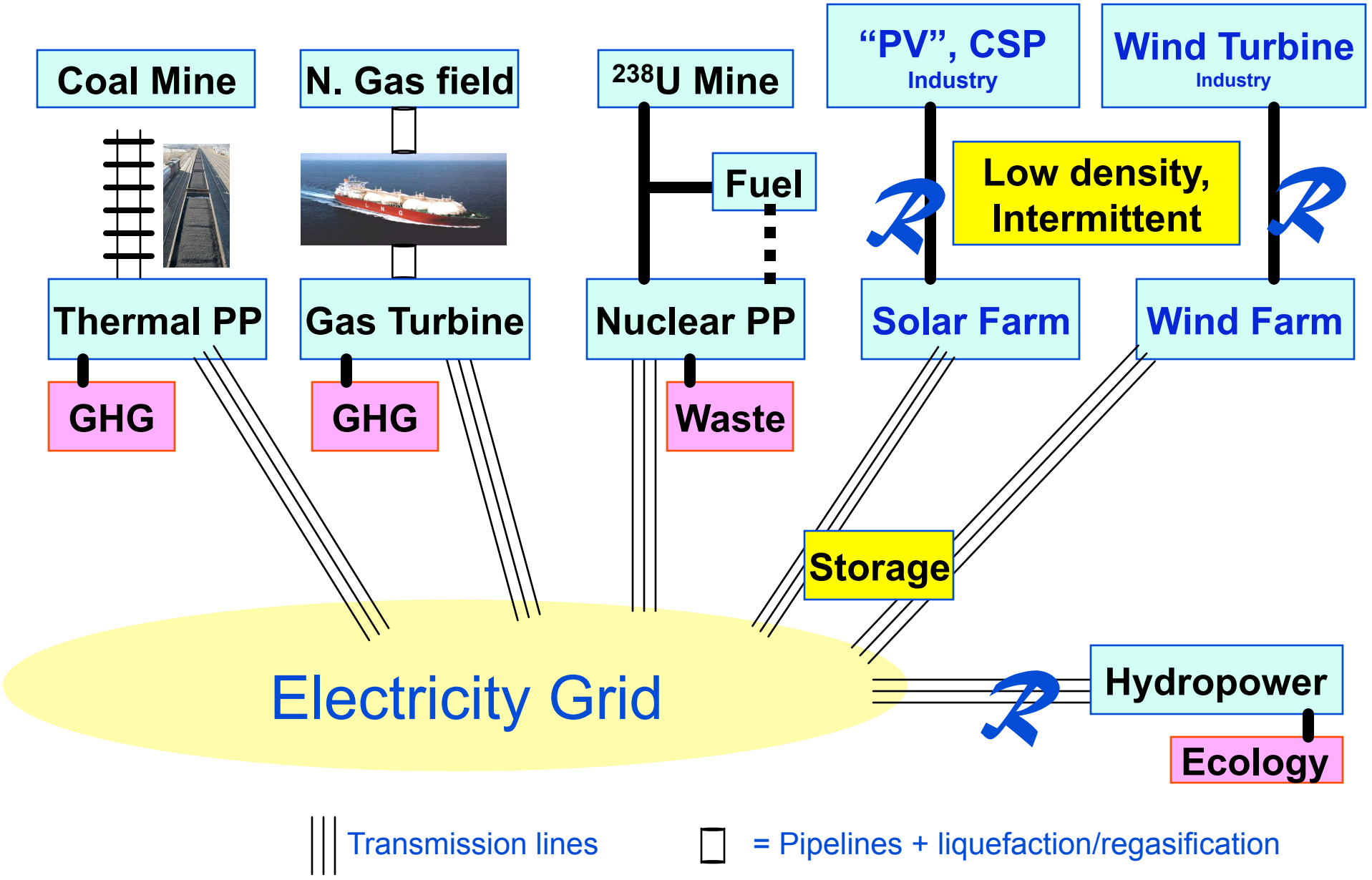
Transportation fuels: Lifecycle cost comparison



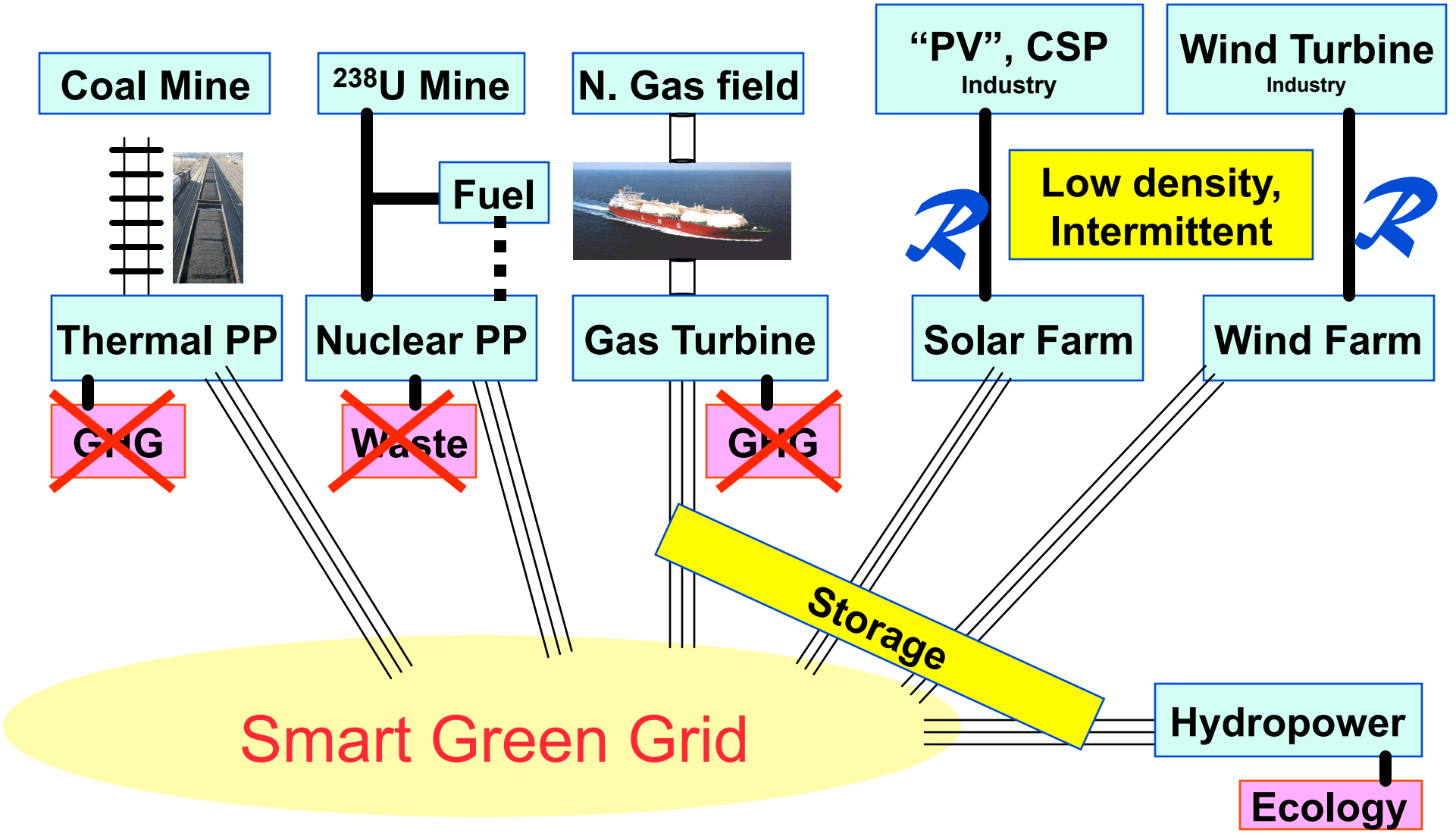
Today ⇒ All Fuels Produce GHG

Future ⇒ [Hybrid] Electric Vehicles

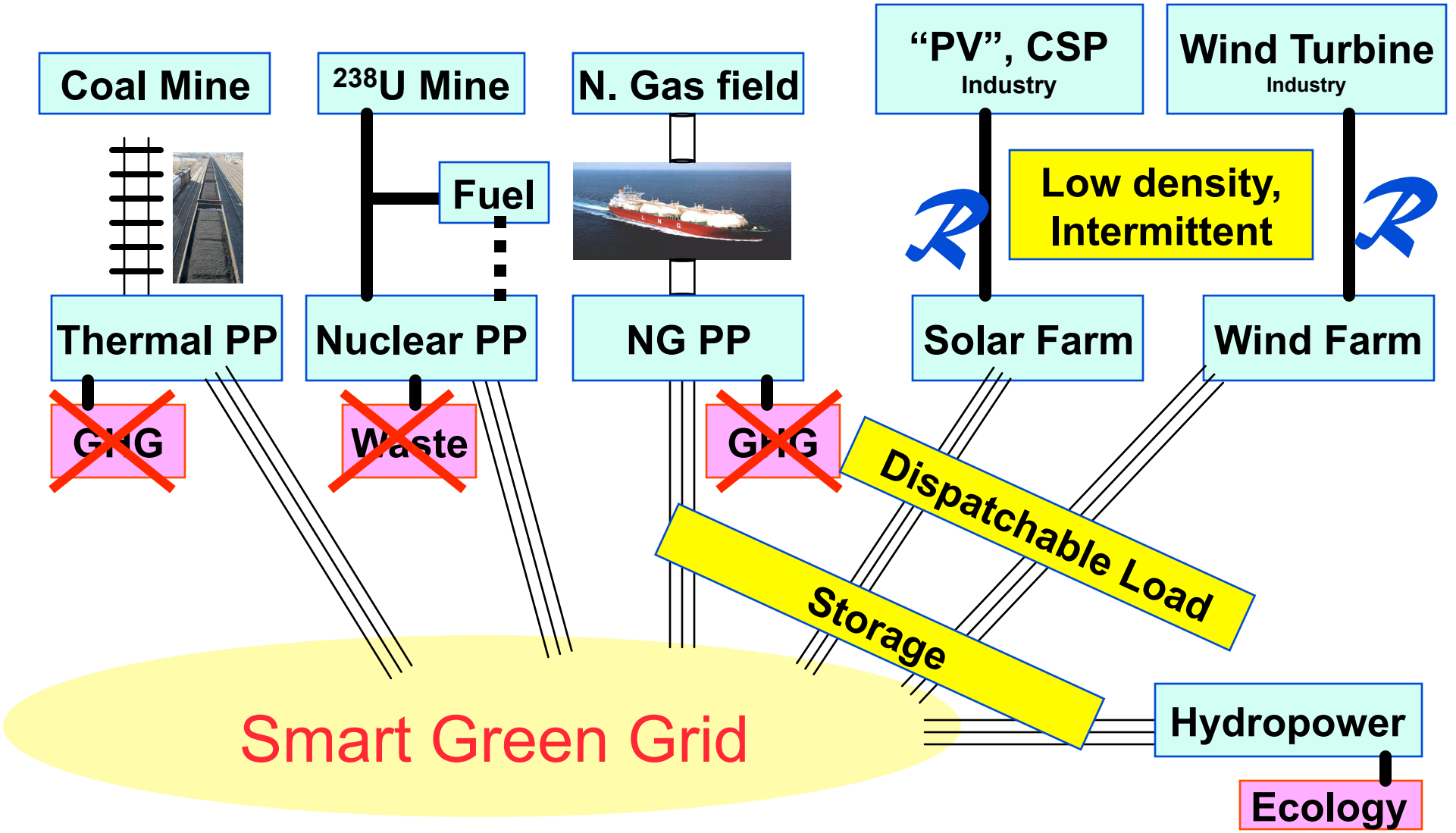
Electric Power System: Lifecycle cost comparison



Electric Power System: Lifecycle cost comparison



Electric Power System: Lifecycle cost comparison



A global infrastructure (>$40 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/diesel**
- **Trucking industry**
- **Service, gasoline stations**
- **Existing coal/gas electricity generation plants**

All alternatives to fossil fuels have a market niche

		Today	Potential
Electric Power	• Nuclear	~370 GW	?
	• Hydro	~400 GW	~600 GW
	• Wind	90 GW_p /(3)	+~20%/year
	• Solar PV	15 GW_p /(4)	+~20%/year
	• Geothermal	25 GW (e+th)	
	• Fossil	~1500 GW	>3000 GW
Fuel	• Biofuels	1.5 MM boe/day	?
	• Oil	85 MM bbl/day	?

But none is large enough today to meet

World Requirements of 10 [20] TW_e

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 / liquid 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"

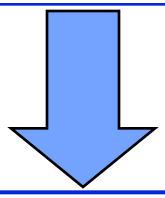
9 Drivers/Challenges

1) USA, Europe, Japan, Korea, China, India, … lack energy security (conventional oil, gas)
2) Climate Change – an uncontrolled experiment
3) The energy infrastructure is huge (>$40 trillion)
4) Middle East (ME) & Russia control oil and gas
5) Increasing competition (China, India, ME, …)
6) Military solutions too costly ($ and lives)
7) Unconventional fossil fuels: 2-3 ⊗ pollution&CO_2
8) Innovation ⇒ Cheap clean energy = markets
   - Alternatives have a market niche but are small today

9) Energy efficiency ↔ behavior change

First Step in the Transition:

An era dominated by Fossil Fuels



Fossil fuels as backup and storage

•Transport:	Electric with gasoline as backup (hybrids)
•Heating & Cooling:	Solar thermal and heat pumps
•Power Generation:	Renewables and Nuclear
	(Gas CHP & hydro as backup)
	Distributed generation & Storage
•Improve Efficiency:	Efficiency & Best Practices (education)
	Demand Reduction and Management
	Grid-wide Automation and Control
	Smart Grid

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 of power systems in step with technology

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

Nuclear Power remains an issue!

How do we engage the public?

- Energy systems are extremely complex
- The scale of the system needed is immense
- Regional Variations
  - Political and Social factors
  - Resource constraints
- Geopolitics, Economics and Markets

Open Collaborative Web Tools

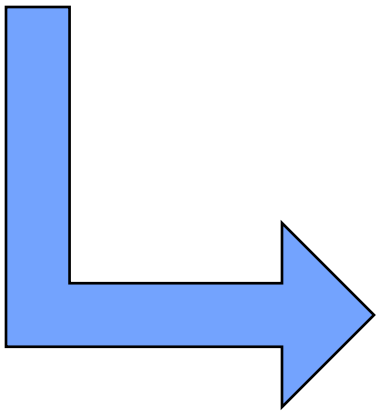
Global Energy Observatory (GEO)

URL = http://GlobalEnergyObservatory.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 (Beta Version):

1. Power Plants
2. Fuels and Resources
3. Energy Transmission
4. Reducing Our CO_2 Footprint

Types of Infrastructure Tracked

Power Plants

* 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

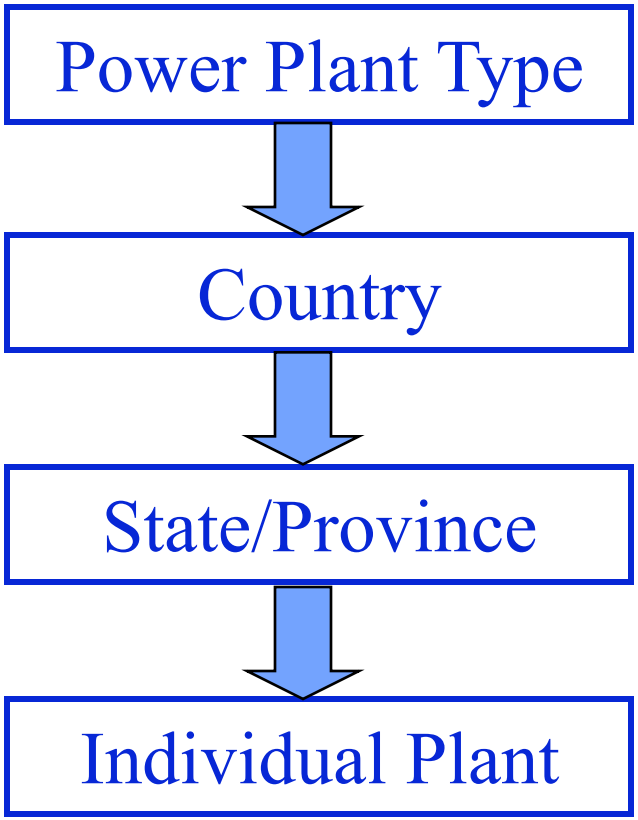
* Gas Fields
* Oil Fields
* Coal Mines
* Uranium Mines
* Crude Oil Refineries
* Solar Potential
* Wind Potential
* Biomass Potential
* CO_2 Sequestration

Transmission

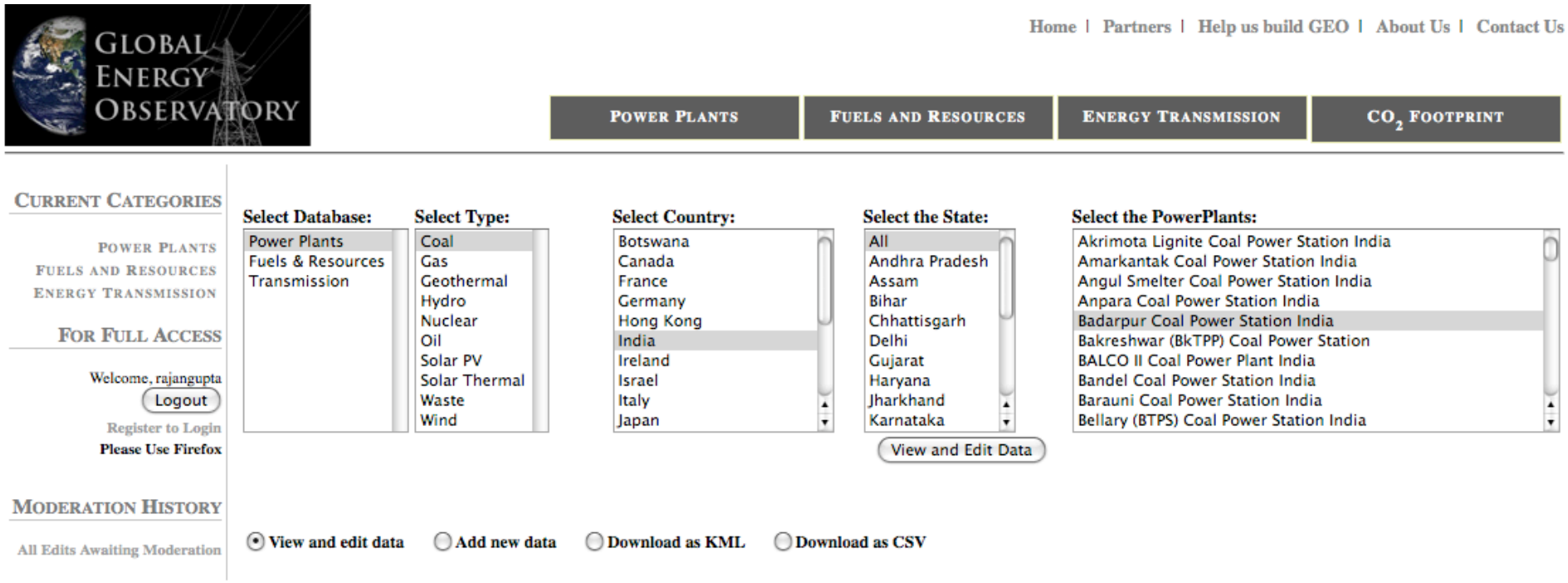
* Gas Pipelines
* Oil Pipelines
* Coal Ports
* LNG ports
* Oil Ports
* Rail Links
* Road Links
* Shipping Lanes
• Electric Power Grid

Beta version

Organization of Databases: Example of Power Plants



http://GlobalEnergyObservatory.org/



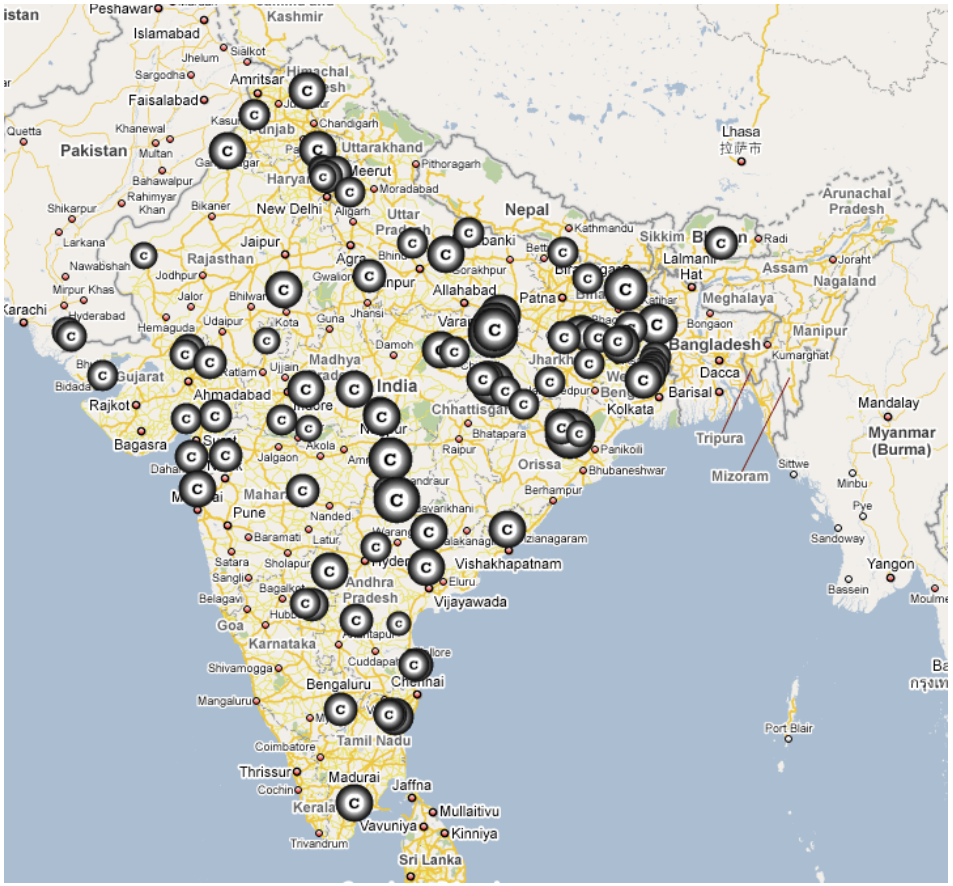
Select power plant to view and edit

Overview of features

- View and Map existing data
- Create a new entry
- Edit and Add data
  - Moderation to preserve scientific integrity
- Download data (KML, Tables, Plots)
- Analyze data
- Map the network of energy systems

Map Data: Visualize Existing Systems

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



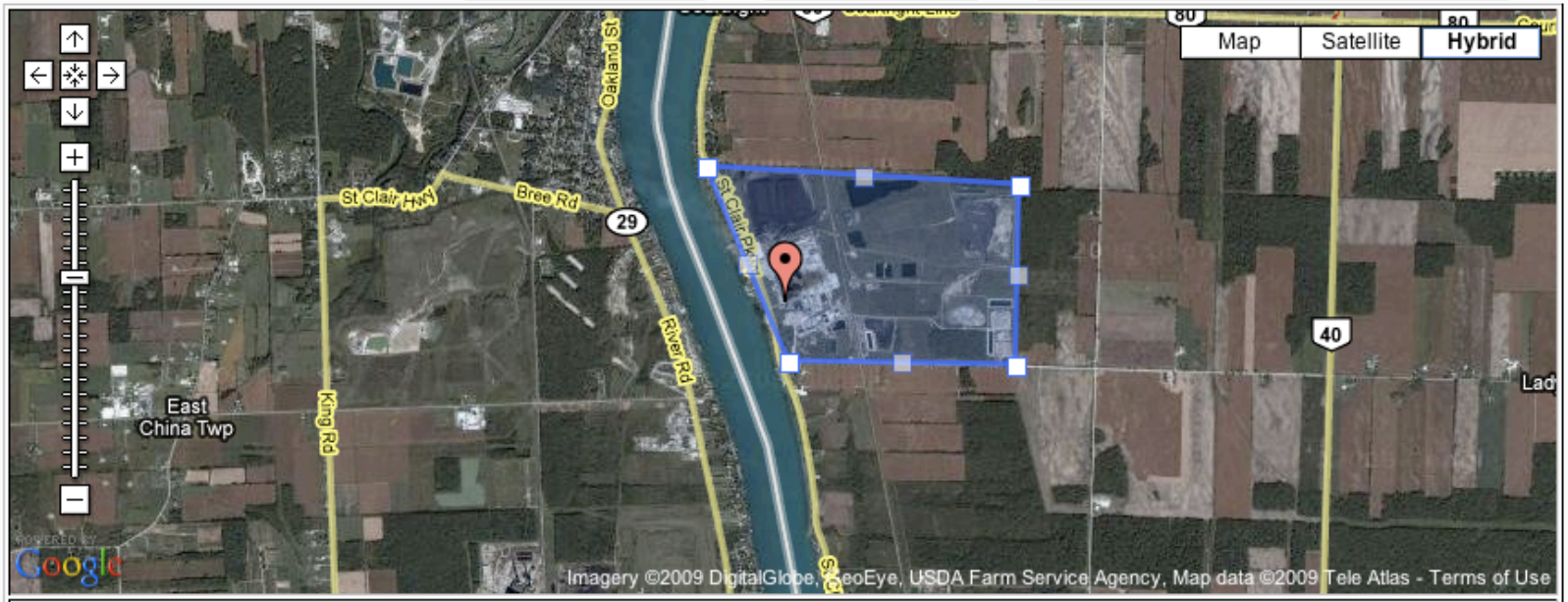
1. Correlate coal, nuclear, hydro, gas power plants

2. Correlate Power Plants, Fuels and Resources & Transmission

3. Correlate Generation, Demand & Growth

Details of 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			

Associated Infrastructure: Morupule Plant

GEOPower	Coal	Botswana	All	Morupule Power Station
GEOResources	Oil	Canada	Central	
	Gas	Hong Kong		
	Nuclear	India		
	Hydro	Ireland		
	Wind	Italy		
	SolarPV	Mexico		
	SolarThermal	South Africa		
	Geothermal	United Kingdom		
	Waste	United States of America		

Create new map Continue in existing map Show Associated Infrastructure

Load MiniMap Below Load Large Map in new tab

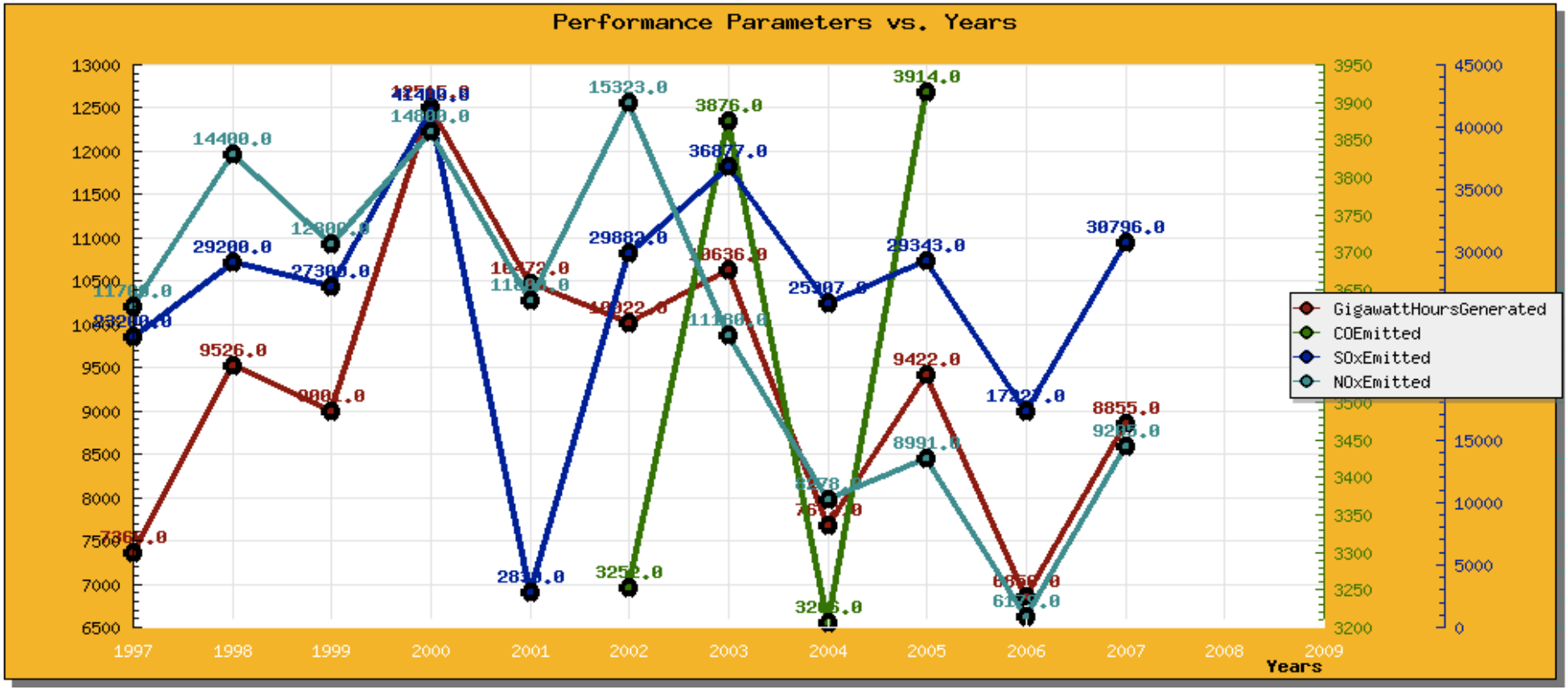
Emissions Tracked

- **Green House Gases (GHG)**
  CO_2, CH_4, N_2O
- **Criteria Air Pollutants (CAP):**
  SOx, NOx (Acid Rain)
  CO, NH_3
  Volatile Organic Matter
  Particulates, Ash
- **Toxic Air Pollutants (TAP):**
  Mercury (Hg)

Adding other fields to the framework takes 2 minutes

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)										



Scientific Database

- Structured Scientific Data input via web forms
  - Geo-location and Footprint
  - Description of the Plant Units
  - Emission control devices and monitors
  - Performance
  - Emissions
  - Associated Infrastructure
  - Major upgrades
  - Ownership
  - Comments
  - References

Collaborative global effort to

- **Enlarge and update the scientific database**
- **Verification and Validation**
- **Visualization and analysis**
- **Timeline of improvements and enhancements**

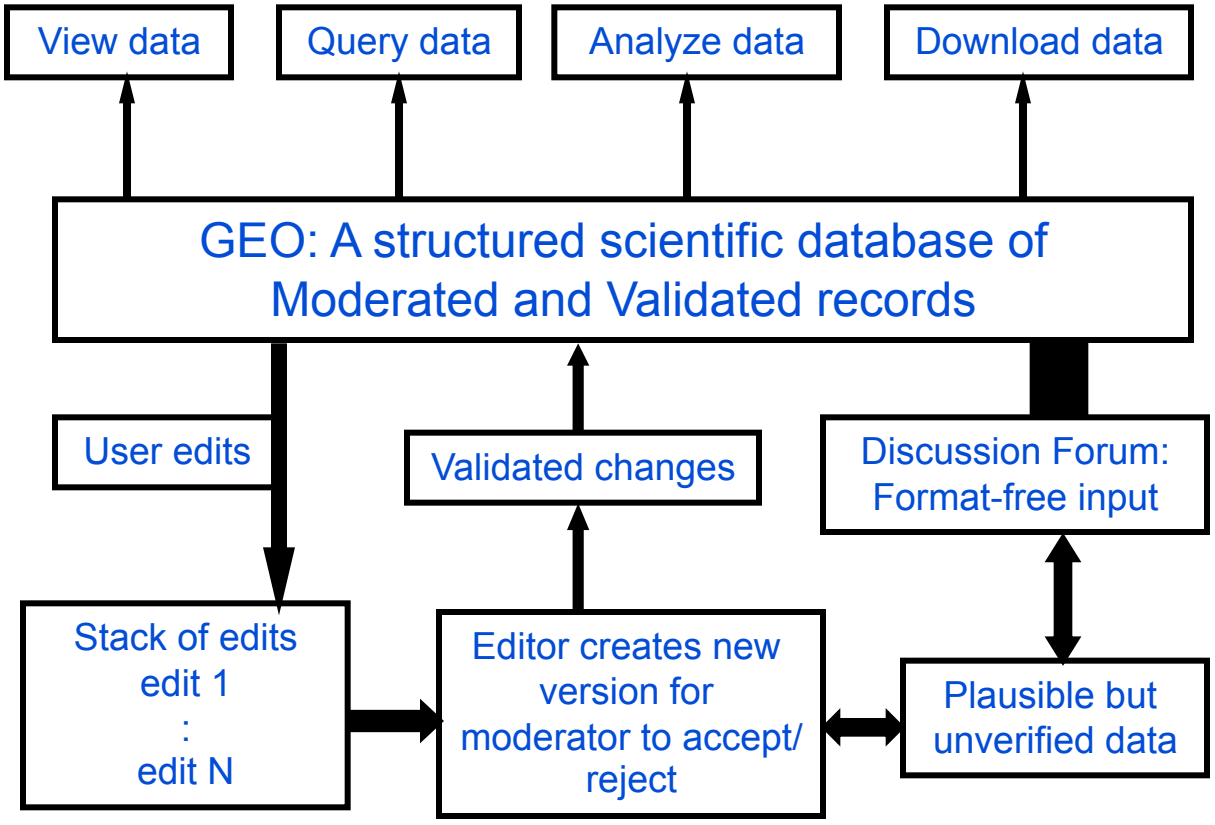
Maintaining Data Integrity

- On view: last moderated version
- Corrections: placed in a viewable stack for moderation
- Moderation: to verify and validate new data

GEO @ GlobalEnergyObservatory.org

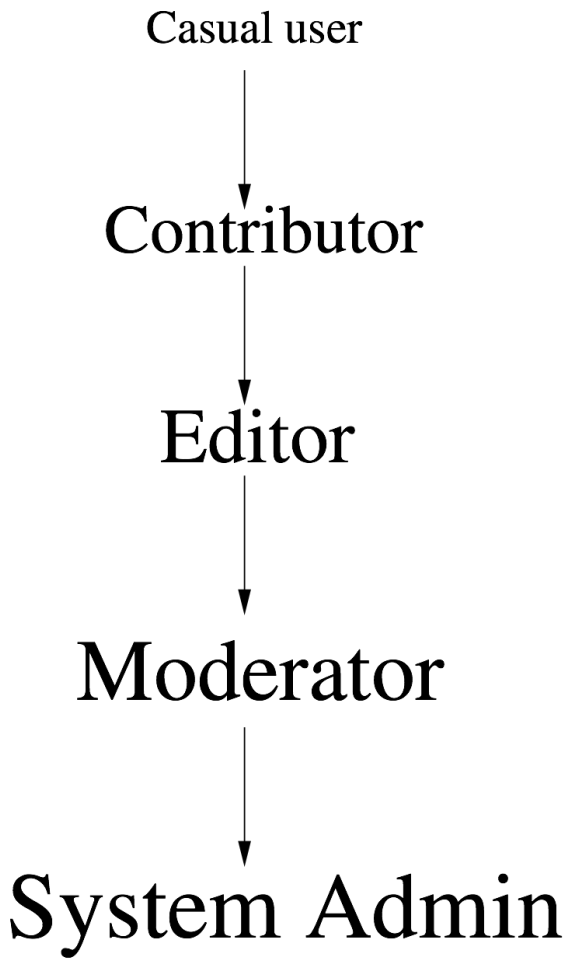
A framework for managing heterogeneous data, contributions, moderation, validation & analysis

Flow Chart of the Global Energy Observatory



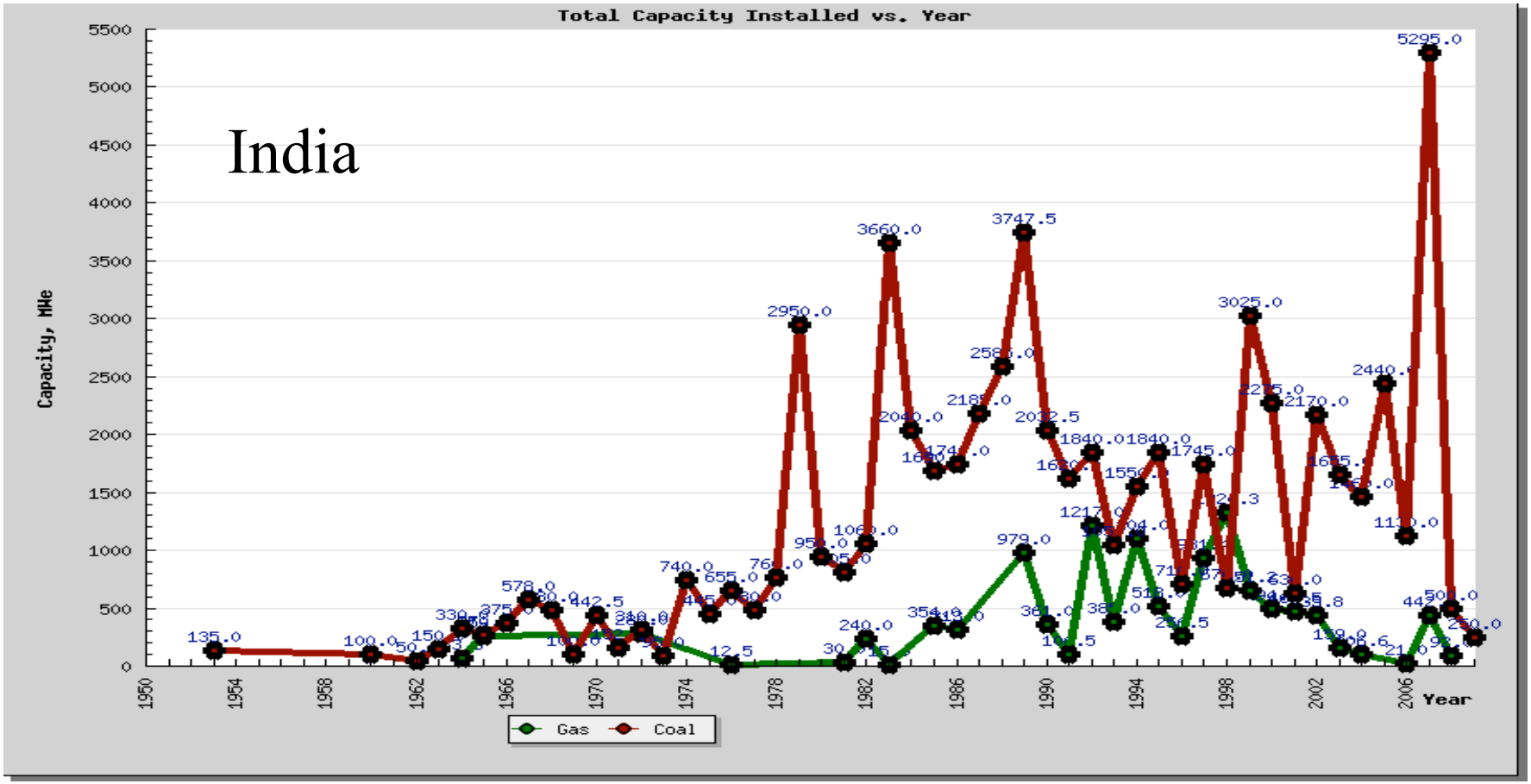
V&V: (ala referee system used by journals)

- 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



Analysis

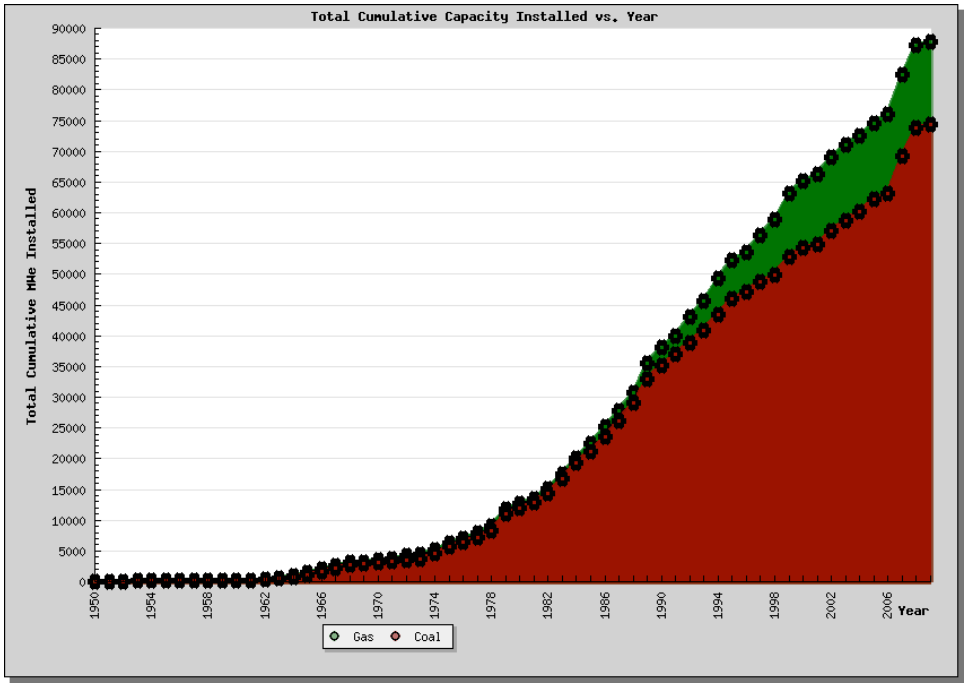
- Understand drivers
- Correlate (growth, scaling laws, …) with
  - demographics
  - economic activity
  - land and water use
- Multi-sector network models:
  - Feedbacks, nonlinearities, tipping points
  - Crisis & Bottlenecks
  - Evolution towards Smart / Green grids
- Understand the dynamics of change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



Coal and Gas-fired Generation Capacity added each year in India.

Planning horizon is ~5 years, lifetime of plants is 40-50 years

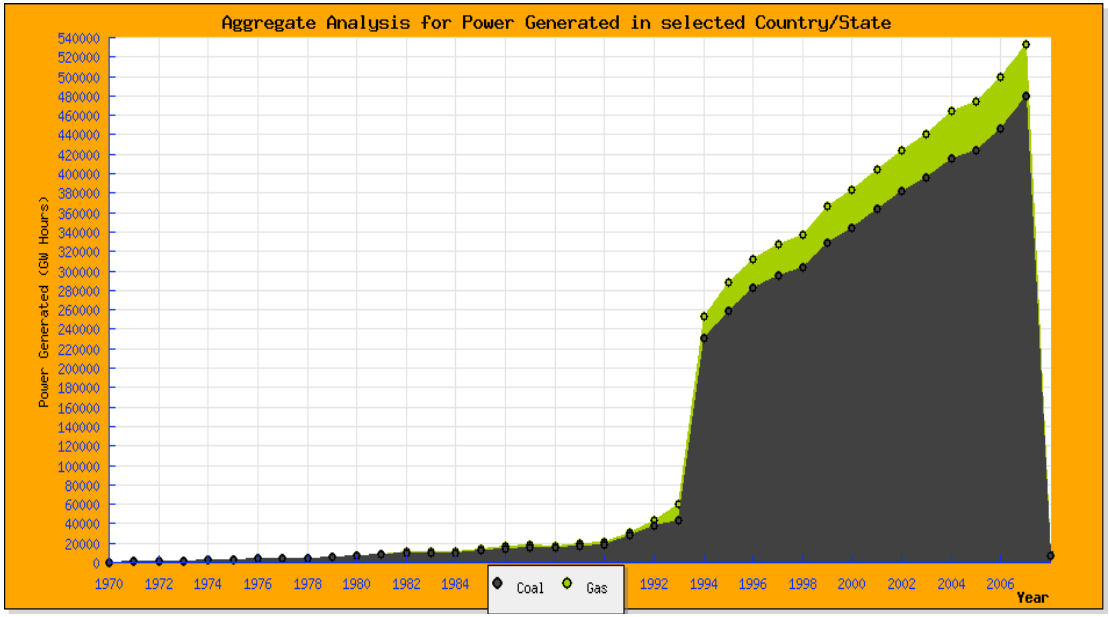
Missing information on Independent (IPP) and Captive (CPP) power plants!



Cumulative (GW) Installed Capacity for Coal and Gas

Annual Generation (GWh) from Coal and Gas

Slope: Coal ~2.2 GW/year
Gas ~0.32 GW/year



2032 -- end of 15th 5 year plan

Population ~1.4 billion (+250 MM)

Coal Capacity ~300 GW ~ 2 G tonnes CO_2
(1.5 Gtonnes of Indian Coal)

Carbon Credit (0.5 KW/person x 200 MM)
~ 0.8 G tonnes CO_2

Modeling

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

Partnerships and Collaborations

- Early User Community – physicists, energy experts
- Students, Academics and Scholars
  - High Schools, Colleges, Universities
  - Think Tanks, Research Institutions
- Planners and Policy Makers
- Utility and Energy Companies
- Special Interest Groups
  - Environmentalists (WWF, Greenpeace, Sierra Club)
  - Journalists
- Informed Public