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Slide No. 1

CO2 Regulation, Renewables, Electricity, Oil, Load, and Their Consequences for Gas

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June 18, 2009

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Slide No. 2

Dr. Dale M. Nesbitt

- Ph.D., Engineering Economic Systems, Stanford University, 1975, dissertation defense with honors, "Policy Ordering in semi-Markovian Decision Processes."
- Employment History
  - Employee #70 at legendary Xerox PARC (1972-4).
  - Stanford Research Institute, Decision Analysis Group (1974-7).
  - Co-founded and built Decision Focus Inc (DFI) into $25 million (sales) company (1977-95).
    - The DFI energy practice has become Altos
  - Co-founded four new companies (1996-07)
    - Altos Management Partners Inc. (management consulting)
    - MarketPoint Inc. (enterprise software)
    - Reticle Inc. (high surface area carbon, water deionization/desalination)
    - Ferritech Inc. (biotechnology/ferric oxidation)

Environment

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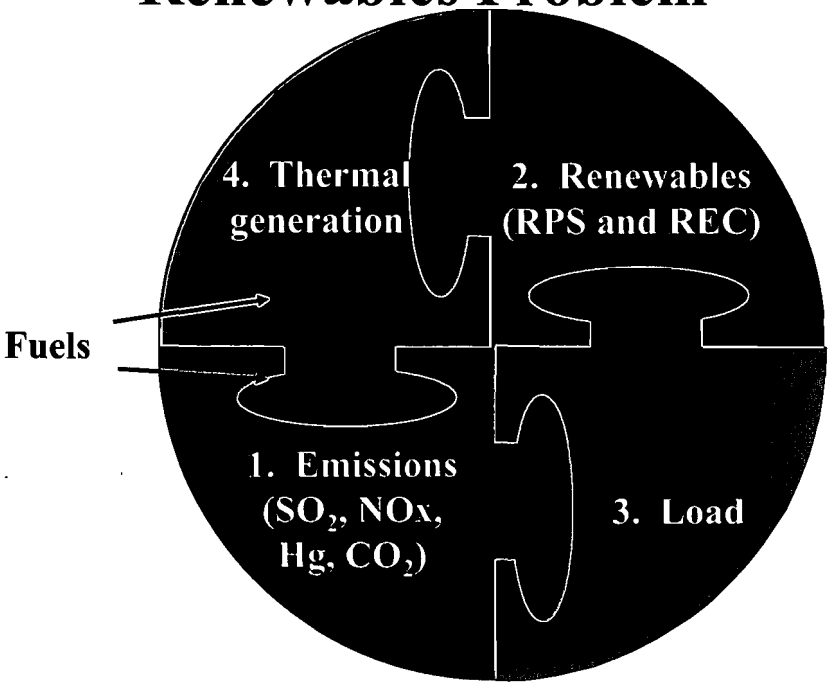
Dimensions of the Gas-CO2-Renewables Problem



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Agenda

1. Emissions (CO_2, NOx, SO_2, Hg)—how does environmental regulation REALLY work?
2. Renewables (Solar, Wind, Biomass, Geothermal, Other)
3. Thermal Generation
4. Storage and load
5. Derived fuel consumption

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1. Emissions: How Does Environmental Regulation REALLY Work?

- How is the electric market going to respond?
- How is that going to affect gas?
- What are the allowance prices going to be? Why?

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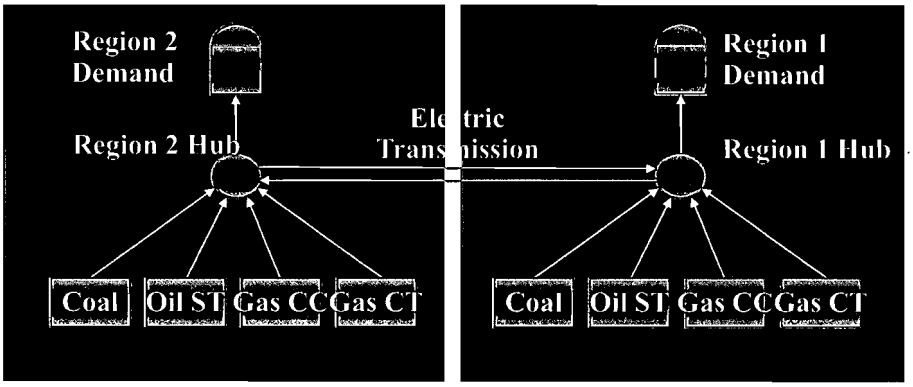
Multiregional Electric Generation/Transmission Situation in the Past

- Disparate regions were managed and dispatched individually
- They were completely disconnected except by transmission and power pooling agreements
- Dispatch was a valid (and local) issue



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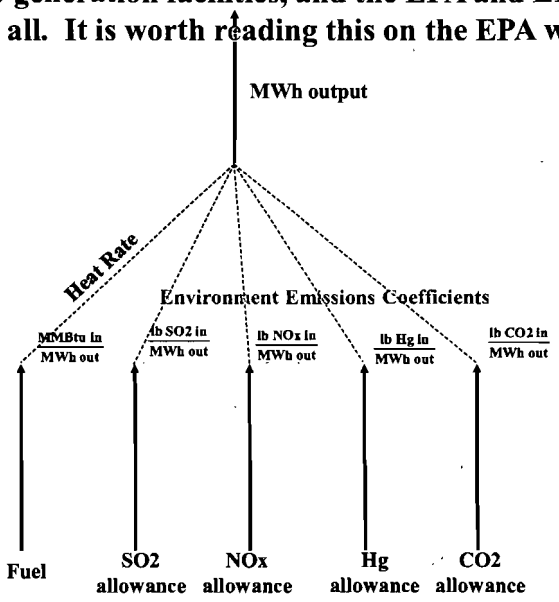
We Have Assembled the Emission Coefficients and Heat Rate for Every Plant in North America for Every Fuel Type

There are 18,500 generation facilities, and the EPA and EIA have done this for all. It is worth reading this on the EPA website.



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Plant Stoichiometry Is Generally Reported as lb Emission Per Unit of Fuel

- This is chemistry, not politics. (It is from the EPA website.)

- Uncontrolled/unretrofit

Plant	Emissions Control	Fuel	CO2 Emission Coefficient (lb/MMBtu)	Hg Emission Coefficient (lb/MMBtu)	SOx Emission Coefficient (lb/MMBtu)	NOx Emission Coefficient (lb/MMBtu)	Heat Rate (Btu/KWh)
Combined Cycle	None	Natural Gas	117.0	0.00000000	0.0	0.15	7,000
Pulverized Coal	None	Bituminous Coal	205.3	0.00001045	2.2	0.35	10,000
Supercritical Coal	None	Bituminous Coal	205.3	0.00001045	2.2	0.35	9,750
Pulverized Coal	None	Sub-bituminous Coal	212.7	0.00000670	1.4	0.35	10,000
Supercritical Coal	None	Sub-bituminous Coal	212.7	0.00000670	1.4	0.35	9,750
Pulverized Coal	None	Lignite	215.4	0.00000979	2.1	0.40	10,000
Supercritical Coal	None	Lignite	215.4	0.00000979	2.1	0.40	9,750

- Controlled (SCR-Scrubber-ACI)

Plant	Emissions Control	Fuel	CO2 Emission Coefficient (lb/MMBtu)	Hg Emission Coefficient (lb/MMBtu)	SOx Emission Coefficient (lb/MMBtu)	NOx Emission Coefficient (lb/MMBtu)	Heat Rate (Btu/KWh)
Combined Cycle	SCR	Natural Gas	117.0	0.00000000	0.000	0.015	7,250
Pulverized Coal	SCR+Scrub	Bituminous Coal	205.3	0.00000105	0.044	0.035	10,250
Supercritical Coal	SCR+Scrub	Bituminous Coal	205.3	0.00000105	0.044	0.035	10,000
Pulverized Coal	SCR+Scrub	Sub-bituminous Coal	212.7	0.00000067	0.028	0.035	10,250
Supercritical Coal	SCR+Scrub	Sub-bituminous Coal	212.7	0.00000067	0.028	0.035	10,000
Pulverized Coal	SCR+Scrub	Lignite	215.4	0.00000098	0.042	0.040	10,250
Supercritical Coal	SCR+Scrub	Lignite	215.4	0.00000098	0.042	0.040	10,000

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Coal CO2 Stoichiometry Is Very Interesting and Revealing

A TON of CO2 for every MWh generated by coal!!!!!

$$\text{Coal}: 205.3\frac{\text{lb } CO_2}{\text{MMBtu bit. coal}} * 10.0\frac{\text{MMBtu}}{\text{MWh}} = 2053\frac{\text{lb } CO_2}{\text{MWh}}$$

- C has atomic weight 6, O_2 has atomic weight 16, all that oxygen multiplies the weight of your coal pile by 3.6!!!
  - **The atmosphere absorbs three and a half times the mass of your coal pile!!!**
  - If you captured your CO_2 and put it into landfill, it would be 3.6 times the size of the coal pile you burned!

Slide No. 9

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Use Plant Heat Rates to Convert to lb/MWh of Generated Output

- Uncontrolled/unretrofit

Plant	Emissions Control	Fuel	CO2 Emission Coefficient (lb/MWh)	Hg Emission Coefficient (lb/MWh)	SOx Emission Coefficient (lb/MWh)	Nox Emission Coefficient (lb/MWh)
Combined Cycle	None	Natural Gas	819.0	0.00000000	0.00	1.05
Pulverized Coal	None	Bituminous Coal	2053.0	0.00010450	22.00	3.50
Supercritical Coal	None	Bituminous Coal	2091.7	0.00010189	21.45	3.41
Pulverized Coal	None	Sub-bituminous Coal	2127.0	0.00006700	14.00	3.50
Supercritical Coal	None	Sub-bituminous Coal	2073.8	0.00006533	13.65	3.41
Pulverized Coal	None	Lignite	2154.0	0.00009790	21.00	4.00
Supercritical Coal	None	Lignite	2100.2	0.00009545	20.48	3.90

- Controlled (SCR-Scrubber-ACI)

Plant	Emissions Control	Fuel	CO2 Emission Coefficient (lb/MWh)	Hg Emission Coefficient (lb/MWh)	SOx Emission Coefficient (lb/MWh)	Nox Emission Coefficient (lb/MWh)
Combined Cycle	SCR	Natural Gas	848.3	0.00000000	0.00	0.11
Pulverized Coal	SCR+Scrub	Bituminous Coal	2104.3	0.00001071	0.45	0.36
Supercritical Coal	SCR+Scrub	Bituminous Coal	2053.0	0.00001045	0.44	0.35
Pulverized Coal	SCR+Scrub	Sub-bituminous Coal	2180.2	0.00000687	0.29	0.36
Supercritical Coal	SCR+Scrub	Sub-bituminous Coal	2127.0	0.00000670	0.28	0.35
Pulverized Coal	SCR+Scrub	Lignite	2207.9	0.00001003	0.43	0.41
Supercritical Coal	SCR+Scrub	Lignite	2154.0	0.00000979	0.42	0.40

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For a Given Emission Price and a Fuel Price (Altos Model Actually Iterates on This)

- We DON'T do this by guessing.
- We run a model to get it

SO2 Price ($/ton)	Nox Price ($/ton)	Hg Price ($/ton)	CO2 Price ($/ton)	Gas Price	Coal Price
$600	$3,000	$40,000,000	$50	$7.00	$2.00

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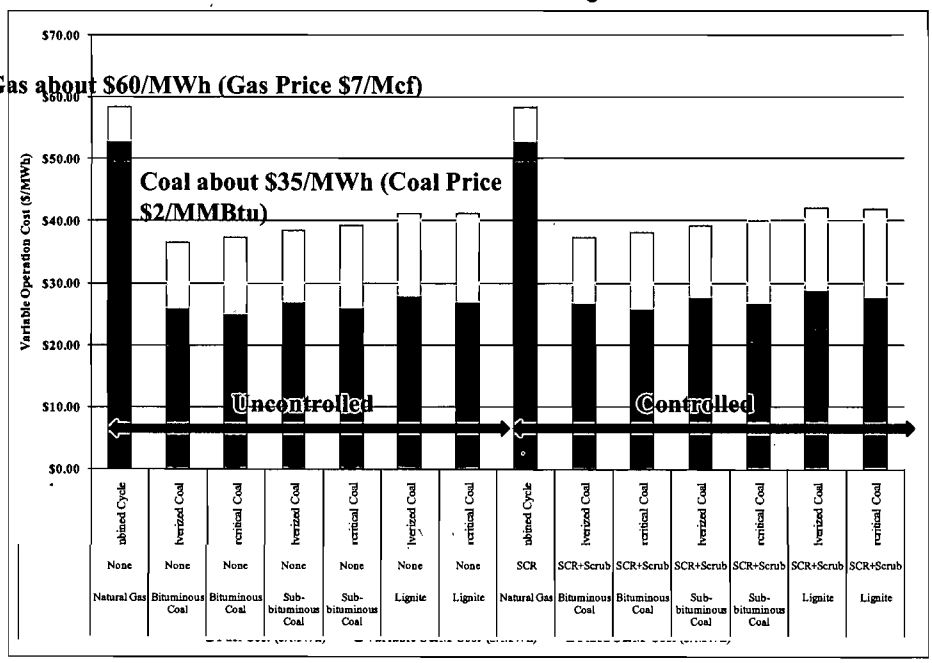
Power Generation Cost—Fuel and O&M Only



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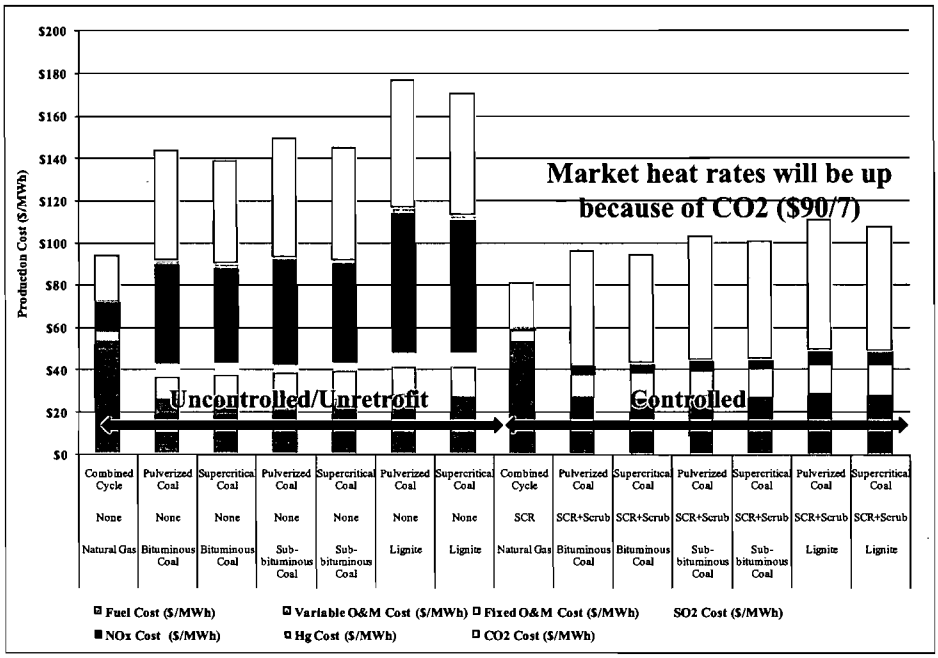
Fully Emissions Burdened Plant Generation Cost (No Depreciation)



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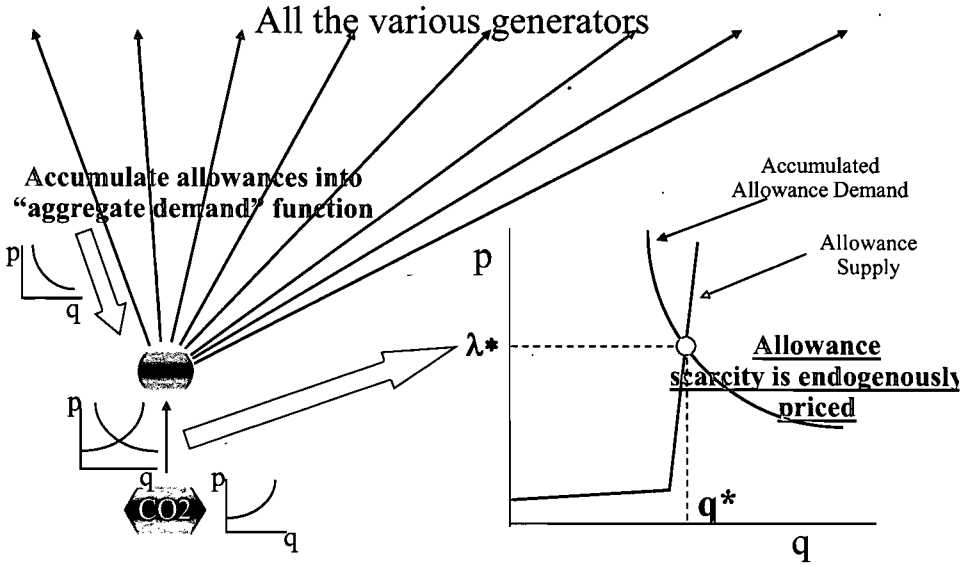
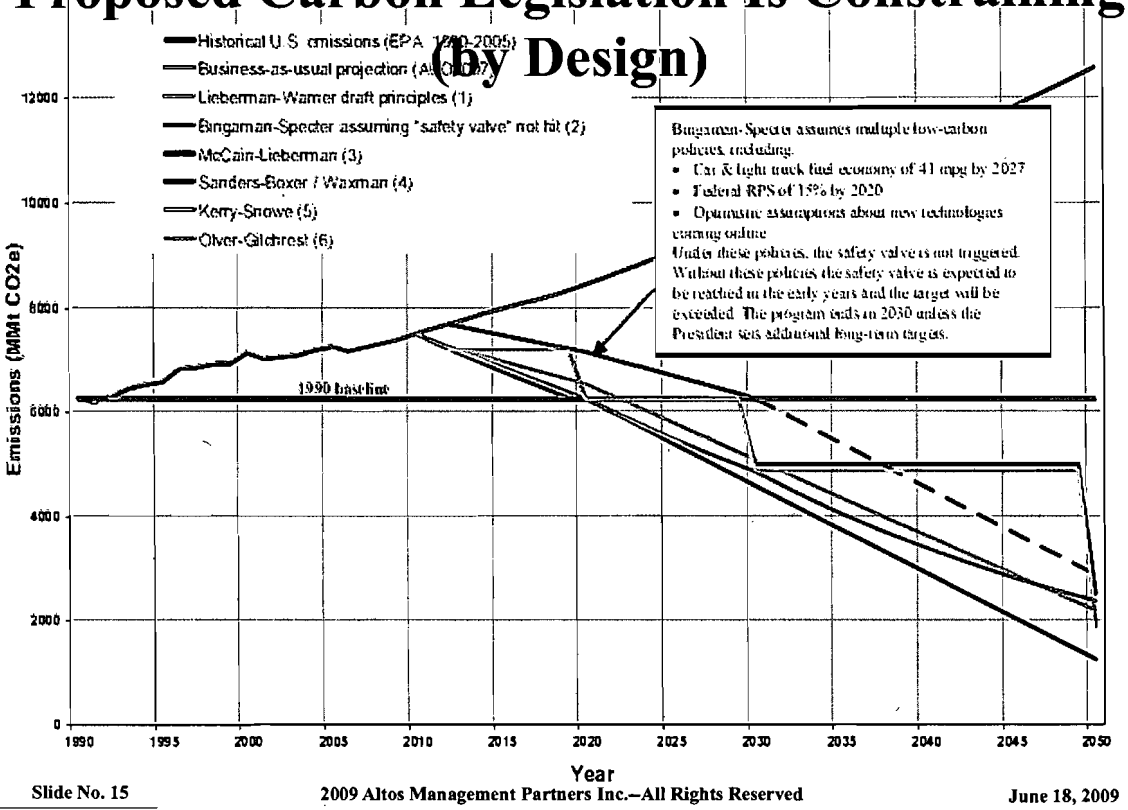
The Regulator (or the Law) Sets the Aggregate Number of Allowances



"Aggregate supply" function is a policy variable

Proposed Carbon Legislation Is Constraining (by Design)



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Carbon "Offsets" Are Being Discussed

- "Plant a banana tree in Honduras."
- This is a method to be used by carbon producers to capture the easy "low hanging fruit" worldwide, demonstrating that they have sequestered easy CO2 and therefore are allowed to produce more than their allowances under the cap.
- There is momentum for and against this.

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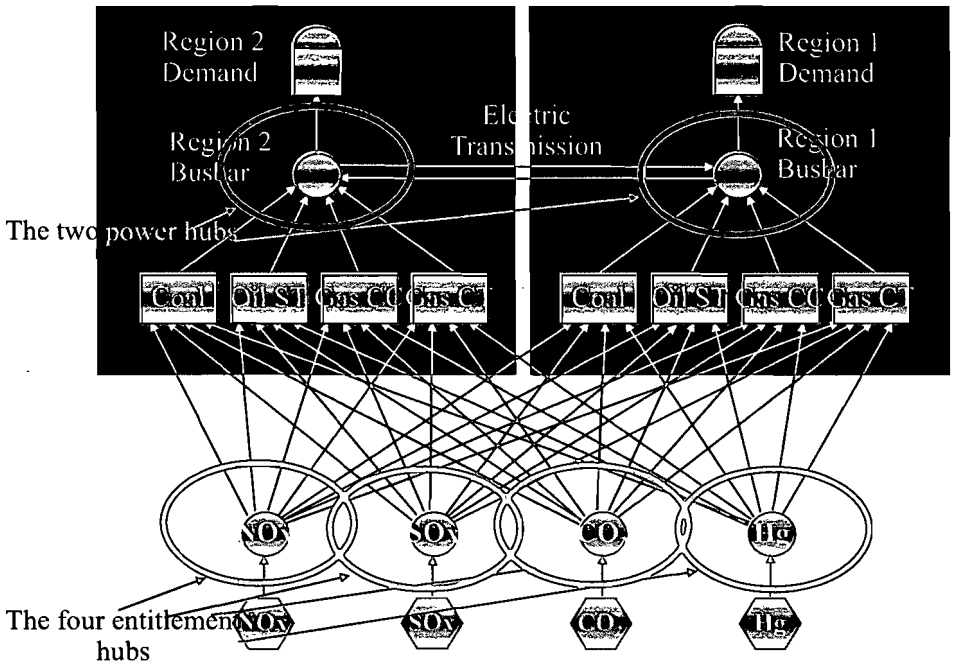
Power Prices Depend on NOx, SOx, Hg, and CO2 Emissions Prices, and Vice Versa



Slide No. 17

June 18, 2009

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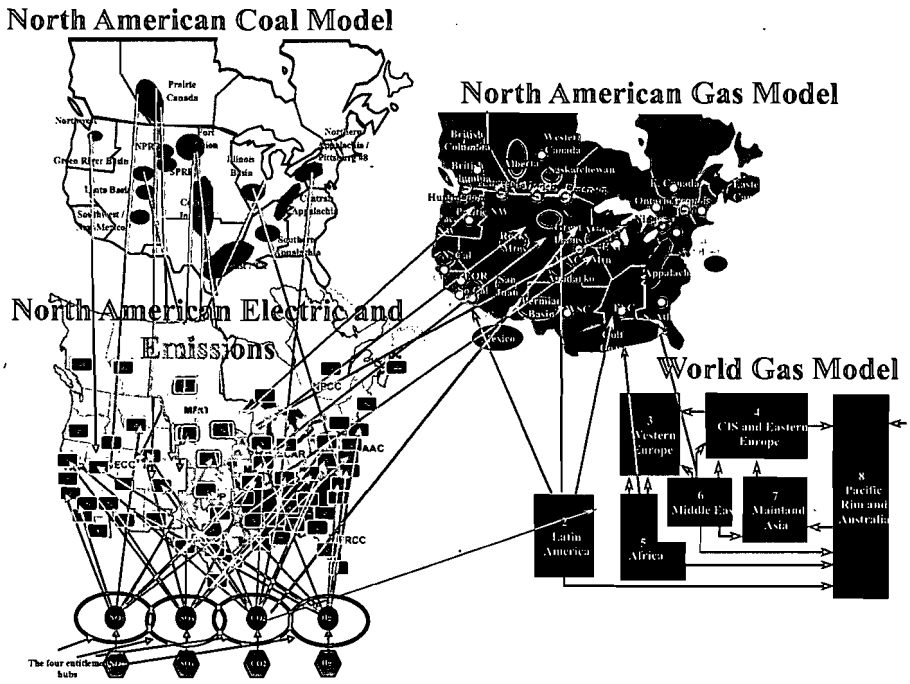
Only Altos' Fundamental, Interconnected Model Can Get the Right Answer



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Altos and Booz Have Teamed to Use This Throughout the Industry

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The Old Way of Introducing Allowances

- **Allocations**—put them in the mail pro rata by last year's generation.
  - Regulated utilities account for them as a REVENUE at market value, i.e., "manna from heaven" mailed to them.
  - Regulated utilities **embed them in dispatch and operations decisions**—they suppress coal and stimulate gas!
  - Regulated utilities decrement that amount of REVENUE from consumer rates, subtracting the manna from heaven from rates
  - Ratepayers do not pay emissions allowance costs directly in higher power prices (they think). This perception is wrong!
- Contrary to vox populi opinion, this is not cost neutral or CO2 neutral!!!!
- Allocations are economically distortionary and lead to inefficient prices and overconsumption. Regulators who are serious do not do this.

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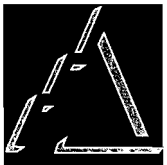
The New Way of Introducing Allowances

- **Original Auction**—start allowances in a government repository.
  - Sell them from the repository to agents in the market who need them to run
  - There is no REVENUE to the utility; there is only an ALLOWANCE PURCHASE COST
  - Regulated utilities then embed those costs in dispatch decisions.
  - Regulated utilities pass those entitlement purchase costs to ratepayers in the form of electricity costs.
  - Ratepayers pay the full emissions allowance cost directly in higher prices.
  - This is NOT distortionary and leads to efficient prices that embed environmental costs.
- Regulators who are serious do this.



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It Is NOT TRUE That CO2 Cap and Trade Regulation Requires Auctions in Order to Be Effectual

- **That is a naïveté promulgated by people without economic models or economic training.**
  - CO2 Cap and Trade with allocations will indeed cut CO2 volumes and increase power prices at wholesale AND retail.
    - However, they will be slower to induce change at retail
  - You don't have to have auctions to affect wholesale and plant utilization.

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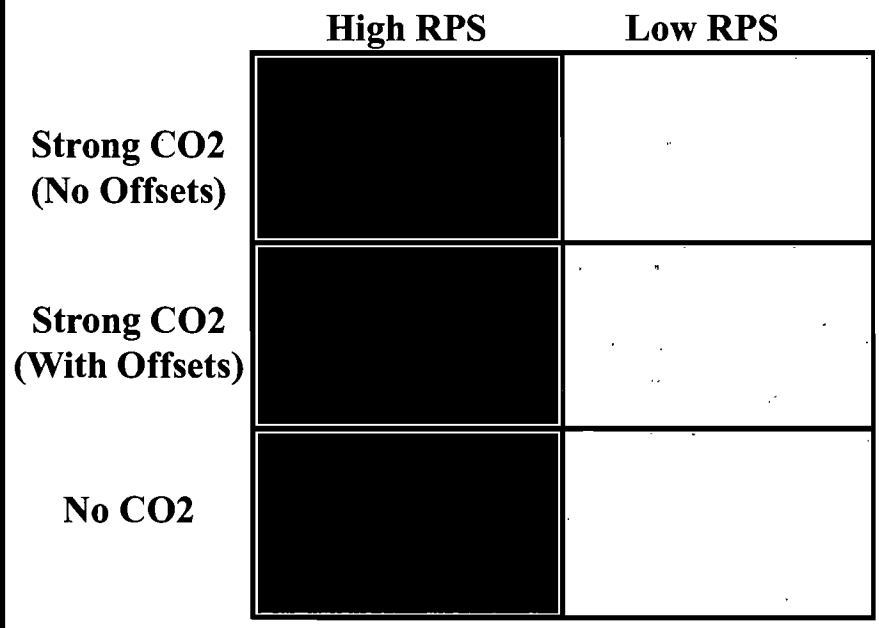
What Companies Ask Us to Do



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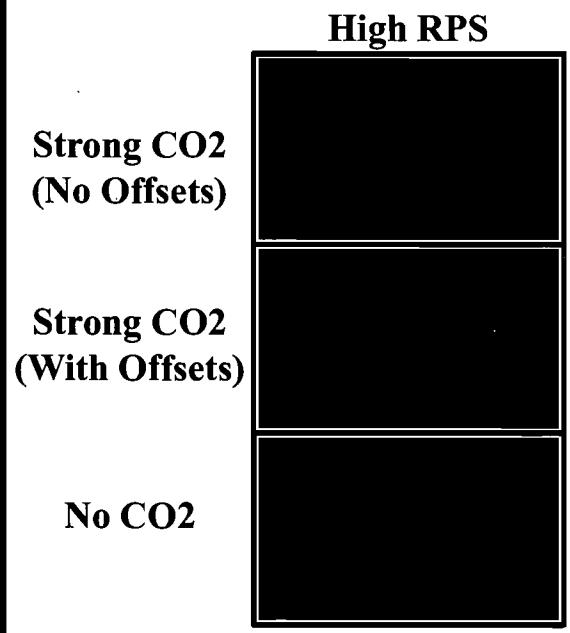
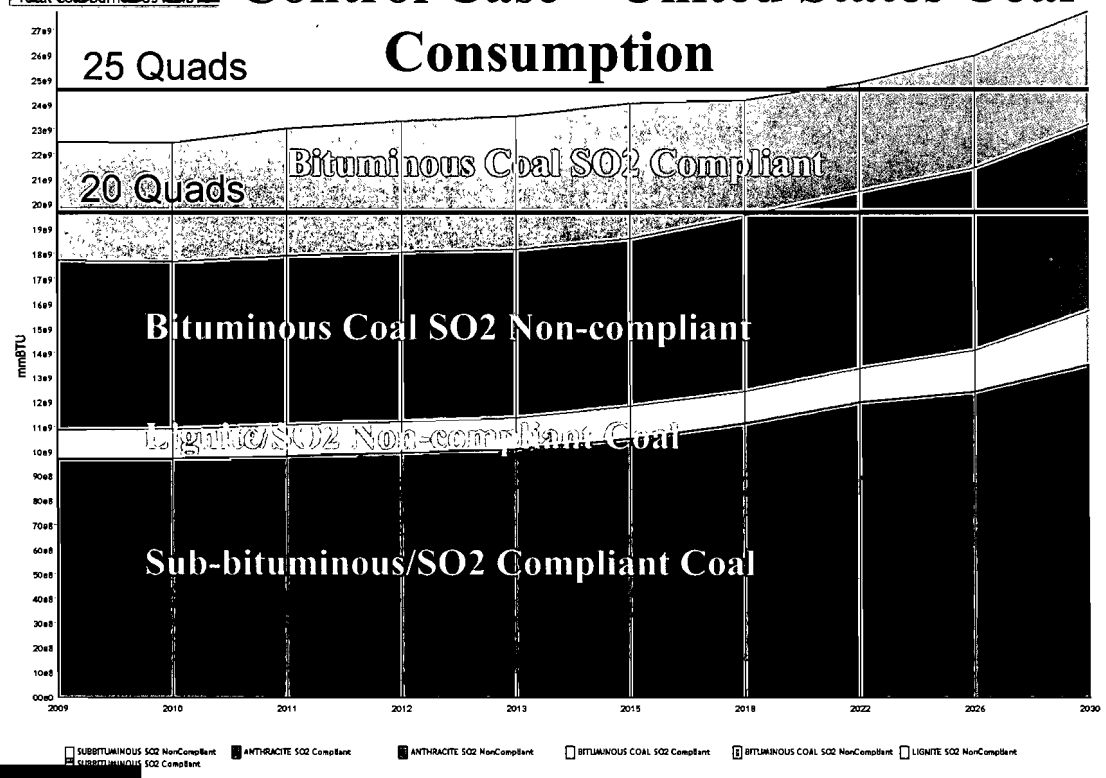
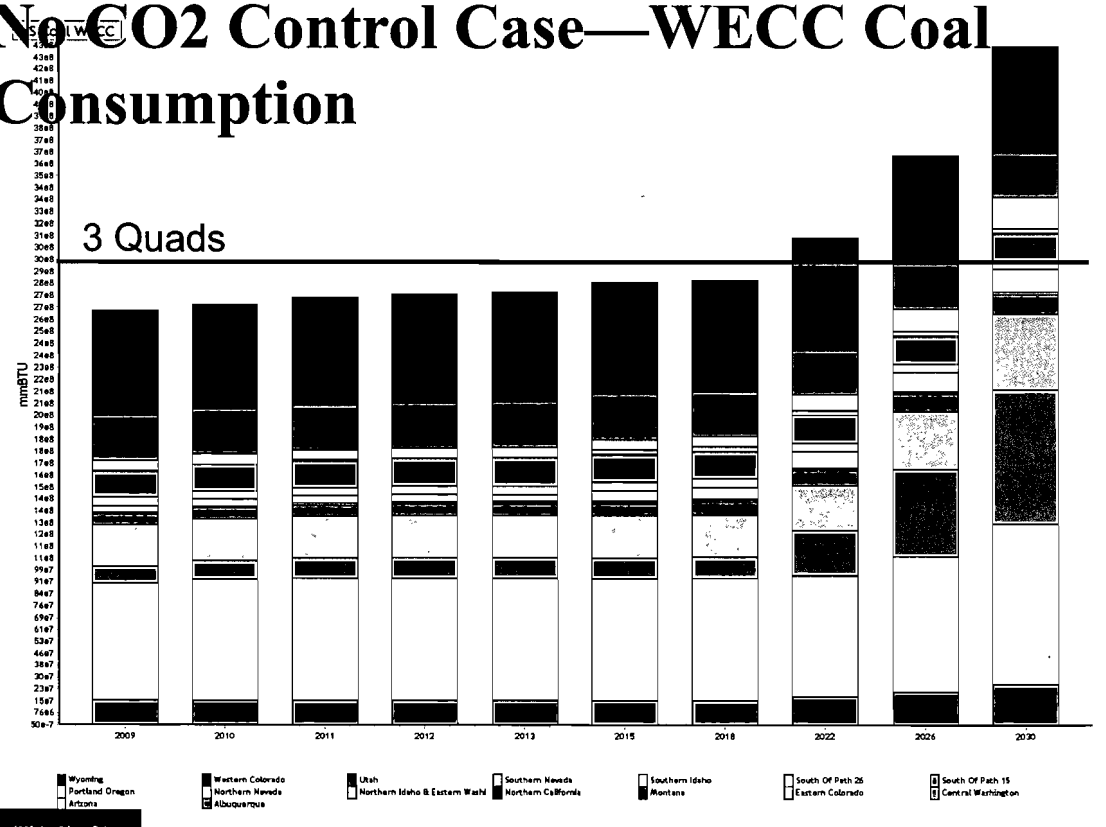
Results Presented Today



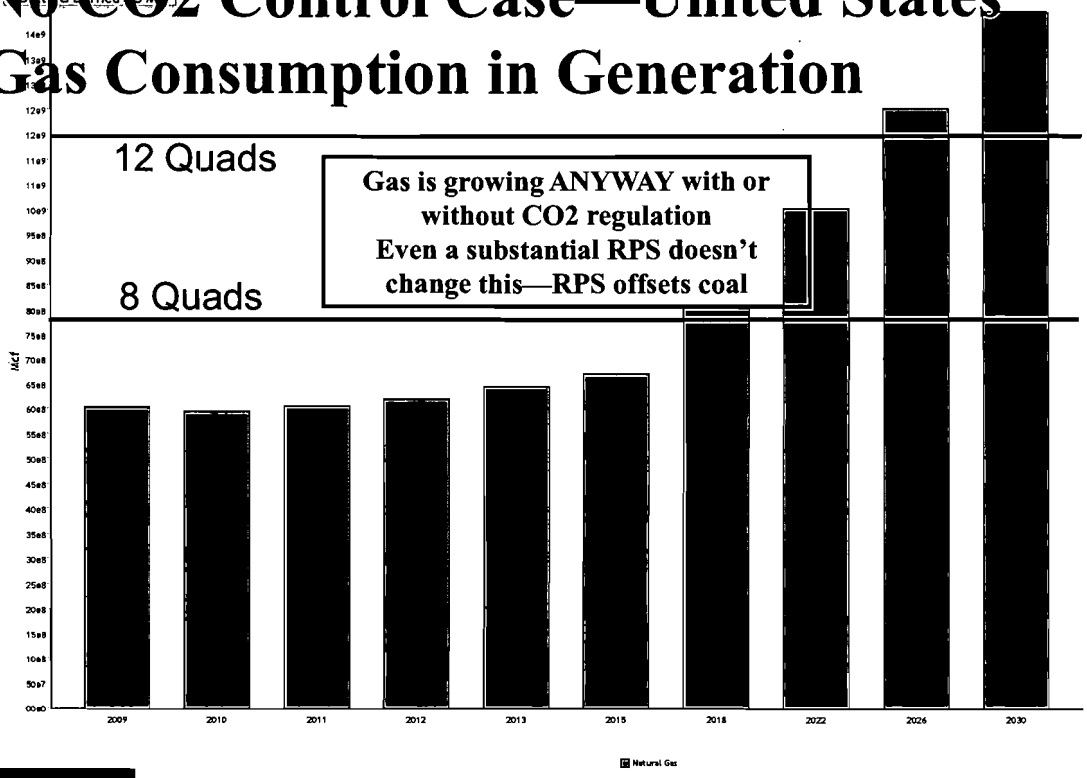
No CO2 Control Case—United States Coal Consumption



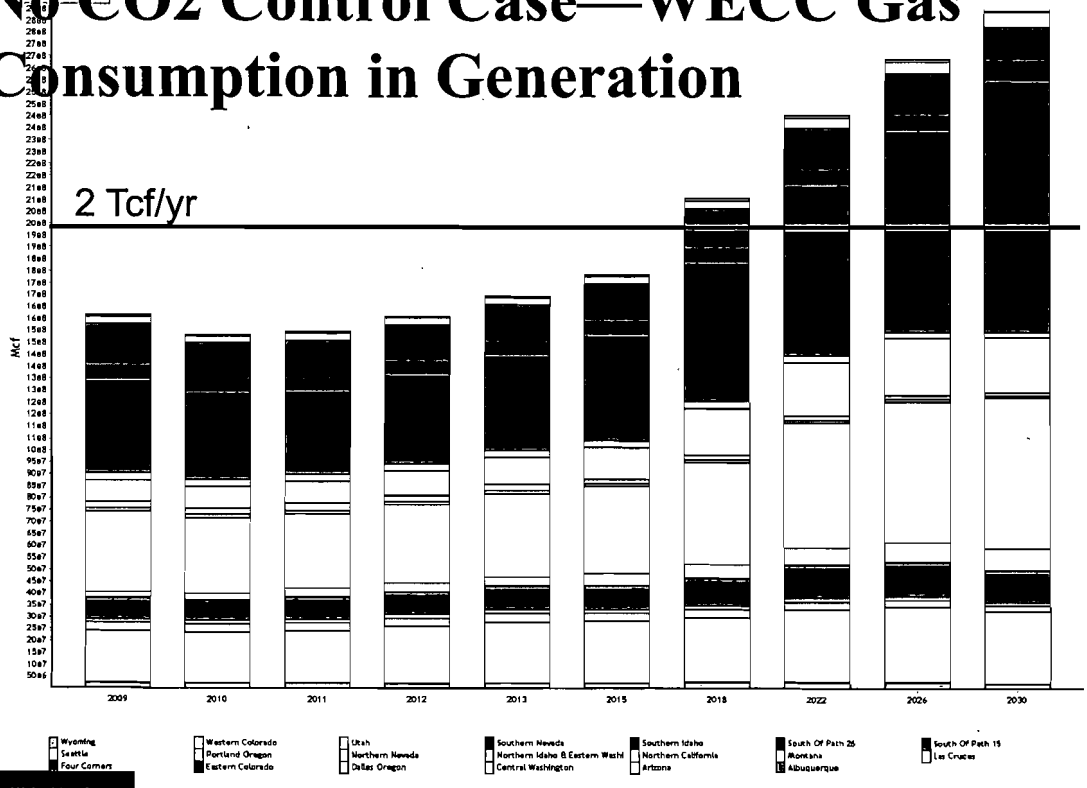
No CO2 Control Case—WECC Coal Consumption



No CO2 Control Case—United States Gas Consumption in Generation



No CO2 Control Case—WECC Gas Consumption in Generation



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Other Results Available (Omitted for Brevity Here)

- Complete generation utilization for all 140 interconnected generation regions.
- Complete slate of capacity additions for all 140 interconnected generation regions.
- Complete transmission utilization and build schedule
- Complete load profile
  - Net energy for load
  - Ancillary services and reserves

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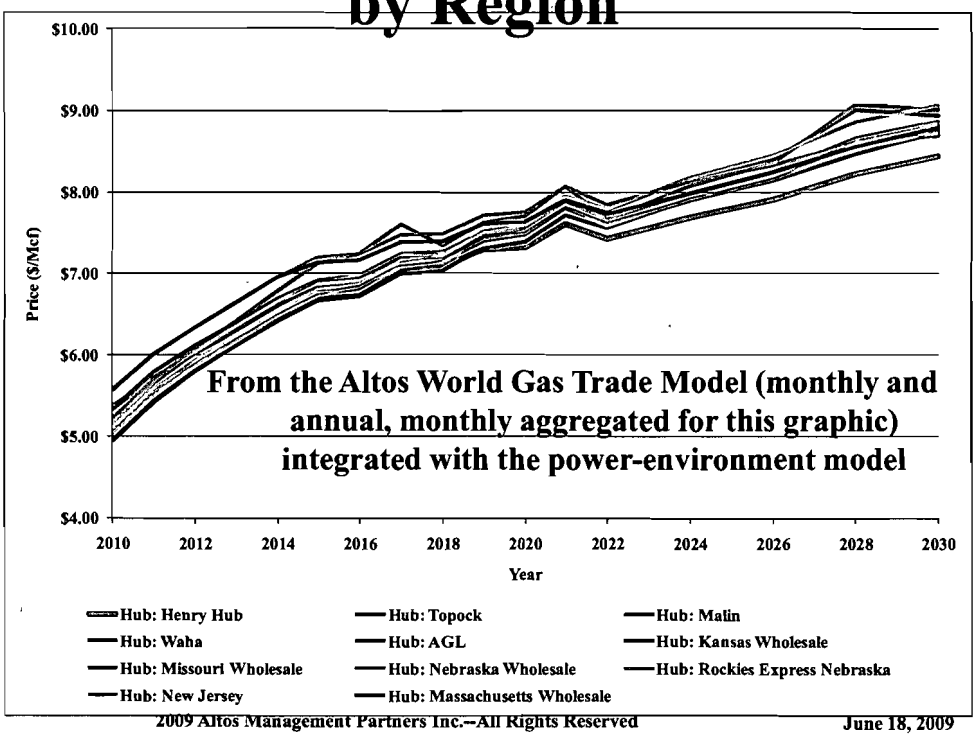
No CO2 Control Case—Gas Price by Region



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The Altos World Gas Trade Model

- Sophisticated temporality
  - **Annual time points.**
  - **Monthly time points for each annual time point.**
  - Fully endogenizes capital investment, storage, pipeline sizing, LNG supply chain sizing and timing, tanker dispatch, and worldwide storage and monthly demand variability.
  - Full endogenizes resource base depletion worldwide.
- Multiregion world focus

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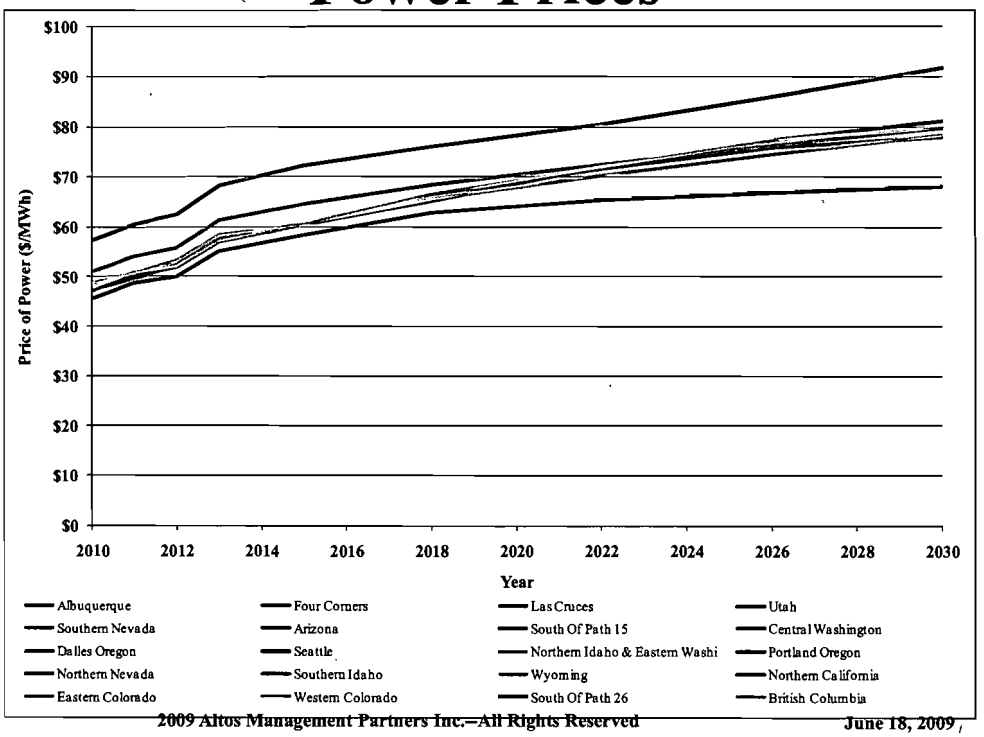
No CO2 Control Case—Regional Power Prices



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First CO2 Control Case—Waxman-Markey with Offsets

- With both CO2 cap and offsets (per Waxman-Markey)
  - 2 billion tons of offsets (total) make a very significant difference.
  - Total effective reduction in emission (including offsets) is assumed to be 10 percent of 2005 levels by 2030 (0.9 times 2005).
    - Allowances and offsets apportioned pro rata between the electric sector and other sectors.
  - RPS increased to Federal standard.

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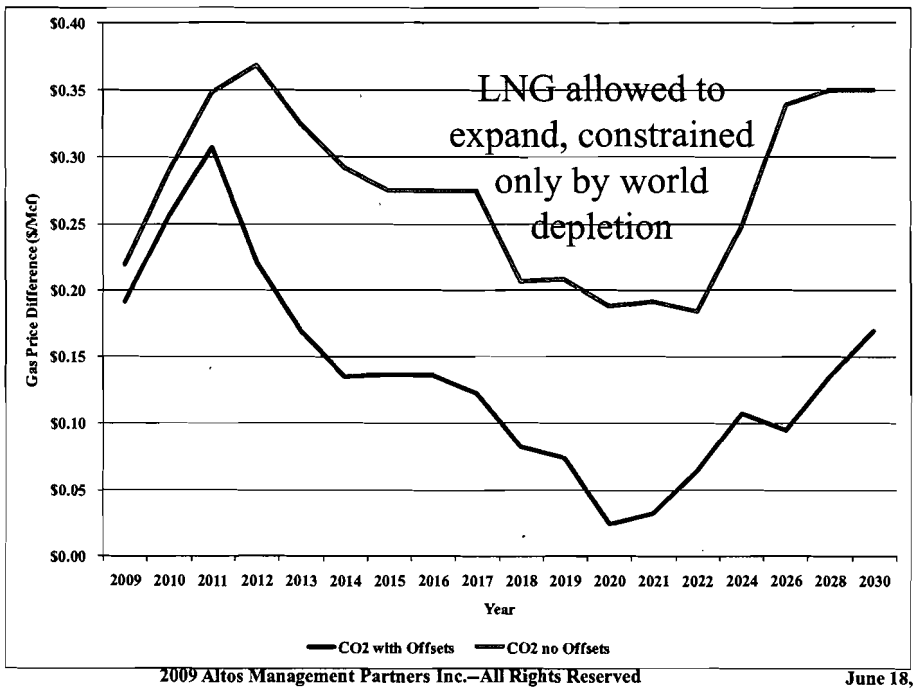
Henry Hub Gas Price Differential



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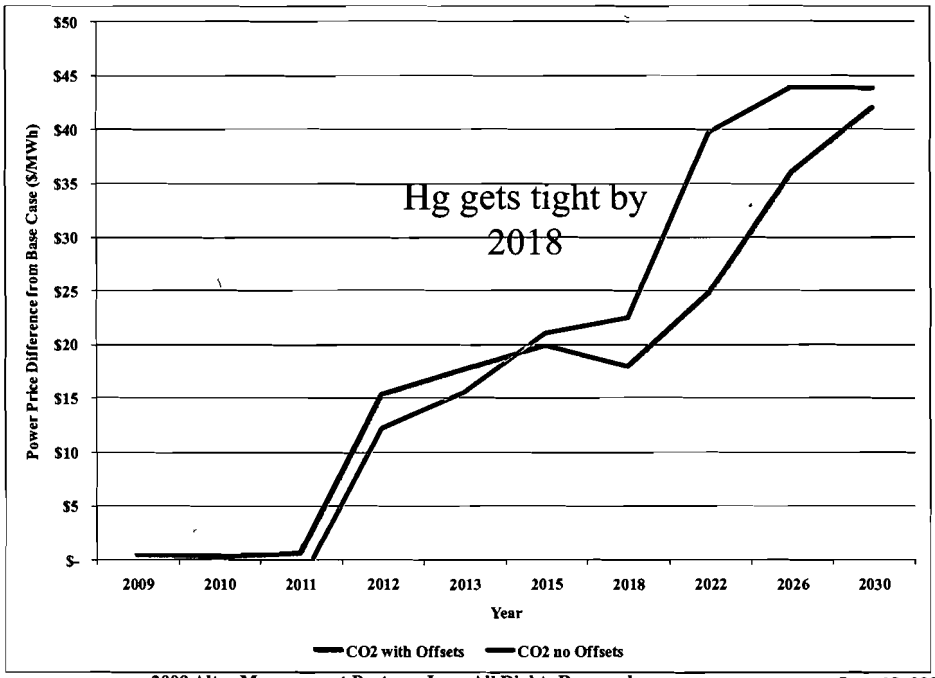
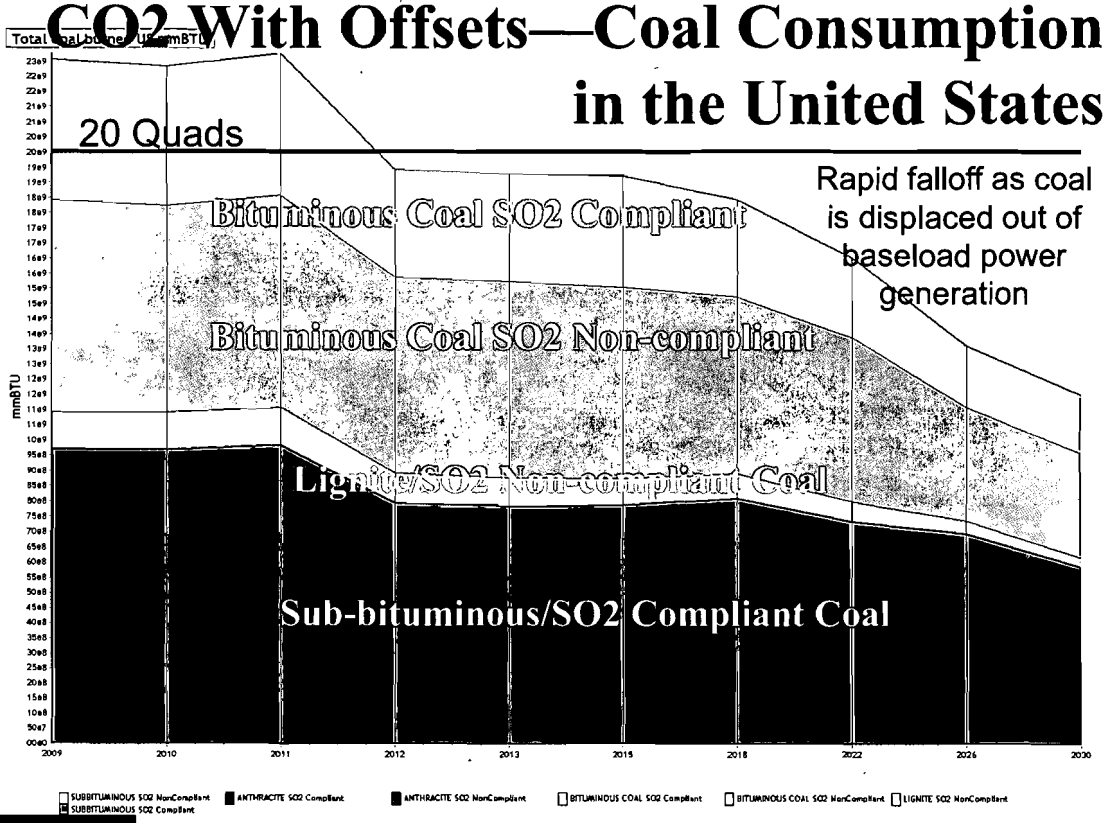
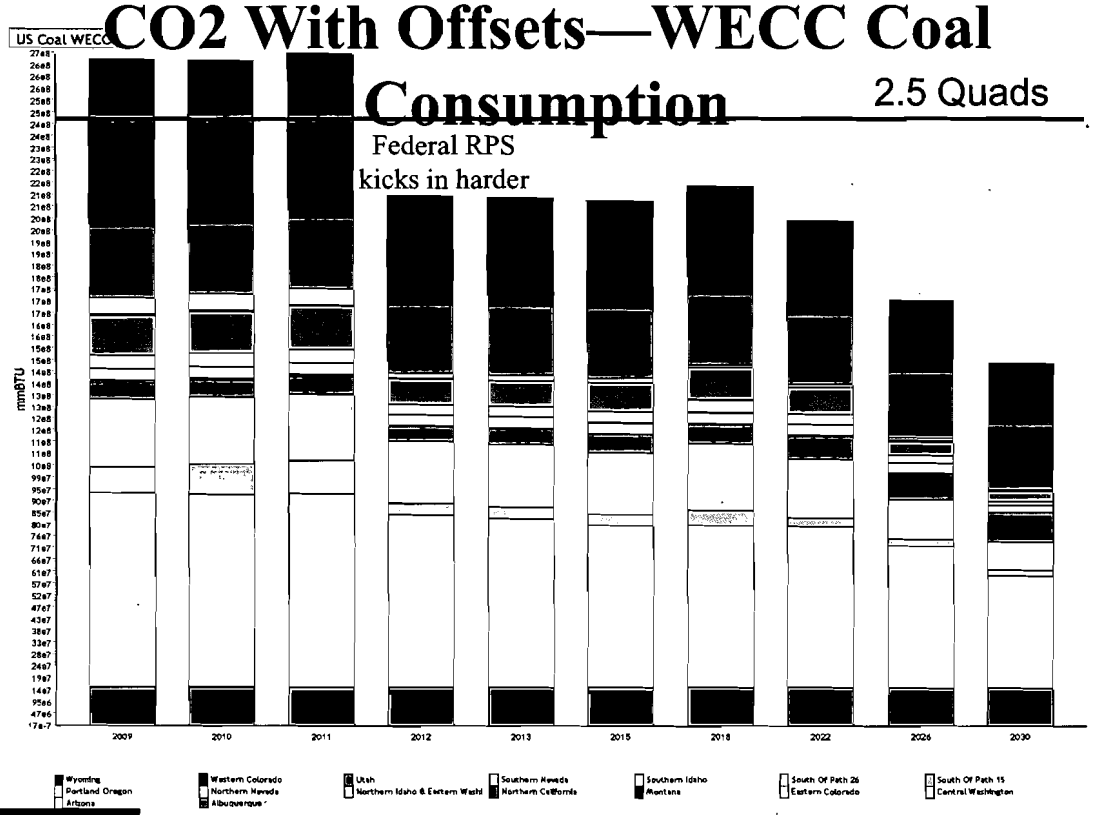
South Path 15 Annual Electricity Price Difference



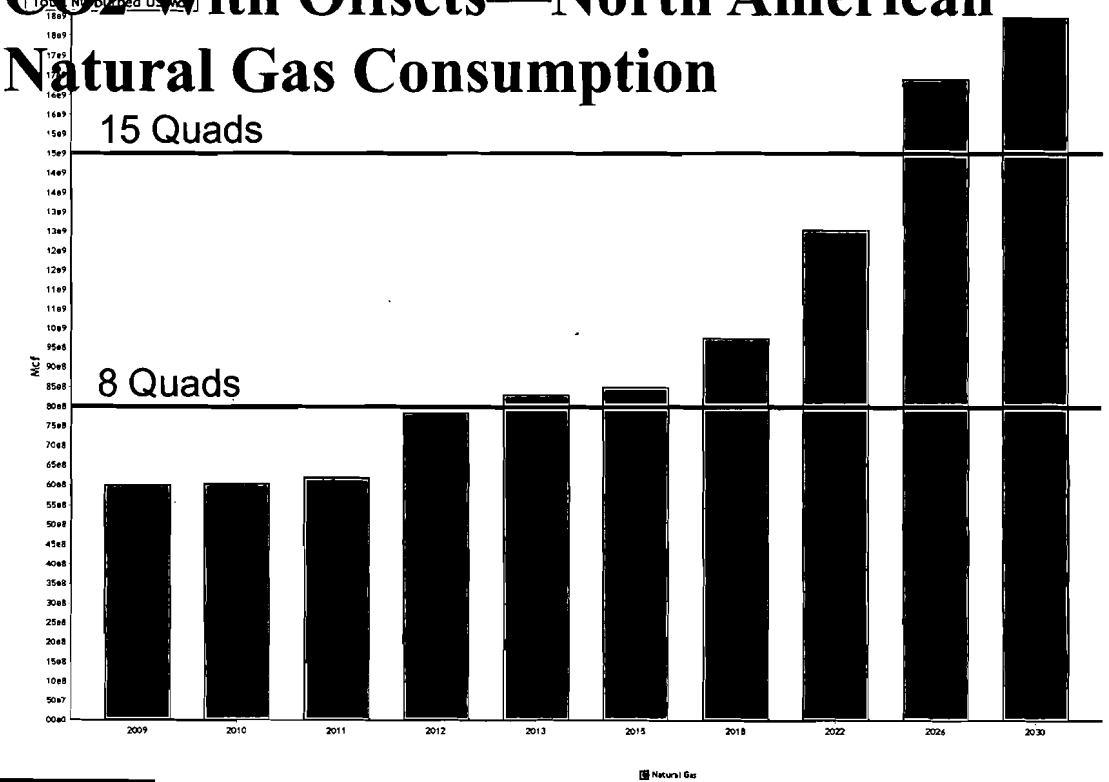
CO2 With Offsets—Coal Consumption in the United States



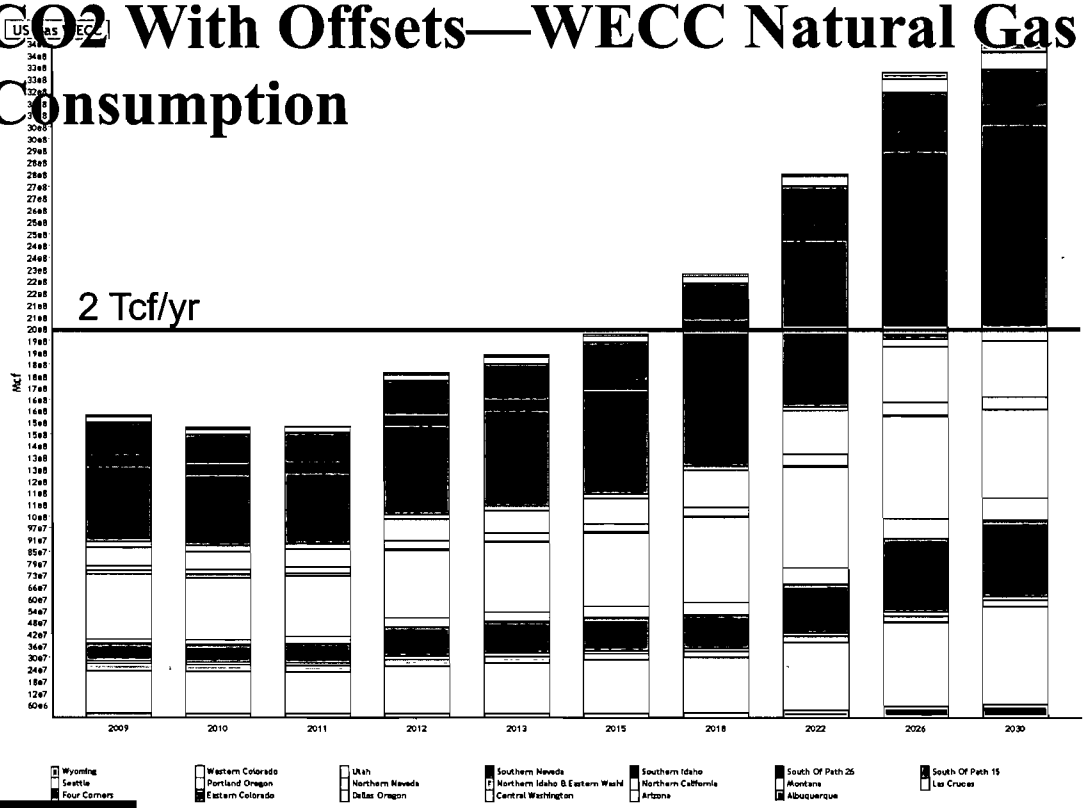
CO2 With Offsets—WECC Coal Consumption



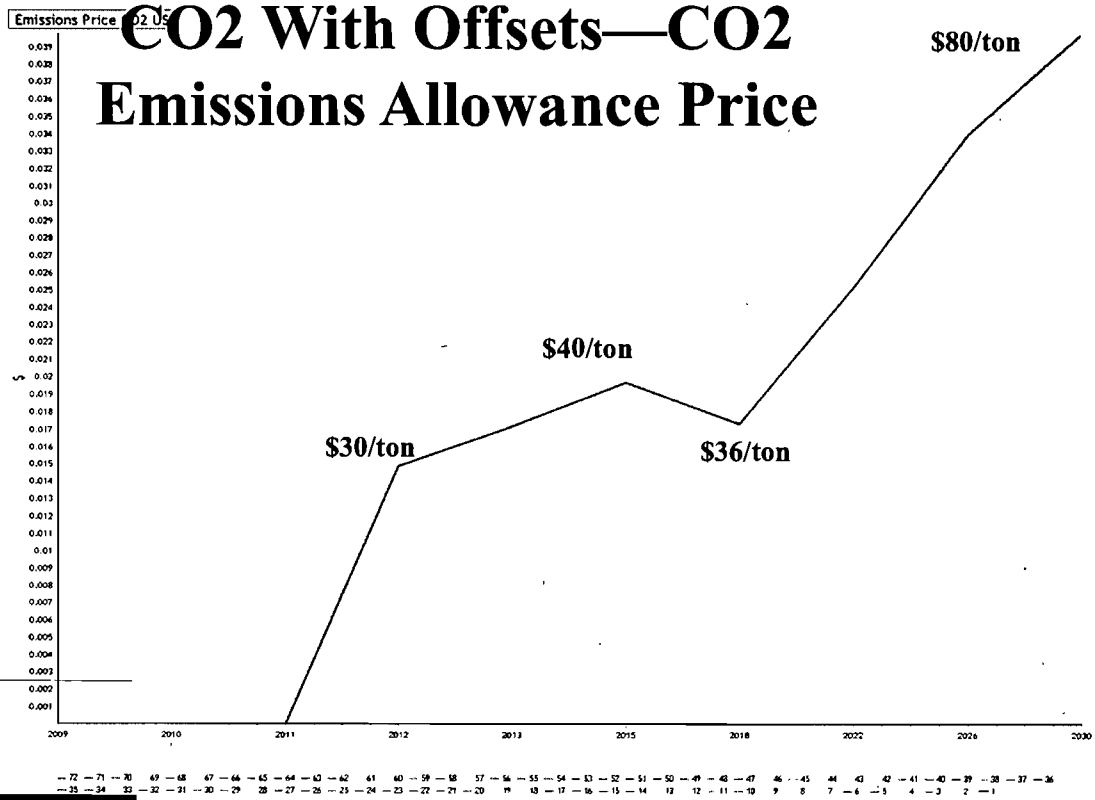
CO2 With Offsets—North American Natural Gas Consumption

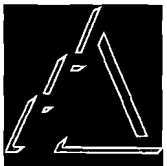


CO2 With Offsets—WECC Natural Gas Consumption



CO2 With Offsets—CO2 Emissions Allowance Price





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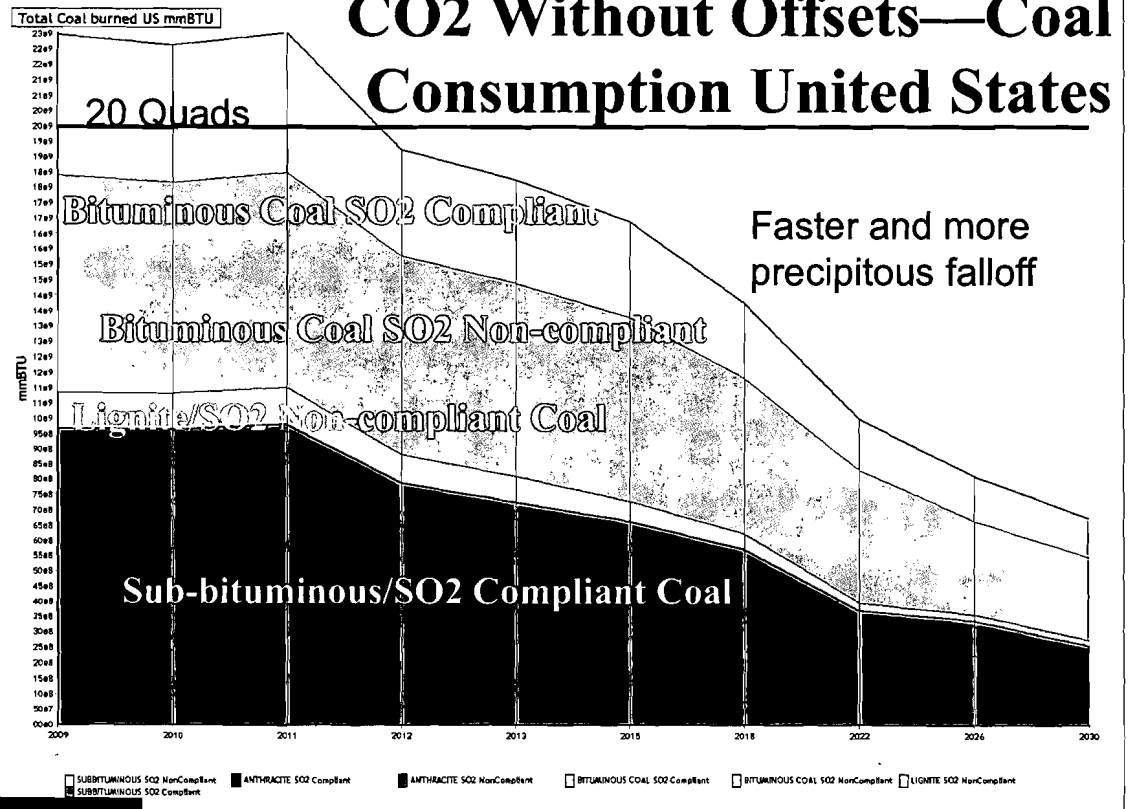
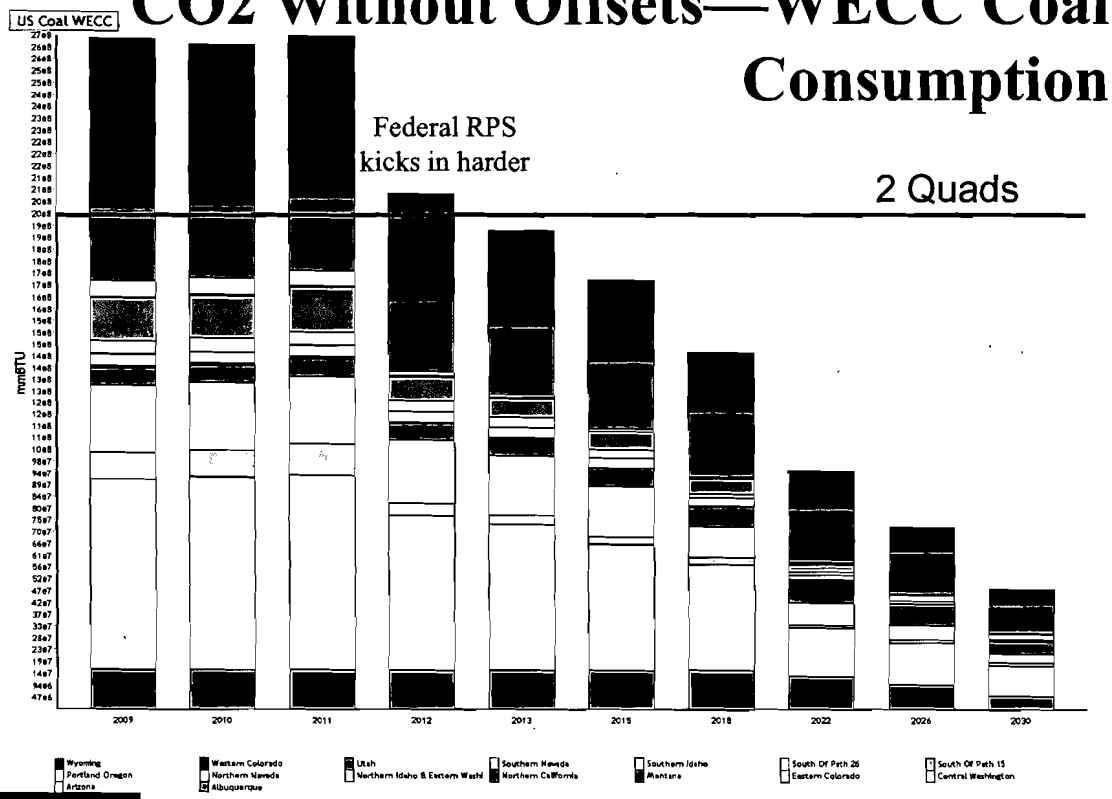
Second CO2 Control Case—Waxman-Markey without Offsets

- Waxman Markey caps but elimination of offsets
  - Tighter carbon cap scenario against generation and transportation
  - Reduction in emissions relative to today
    - CO2 cap at 42 percent of 2005 levels by 2030, (i.e., 58 percent reduction between now and 2030).
    - Not markedly different in the longer term from the original Lieberman-Warner legislation proposed last year, but a slower initial path to get there.

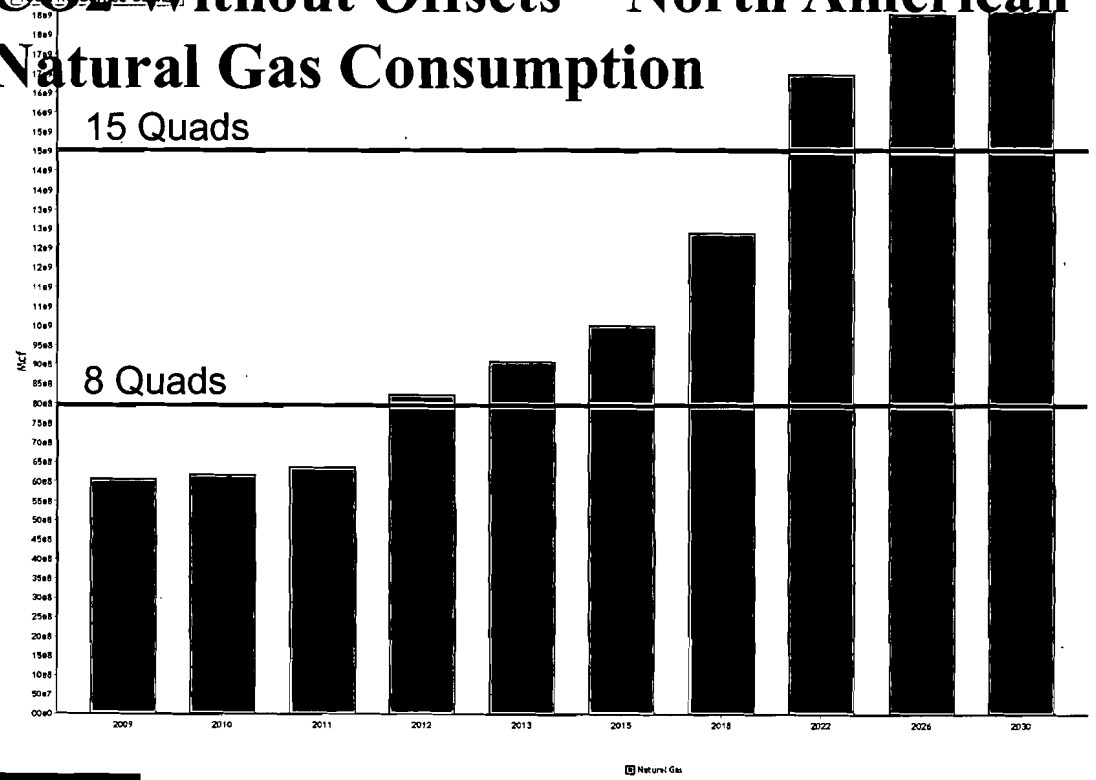
CO2 Without Offsets—Coal Consumption United States



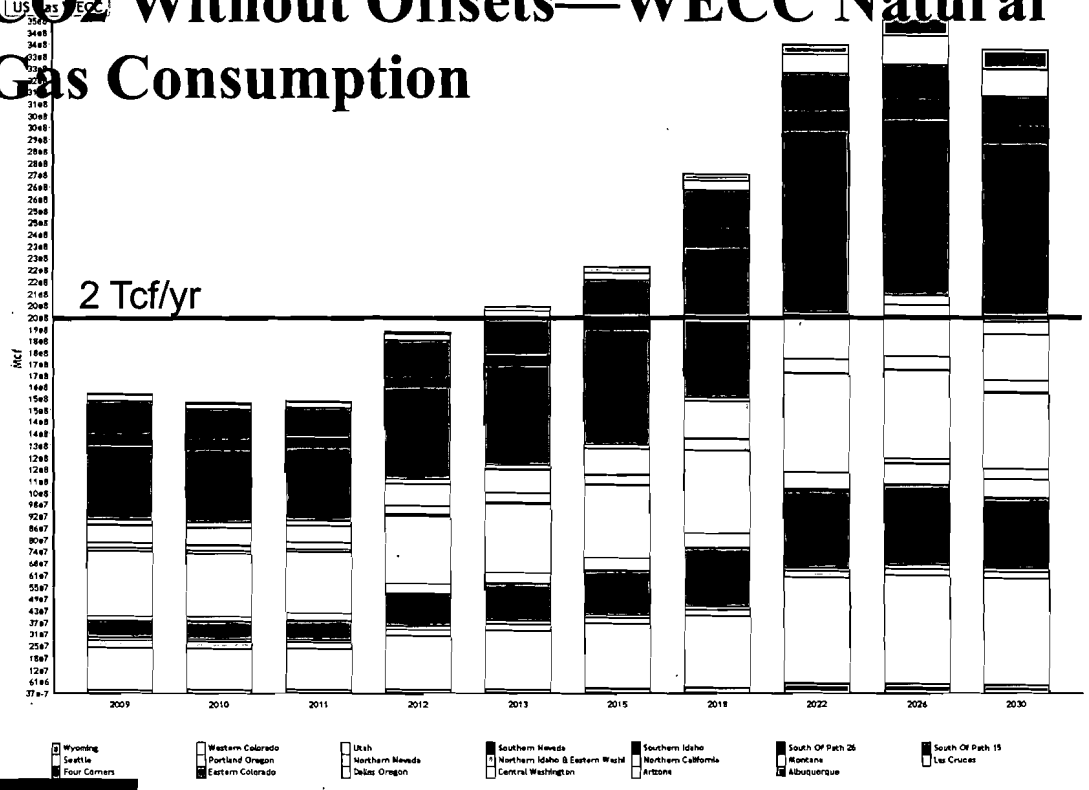
CO2 Without Offsets—WECC Coal Consumption



CO2 Without Offsets—North American Natural Gas Consumption



CO_2 Without Offsets—WECC Natural Gas Consumption



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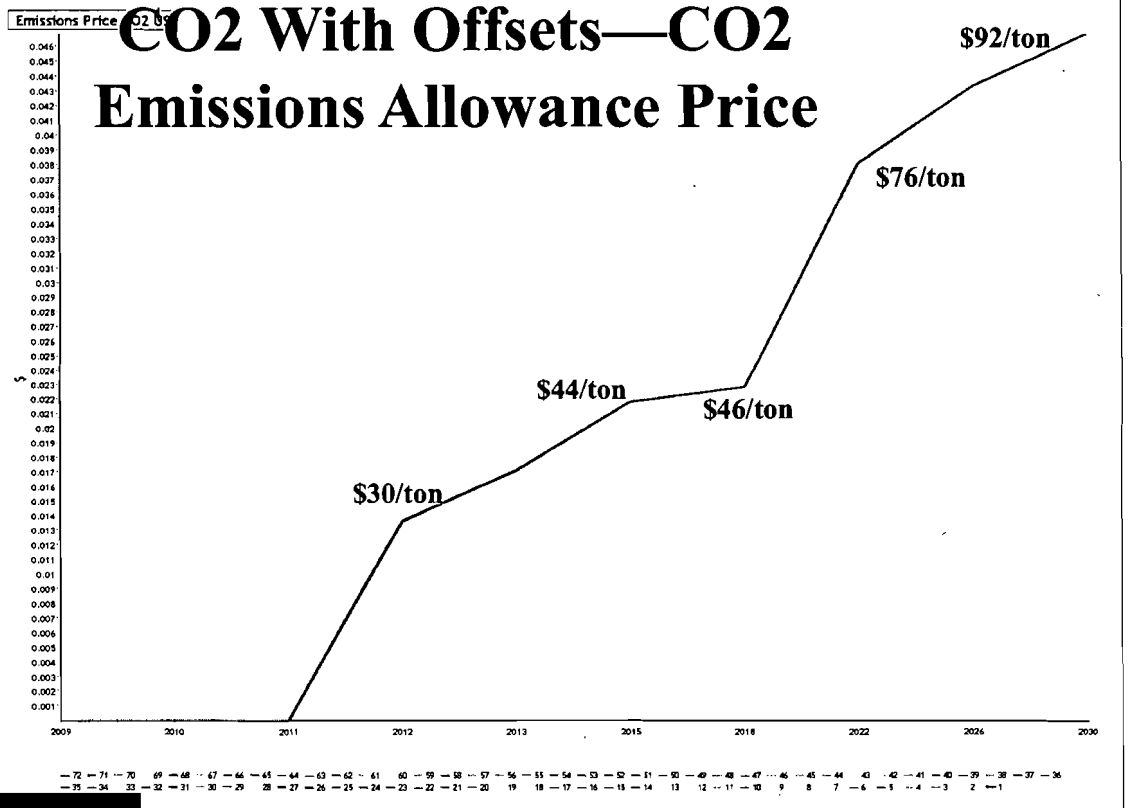
Gas Consumption <u>Has to Increase Markedly</u> with or without Offsets

- There is no alternative.
  - The benefits of gas and renewables are strongly synergistic; they go hand in hand.
  - As a matter of policy, **<u>one does NOT want to restrict gas supply</u>**, whether LNG, domestic production, or unconventional gas production.
  - Gas is the friend of renewables, not the enemy.
- Gas consumption is going to increase even without CO2; SO2, NOx, and mercury regulations and high cost of new coal generation are enough.

CO2 With Offsets—CO2 Emissions Allowance Price



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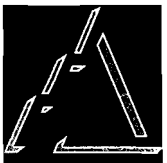
Is This Reasonable? Correct?

- Let's overlay the economics with the stoichiometry to see why it is very reasonable.



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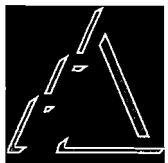
Typical Power Plant Production Cost

- Gas steam turbine (marginal):
  - $7.00/MMBtu * 10.0 MMBtu/MWh +$3/MWh = $73/MWh
- Coal steam turbine:
  - $2.5/MMBtu * 10.0 MMBtu/MWh + $9/MWh = $34/MWh



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Let's Calculate Generation Cost of Coal and Gas (With Retrofit), Taking Account of a To-Be-Calculated Carbon Price

Gas CC Production Cost

$$73\frac{\$}{MWh}+p_C\frac{\$}{lb\ CO2}\ (\text{Carbon price})\ 117\frac{lbCO2}{MMBtu\ gas}\ (\text{Emission coefficient—Chemistry})\ 10.0\frac{MMBtu\ gas}{MWh}\ (\text{Heat rate})$$

$$=73+1170p_C$$

Coal Production Cost

$$34\frac{\$}{MWh}+p_C\frac{\$}{lb\ CO2}\ (\text{Carbon price})\ 205.3\frac{lb\ CO2}{MMBtu\ coal}\ (\text{Emission coefficient—Chemistry})\ 10.0\frac{MMBtu\ coal}{MWh}\ (\text{Heat rate})$$

$$=34+2053p_C$$

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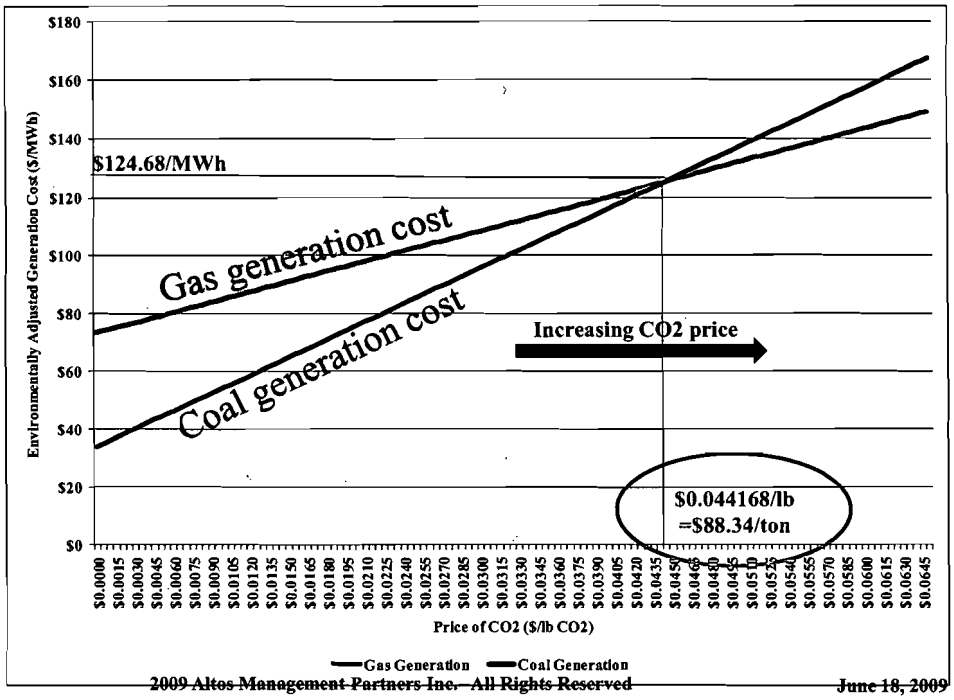
Plot Gas and Coal Generation Cost as a Function of CO2 Price



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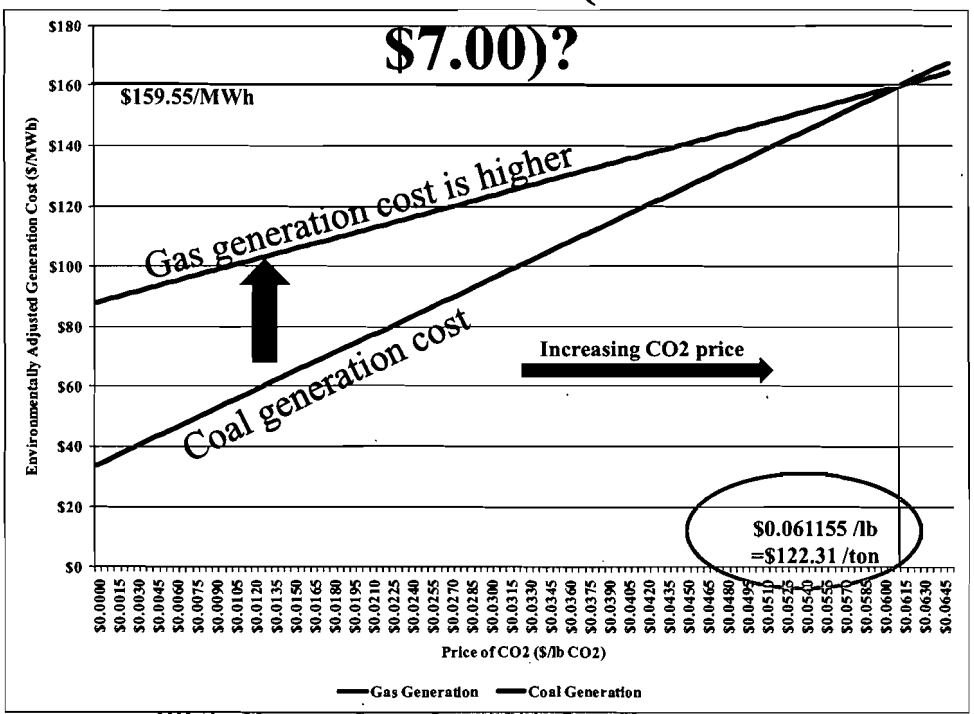
Higher Gas Price—What If Gas Were $8.50/MMBtu (Rather Than $7.00)?



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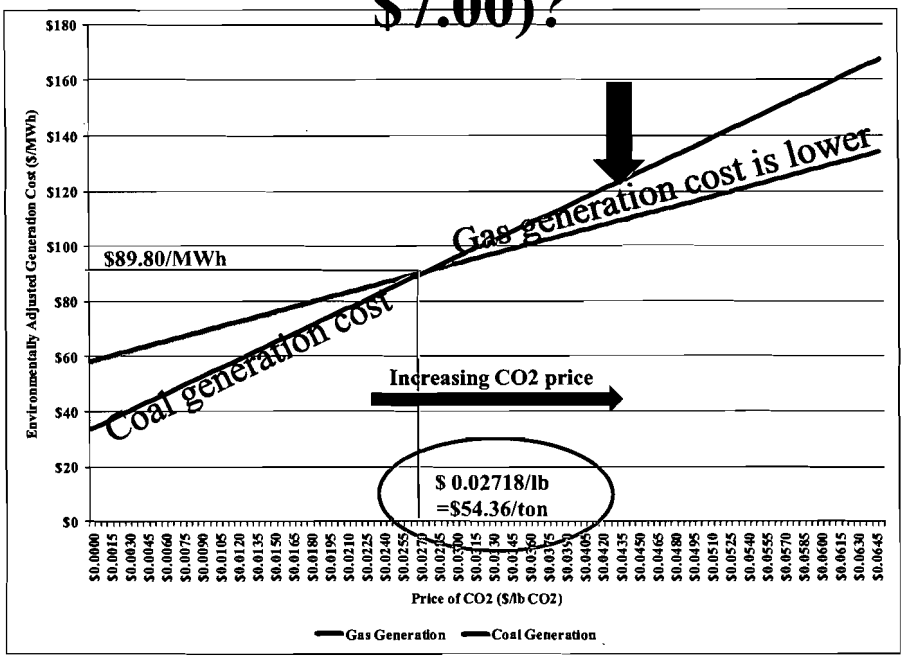
Lower Gas Price—What If Gas Were $5.50/MMBtu (Rather Than $7.00)?



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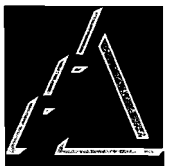
Insight

- CO2 price must **close the entire gap between coal and gas production cost**; otherwise, the cap is not going to be met.
- In reality, SO2, NOx, and Hg contribute (CO2 doesn't have to do all the work), and they decrease this CO2-only price to the levels calculated and displayed in the model.
- **The gap IS a function of coal and gas price.**
  - It is the magnitude of the gap that matters.
  - This is true no matter how high gas price gets!!!!



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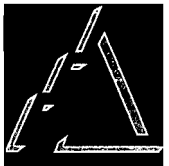
You CANNOT Run Scenarios on CO2—Scenarios Are Entirely Specious

- The CO2 allowance price is an **endogenous** function of gas-to-coal price differential (AND all other emissions prices).
- CO2 price doesn't just materialize out of thin air.
- The idea of sticking
  - $10/ton
  - $20/ton
  - $30/ton
  - $50/ton
  - $60/ton

  into a production simulation model of the power system is preposterous.
- ALL ARE WRONG; you now know WHY.
  - CO2 price is endogenous to the fuel and generation selection decision, and we model that.



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CO2 Capping Raises Rates to Electricity Ratepayers

- CO2 cap and trade will increase baseload power cost by a factor of 2-5.
- Who bears the consequences of that?
  - Residence (No!)
  - Commercial (Some!)
  - 24/7 Industry (Yes, if they remain in North America)
  - Casinos, discos, bars, Denny's, speakeasies, Elliot Spitzer's hotel room, piano bars, and IHOPs (Yes!)
- There will be hundreds of billions of dollars of electric rate increases in the United States economy with or without allocation/auction.

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A "Safety Valve" Is Just a Tax

- A safety valve CO2 price, if binding, means that we are producing CO2 in excess of the stated cap; we are not hitting the cap.
- If not binding, the regulators will reduce it until it IS binding.
- When prices are zero, regulators reduce caps.
- This isn't hard, and regulators will not face a Senate committee if the market price of CO2 is zero!

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If You Have a CO2 Cap

- You don't retrofit today's coal plants with SCR, scrubbing, or mercury.
  - To do so would be imprudent.
  - You would rather run them uncontrolled until such time as CO2 retires them, decommission them, and bear costs at that time.
  - Impending CO2 capping has already decremented new coal generation construction.

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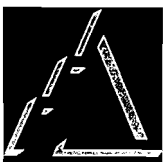
Clean Coal Is Difficult

- CO2 control—four methods
  1. **Direct arrest and removal of CO2 gas from flue gas.** This is the only viable option. I am affiliated with a startup company endeavoring to do this.
  2. **Oxygenation.** (This is what "oxygen blown coal gasification" strives to do)
  3. **Hydrogenation.** (This is what coal gasification strives to do)
  4. **Doing without, just sequester in deep aquifers.** This is expensive and difficult and my not sequester the CO2 because of leakage.



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2. Renewables and Renewable Energy Credit

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Qualified Renewables (by Law or Regulation)

- Solar Water Heat
- Solar Thermal Electric
- Photovoltaics
- Landfill Gas
- Wind, Biomass
- Hydroelectric
- Geothermal Electric
- Geothermal Heat Pumps
- Tidal Energy
- Wave Energy
- Ocean Thermal
- Municipal Solid Waste
- Anaerobic Digestion
- Biodiesel
- Fuel Cells using Renewable Fuels

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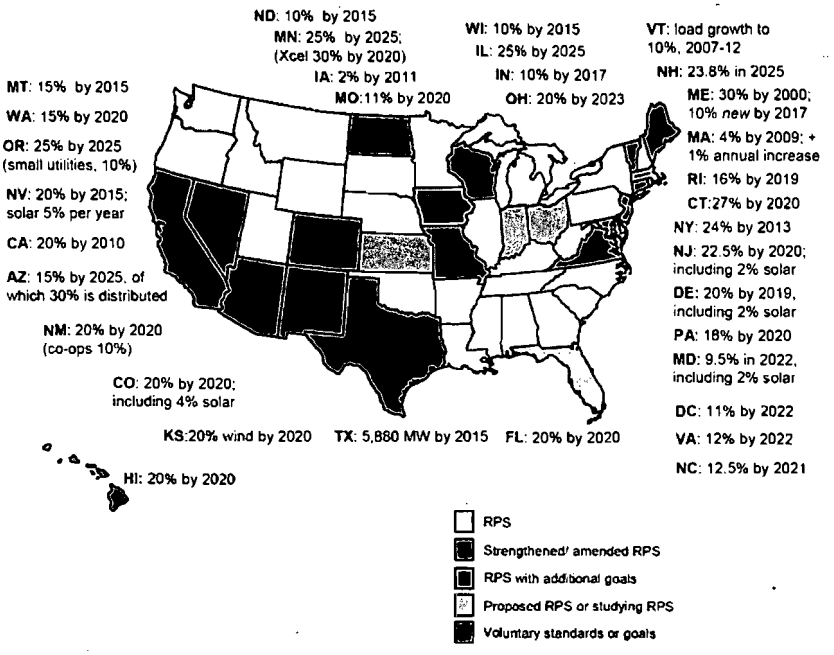
Most States (and the Fed) Have Imposed Renewables Portfolio Standards



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1. **Wind**
2. Solar
3. Biomass
4. Geothermal
5. Other

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What Do We Know About Wind

- The best wind turbines generate about 30 percent of the time because that is the frequency of occurrence.
  - They do NOTHING the other 70 percent of the time.
- Altos/Booz gathered wind patterns everywhere in the United States
  - The generation pattern is random with one critical exception—wind does NOT blow during the hottest part of the day because there is generally temperature inversion.
- Wind capacity factors are lowest during time of absolute peak; wind turbines don't spin during temperature inversion.
  - ERCOT during summer 2008
  - California during heat storm of 2007

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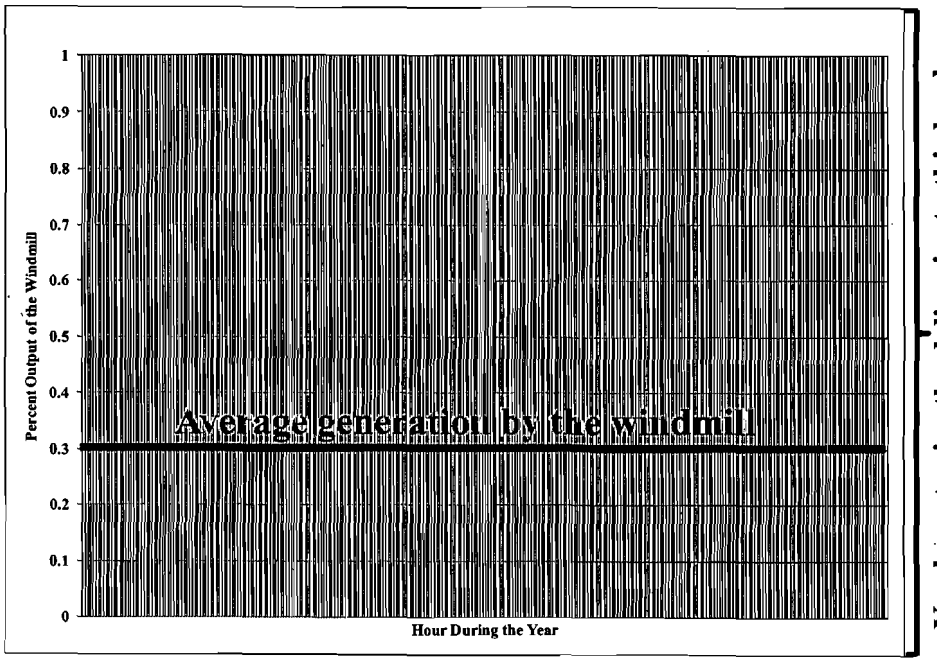
How Wind Generates



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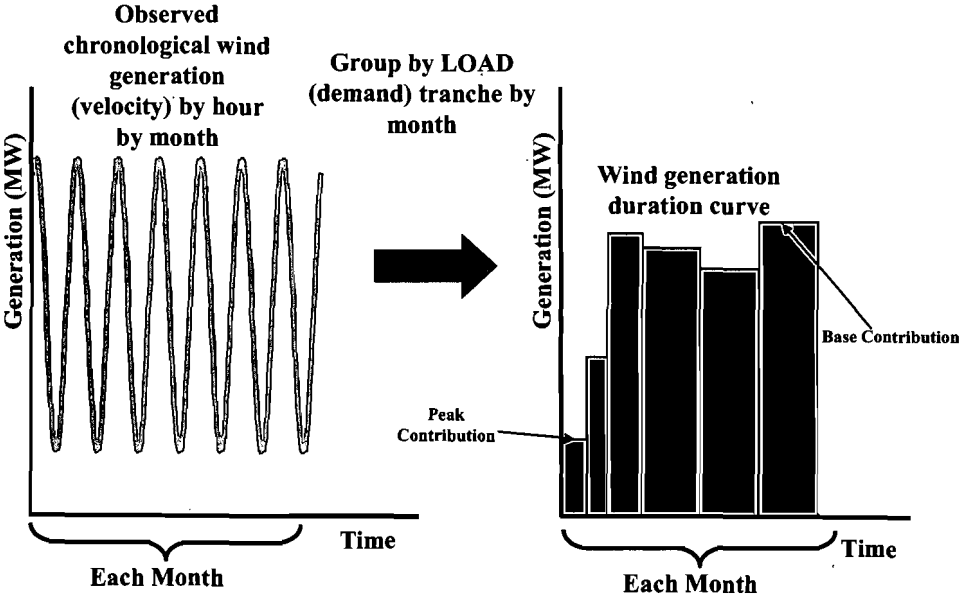
Group Hourly Wind Generation for Each Month into the Peak-Intermediate-Base Hour Tranches



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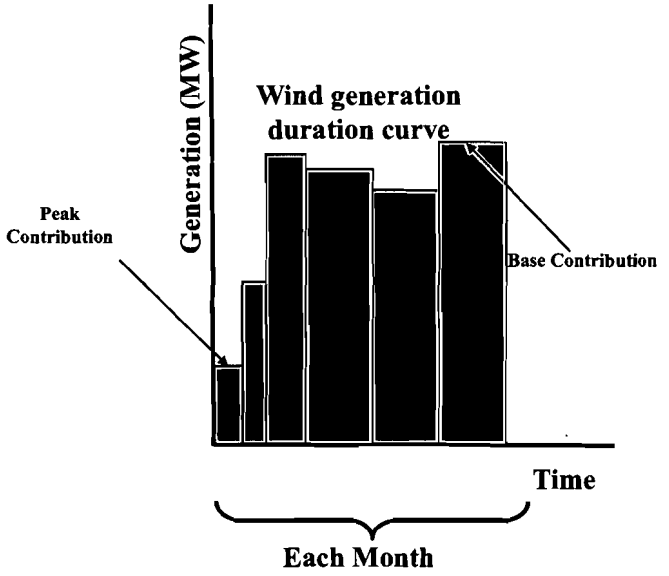
The Wind Duration Curve Per MW of Wind Capacity



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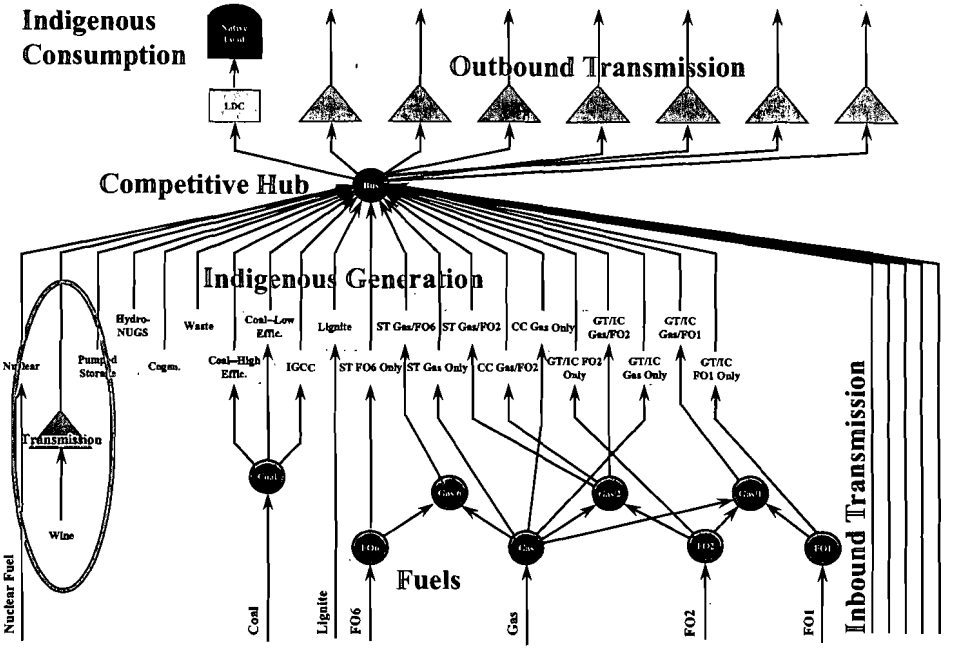
Wind Fits into the Supply Mix with Its Generation Duration Curve



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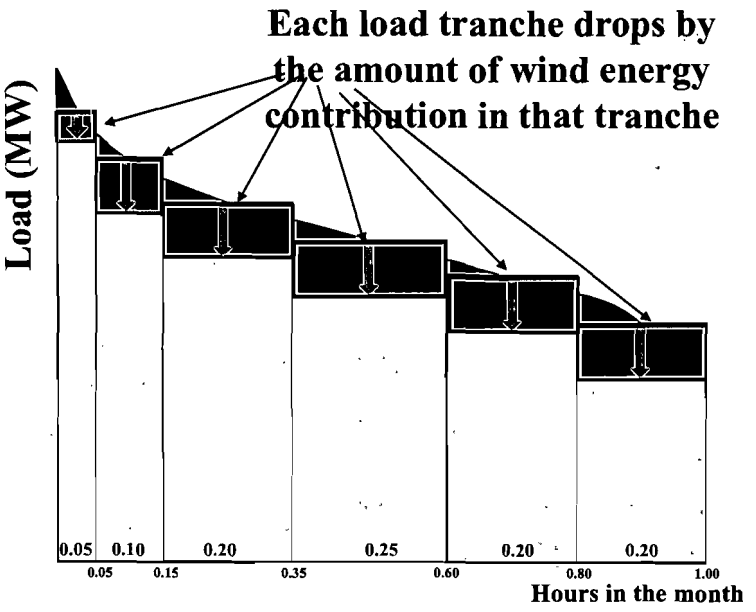
Wind Decrements Hourly/Monthly Residual Thermal Demand



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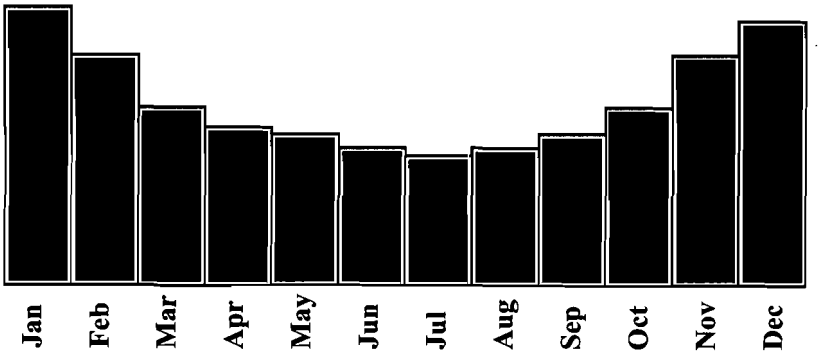
Wind Energy Generated by Month in a Given Region



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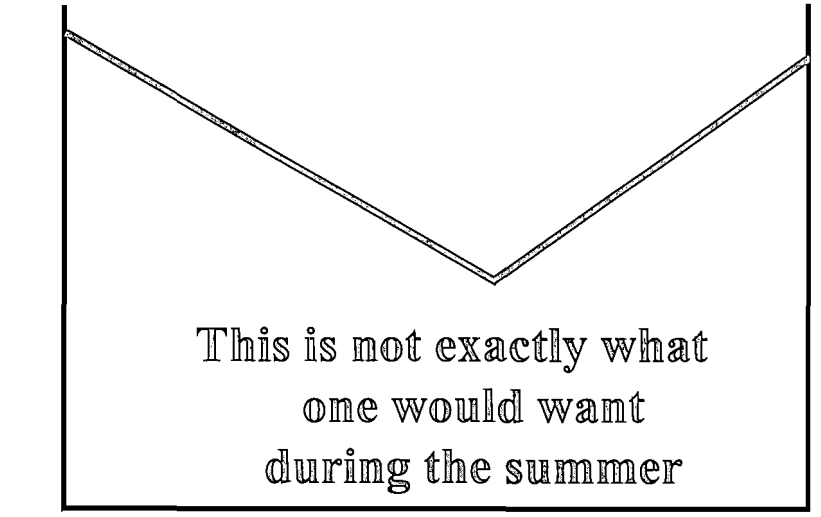
Here Is What the Diurnal Wind Pattern Looks Like During the Summer



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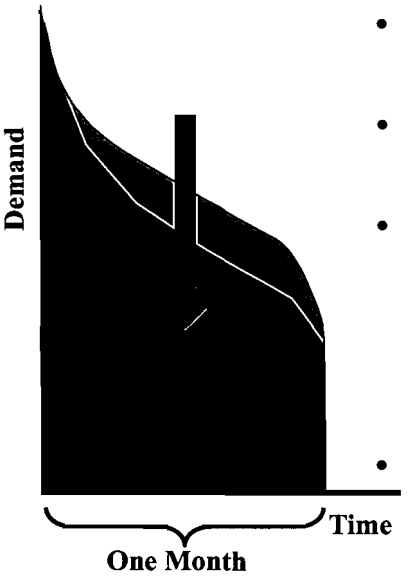
The Residual Thermal Load After Wind Looks Like This



- Wind pushes down the off peak much more than the peak.
- This makes the load shape more peaked for the thermal plants.
- This is already happening in California and Texas; they dump wind energy at time of base and there is little or none at time of peak.
- You need redundancy at time of peak (gas) or else system reliability drops (potentially to "developing country" levels)

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1. Wind
2. Solar
3. Biomass
4. Geothermal
5. Other

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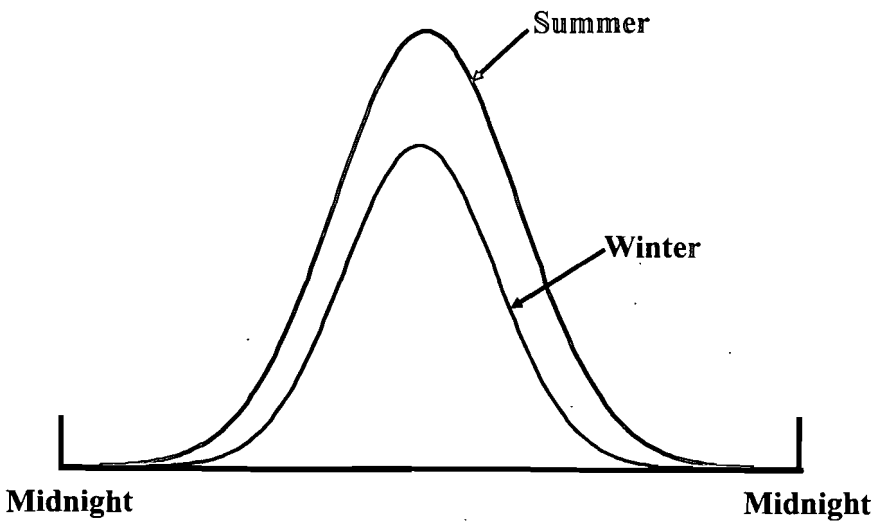
Solar Insolation During The Day-Night Cycle



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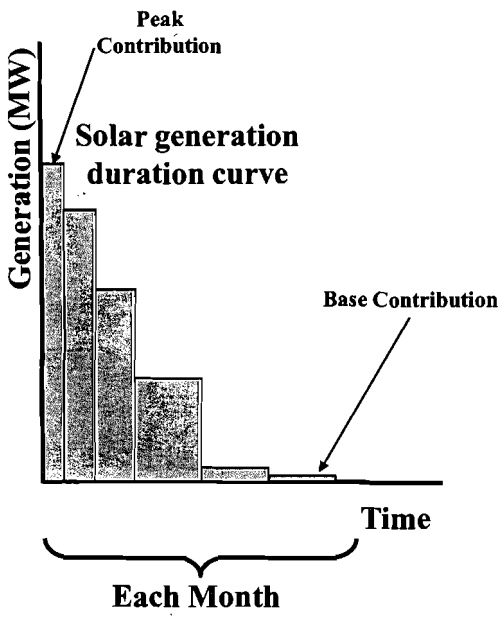
Solar Generation Duration Curve



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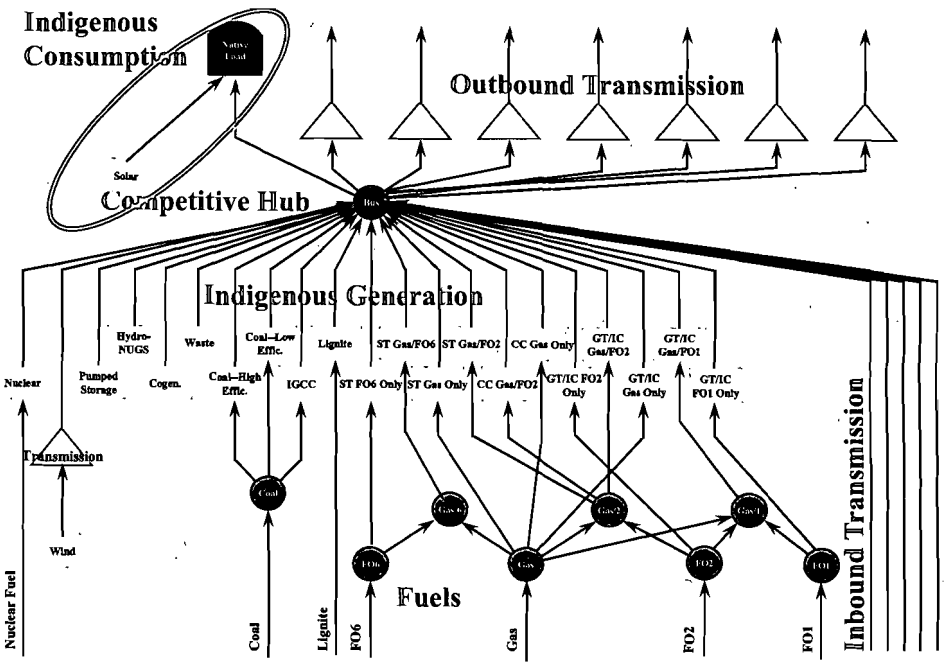
Solar Fits into the Consumption Mix with Its Generation Duration Curve



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Biomass

- Biomass is fuel limited
- Biomass can be seasonal
- Generators have flexibility to burn at certain peak times
- We have surveyed, estimated, and inserted regional biomass generation duration curves

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Geothermal

- Site-specific
- Generally base loaded
- Water reinjection to sustain output rating

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Why Do All This?

- Because energy and capacity prices will depend CRITICALLY on this.
- Because any asset in the portfolio will generate energy and capacity revenues based on this.
- Renewables will generate revenues from the market (that is often forgotten) under many contractual type schemes.
- Renewables profitability are market affected

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Tradable RECs

- RECs and tradable RECs are hugely important.
- They interact with CO2 and other environmental rules because they reduce the demand in the system for emissions allowances.

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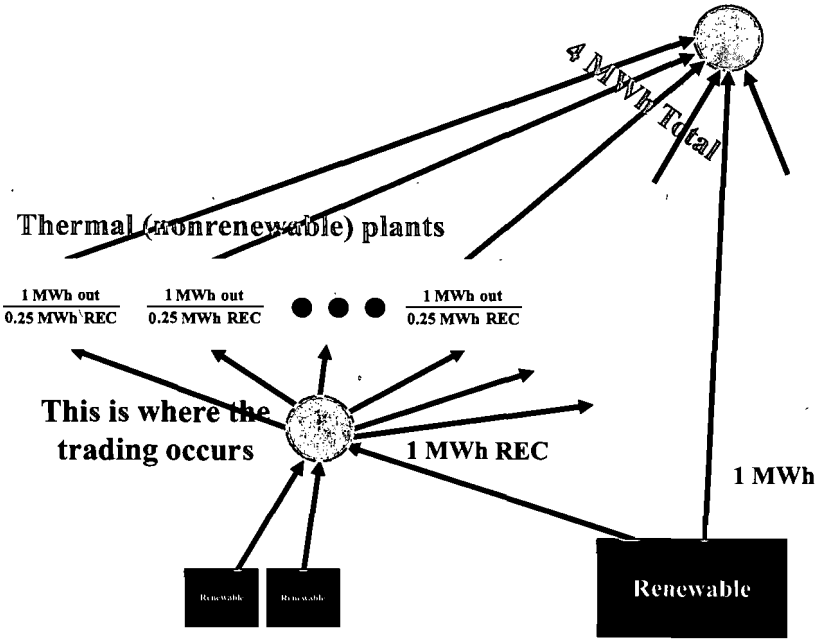
How Tradable RECs Work



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Tradable RECs

- You get a REC by building and running an approved RENEWABLE plant and generating a MWh.
  - RPS and REC are generally MWh, not MW, based
  - That REC has to be purchased by thermal generators, who have to surrender ¼ REC for 1 MWh generated.
  - If renewables are expensive or short, the price of a REC goes up; throttling of thermal is what incentivizes renewable entry

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Tradable RECs

- The Altos model with its endogenous build structure builds renewables along with thermal units and ensures the REC ratios.
- The price of a REC floats and is determined by the model (just as it is determined by the market)
- We can add a bank for RECs if we like, allowing intertemporal trading
- We can add a speculator, allowing people to buy up and husband RECs if they de facto want to strengthen the RPS and constrain nonrenewable generation

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Electricity Storage—What Is Its Effect on Renewables, Coal, Gas, and Other Thermal?

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Gas Storage Analogy

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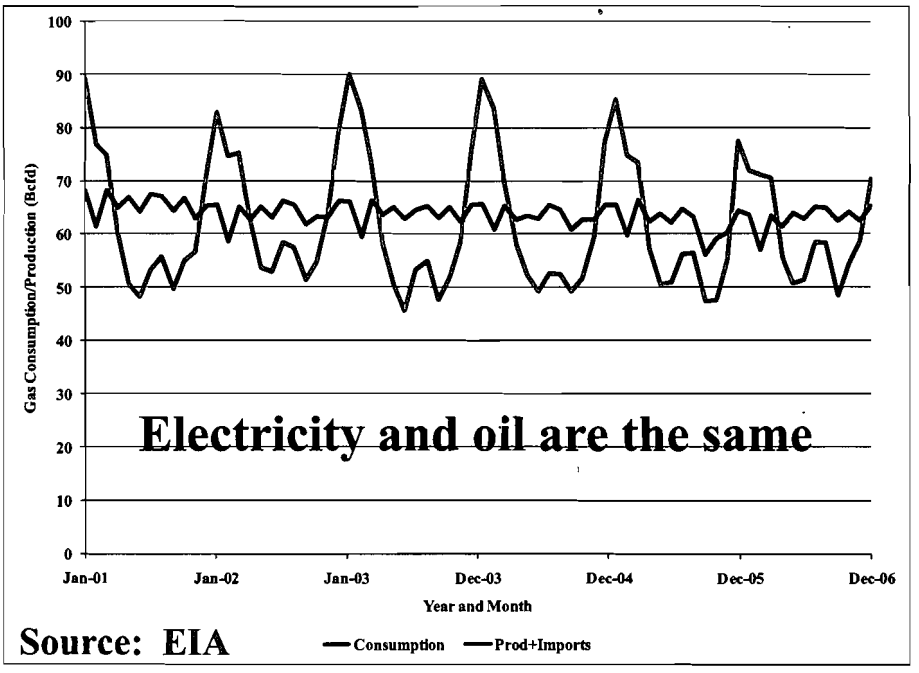
Natural Gas Storage Works This Way



Electricity and oil are the same

Source: EIA

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