Climate Change: Designing an Effective Response

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Outline

- Five Myths Meet their Maker
- Toward an effective Climate Strategy

Five Myths

1. Climate Change isn't a problem

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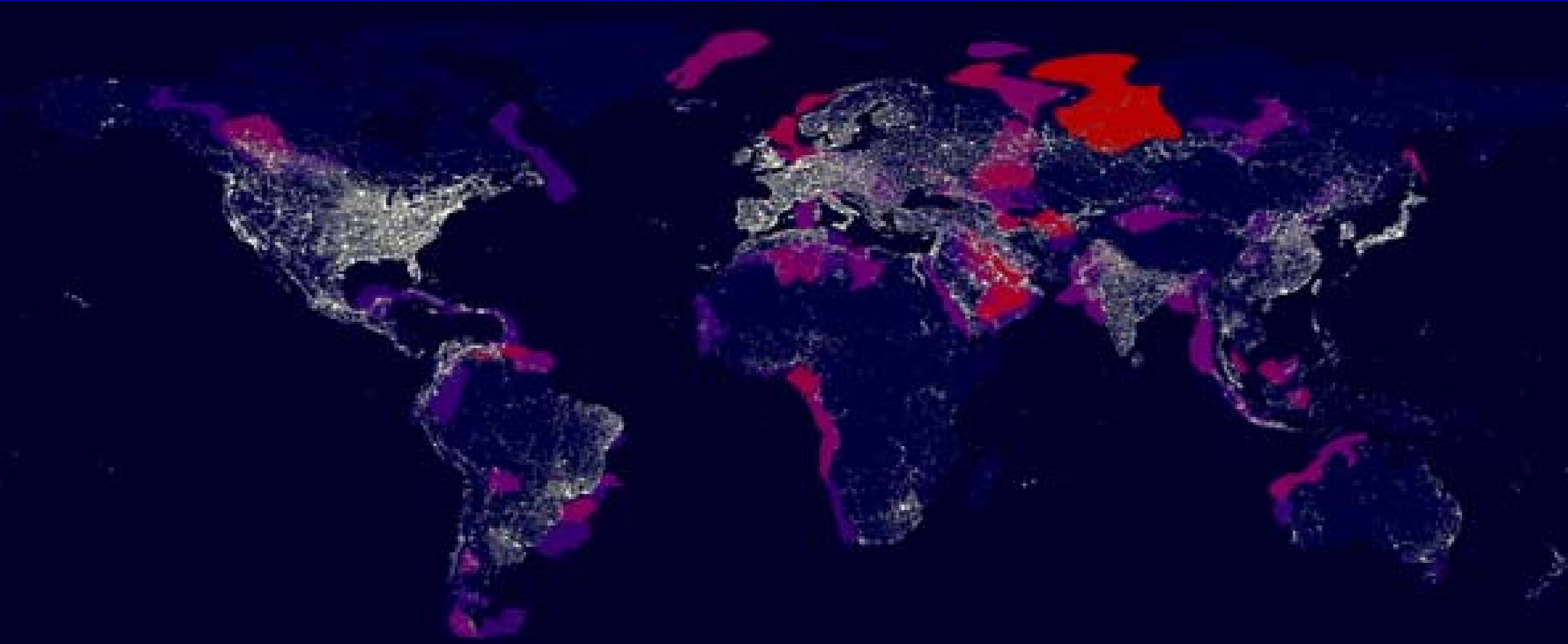
1. Climate Change isn't a problem
2. Fossil Fuels will Run Out Shortly

Tapping the World's "Infinite" Gas Resources



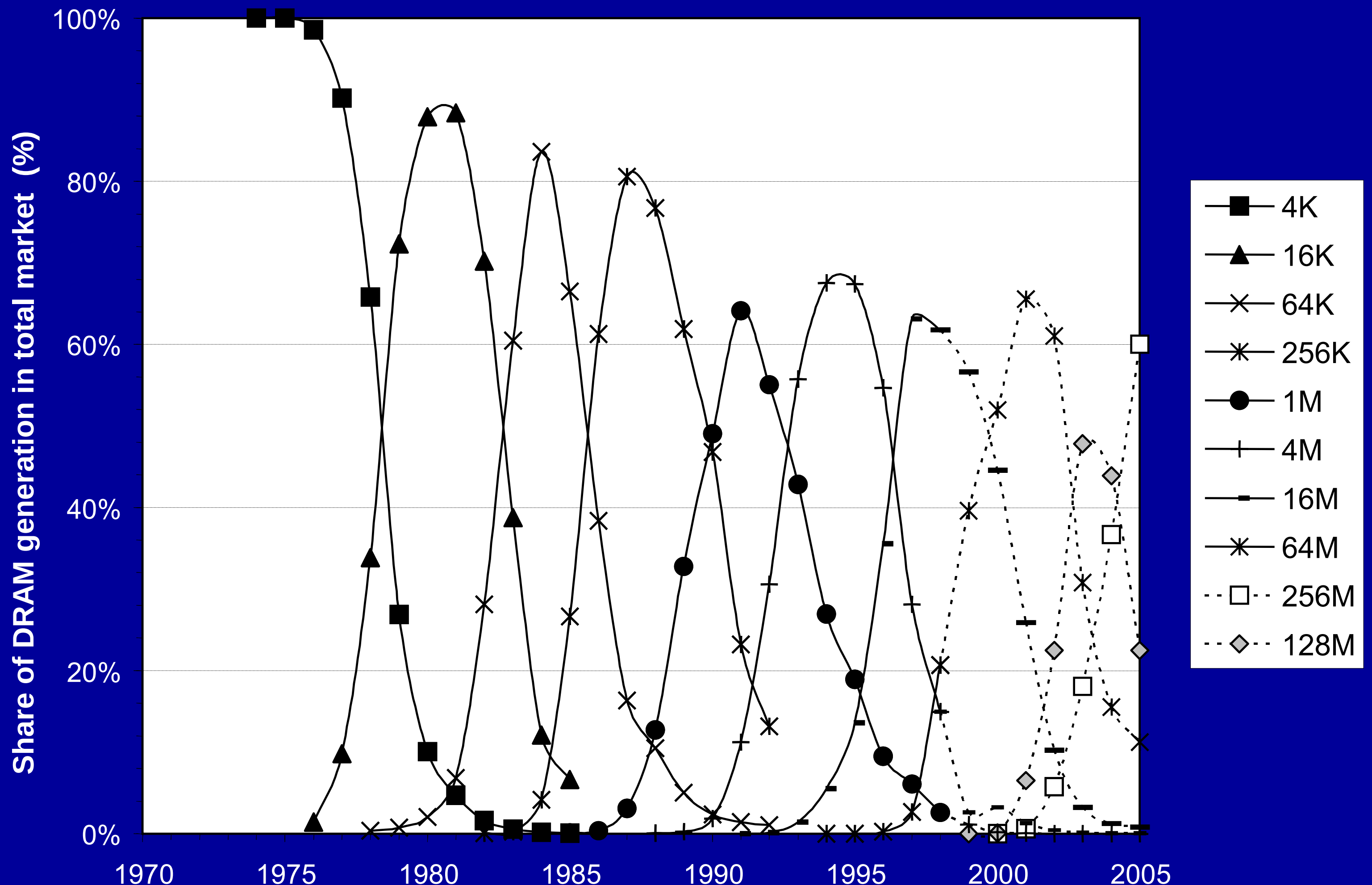
White: <u>where the lights are on, satellite imagery</u>
Blue → Red : Gas resources, with increasing size (USGS)

Source: Baker Institute (Rice) and PESD (Stanford) Joint Study on the Geopolitics of Gas (CUP, forthcoming

Five Myths

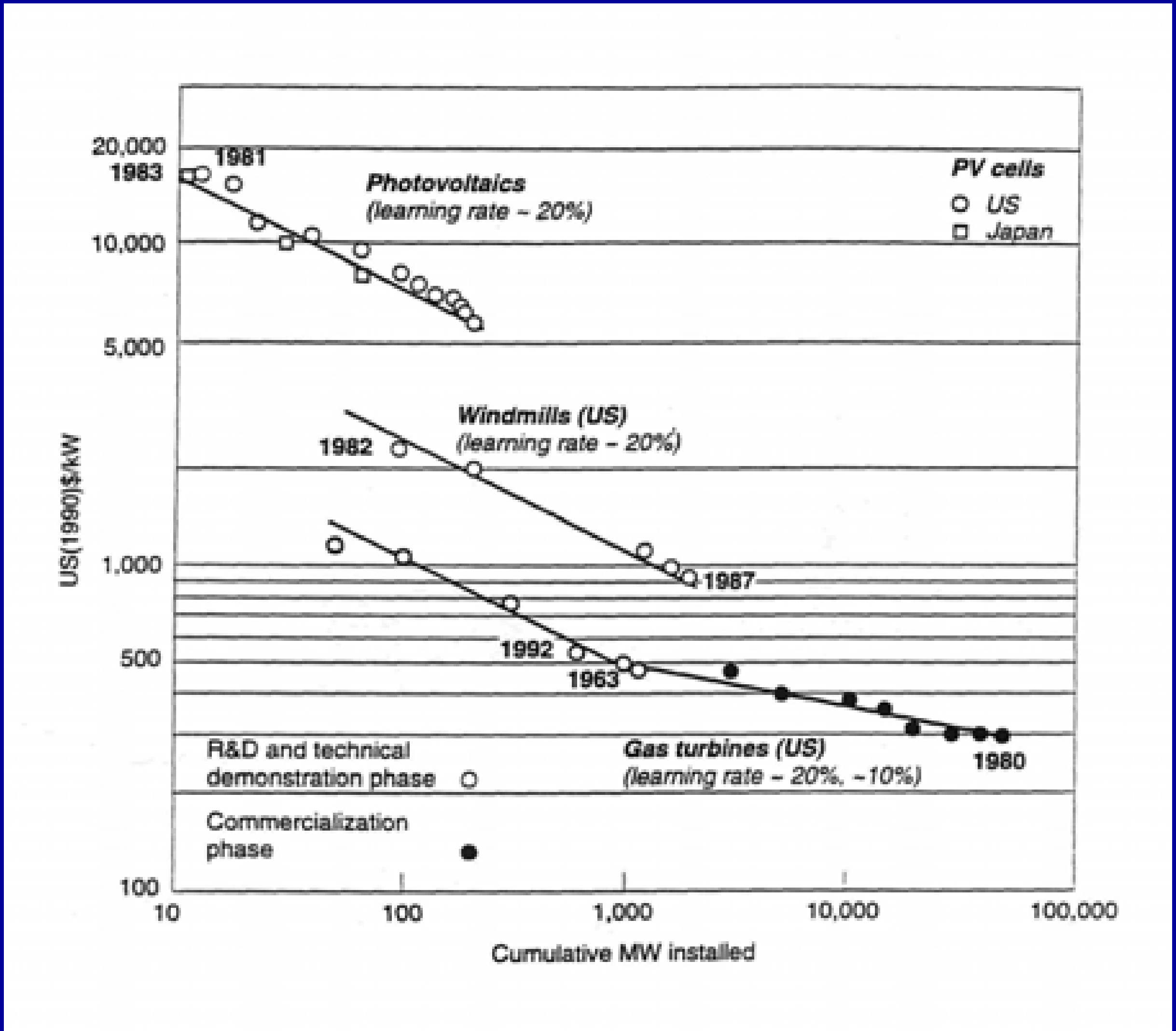
1. Climate Change isn't a problem
2. Fossil Fuels will Run Out Shortly
3. The "Engineer's Myth"
    - Technological Solutions, once identified, can spring forth and multiply
    - The question is the speed, scale and price paths of varied technical possibilities
    - Past experience
        - Rand study found average 150% cost overruns on estimated costs of first of a kind demonstration plants
        - Commercial scale and diffusion not studied by labs or other initiators
        - Time for substitution effects (and fight back by incumbents)
    - Questions about the capacity of the state to induce technological change over endogenous (BAU) behavior
        - Portfolio values (Japan and US returns)

Rapid Evolution: DRAMs

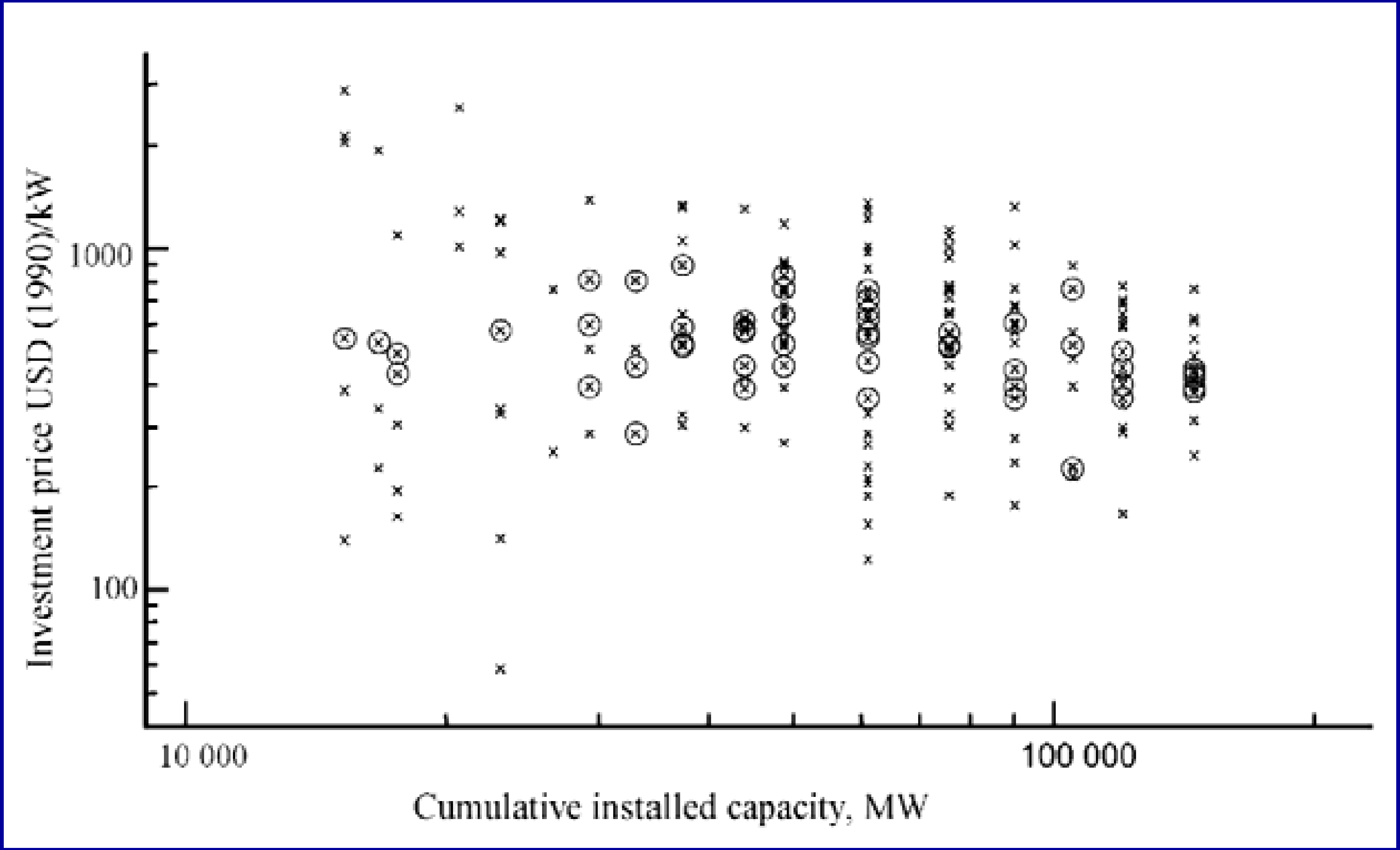


Source: Ausubel and N. Victor

Learning Curves

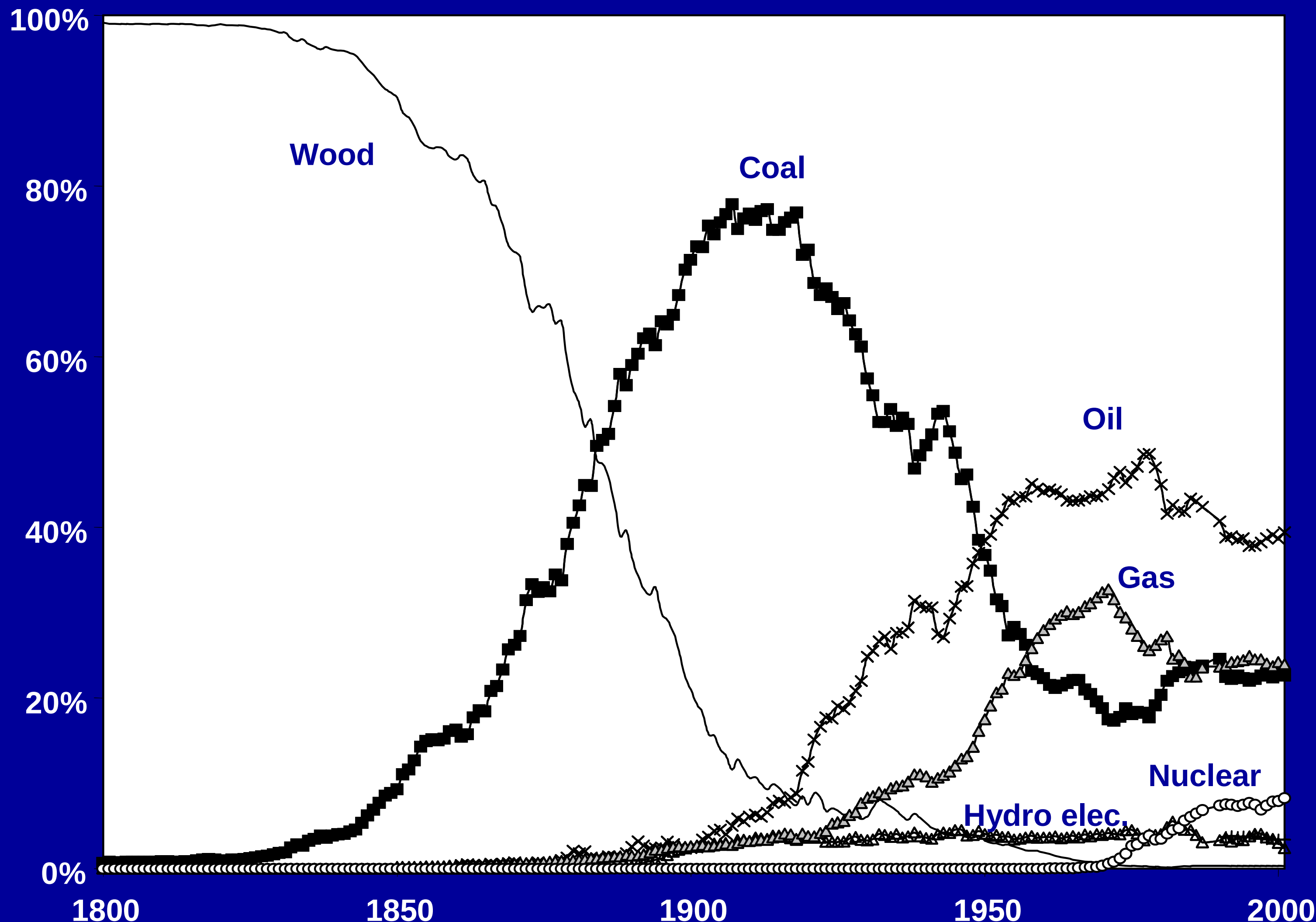


When does Learning Stop? The experience with gas turbines



Source: Colpier and Cornland. 2002. "The Economics of the Combined Cycle Gas Turbine – An Experience Curve Analysis." Energy Policy *30: 309-316.*

Slow Evolution: Primary Energy Systems



Source: Nakicenovic and Grubler; IIASA

Five Myths

1. Climate Change isn't a problem
2. Fossil Fuels will Run Out Shortly
3. The "Engineer's Myth"
4. The "Planning (Economists') Myth"
    - Governments and firms optimize with full information and leverage
    - The primacy of economics
        - Cost-benefit analysis
        - Policy as marginal, linear change
        - No theory of the firm or organizational behavior

The architectural priority of economics in climate change

- Climate is a global collective good– inclusive membership
- Cost-benefit analysis to set the level of stable concentrations
- Property rights for efficient implementation:
  - Cap and trade system
  - A single global price
- Hard law compliance
- Graduation as differentiated responsibility

Difficulties in implementing the architecture

- Asymmetrical information on demand and supply: strategic behavior
- Uncertainty on cost functions: escape clauses and no regrets pools
- Property rights distribution and equity claims
- Trading (financial markets) requires sound institutions
- Single price signal for disparate goals
  - Gasoline demand at $100/ton CO_2 ($40 increase per barrel oil)?
  - Fuel shifting at $22/ton $CO_{2?}$
  - Marginal shifting to renewables at low price signal?
  - Ratcheting up the signal?
  - Benefits?

Political economy

- Local resources will be used: nationalism and energy security
- Climate change priorities are low relative to development and local pollution
- Politics are less barriers than constraints
  - (Perceptions of) corruption and political commodification in electricity reform
- (Effective) policy usually follows technology or price shocks, but rarely leads them
  - Compare telecommunications to energy reform

Political economy

- Competitive markets vs. regulated sectors
  - First best policies for second best contexts
  - Who benefits from climate: subsidies and rents?
- Energy examples
  - Long term gas contracts in the rate base? IGCC?
  - Bio-fuels and corn based ethanol?
  - Renewable portfolio standards
    - Sunsets and learning curves
  - De-linking gas prices from oil?
  - Mandated fuel supplies at administered prices?
  - Generation tariff subsidies and power distribution in New Delhi?

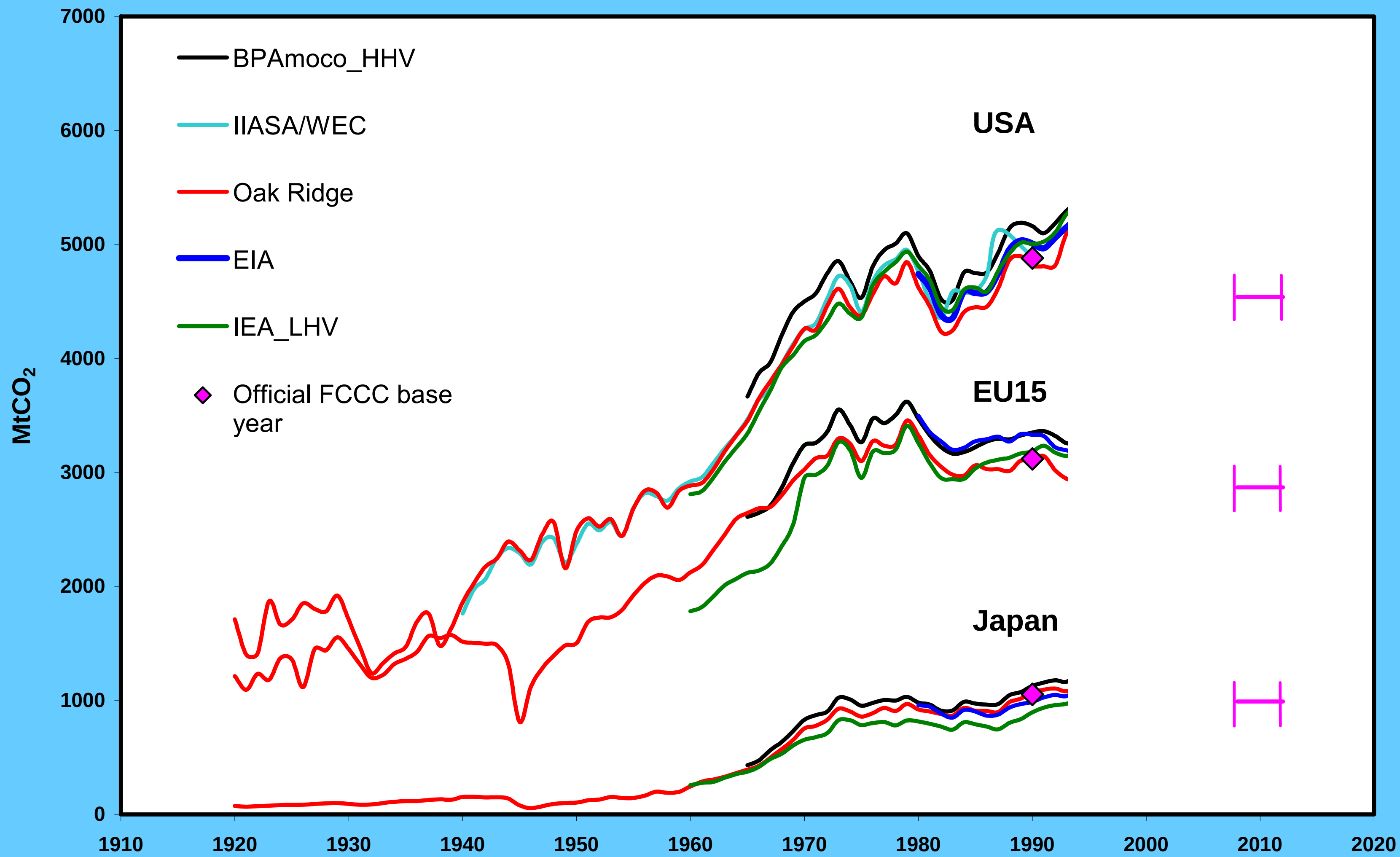
Organization theory

- Organizations do what they do
  - Flexibility is limited
  - Resistance and fight back
- Capacity to integrate across departments and agencies is scarce
  - Optimization across sectors is weak
- Government agencies are fragmented and reproduce their routinized political cultures
  - Environmental ministries vs. finance and energy
  - Political constitution, cultures and instrument preferences
- Margins change little
  - Economists think marginally; financiers use step-functions

Five Myths

1. Climate Change isn't a problem
2. Fossil Fuels will Run Out Shortly
3. The "Engineer's Myth"
4. The "Planning Myth"
5. The "Diplomats' Myth"
    - Policy Planning can be extended to the global level
    - All countries should be involved in the most effective solutions
    - Enforcement is based on sovereign state model

Trends in Fossil Carbon Emissions
(Trajectories and Kyoto Commitments)



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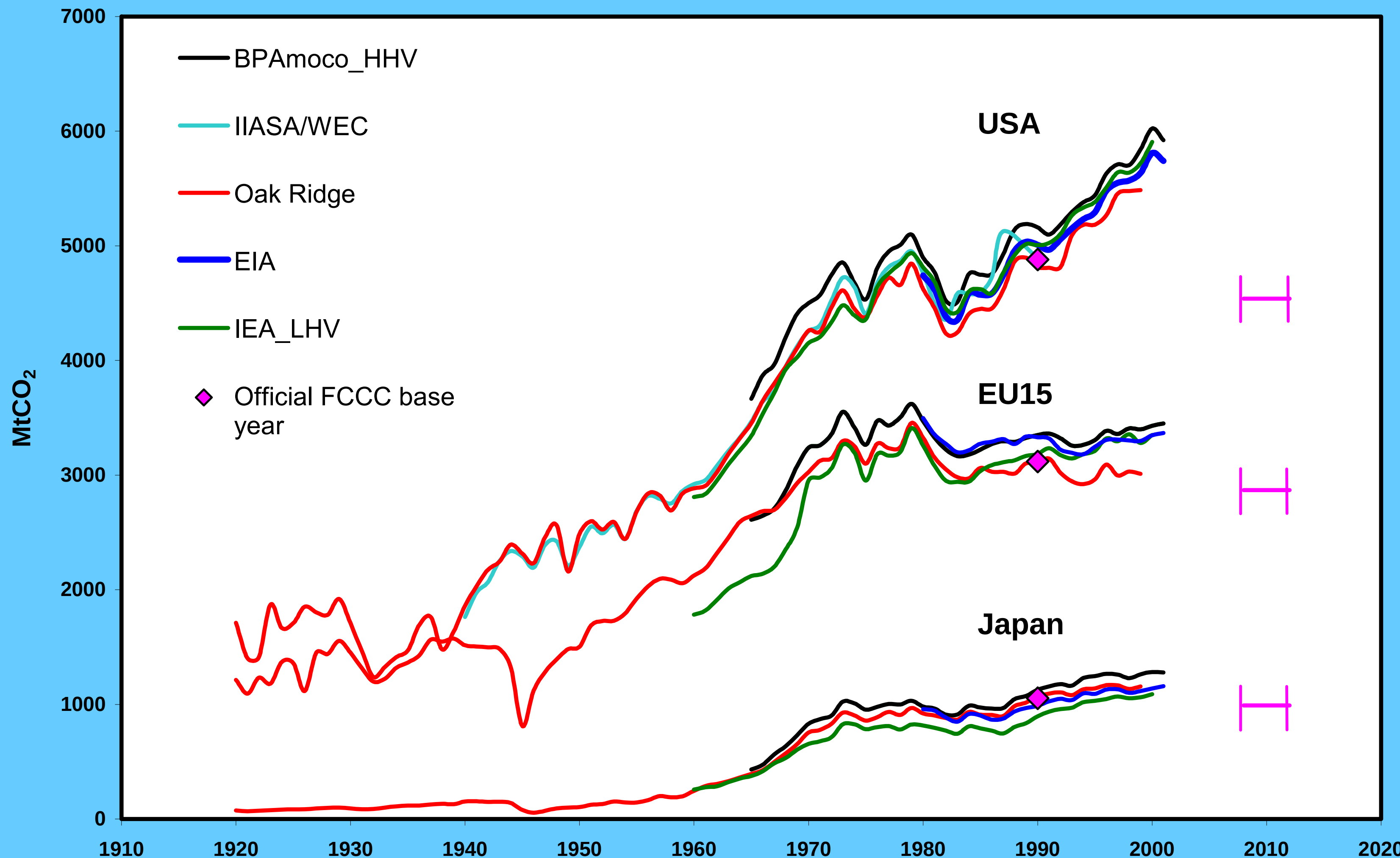
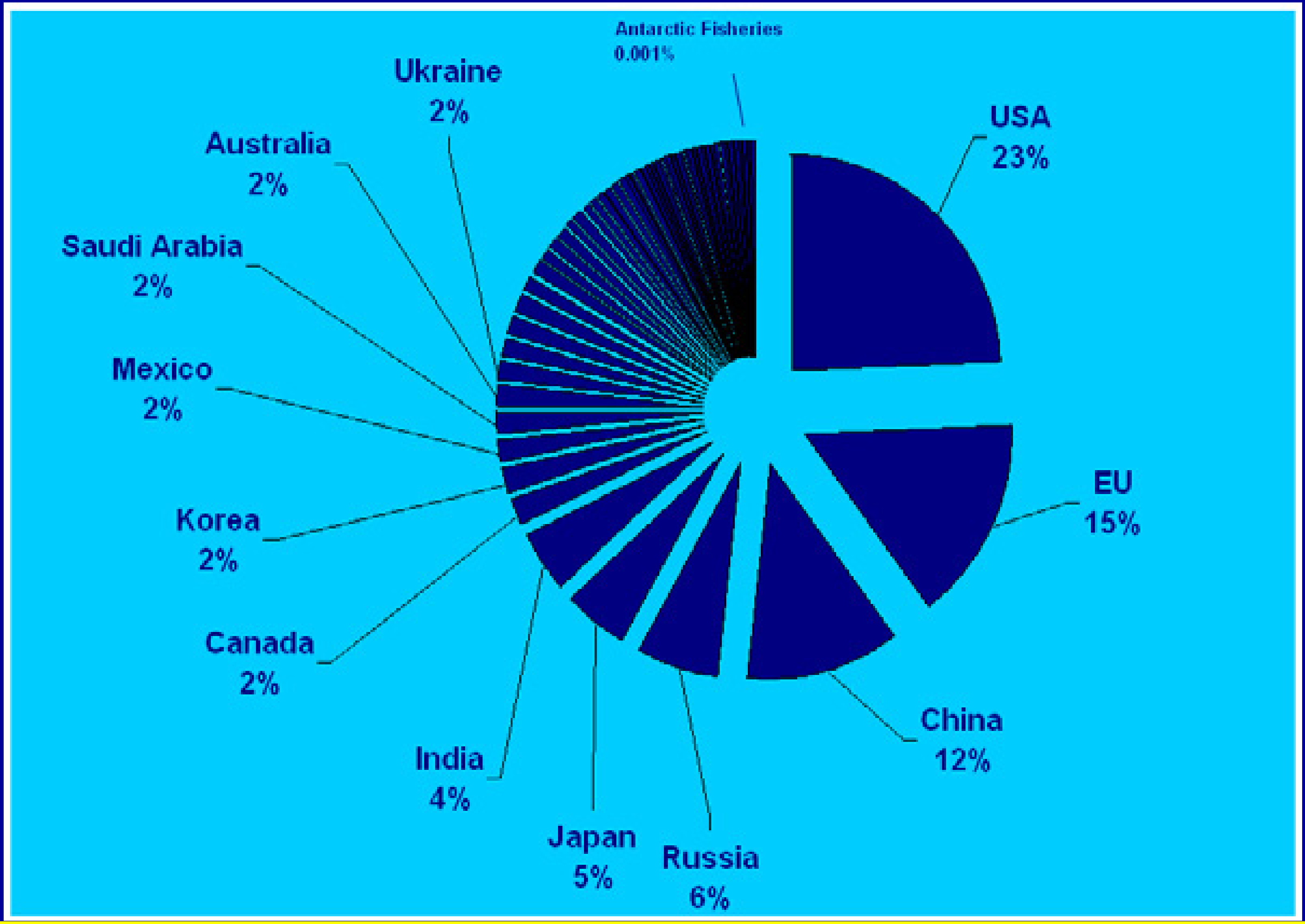


Allocation of World Emissions: Only a Few Countries Really Matter



Toward and Effective Climate Strategy

Building Blocks: Sectors

- Climate is a derivative problem of three economic sectors central to growth and development
  - Energy
  - Transportation
  - Land Use

Building Blocks: Sectors

- Government actors from these sectors make decisions on the development paths their economies will follow
  - Line ministries
  - Finance ministries
- Political priorities of these actors are nowhere focused on climate, especially in developing countries
  - Environmental constraints on emitting sectors are resisted unless they advance higher priority goals
- Actors from key emitting sectors are rarely represented in climate negotiations

Building Blocks: Problems

- Climate change can be broken down into three separate problems
  - The immediate need for a low level carbon price signal
    - Incentives to look for mitigation opportunities that save costs and carbon (no regrets pools)
    - Incentives to adopt options to mitigate carbon whose incremental costs are only marginal (below price signal)
  - The mid-term need to diffuse more rapidly than business as usual existing commercial technologies that are relatively less climate damaging
    - Cooperative measures to engage leading developing countries with rapidly growing carbon emissions
  - The long-term need to develop energy, transport and land use technologies that are currently across the commercial horizon

Building Blocks: Pillars

- Each separate climate problem is best approached through separate institutional pillars that are tailored to the specific problem
- The climate regime should be composed of multiple pillars differentiated from one another according to:
  - The nations involved
  - The actors from each nation with policy authority
  - The timelines demanded
  - The instruments and measures to be used
- The Kyoto Protocol, particularly tailored to low level price signals, should be maintained in the UNFCCC framework, but should also be supplemented by new pillars tailored to the diffusion and technology development problems

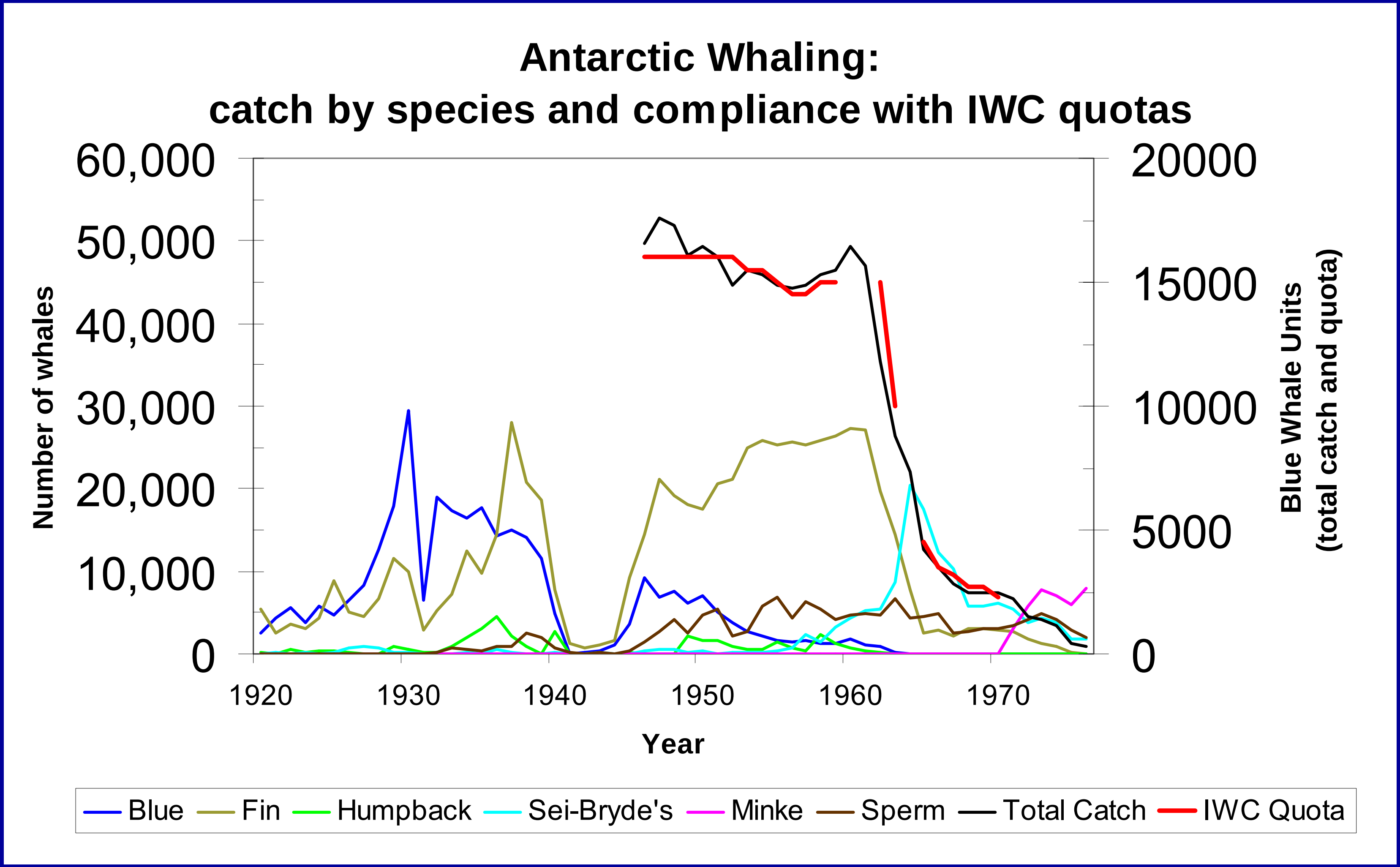
Building Blocks: International Regimes

- Multiple clubs with members sharing local cooperative solutions are more likely to support international regime growth than comprehensive multilateral arrangements
  - The more closely agreements are built around non-cooperative solutions, the more likely they will be implemented
  - Most international environmental regimes in the past half century have less than 7 members
  - Trading across fragmented international regimes is limited, reducing the value of wide and diverse membership in each regime

Building Blocks: International Regimes

- Non-mandatory regimes may be more effective in setting and encouraging ambitious behavioral targets
  - Effectiveness is not equal to compliance
  - Compliance with international regimes is high because:
    - Formal obligations are bargained down ex ante to what nations can and will do
    - Ambiguities in norms allow ex post claimed compliance through shifting interpretations of compliance behavior

Antarctic Whaling: Perfect compliance



Building Blocks: International Regimes

- International system shift
  - 1950-2000 international system composed of negotiating blocs of developed (OECD or Annex I) countries, socialist countries, developing countries G-77 and China
  - International system responsibilities (market stability and regimes) largely devolved on the OECD (Annex I) nations
  - Shift after 1990 in growth rates, principally in India and China, raises issues of increased dependency on international markets with commodified products
  - Unclear whether the economic position of emerging market large nations moves their international interest away from G-77 toward OECD and strategy toward support of markets and regimes or towards mercantilism

Building Blocks: International Regimes

- Shift context for market behavior rather than regulation
- Price signals that adequately address three different dimensions of climate change not politically feasible
- Take political constraints and the actors who represent them seriously
- Climate is a derivative problem of politically regulated sectors
- Pillars and political cultures (instrument choice)

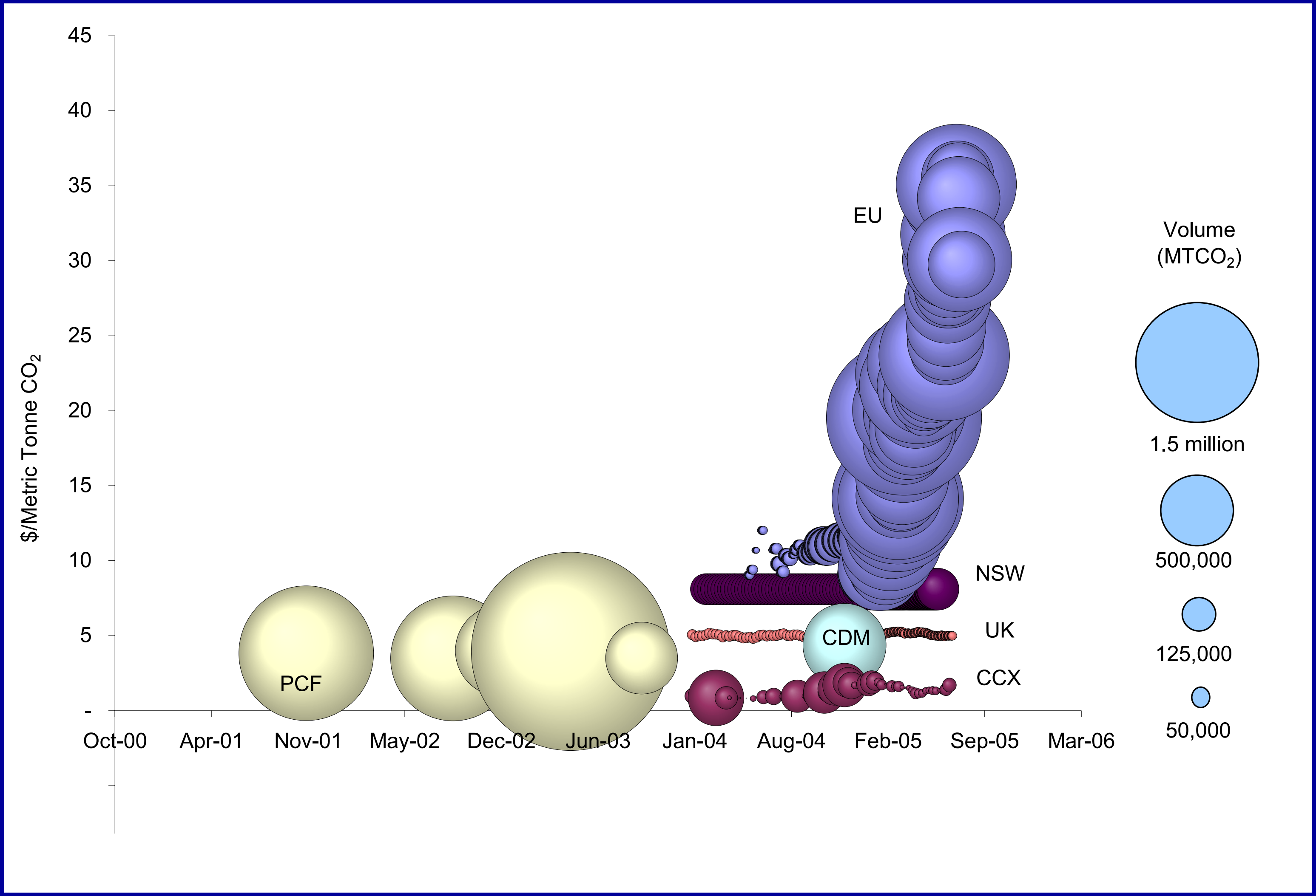
Low Level Price Signals in the EU

- Salience of the EU regime
  - Of the nations that have signed the Kyoto Protocol, only (some) EU member states have taken on positive cost obligations
    - Canada?
    - Japan?
  - All former Soviet bloc nations and developing countries are permit sellers
  - US and Australia have withdrawn

Low Level Price Signals in the EU

- Structure of the EU regime
  - Internal burden sharing agreement
  - European Trading System vs. EU and member state policies and measures
  - ETS linkage to CDM and JI when accession nations file their allocation plans
    - Market is thin in first period while rules are uncertain and second period allocations are not politically decided
- Compliance?
  - Expected behavior on current track?
  - Article 17 purchases if ETS trading prices rise and supply of CDM/accession country permits is not adequate
  - Sanctions and soft law in the EU

A Madisonian Perspective: Emerging Carbon Currencies



Sources: PointCarbon, International Emissions Trading Association

Reprinted from Victor, House & Joy (2005)

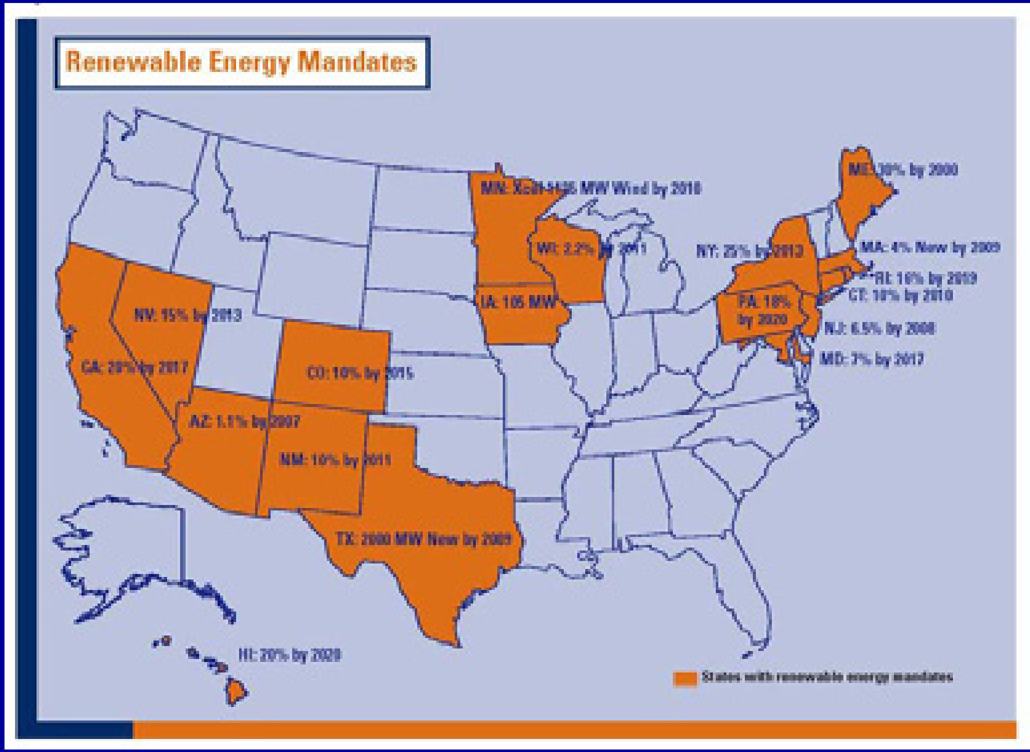
Low Level Price Signals: US

Plan	Details
Bush Administration	Voluntary target of 18% reduction in GHG intensity between 2002 and 2012.
McCain-Lieberman	Cap 2010 emissions at 2000 levels for electricity, transportation, industrial and commercial sectors.
Hewlett Foundation	Economy-wide cap and trade beginning in 2010 targeting 2.4% annual reduction in GHG intensity. $7/ton safety valve.
Hagel Bill(s)	Investment incentives for advanced climate technologies; assistance for developing countries; R&D incentives.

“Carbon Intensity” of the U.S. Economy (1800-1998)

Intensity: grams C per 1990 USD(mer)

U.S. Climate Change Policy: State-driven process



Source: Pew Center on Global Climate Change

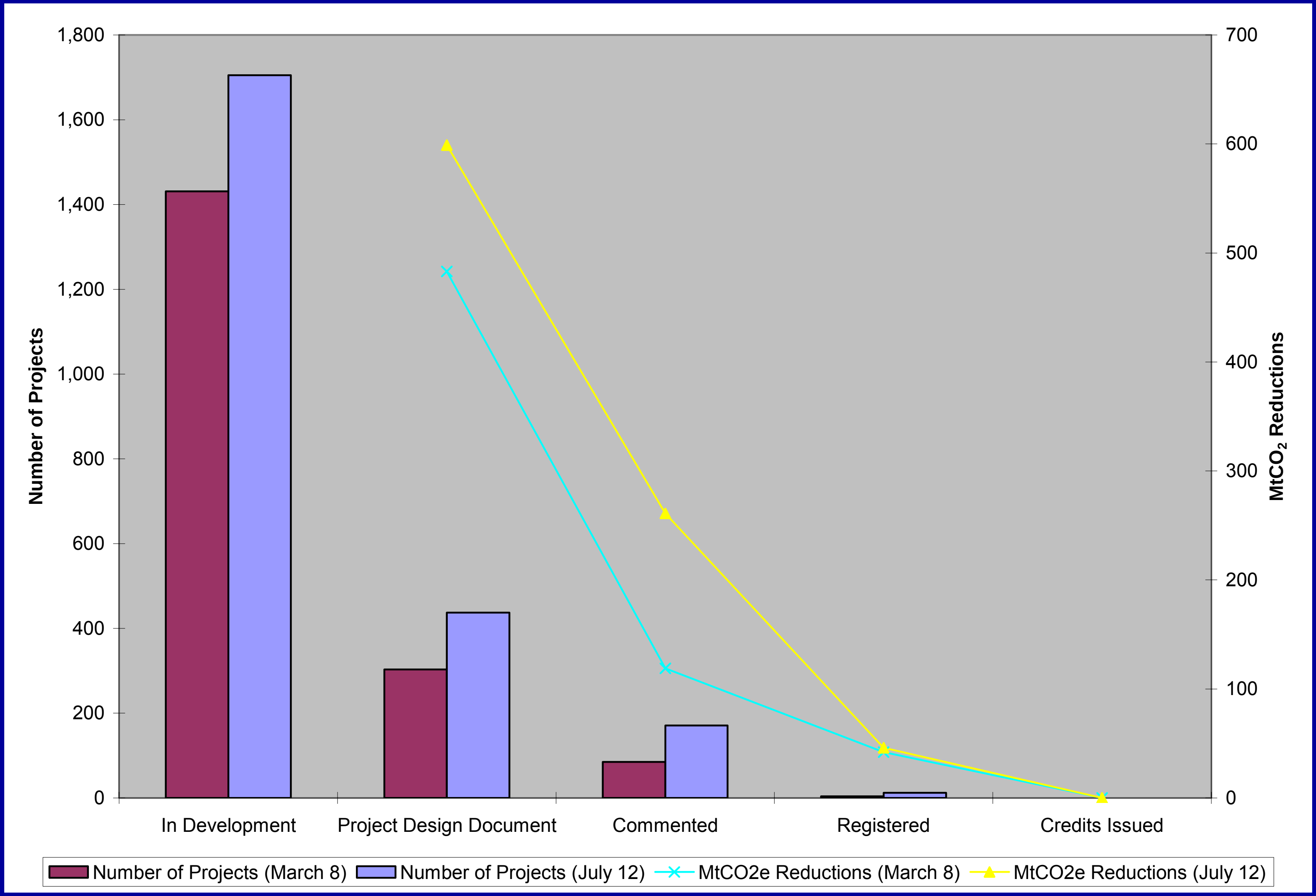
Climate Architecture and Development

- Regime architecture is climate-centric and flows from output (constraint) to input (development)
- CDM holds only limited prospect of increased or redirected flows
- No assurance of stable assistance from developed to developing countries

Limitations of the CDM Model

- **Tropical "hot air": currency devaluation**
  - CH_4: land fill and flaring
    - Rising natural gas prices
    - Local environmental controls
  - HFC23: industrial processes gases
  - Renewable Portfolio standards withdrawal
- **High transaction costs**
  - Small Scale Projects
  - No methodologies for large-scale energy efficiency and fuel switching
- **Baseline identification**
  - Baselines feasible only for marginal activities

Engaging Developing Countries: The Clean Development Mechanism (CDM)

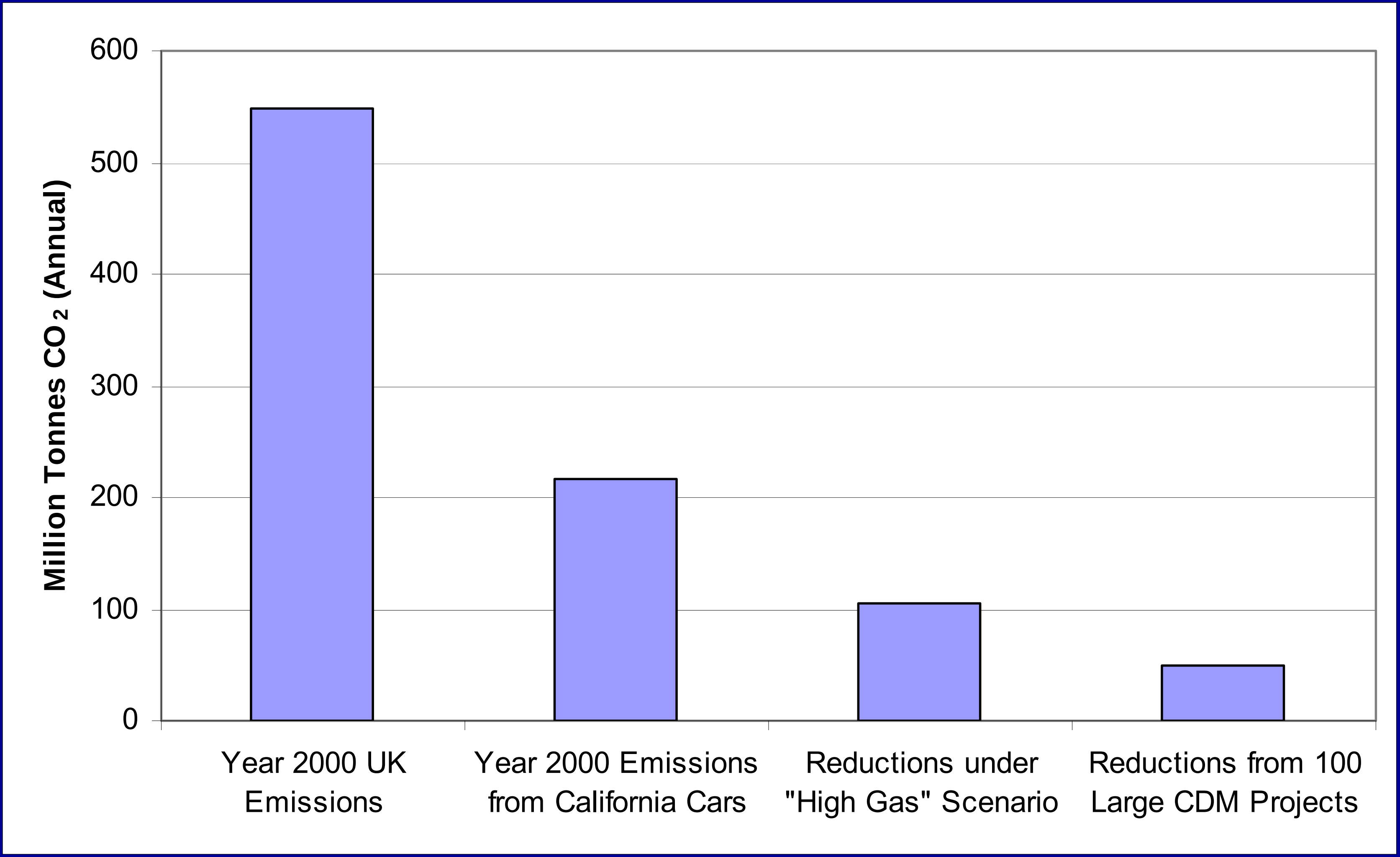


Source: PointCarbon

Climate-Friendly Development Pathways

- **Example: CO_2 Savings from Natural Gas**
- **IEA forecast for China in 2020:**
  - 560GW (coal)
  - 67GW (gas)
- **What happens if you switch 80GW from coal to natural gas combined cycle?**
  - Saves 105 Million Tonnes CO_2 per year beginning in 2020

CO_2 Savings in Perspective

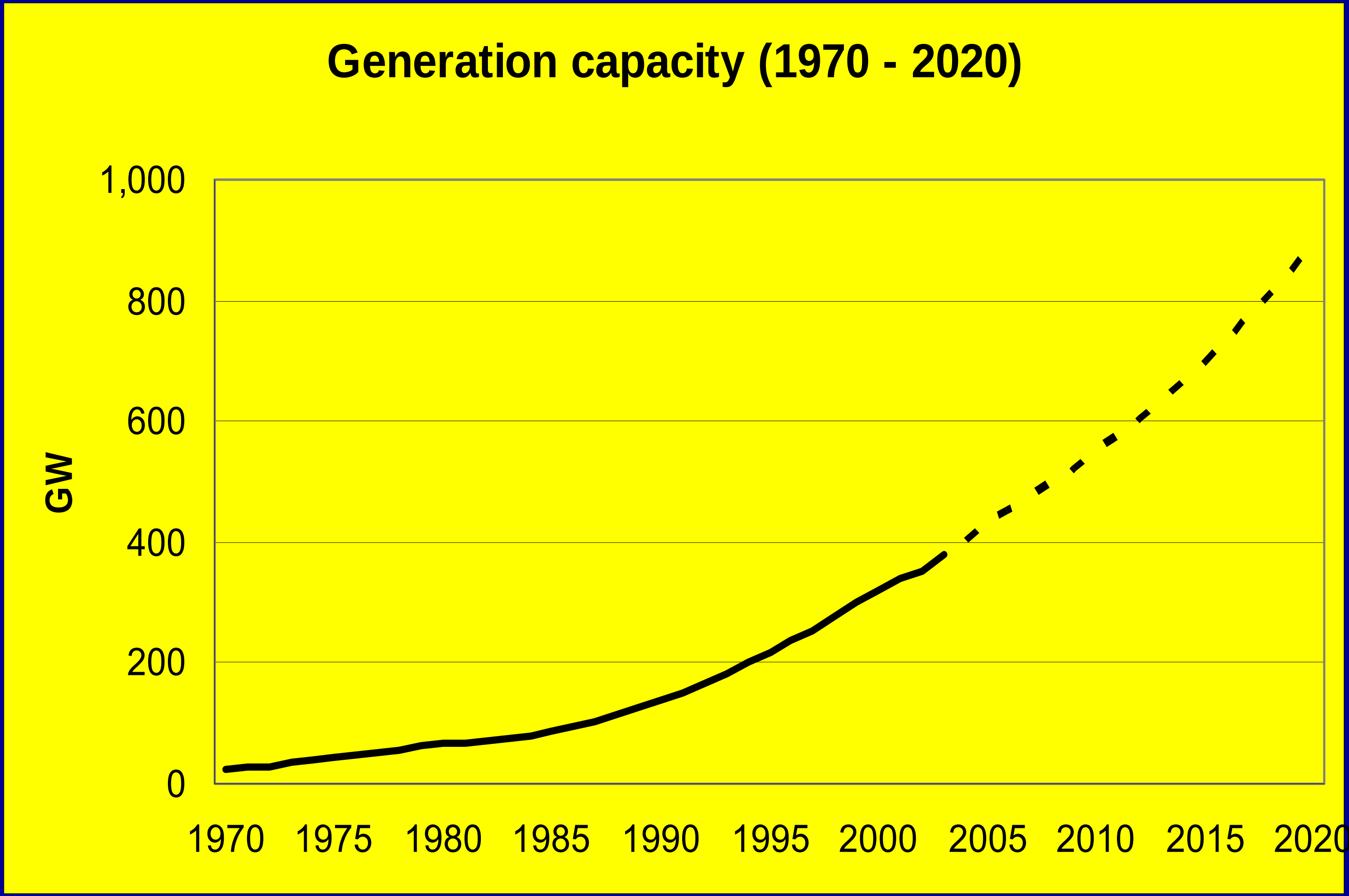


Chinese total energy consumption: IEA

2000		2030	
Coal	69%	Coal	60%
Oil *	25%	Oil*	27%
Gas	3%	Gas	7%
Nucl./hydro	2%	Nucl./hydro	6%

*imports 37% Imports 63-70%

Overview - capacity



Supply growth in China (national)

- 2004 installed capacity about 440 GW; 900 in 2020
- Portfolio managed mainly at provincial level during high growth
- Market reform is slow in high growth
- Energy intensity estimates key to demand estimates
  - Energy intensities rise recently over 1990-2003 period
  - Electricity grows faster than energy

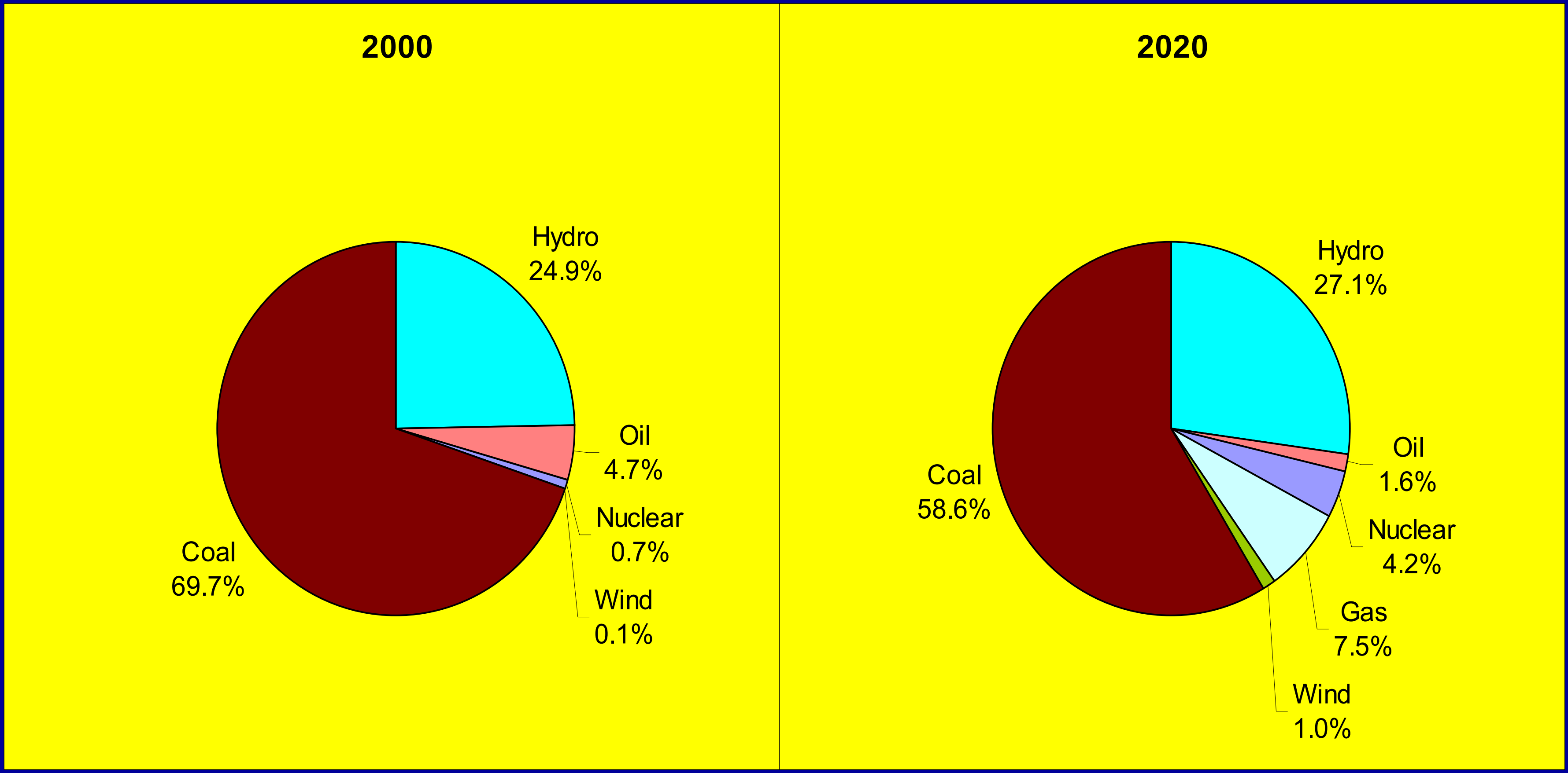
Overview -- 2004 Boom

	2004	2003	Growth %	Structure %
Installed capacity (GW)	441	391	13	100
Hydro	108	95	14	25
Thermal	325	290	12	74
Nuclear	7	6	11	2
Generation (TWh)	2187	1905	15	100
Hydro	328	281	17	15
Thermal	1807	1579	15	83
Nuclear	50	44	14	2
Operating hours	5460	5245	4	
Hydro	3374	3239	4	
Thermal	5988	5767	4	
Consumption (TWh)	2174	1892	15	100
Agriculture	61	60	3	3
Industries	1626	1396	16	75
Services	244	211	15	11
Residential	243	225	8	11
Urban	147	136	8	7
Rural	96	88	9	4

Central Government Plan to 2020

- Real GDP grows 7-8% per year; GDP p.c. reaches $10,000 (PPP basis)
- Primary energy consumption grows 4.5-5% per year
- 520 GW (30 GW per year) generation capacity will be added
- Natural gas to provide new and clean sources of energy
  - Over 7% annual growth rate
  - Consumption to increase from 40 bcm to between 140 and 160 bcm under various policy scenarios

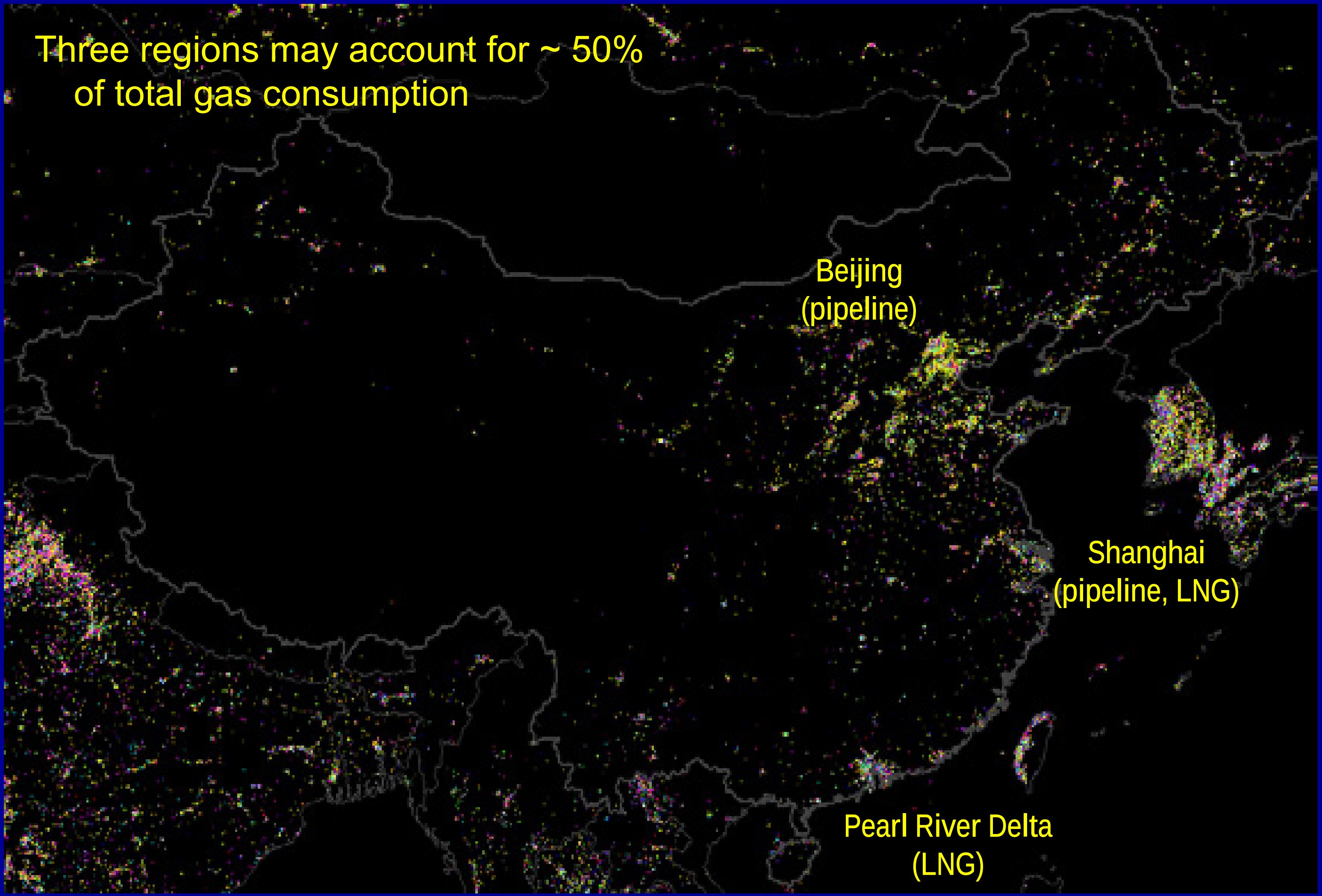
Overview – fuel structure



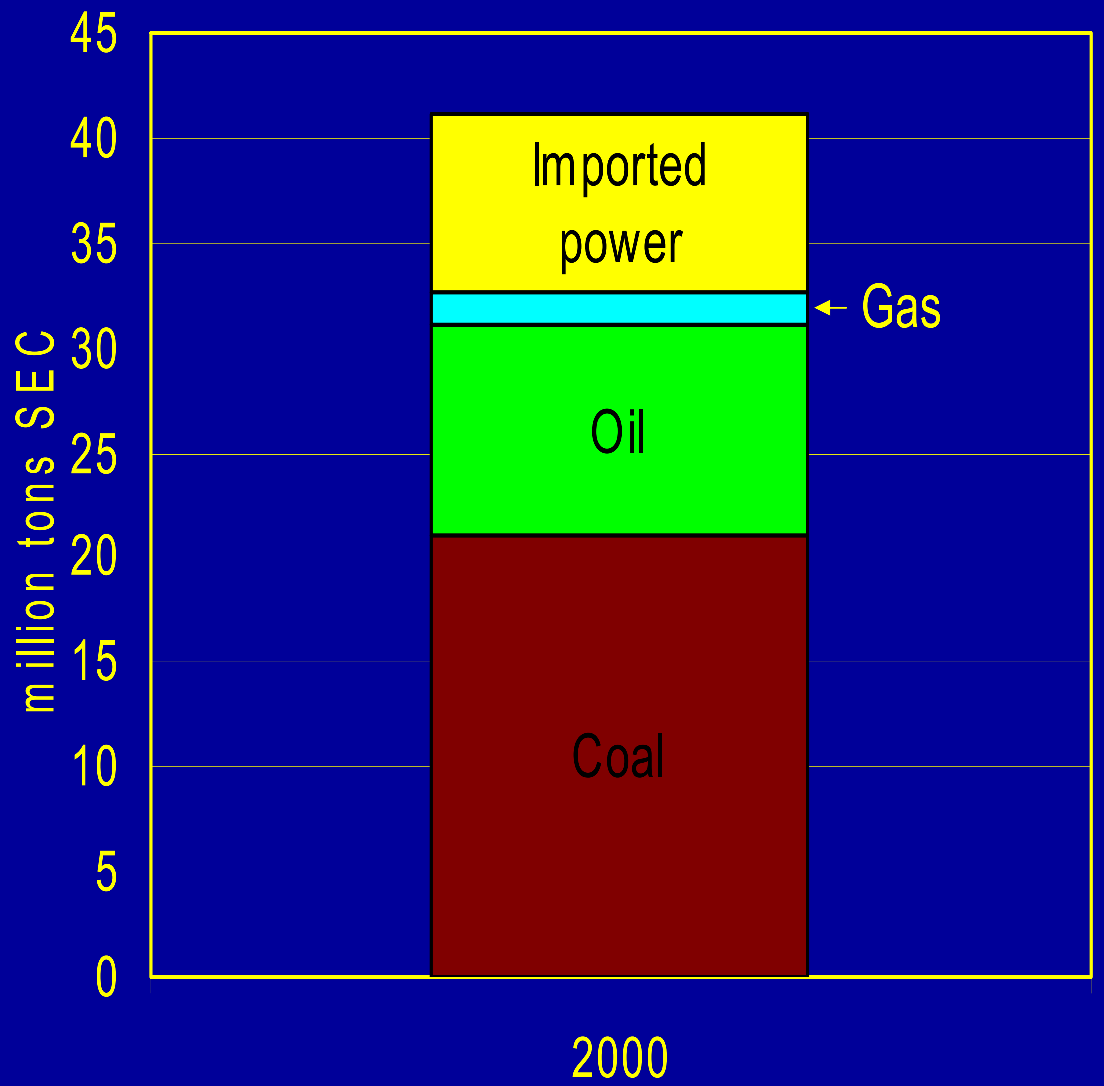
Central Government Plan

- Demand Uncertainty
  - Domestic (Chinese) gas forecast driven by higher price for gas than coal, driven by
  - Higher gas costs
    - Security requirement – 2/3 domestic production, 1/3 imports
    - Domestic production costs
    - Infrastructure development costs

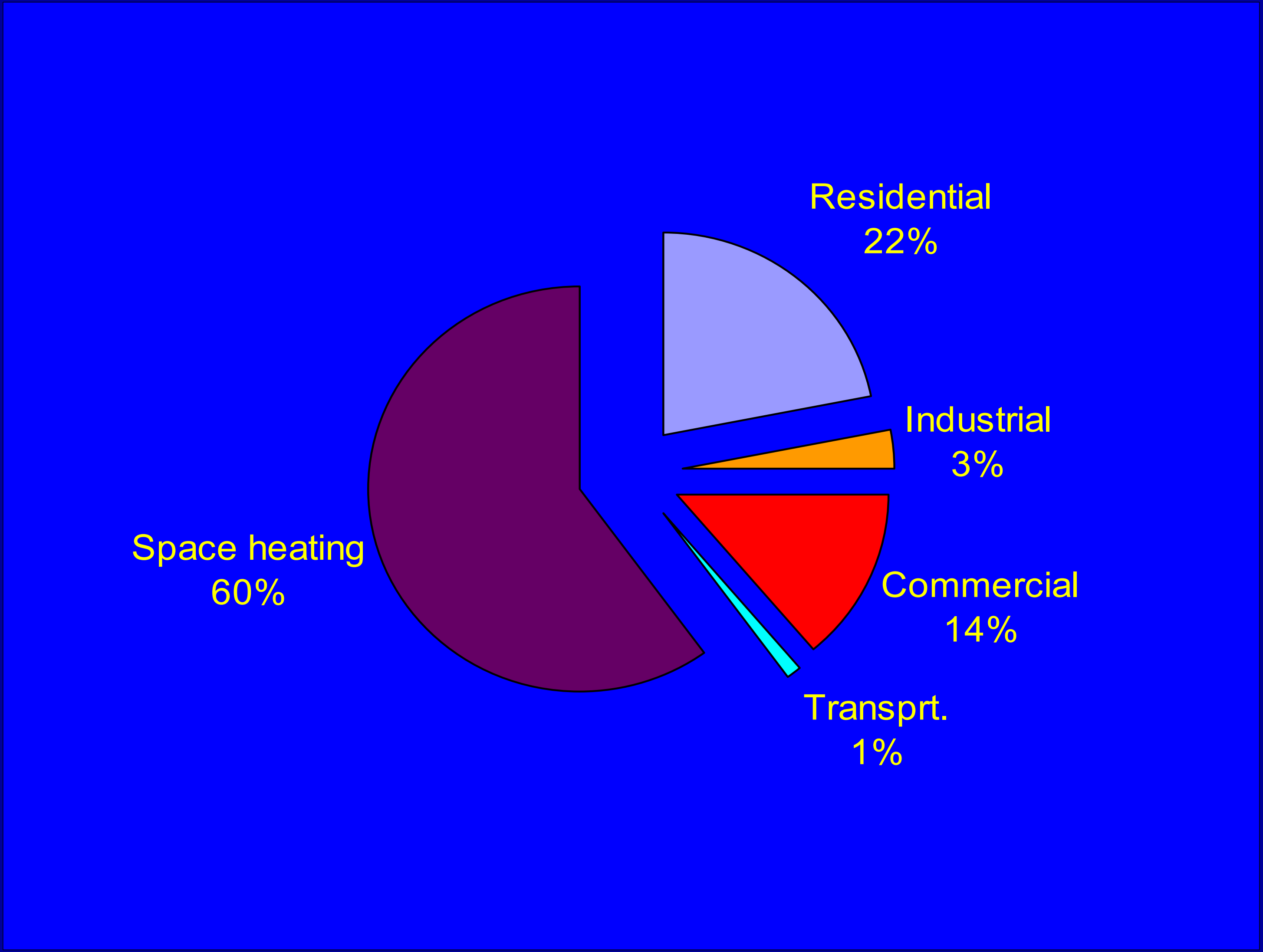
2. Potential Markets: Beijing, Shanghai,Guangdong



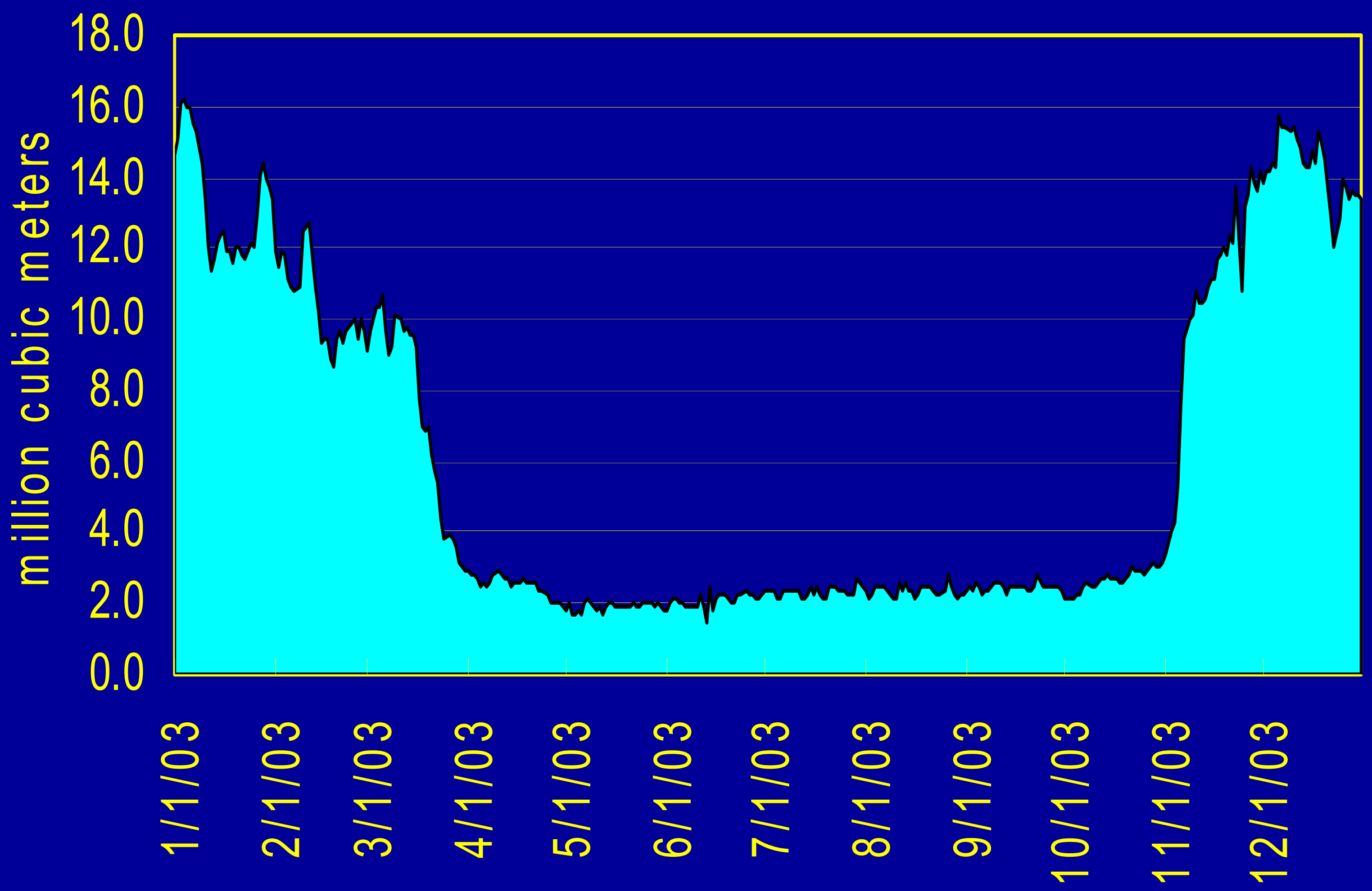
Beijing – Energy consumption



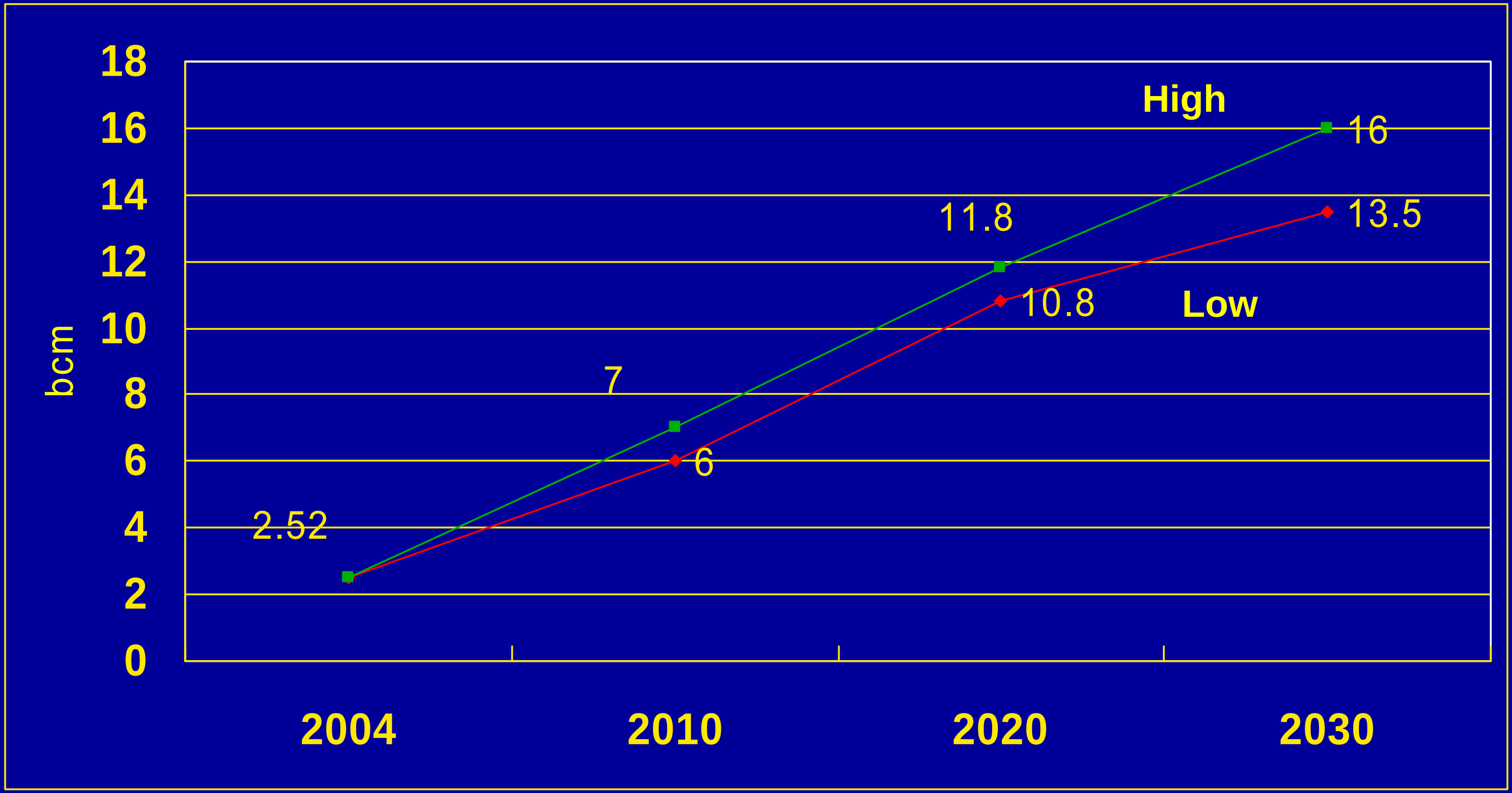
Beijing -- NG Consumption Structure (2003)



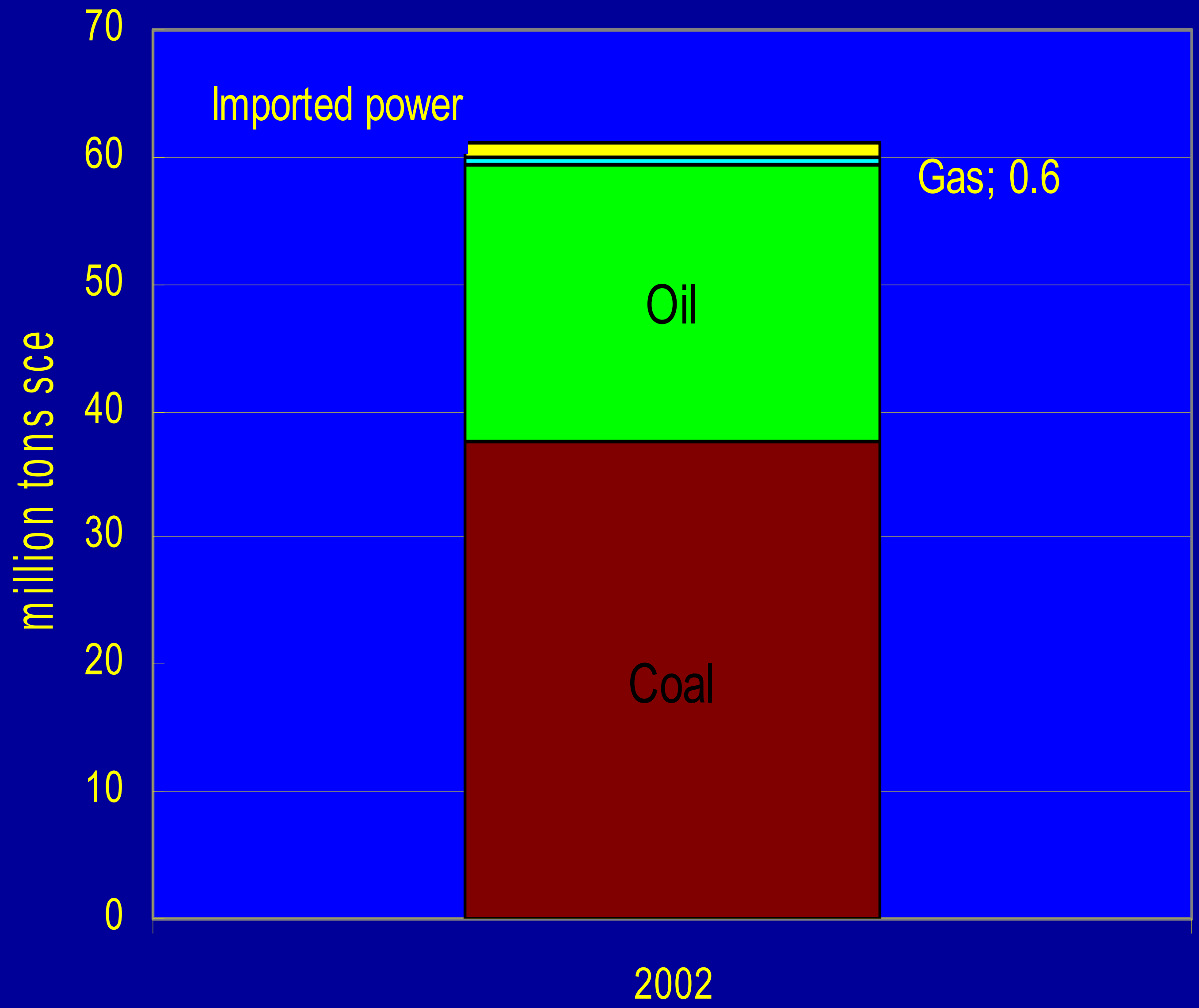
Beijing Seasonal NG Load Curve



Beijing -- Gas Demand Projection



Shanghai – Energy consumption

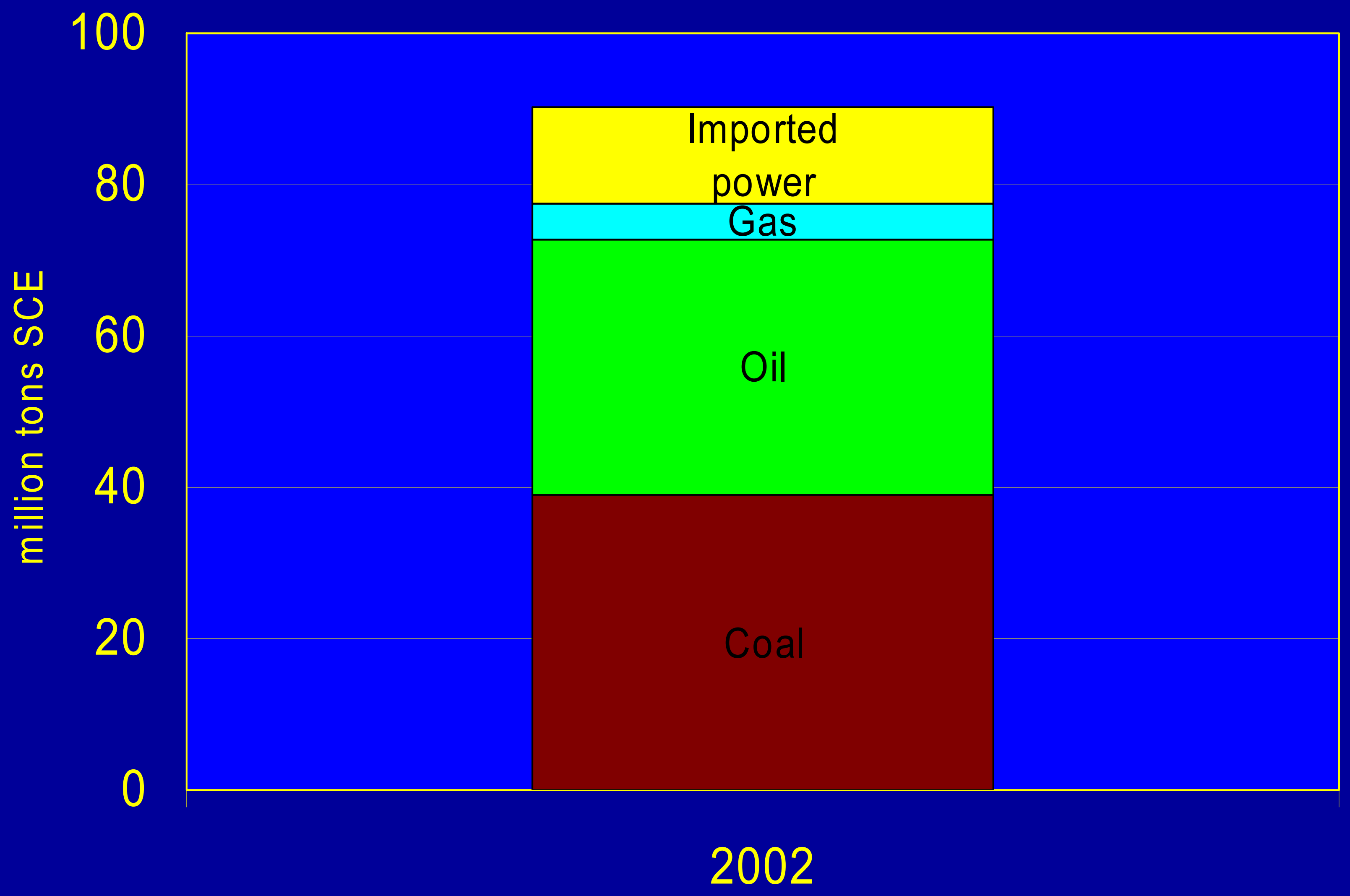


Shanghai – Future NG Applications

- CCGT
- Industrial boilers
- Distributed generation
- Heating/cooling

2 X 350 MW CCGT under construction

Guangdong – Energy consumption



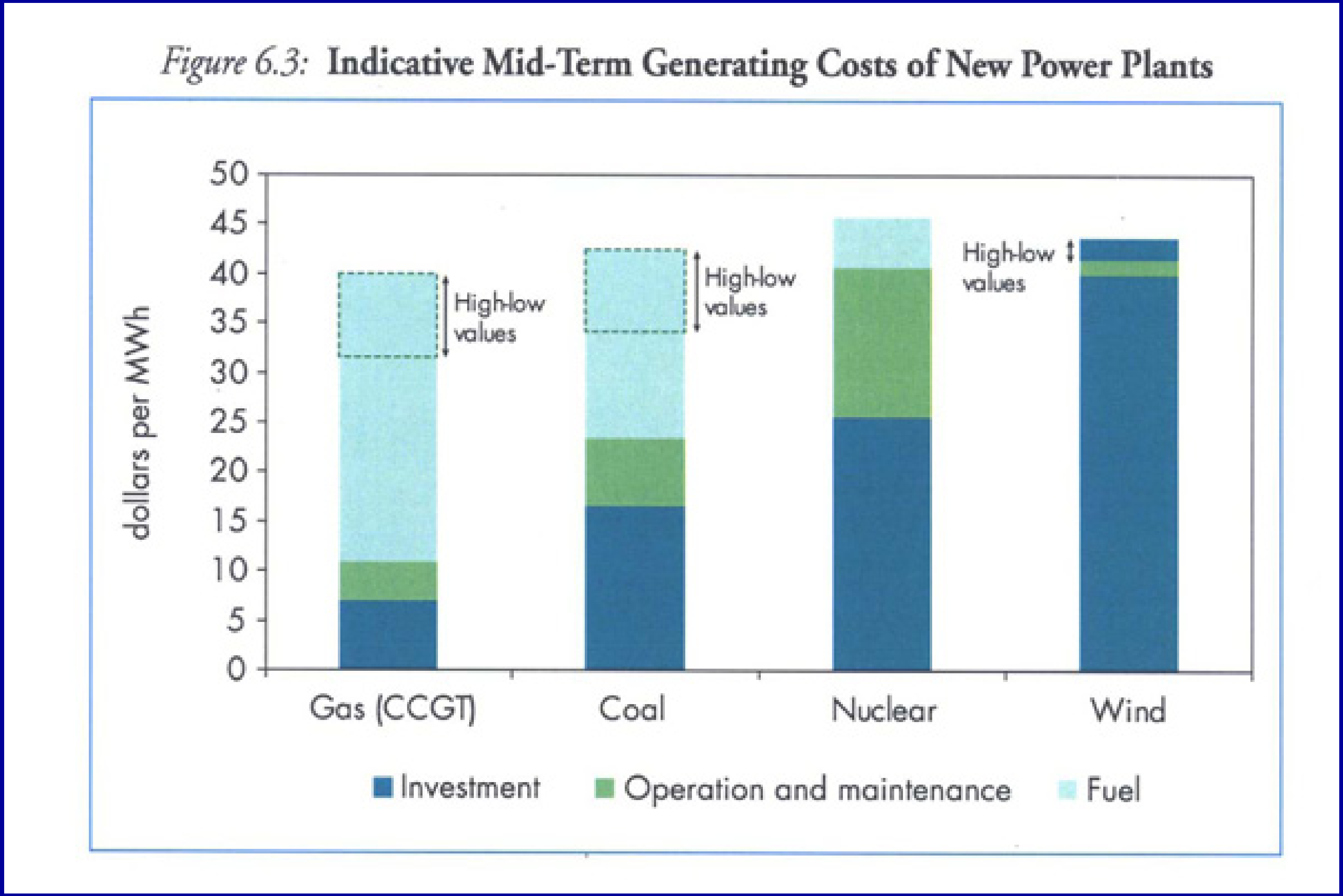
Guangdong – Natural gas application

- Electricity sector will be the largest off-taker
  - Current (end 2004) 40 GW projected to 100 GW (2020)
  - 9 units nuclear @ 1 GW per
  - 7 or 8 (4x600) MW coal plants being built (17-20+GW)
  - 11 gas units (online 2006) or 3.3 GW of planned 30-40 units (10 GW gas fired power total) by 2020
  - Hydro contracts from West and Three Gorges (11-18GW)
- Residential and commercial sector
- Other industrial uses

Plans and prices: is the standard story about to change?

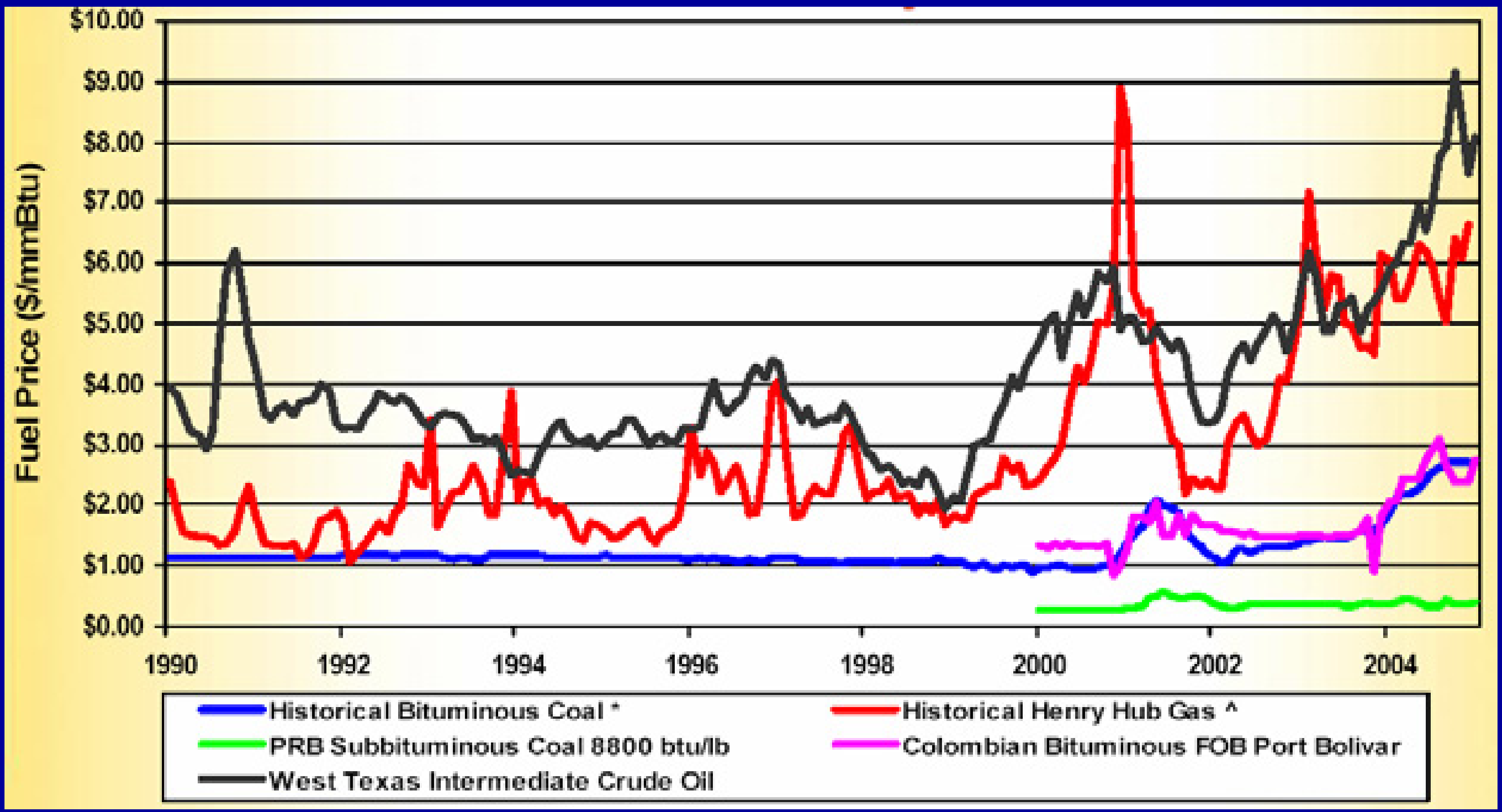
Relative Electricity Costs: Guangdong, August 2004

- ***Hydro***: 32-34 cents/kwh (fen in levelized costs);
- ***Coal without FGD:*** 37 cents/kwh;
- ***Coal with FGD***: 40 cents/kwh;
- ***LNG*** (all in): 43 cents/kwh;
- ***Nuclear***: 47-50 cents/kwh
- $4/mbtu gas = $70/ton coal

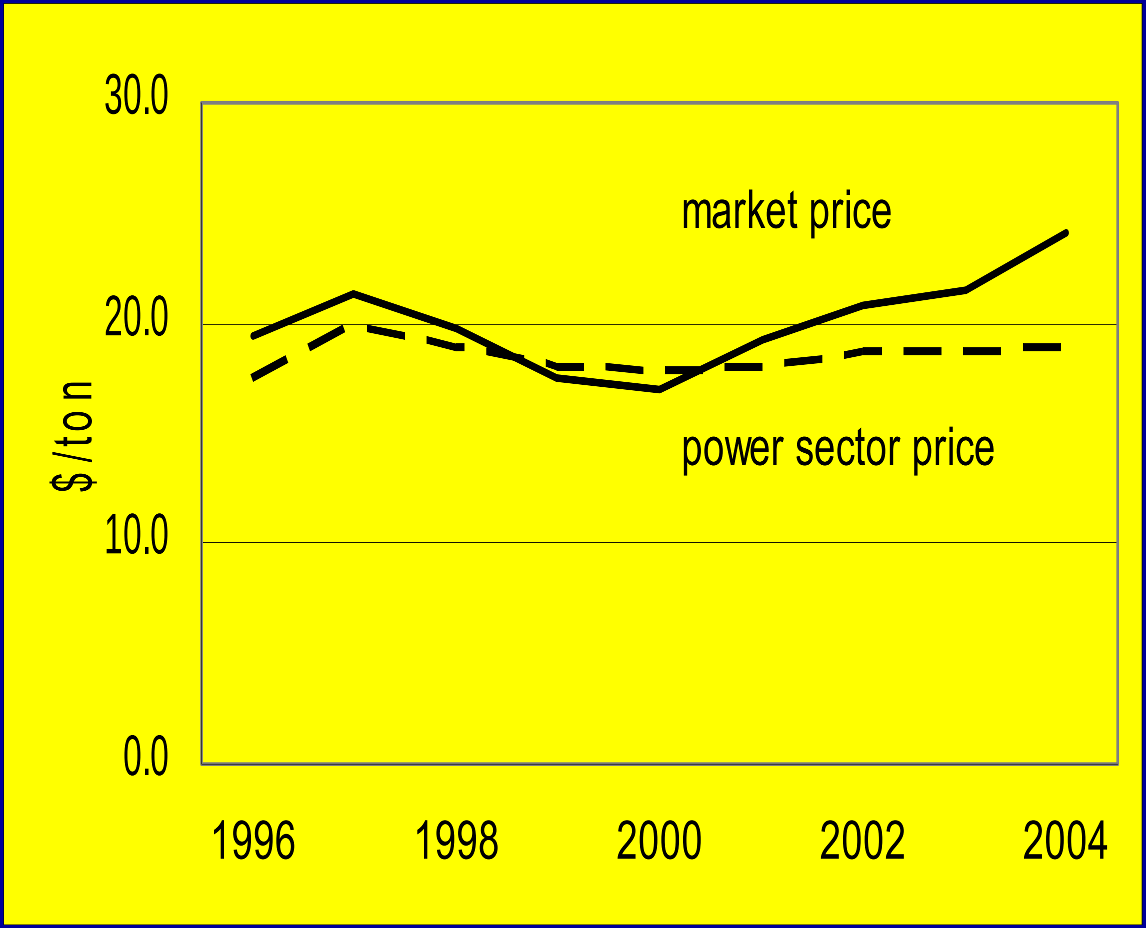


Source: IEA, World Energy Outlook 2004

Relative prices: Coal, gas ,oil



Mine mouth coal price



- 2004: Jan – Sept.
- Actual price for power generation is higher ($22/ton) due to sellers' resistance against planned price
- End-user prices are much higher, reaching $60 – $70/ton ($50 - $60 for power generation).

Supply Chains in Comparison

- **Coal**

Mine mouth → State-Owned Railroads → State-Owned Shipping → Plant

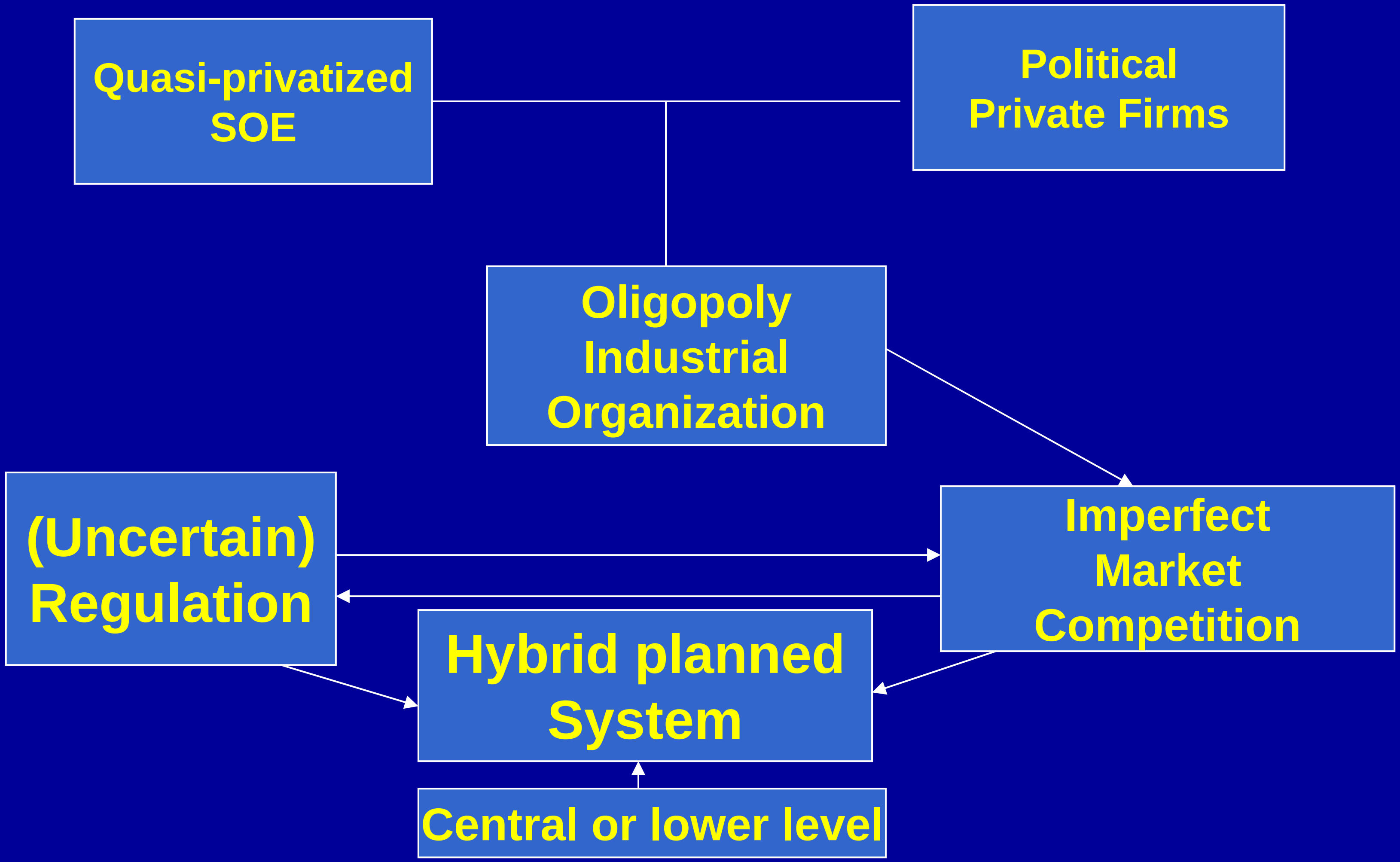
- **Natural Gas**

Well → Liquefaction → Shipping → Re-gas → Pipe → Plant

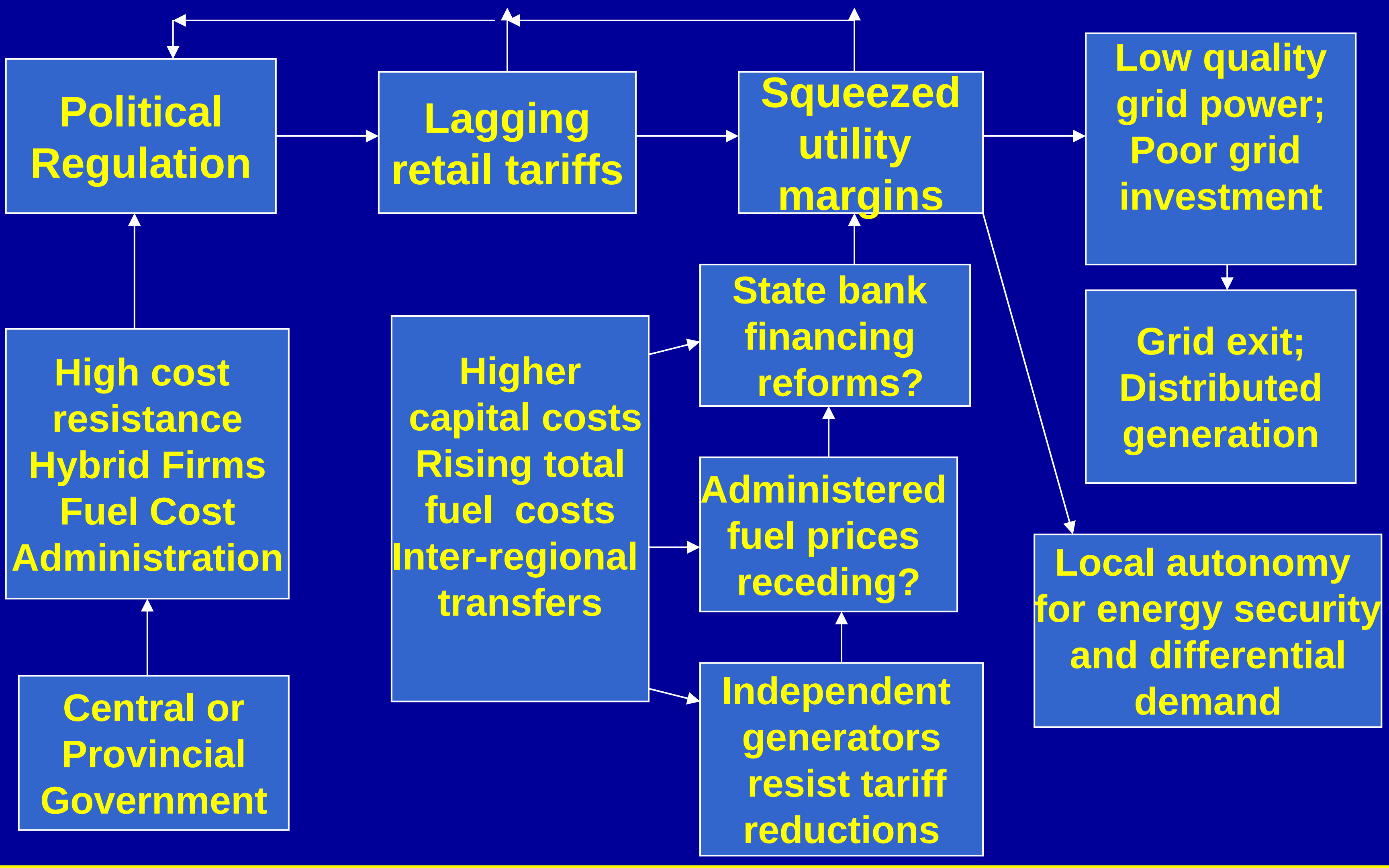
Non-price drivers of gas development

- Local autonomy (federalism)
- Chinese oil majors
- Environmental concerns
- Peak pricing
- Exchange rates
- Capital Market reforms
- Reliability and distributed power

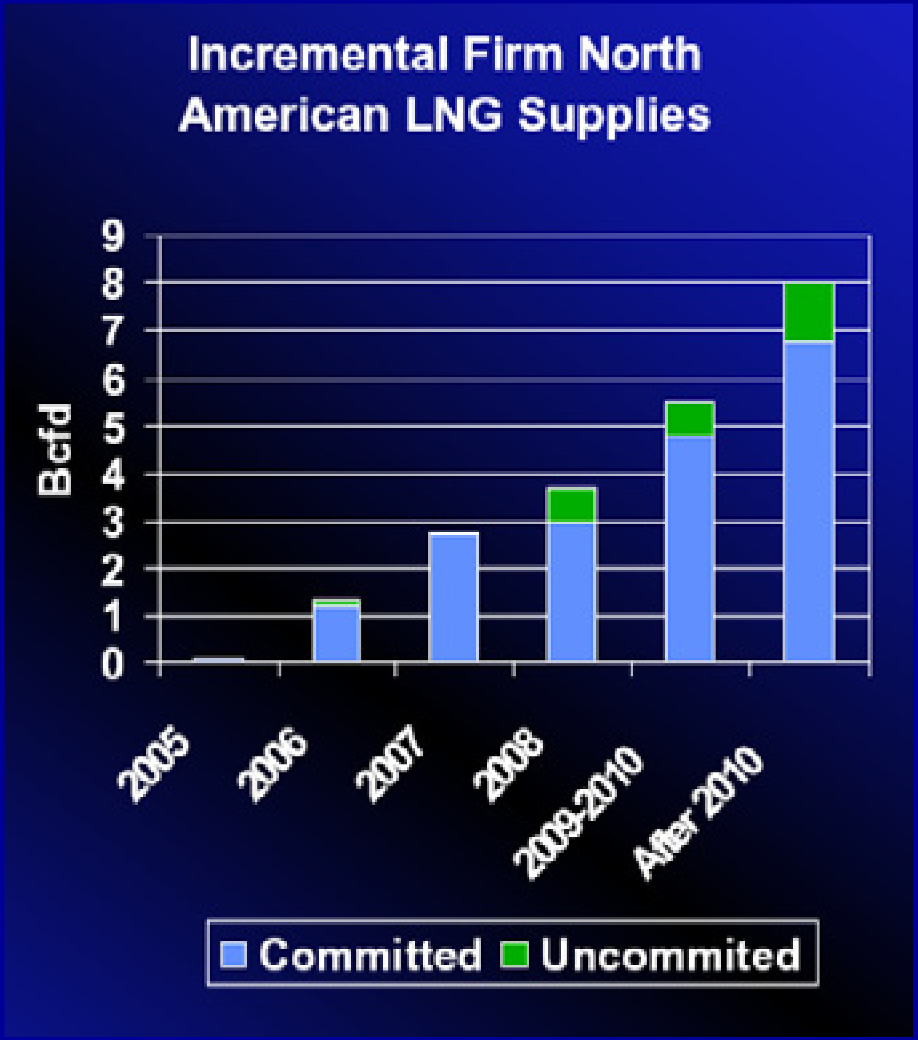
Electricity Reform Experience



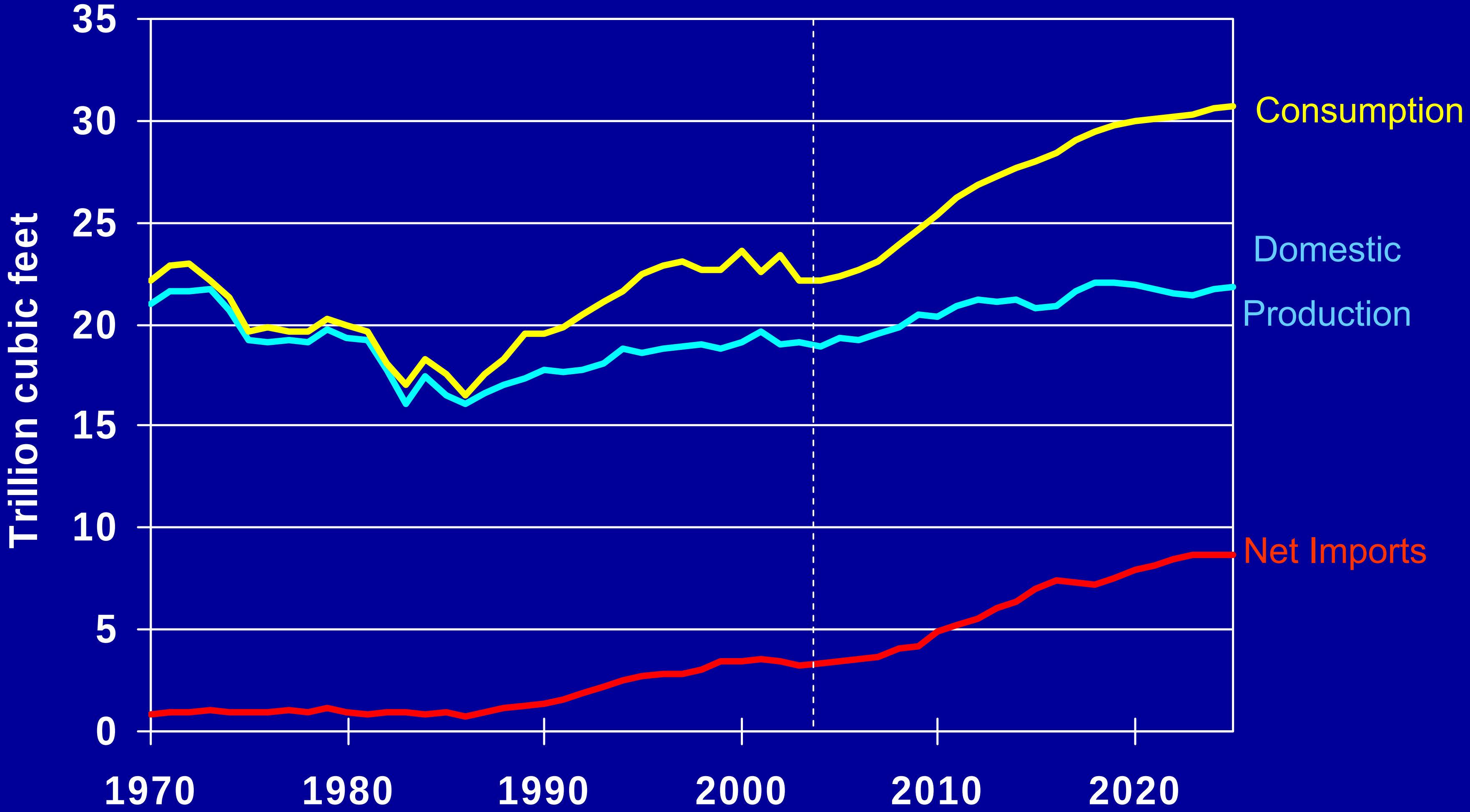
Regulatory Instabilities:



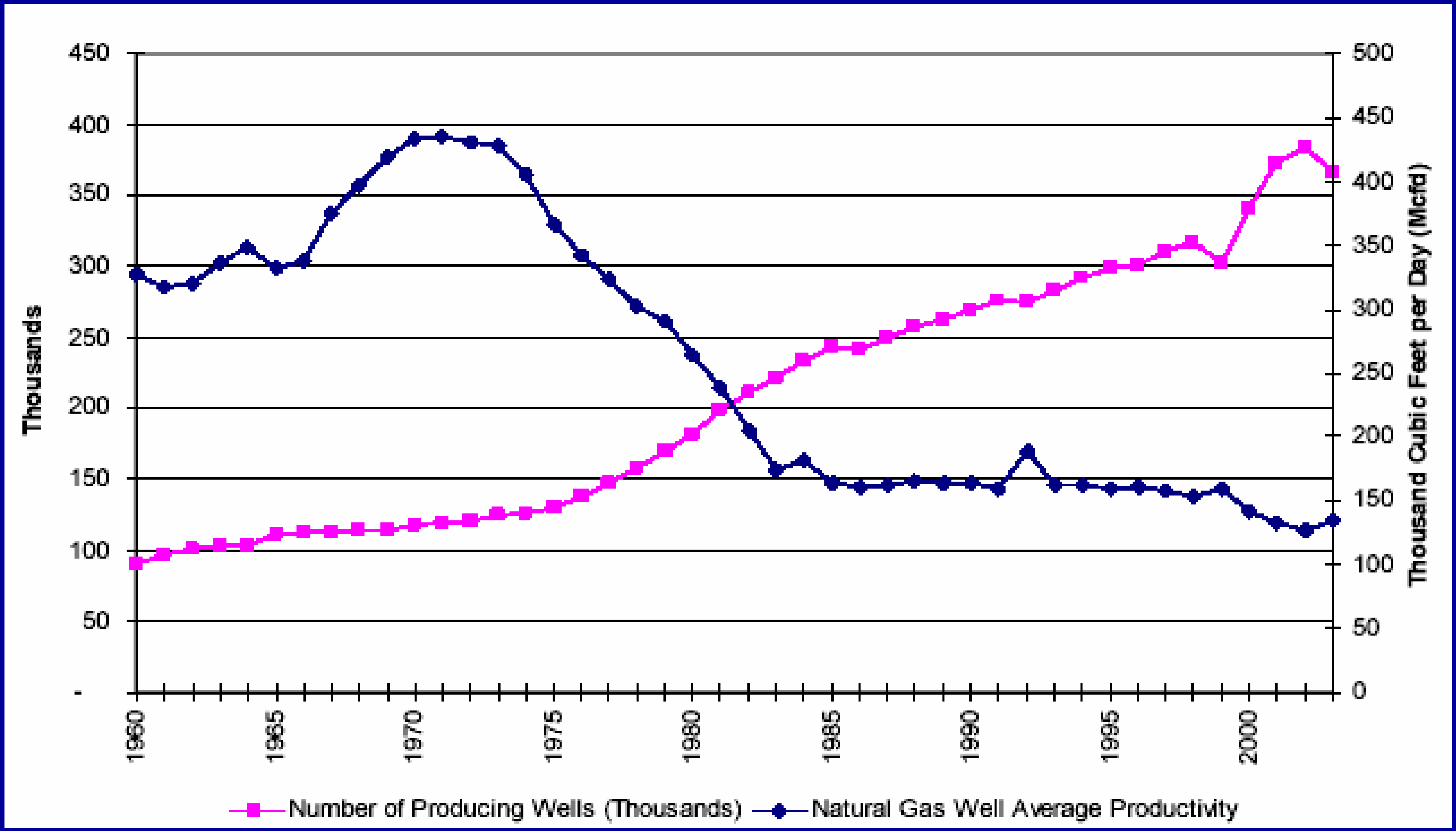
Incremental North American LNG



US Gas Supply and Demand (1970-2025)
EIA-AEO 2005



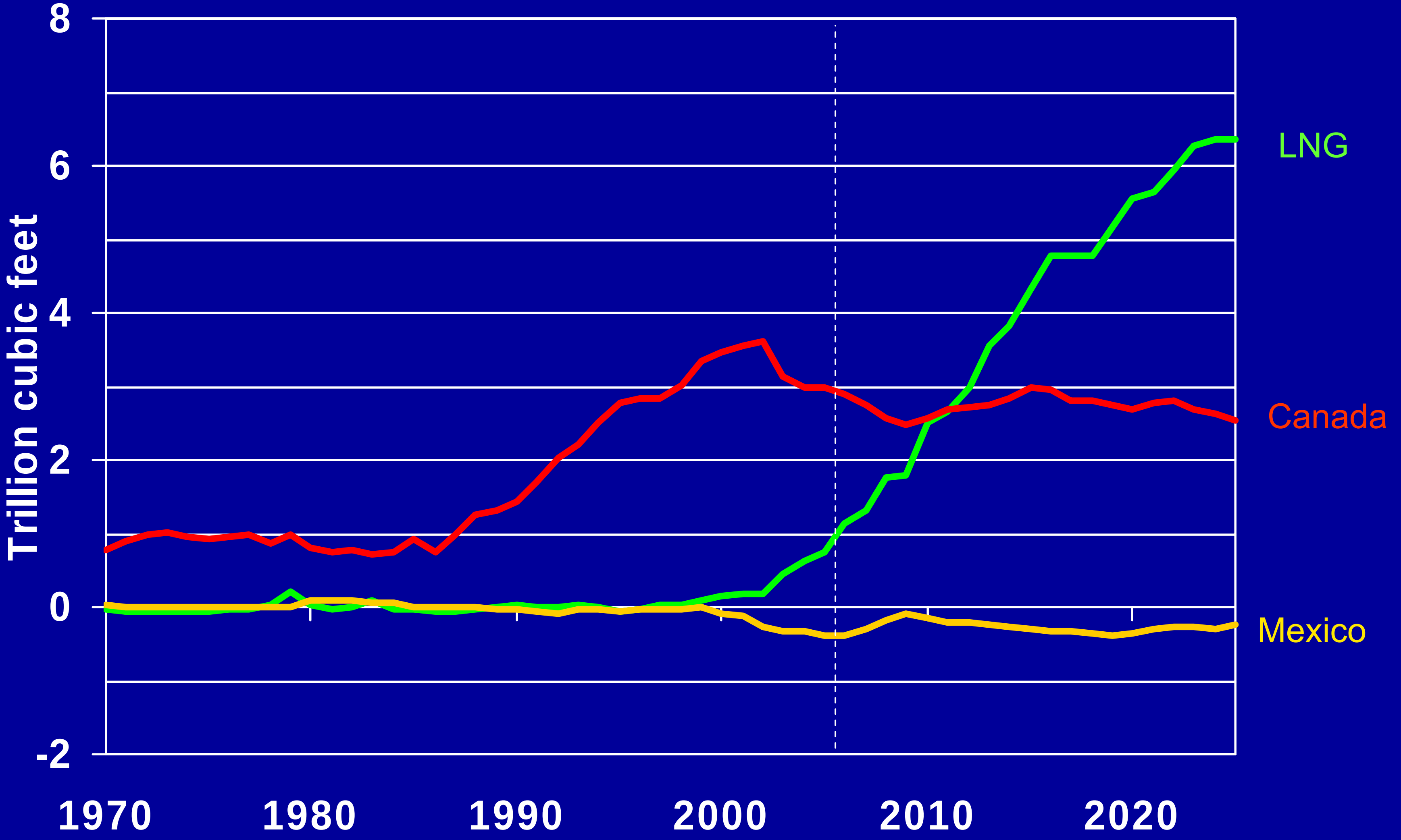
of Wells vs. Avg. Productivity



Source: US EIA

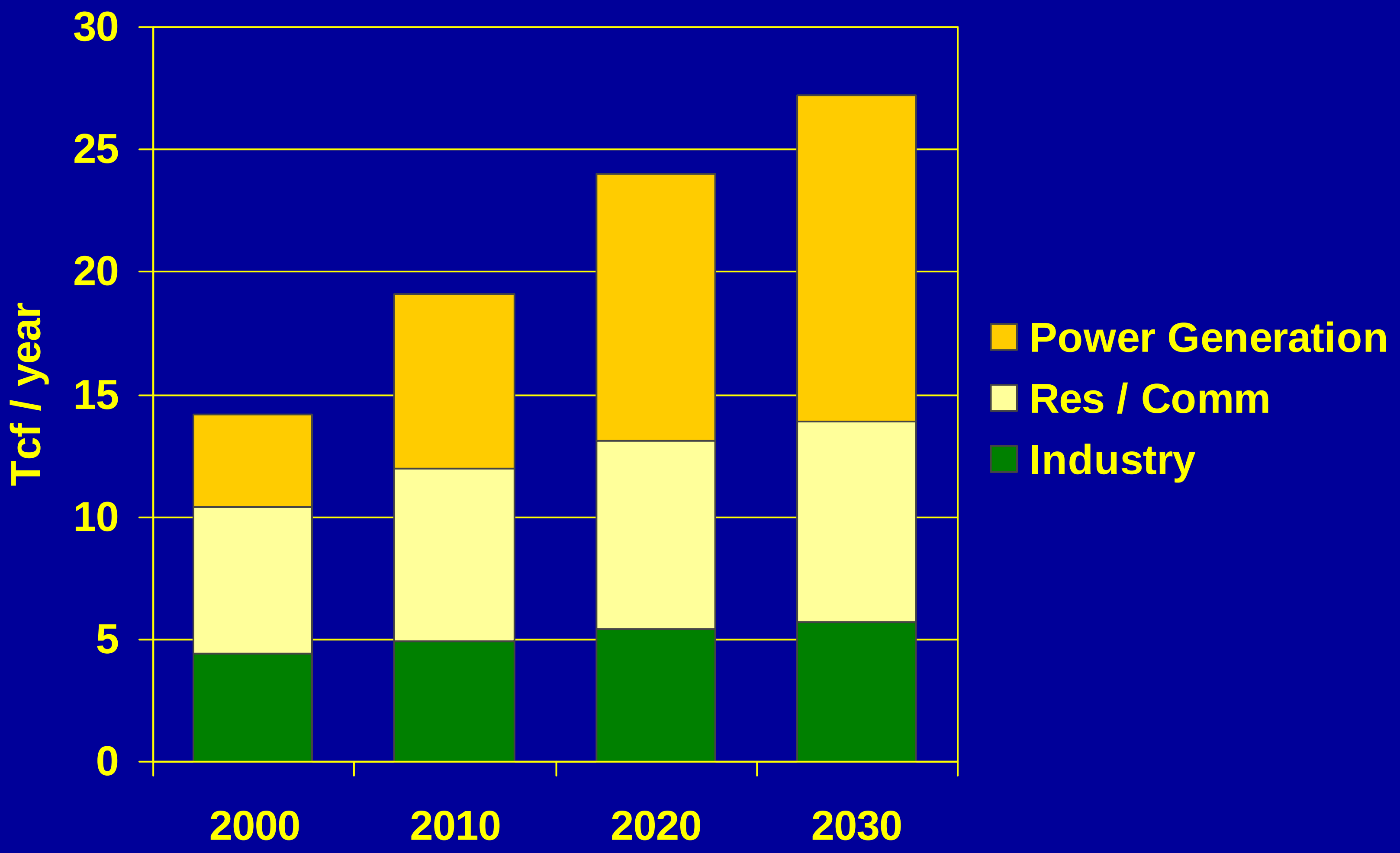
Net US Gas Imports, 1970 – 2025

EIA-AEO 2005

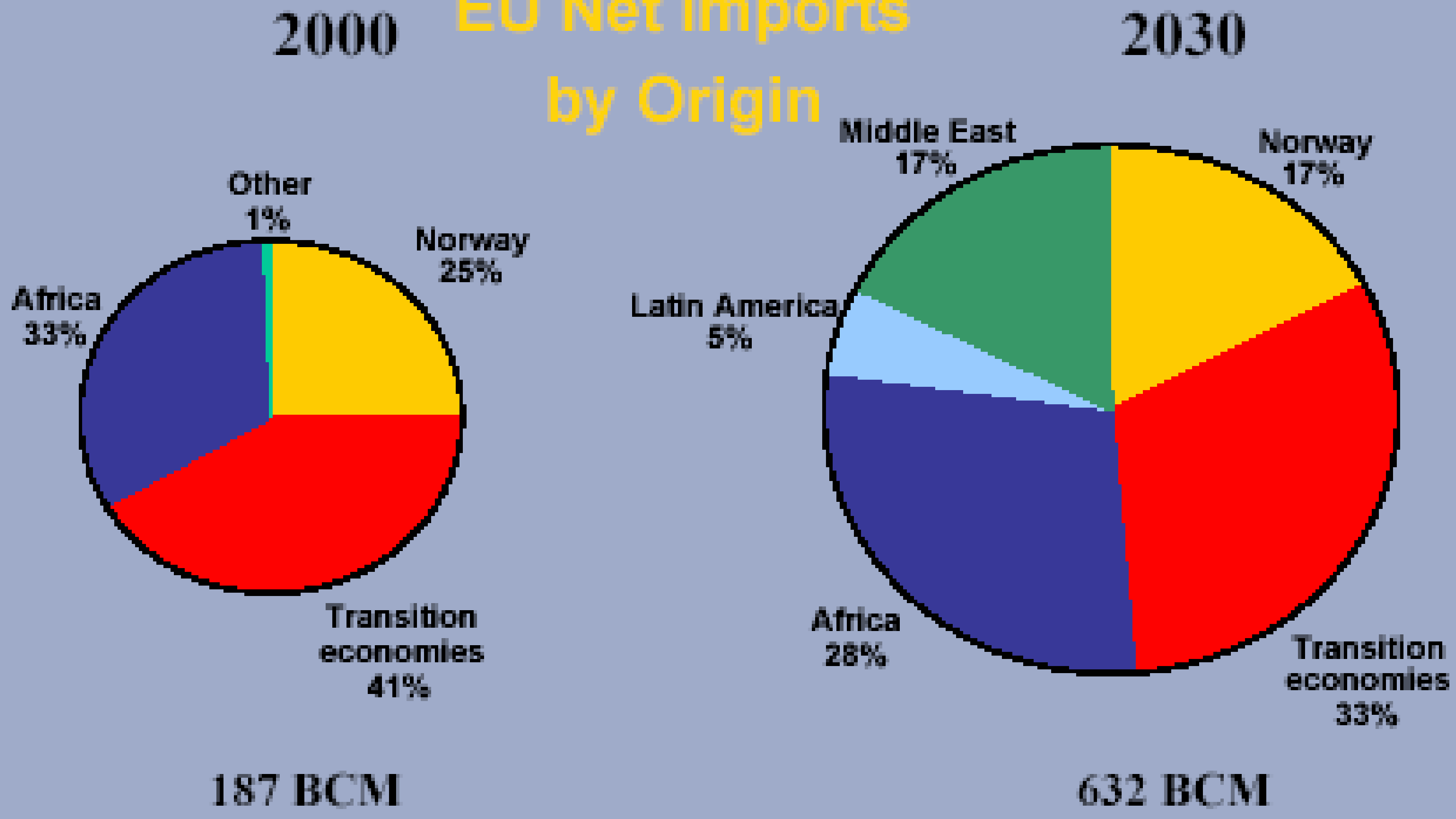


European Gas Consumption by Sector to 2030

IEA-WEO, 2002



EU Net Imports by Origin



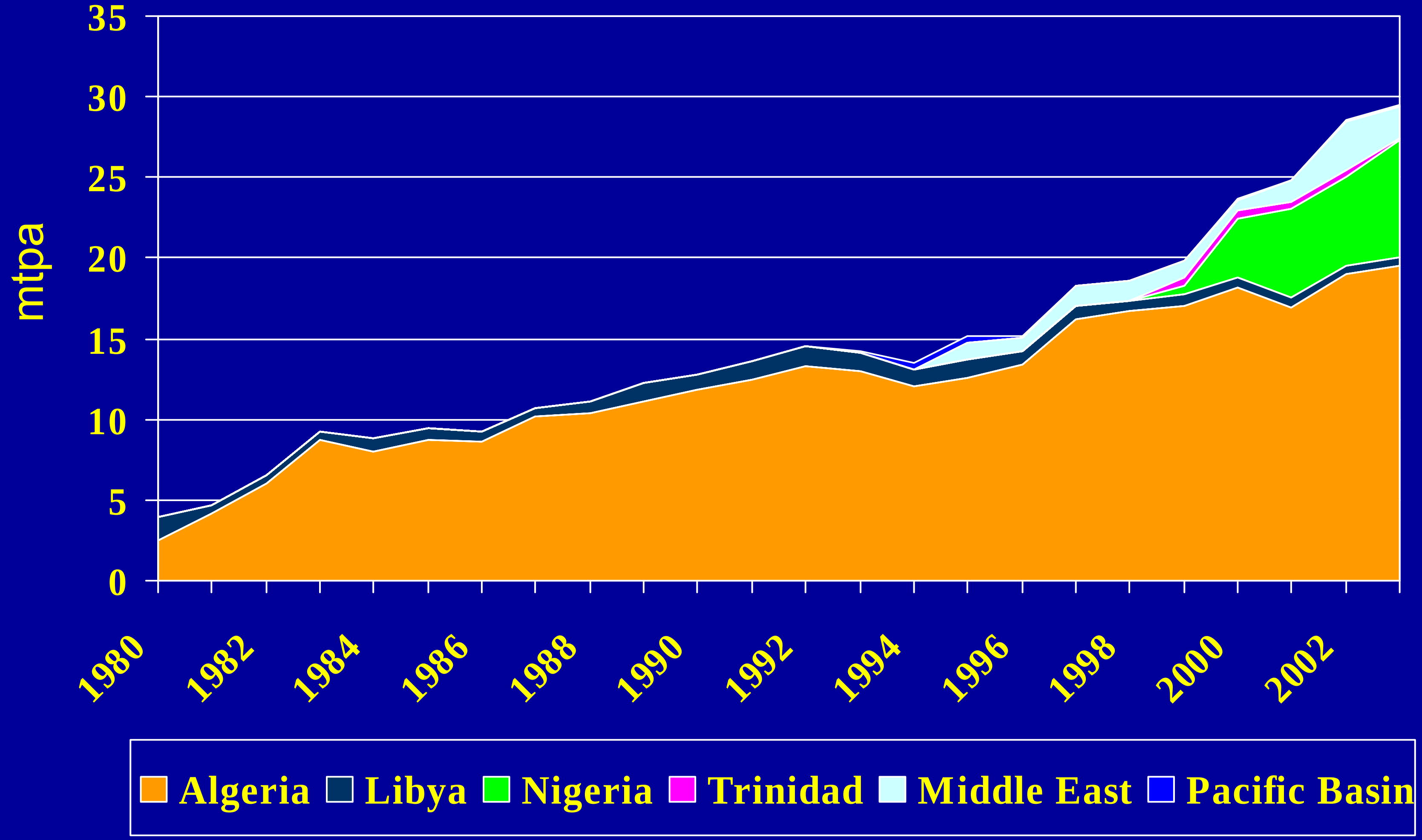
EU Consumption
Y2000 = 15 Tcf
Y2030 = 27 Tcf

Domestic gas production:
Y2000 = 8 Tcf
Y2030 = 5 Tcf

Source: IEA-WEO, 2002

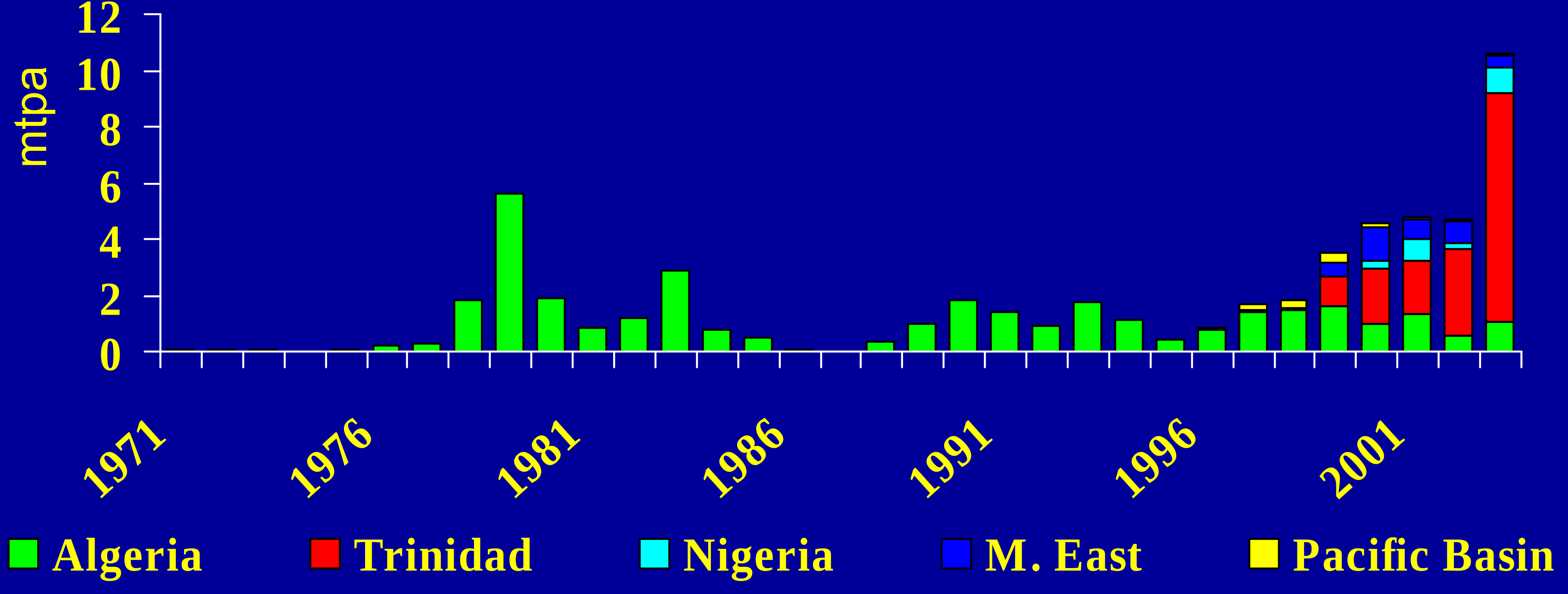
Sources of European LNG

1980 - 2003 (million tonnes per annum, mtpa)



Source: Alphatania

US LNG Imports by Source
1971-2003



Source: Alphatania

Revolution in Global LNG Markets (1)

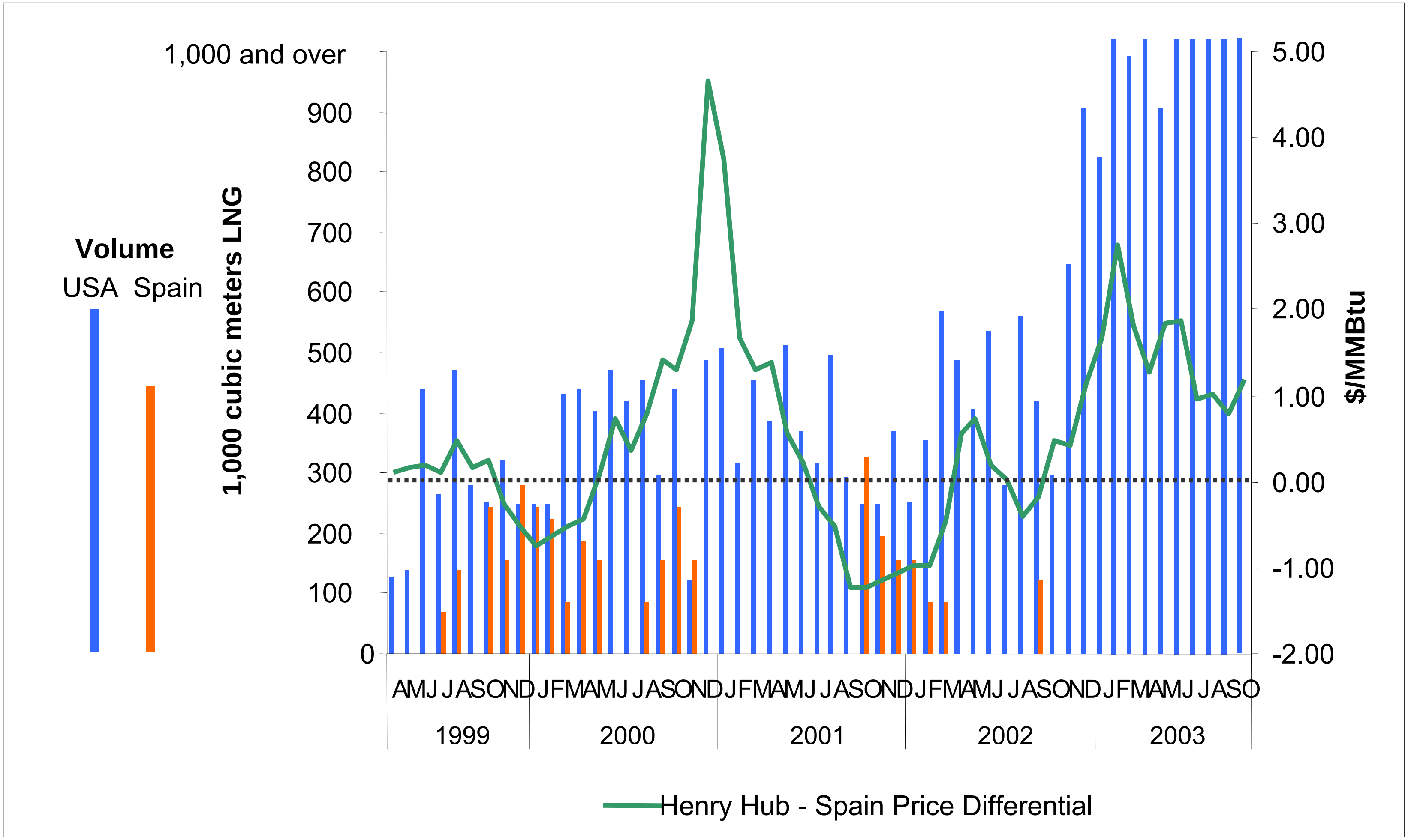
- Shift from “old world” defined by:
  - Few importers
  - Rigid long-term, take-or-pay contracts with destination clauses
  - Muted price incentives to divert cargoes
  - “Buyer takes the volume risk and seller takes the price risk”
  - Captive customers of regulated utilities ultimately backed contracts

Revolution in Global LNG Markets (2)

- Toward a “new world” defined by more flexible LNG trade and driven by:
  - Liberalization of gas and electricity markets
  - Declining LNG costs (esp. liquefaction and regas)
  - Growth of new markets (Spain, US, UK)
  - Entry of energy super-majors to gas trade

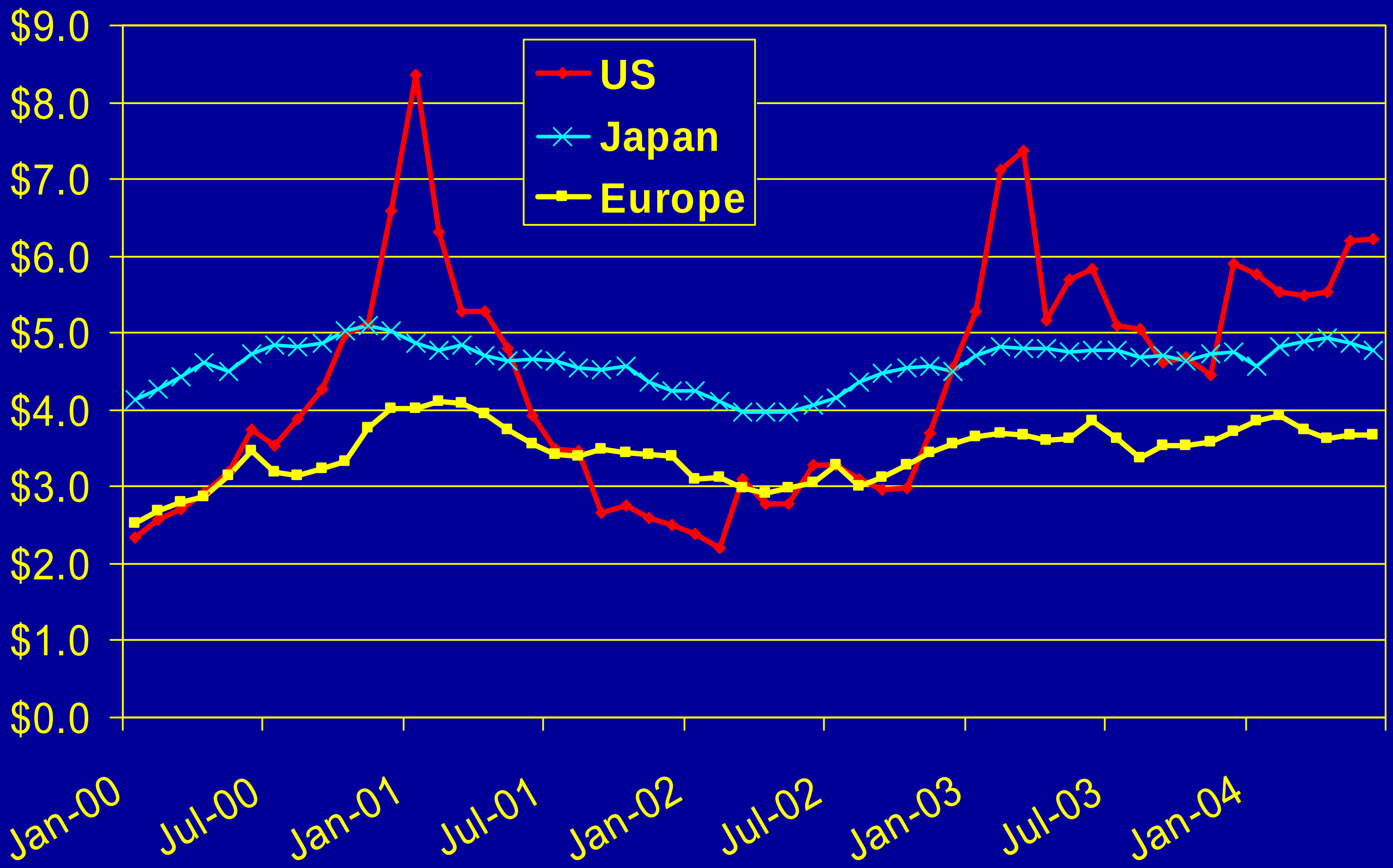
- Flexible LNG trade will integrate US and European gas (and electric power) markets

Trinidad's ATLANTIC LNG Cargoes Already Follow US-Spain Price Differential:



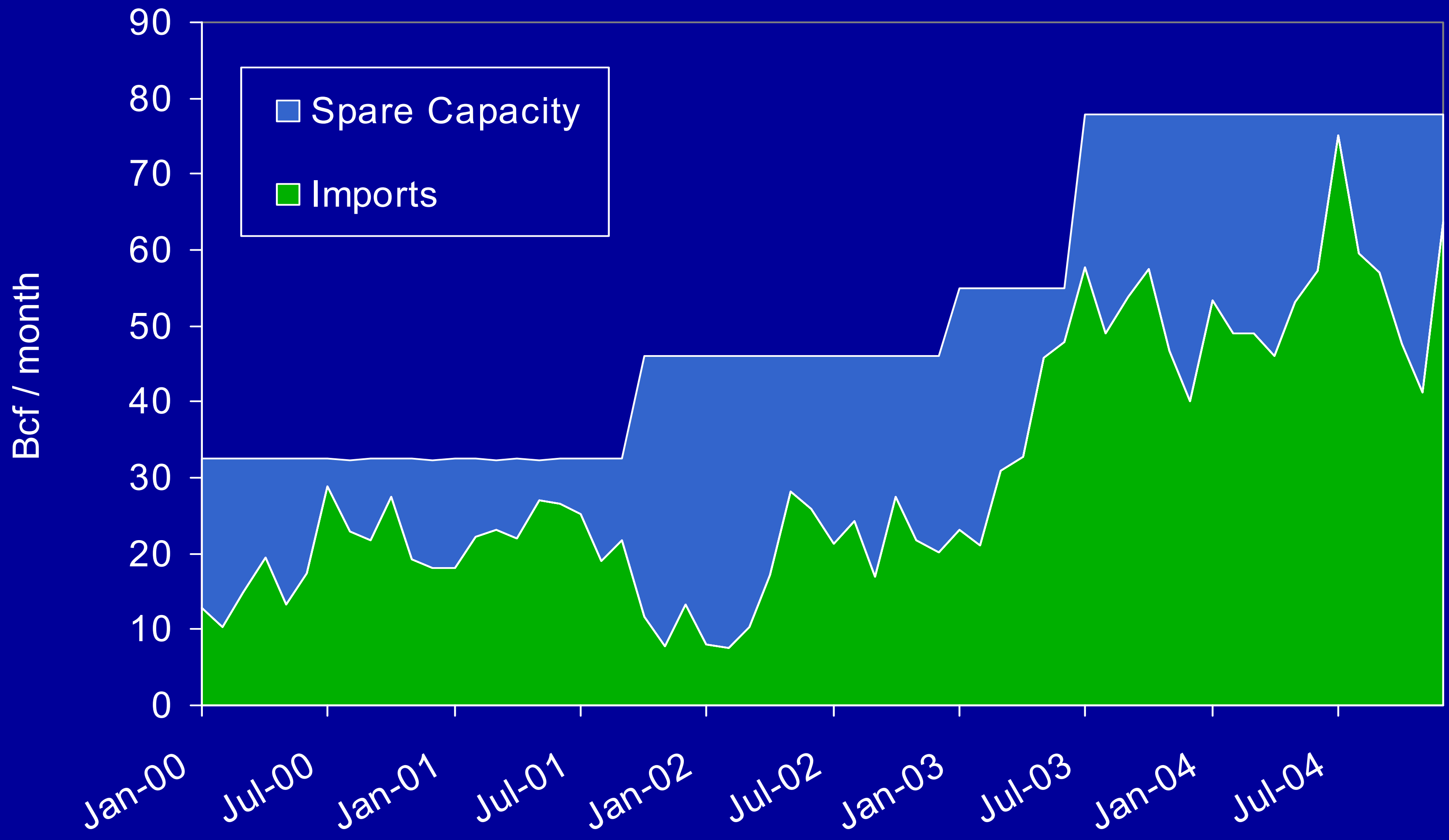
Gas Strategies Consulting Ltd.

US Spot, Japanese & European LNG Prices
($/MMbtu)



**Henry Hub for U.S. data, average of Japanese & European landed LNG prices*

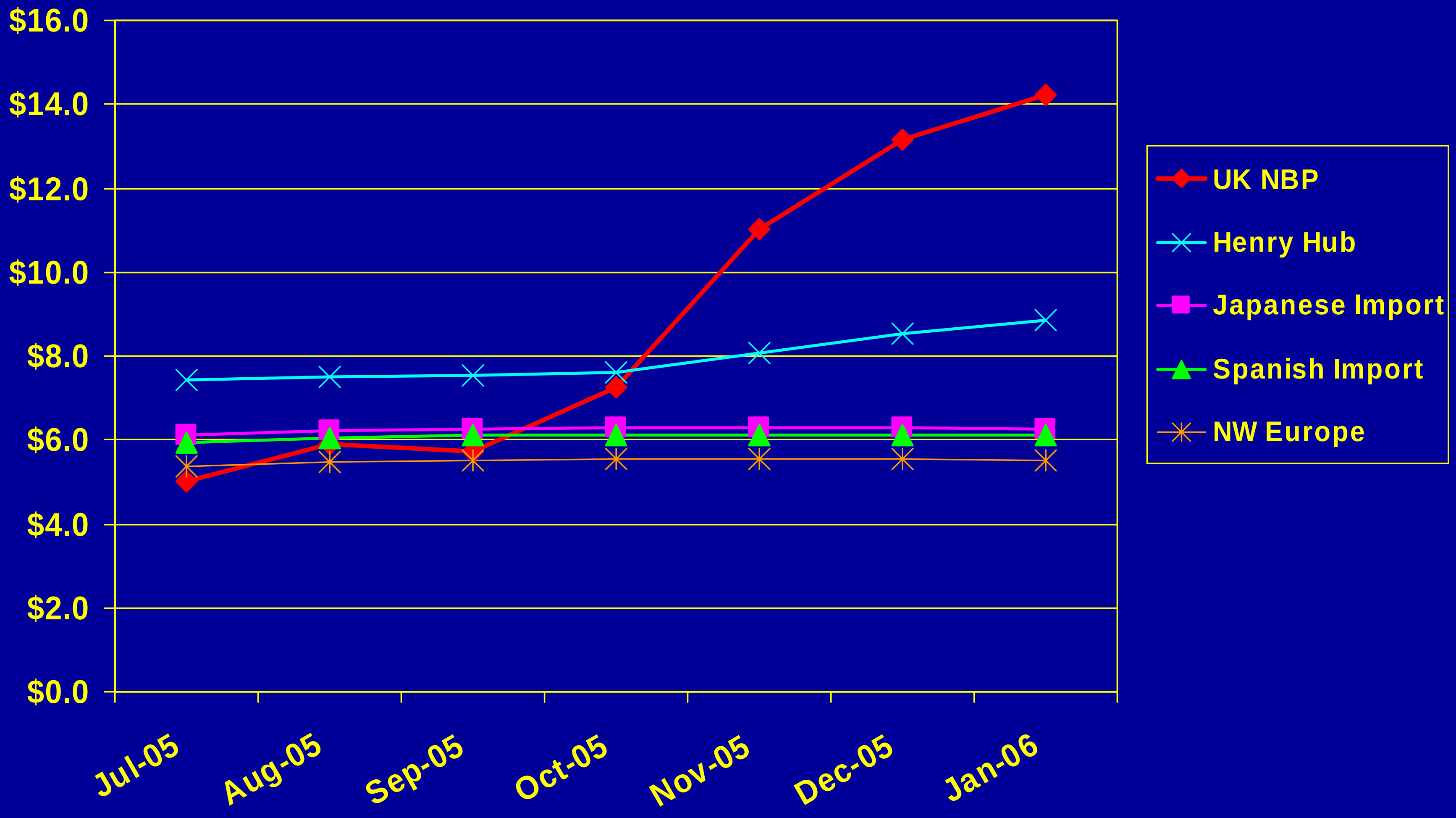
US LNG Import Capacity Utilization



US EIA

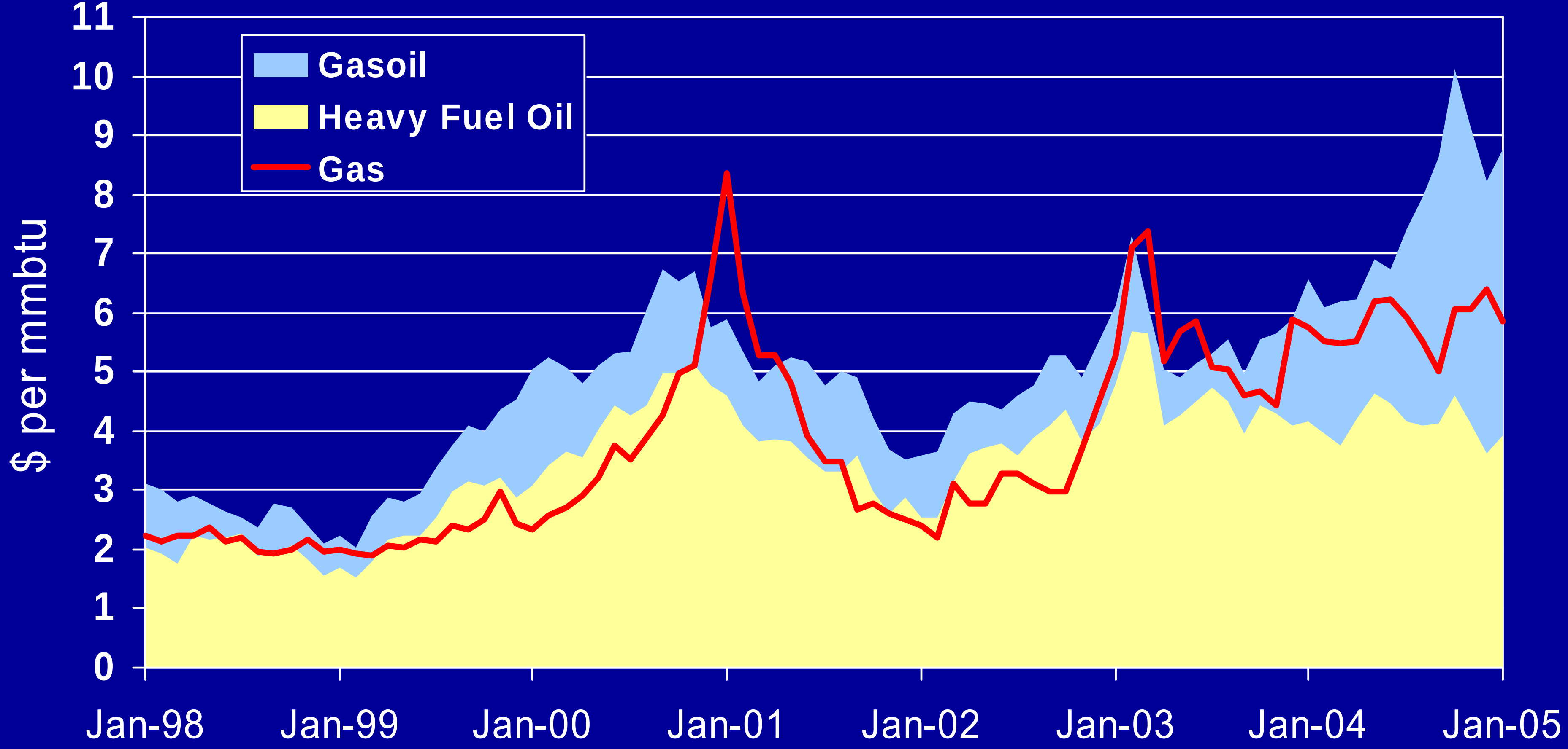
Forward Prices in Key LNG Markets

(US$/MMbtu; 20 July 2005)



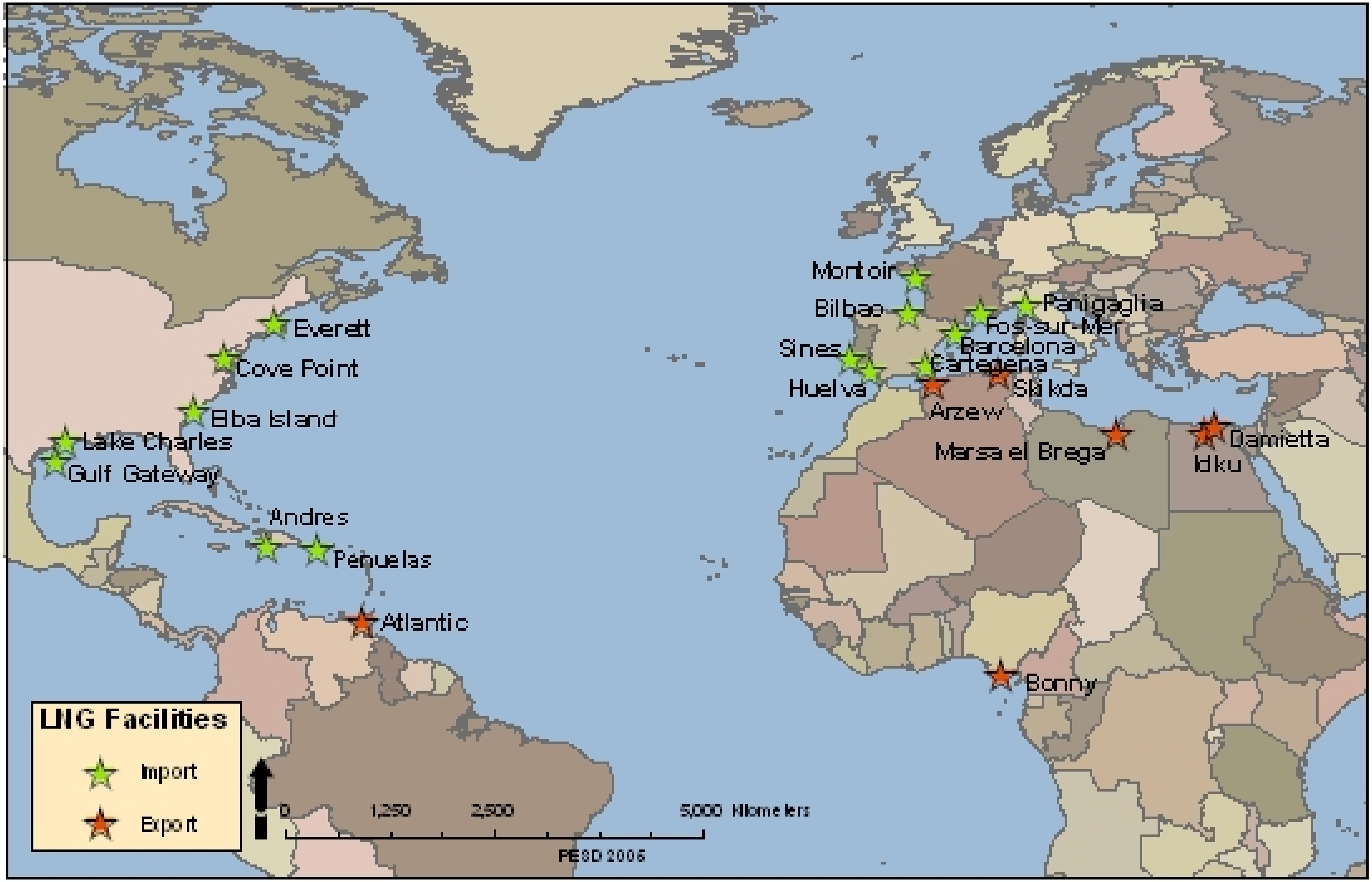
Source: Heren LNG Markets

US Gas Prices Linked to Oil Products

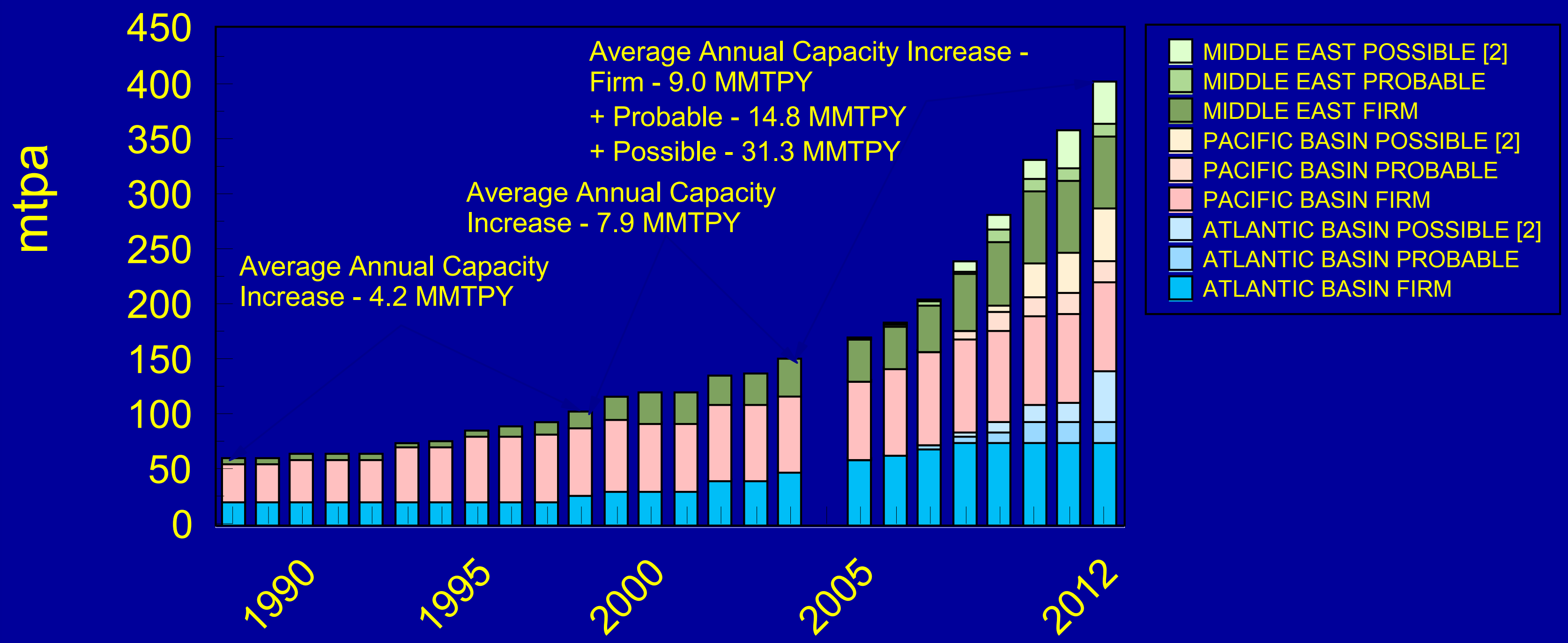


Purvin & Gertz 2005

Atlantic Basin Players



Global LNG Supplies



Source: James Jensen

Key Factors Shaping Atlantic Basin Market

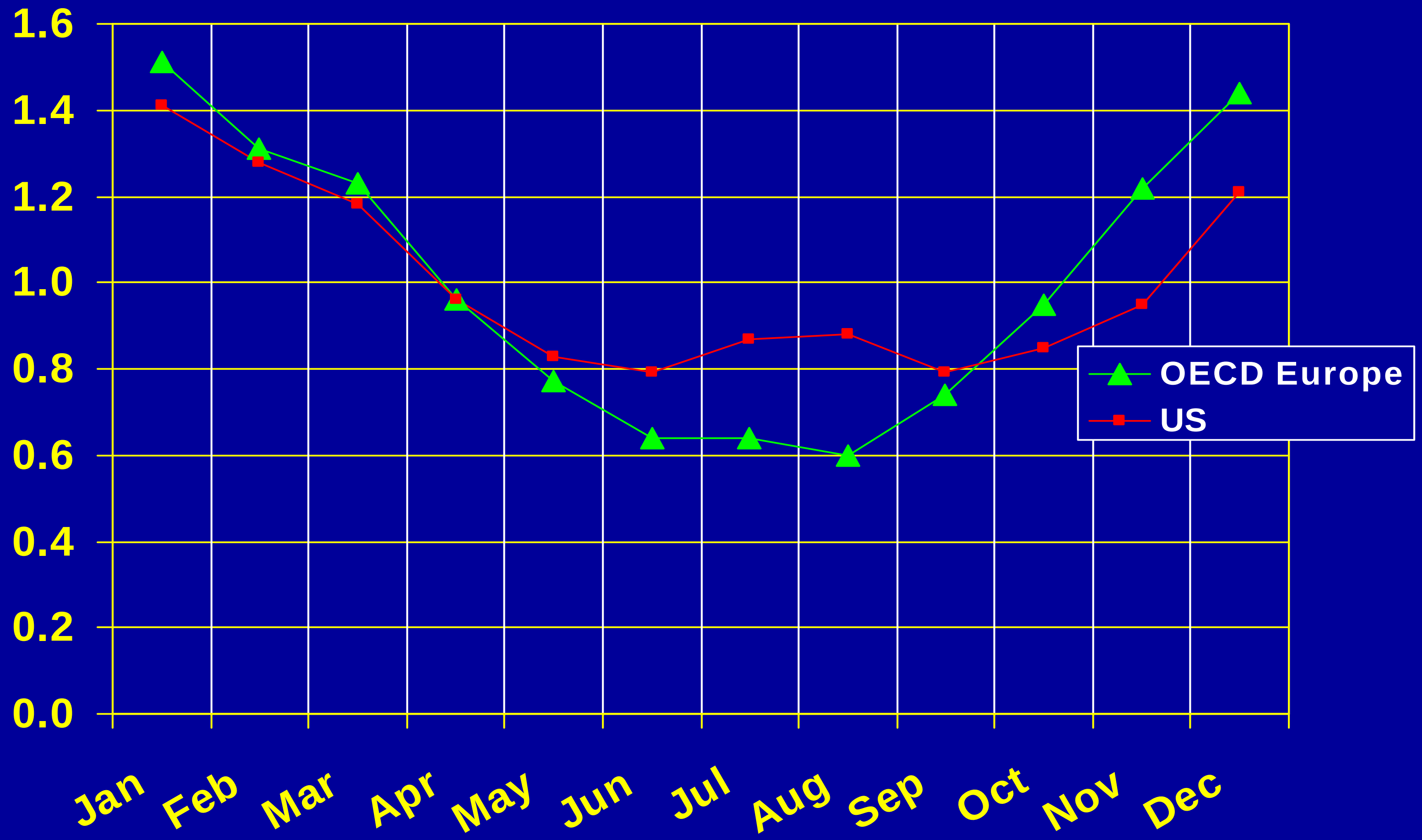
1. Market fundamentals
   - Fixed and variable costs for each segment of LNG supply chain

2. Seasonal, stochastic variations in gas demand in Atlantic Basin markets

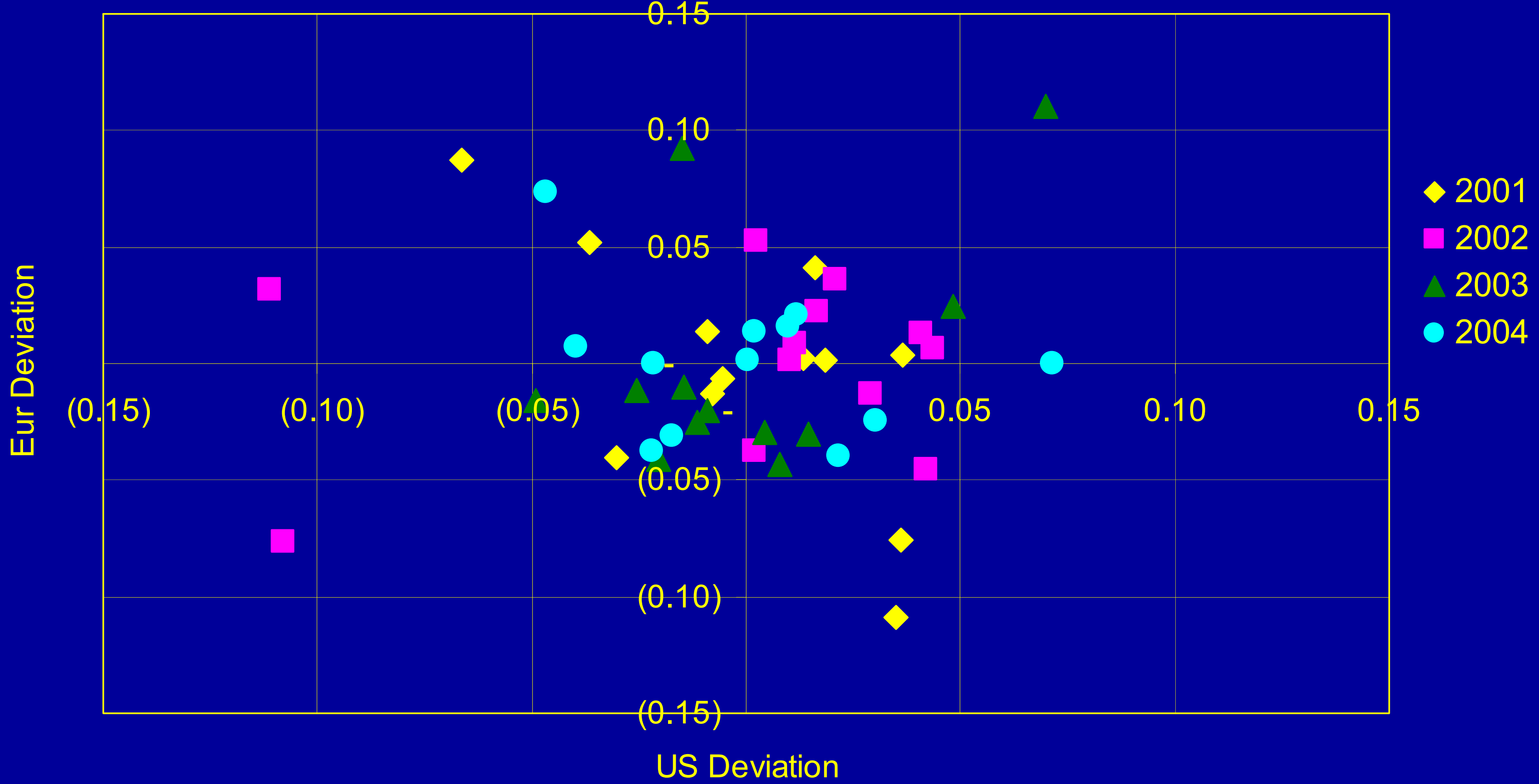
3. Market rules in gas and electricity for US & Europe
   - Contract provisions (oil-linked, regulatory constraints on term and pricing provisions?)
   - Contracting strategies of buyers and sellers

4. Price elasticity of demand for Atlantic Basin markets
   - composition of demand (electric power, industrial, residential)
   - market rules (see above)

Monthly Demand Index: US vs. OECD Europe
Average 2001-2004



Monthly Consumption Deviations from 4-Yr Avg.
(2001-2004); US vs. OECD Europe



Key Issues

- Do LNG terminals get built? If so, where?
- What are the access provisions to regasification terminals?
  - FERC’s Hackberry decision
  - “Use it or Lose it”—the UK model
  - Open access, ala US interstate pipelines
- LNG procurement contracts and regulatory approval?
  - Pricing structure (fixed price, Henry Hub-linked, $/MWh linked?)
  - Term-length
  - Availability of cargoes?
- “Security of Supply” concerns and regulatory oversight

Factors Driving U.S. Natural Gas Demand

% Δ Gas Demand =

+ 1.000 x <u>% Δ Real GDP</u>

+ 0.250 x <u>% Δ Heating Degree Days</u>

+ 0.075 x <u>% Δ Cooling Degree Days</u>

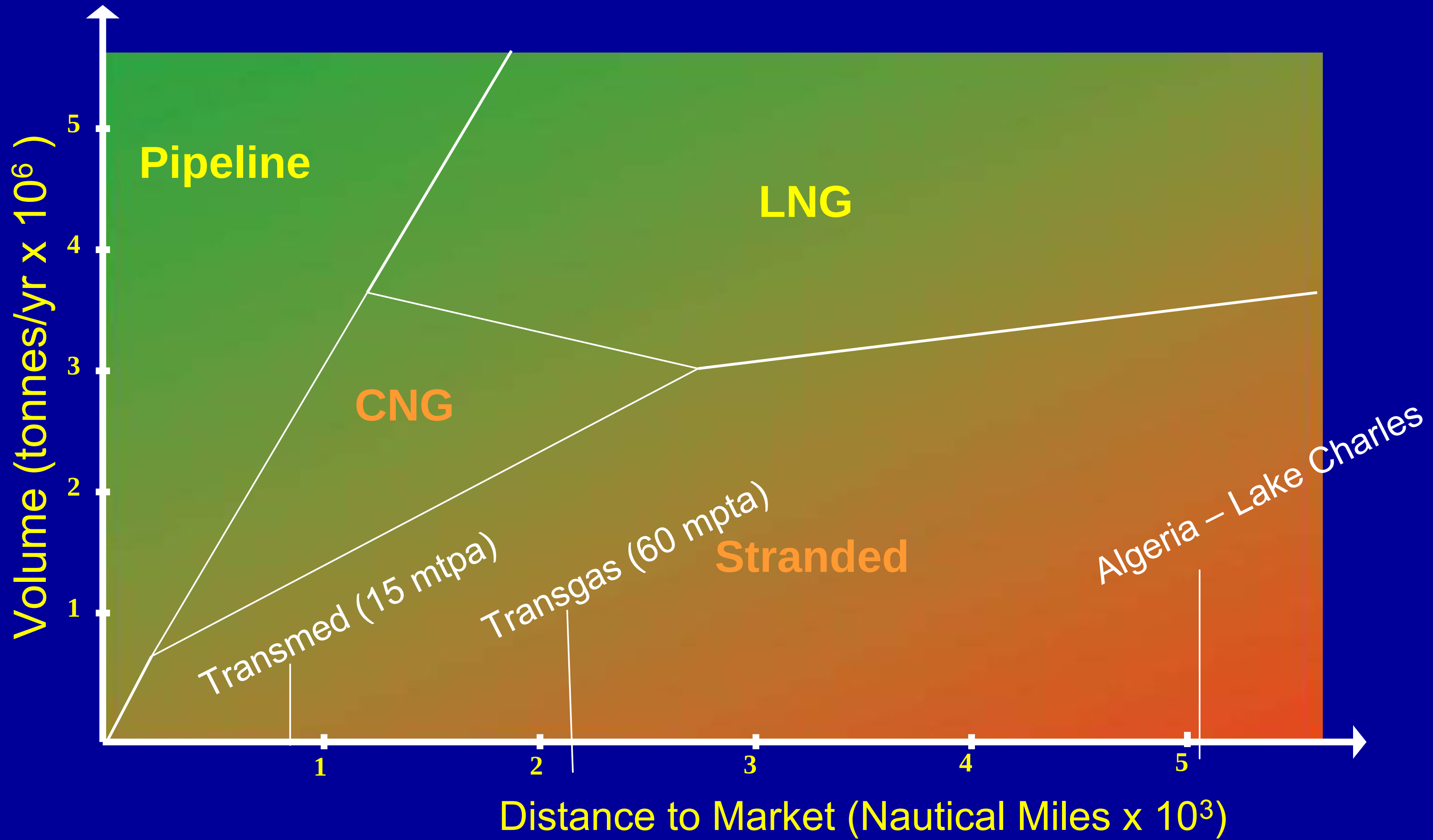
+ 0.075 x <u>% Δ Real Oil Price</u>

- 1.000 x <u>% Δ Real Gas Price</u> (lag)

- 0.300 (constant)

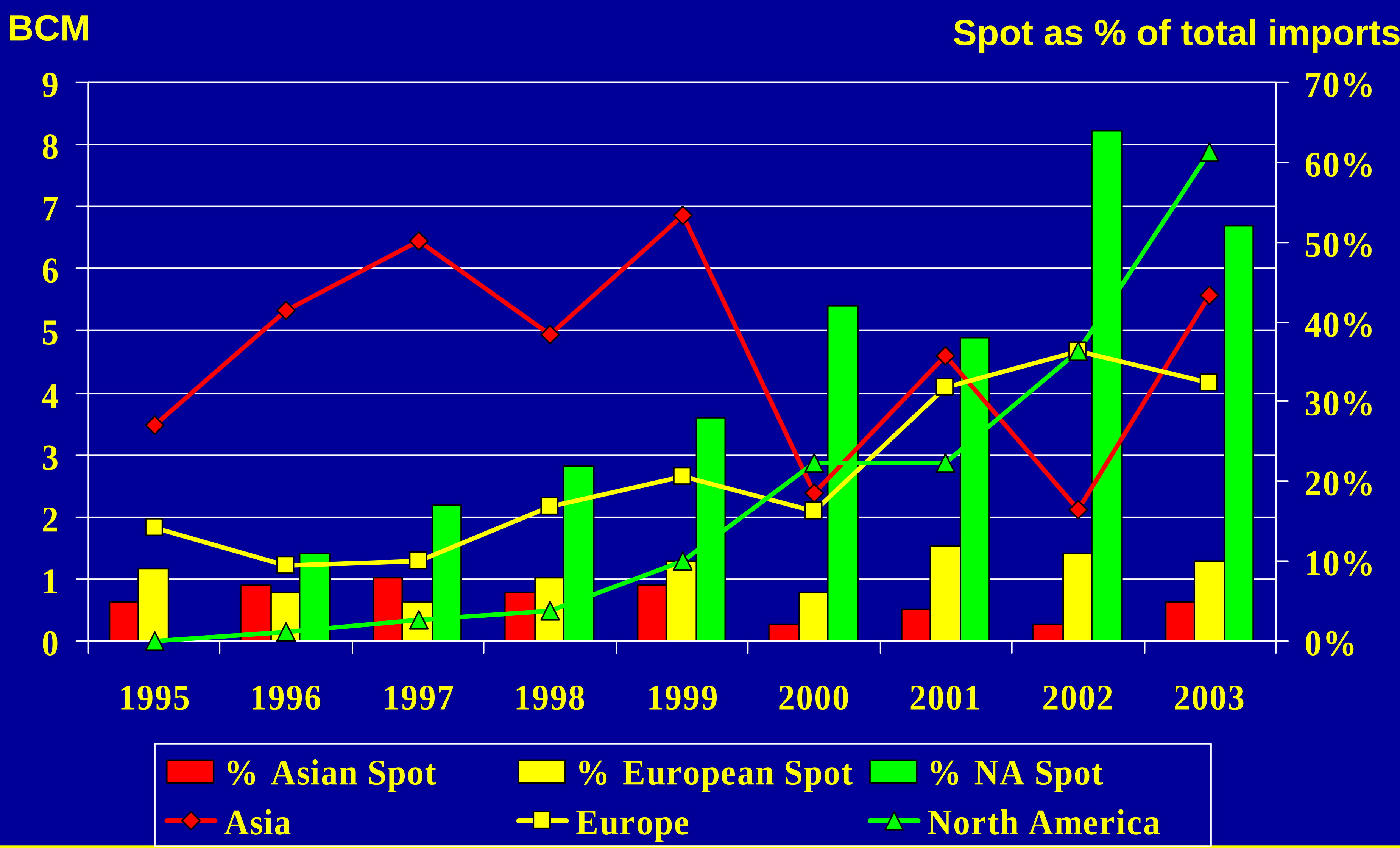
Source: Deutsche Bank

Volume, distances determine transit mode

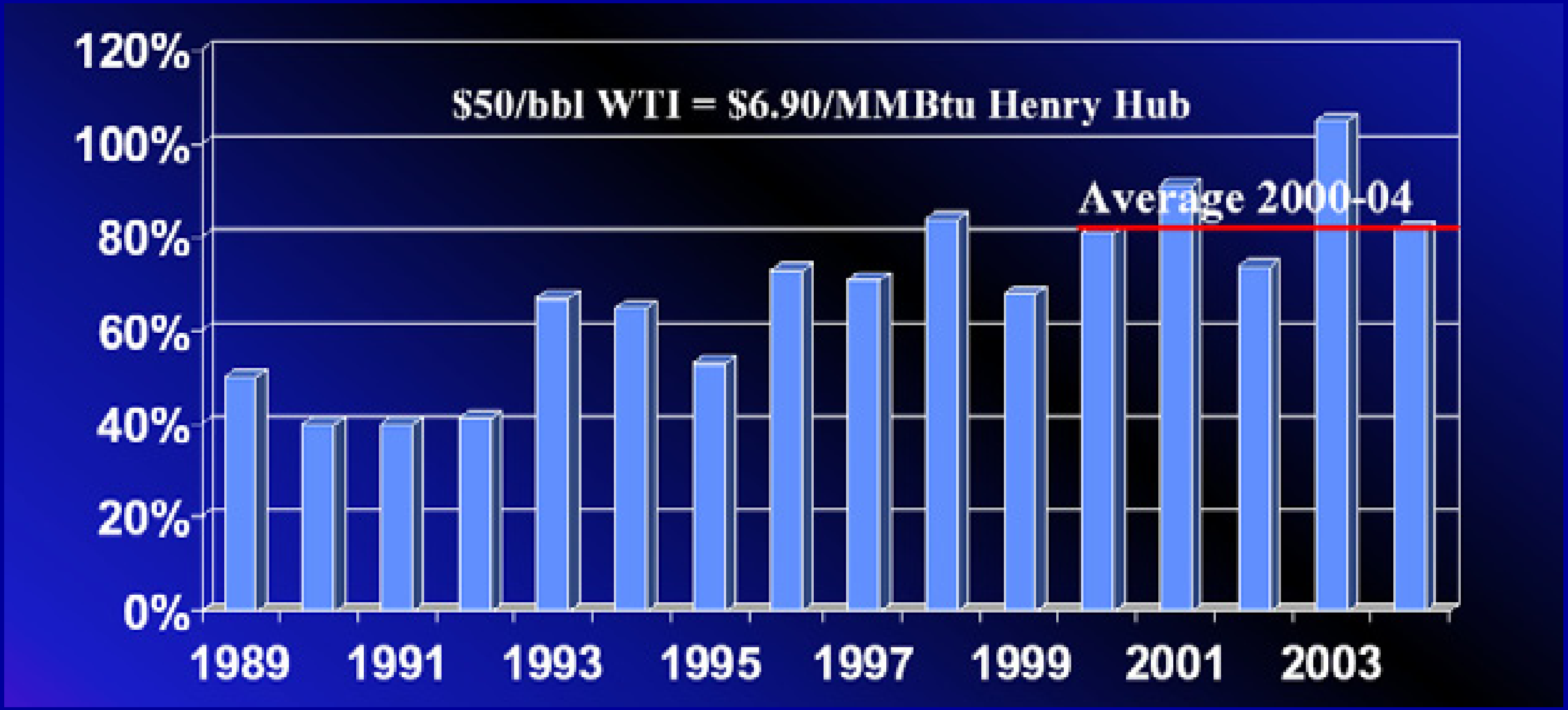


CE Tech

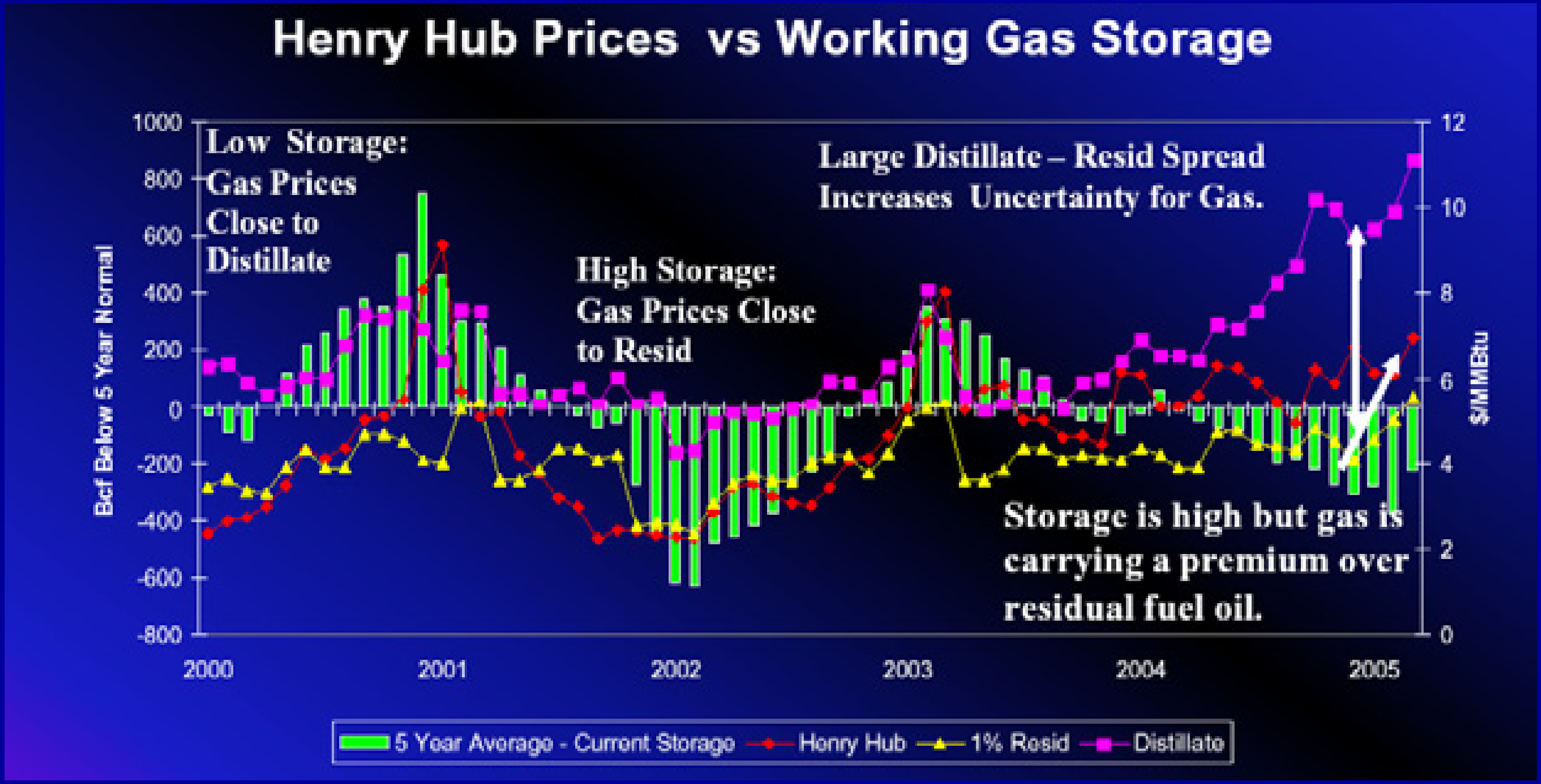
Spot Imports by Region



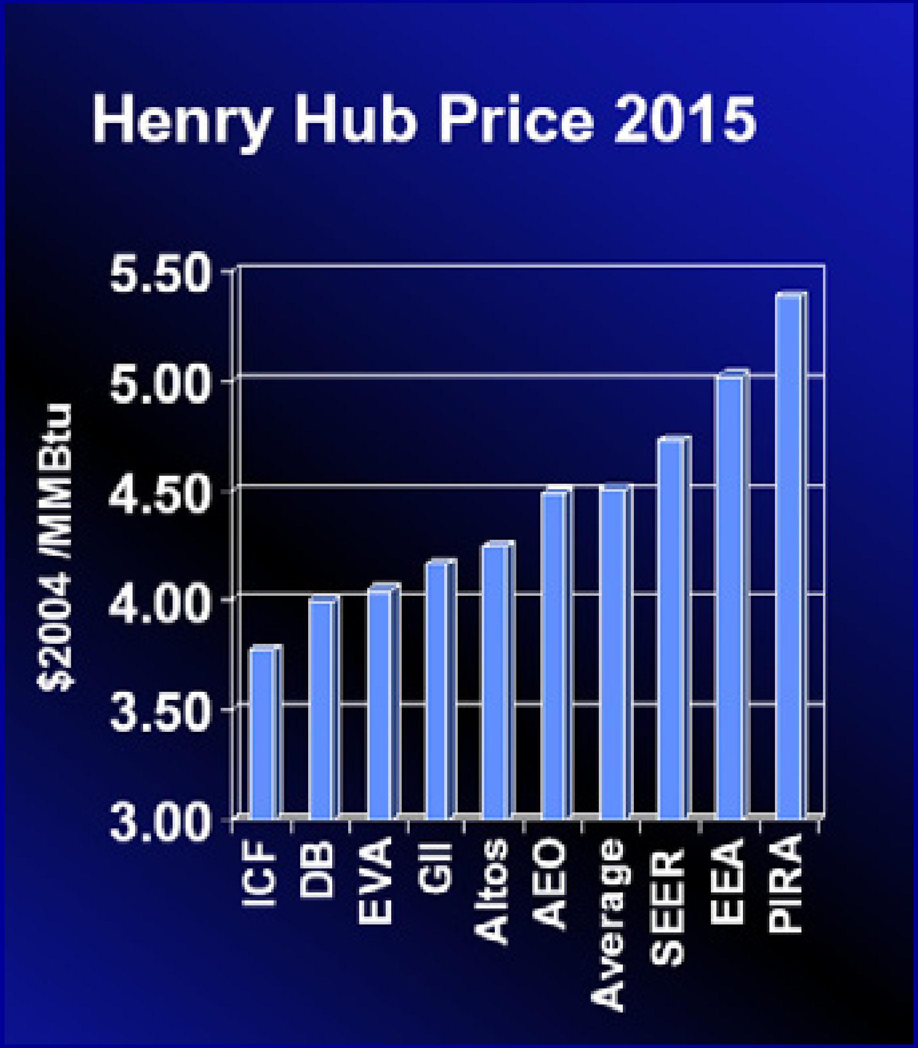
Henry Hub Gas vs West Texas Crude prices



Henry Hub gas prices vs. storage, fuel oil, distillates



Predicted Atlantic LNG prices: 2015



LNG vs. other North American gas supplies

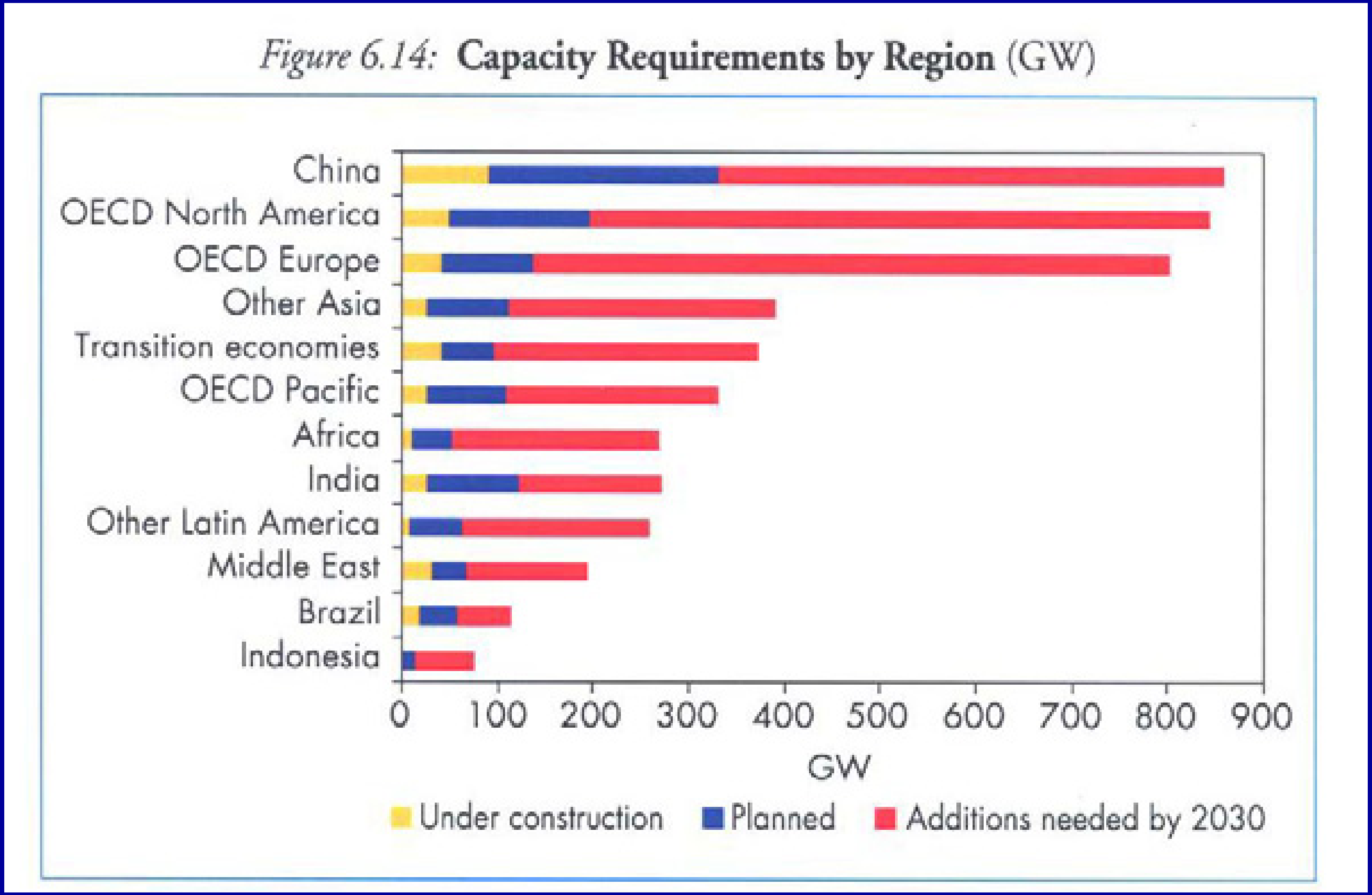
US Gas Supply (Bcfd)					
	2003	2004	2005	2006	2007
LNG	1.2	1.6	1.7	2.5	3.1
Canada, Mexico	7.5	7.6	7.9	7.9	8.1
Net Imports	8.7	9.1	9.6	10.3	11.2
US Production	52.0	51.5	52.2	53.0	53.7
Ref Supply	60.7	60.6	61.8	63.3	64.9
%Change Supply		**-0.1%**	**2.0%**	**2.5%**	**2.5%**
US Production (L. Gulf)	52.0	51.5	51.9	52.2	52.5
Low Supply	60.7	60.6	61.5	62.5	63.7
%Ch Lower Gulf		**-0.1%**	**1.5%**	**1.6%**	**1.9%**
High LNG	1.2	1.6	1.9	3.0	4.4
High Supply	60.7	60.6	62.0	63.9	66.2
%Ch High LNG		**-0.1%**	**2.3%**	**3.0%**	**3.6%**

Impacts on Climate Change

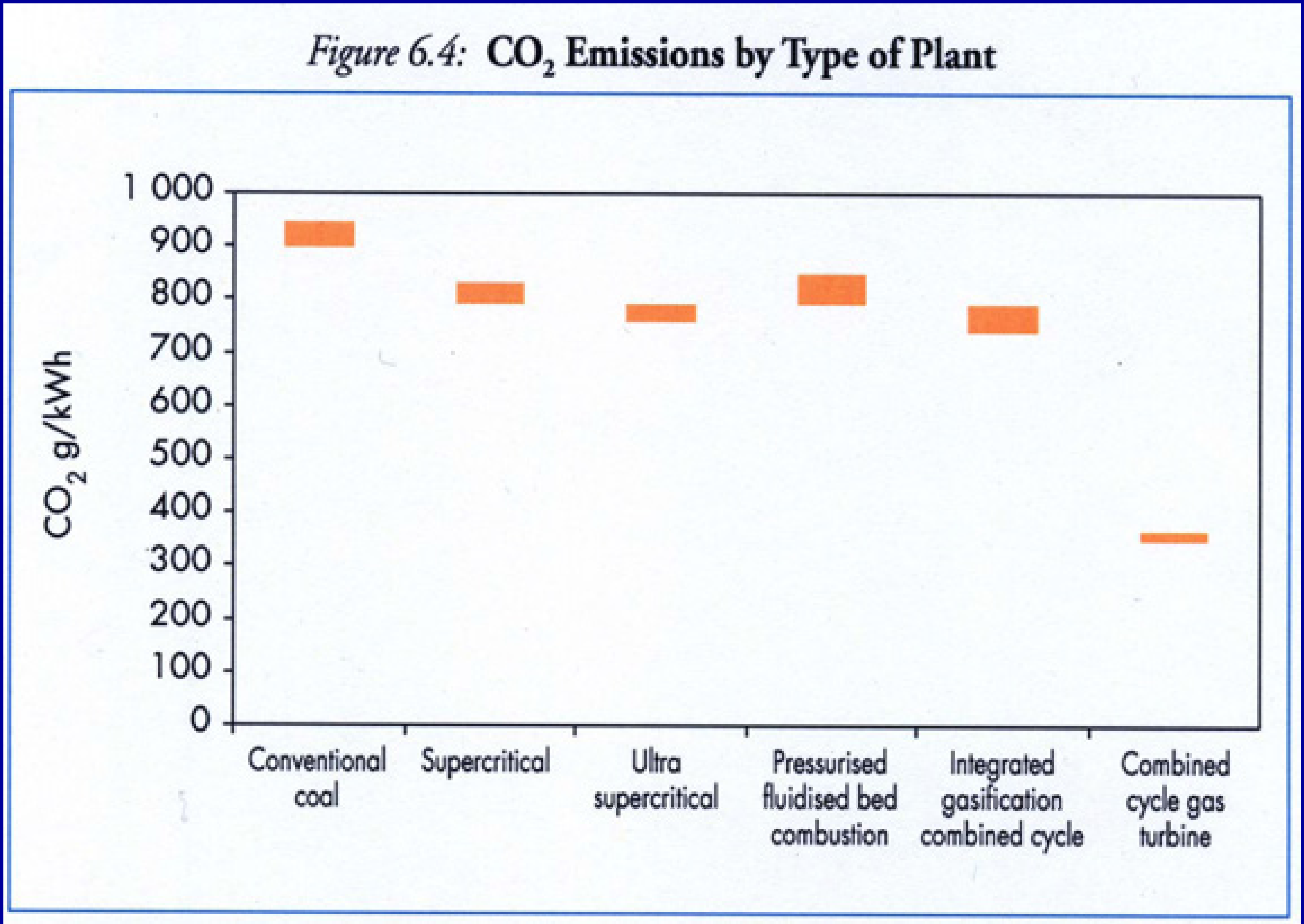
- IEA forecast for electricity capacity in China in 2020
  - Coal: 560 GW
  - Gas: 67 GW

- What are CO_2 savings if:
  - 480 GW of coal and 147 GW of gas?
  - 460 GW of coal and 167 GW of gas?More?

- Can this be accomplished using CDM?

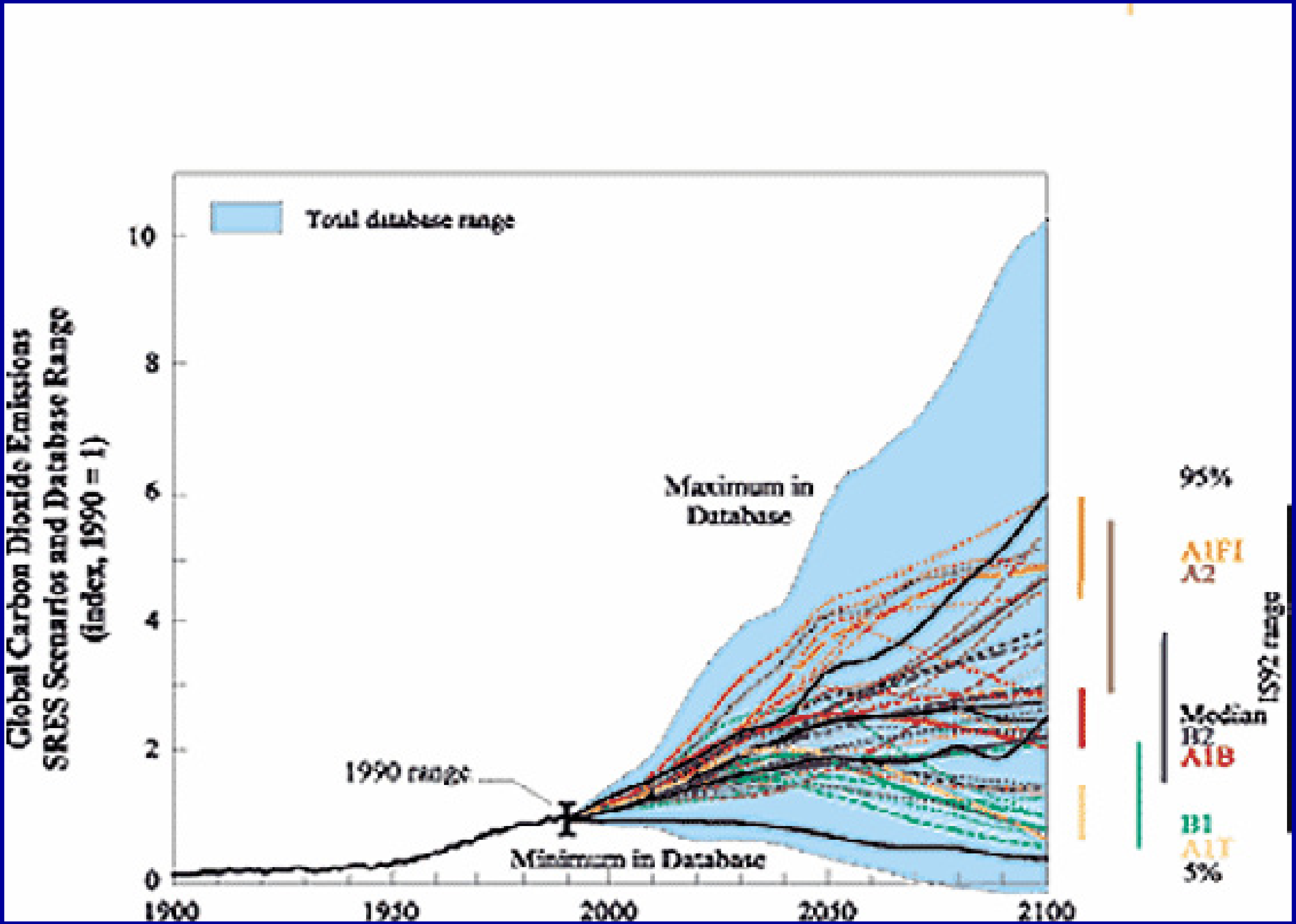


Source: IEA, World Energy Outlook 2004

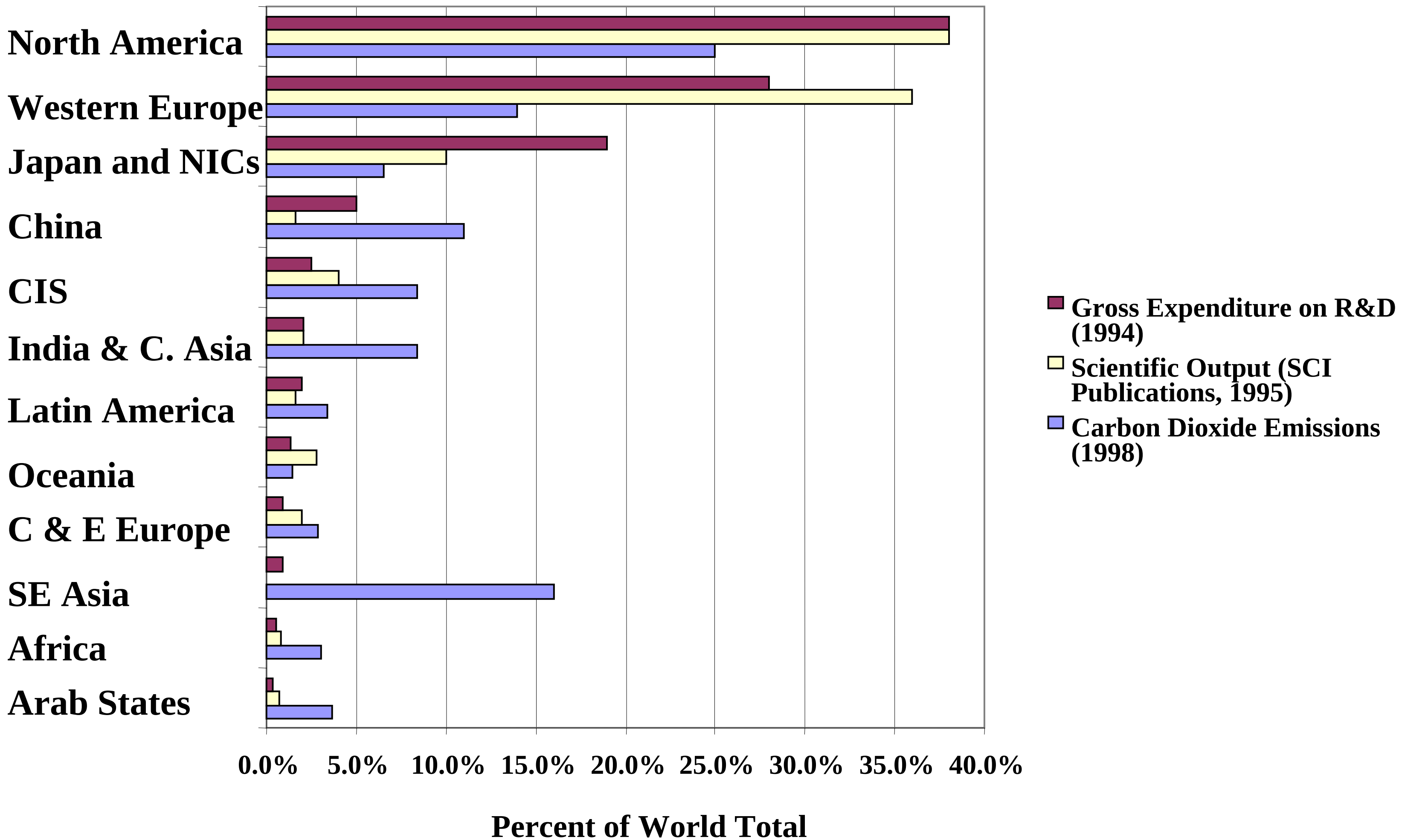


Source: IEA, World Energy Outlook 2004

Full Range of Published Scenarios



Top Innovators and Emitters by World Region



Elements of a Technology Strategy

- Diverse Country-Based Initiatives
  - Loose international coordination among nations with diverse national cultures of innovation
- Price and technology progress are not either/or
  - Politically acceptable price signals tend to operate at margins, while vintage shifts may require dedicated policy programs
- Technology development involves a long pipeline from scientific conceptualization through diffusion of commercial production
  - Common pitfall: premature selection of winners
  - The pace of development along a pathway is affected by predictable and diverse problems that will crop up along the pipeline, which may be subject to diverse policy influence
  - Infrastructure development, finance (risk allocation) and law may dominate engineering in much of the pipeline
  - The feasible technology portfolio may be limited with search space more diverse within a particular pipeline than between technologies in the portfolio
  - Industries with experience in R&D in particular pipelines more likely than governments to explore successfully this internal search space

Future Gen Power Plant

•Design, build, and operate a nominal 275 MW prototype plantthat produces electricity and hydrogen with near-zero emissions

•Sequester 90 percent of CO2emissions with the future potential to capture/ sequester nearly 100 percent

•Validate CO2sequestrationeffectiveness, safety, & permanence

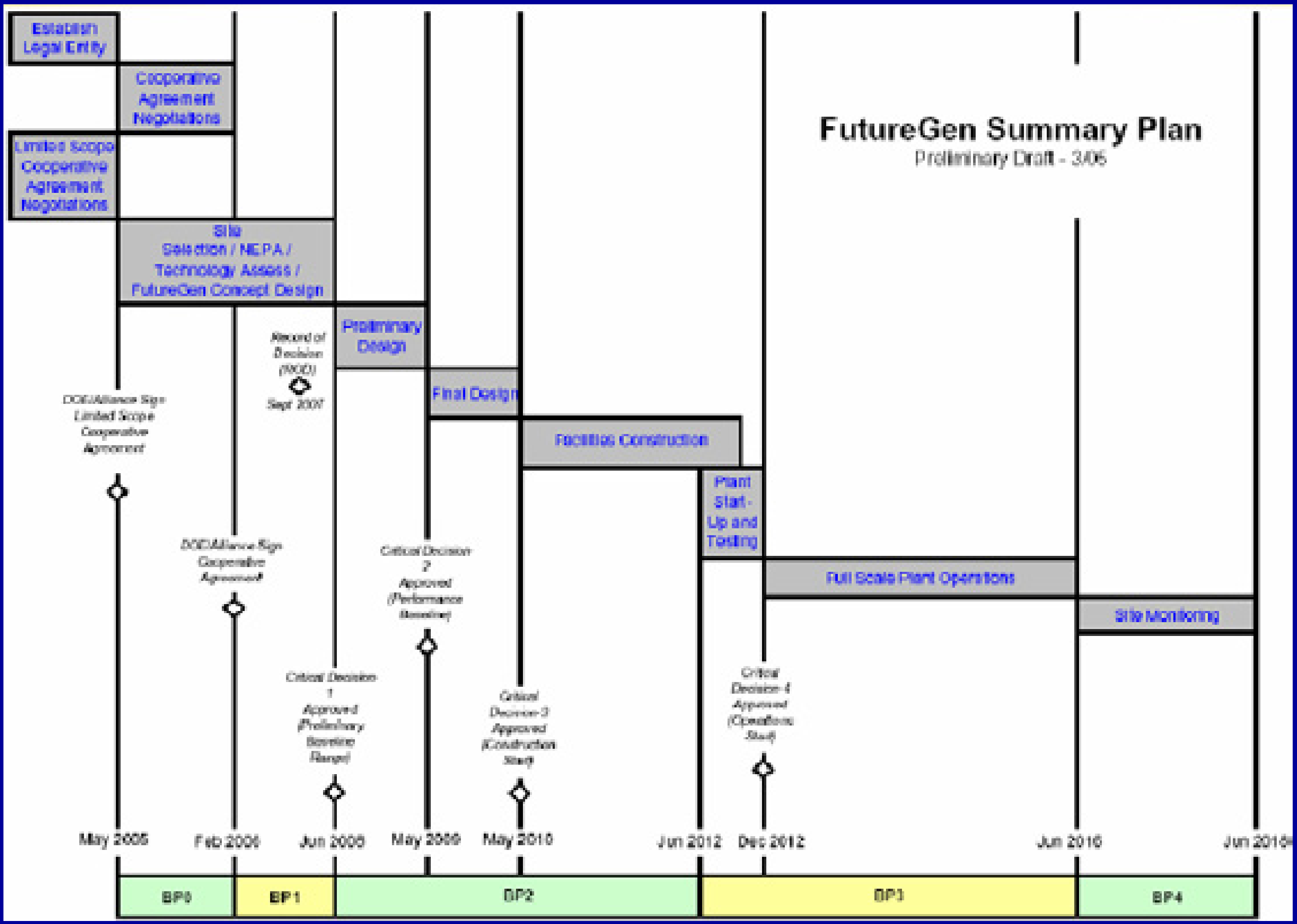
•Confirm standardized technologies and protocols for CO2measuring, monitoring, and verification

•Confirm the engineering, economic, and environmental viability ofadvanced coal-based, near-zero emission technologiesthat by 2020 will

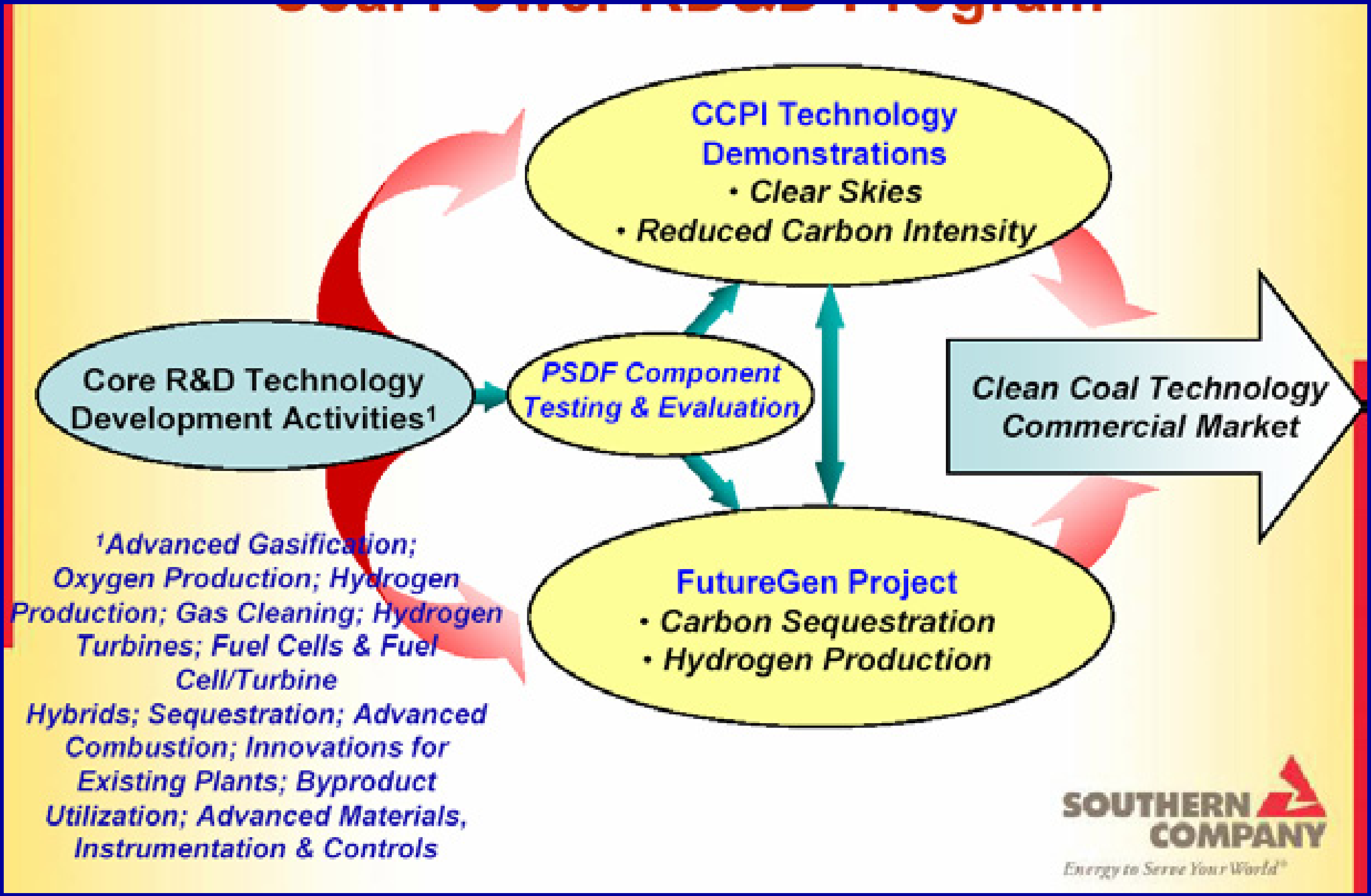
-Generate electricity with less than 10% cost increase compared to nonsequestered systems

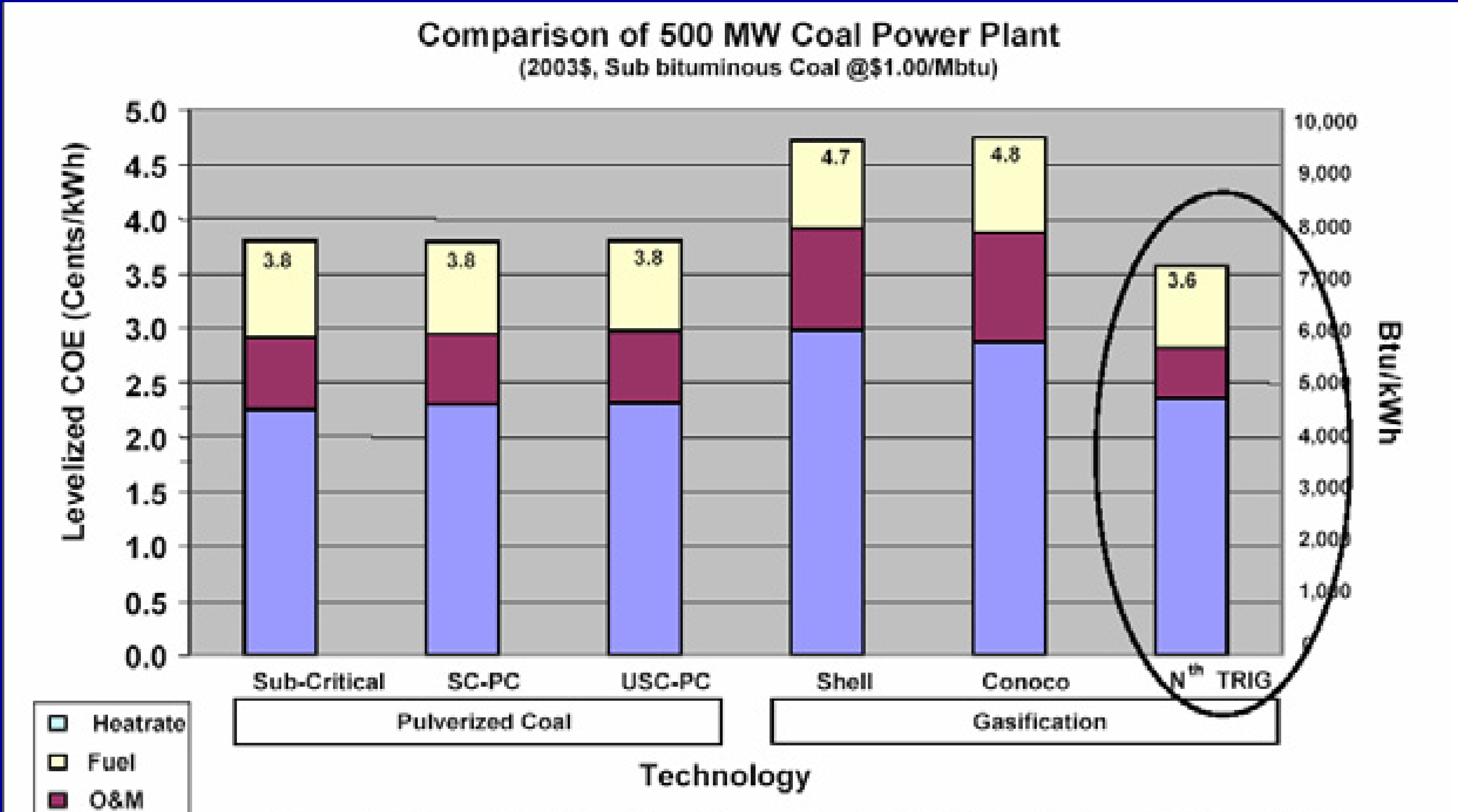
-Make hydrogen at $4.00/million Btu(wholesale)

Future Gen Summary Plan



Clean Coal Technology Programs





- Transport gasifier cost from SCS studies. Other costs adjusted to SE location from an EPRI report titled: "Updated Cost and Performance Estimates for Clean Coal Technologies including CO_2 Capture - 2003