Other Fossil Strategies - Gas & Oil

Presentation to the

Aspen Global Change Institute

Long-Term Technology Pathways to Stabilization of Greenhouse Gas Concentrations

July 6-13, 2003

Aspen, Colorado

by

Dale Simbeck

SFA Pacific, Inc.

444 Castro Street, Suite 720
Mountain View, California 94041
web home page: www.sfapacific.com

phone: 1-650-969-8876
fax: 1-650-969-1317
e-mail: simbeck@sfapacific.com

SFA Pacific, Inc.

Background

At current fossil fuel consumption plus modest technology improvements & gas/oil discovery rates, resources are about:

- 50 years supply of oil
- 70 years supply of natural gas
- 250 years supply of coal

There are key technologies available today to greatly improve both gas & oil utilization efficiency & resource recovery

- Cogen, repowering, EOR, CBM, heavy oil recovery & upgrading,

Syngas (H2 & CO) from oil residues, remote gas, coal & biomass can make low CO_2 emissions synthetic gas & oil + H_2

- Key issue is massive CO_2 capture & storage with <0.1%/yr leakage

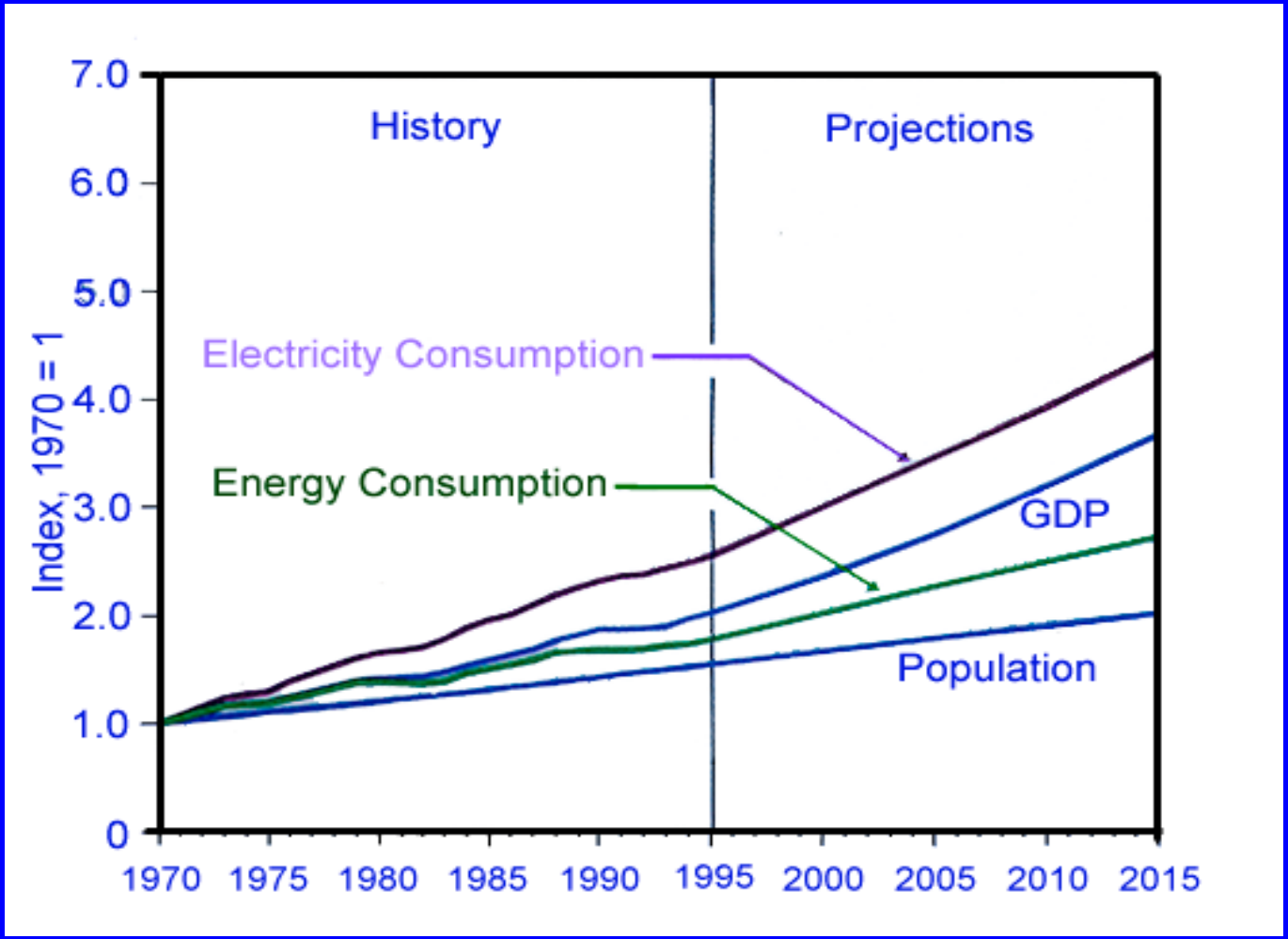
Standard of Living & Fossil Fuels Consumption

The fundamental greenhouse gas (GHG) issue

Source: Scott Willis of the San Jose Mercury News (California)

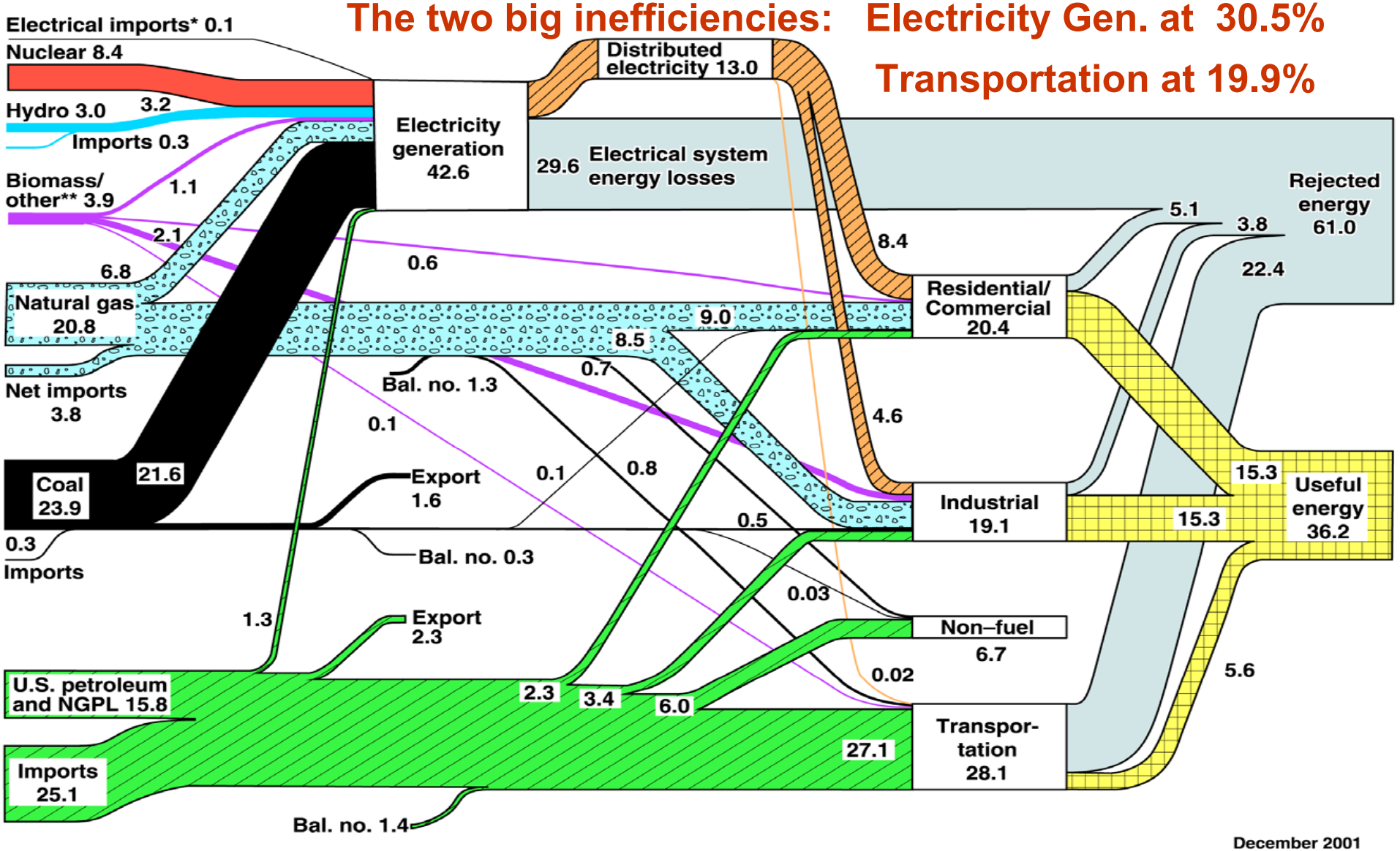
World Energy, GDP & Population Trends

Clearly Show Electricity is the Energy of the Future



Source: 1997 US DOE/EIA International Energy Outlook

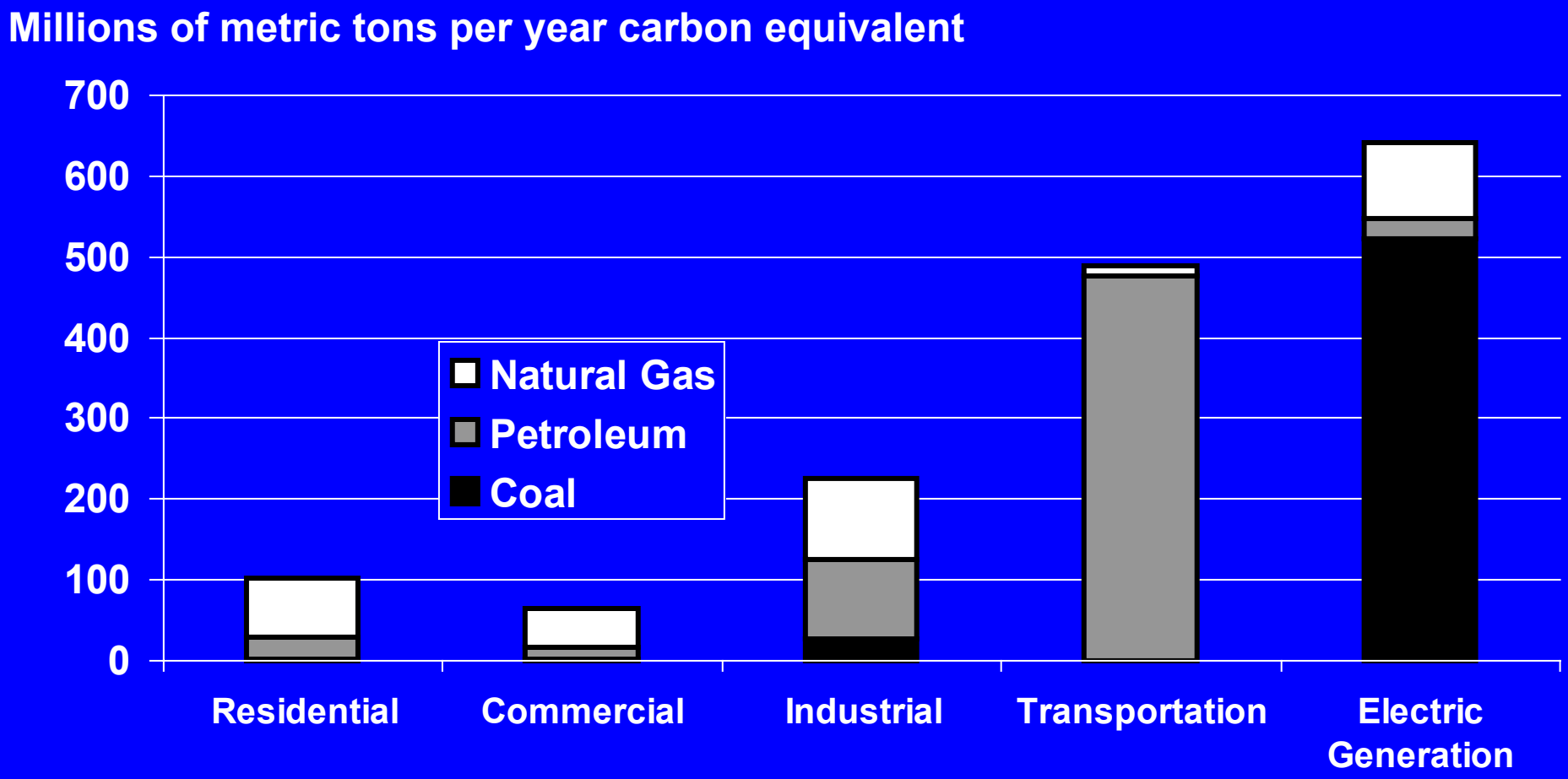
U.S. Energy Flow Trends – 2000
Net Primary Resource Consumption 104 Exajoules



Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 2000*
*Net fossil-fuel electrical imports
**Biomass/other includes wood and waste, geothermal, solar, and wind.

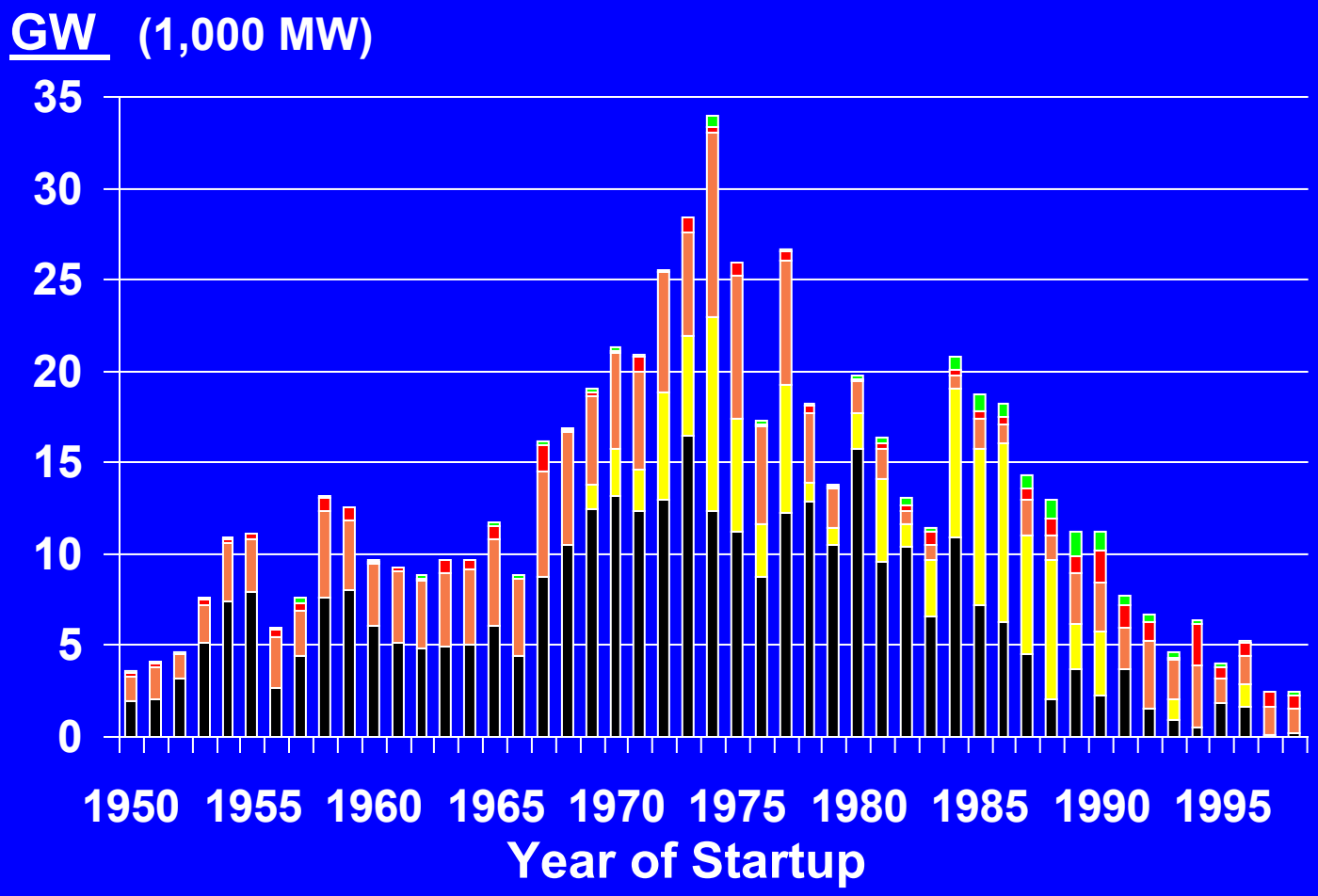
December 2001
Lawrence Livermore
National Laboratory
http://en-env.llnl.gov/flow

United States CO_2 Emissions by Sector and Fuels in 2000



Source: U.S. EPA Inventory of Greenhouse Gas Emissions, April 2002

Operating U.S. Power Plants in 2000
By Years of Startup for the Last 50 Years



Existing Coal Units

322 GW summertime

52% of total MWh

70% utilization

33% efficiency HHV

28 yr. MW wt. age

- Renewables
- Others
- Oil & NG
- Nuclear
- Coal

Source: SFA Pacific from EIA, FERC, NETL & EPA power plant data bases

SFA Pacific, Inc.

EIA 2000-2020 Projection of U.S. Capacity Additions & Total Electricity Generation

If 25% more coal-base generation but only 10% new coal capacity requires higher utilization of the existing coal capacity

Figure 48. Projected electricity generation and capacity additions by fuel type, including cogeneration, 2000-2020 (gigawatts)

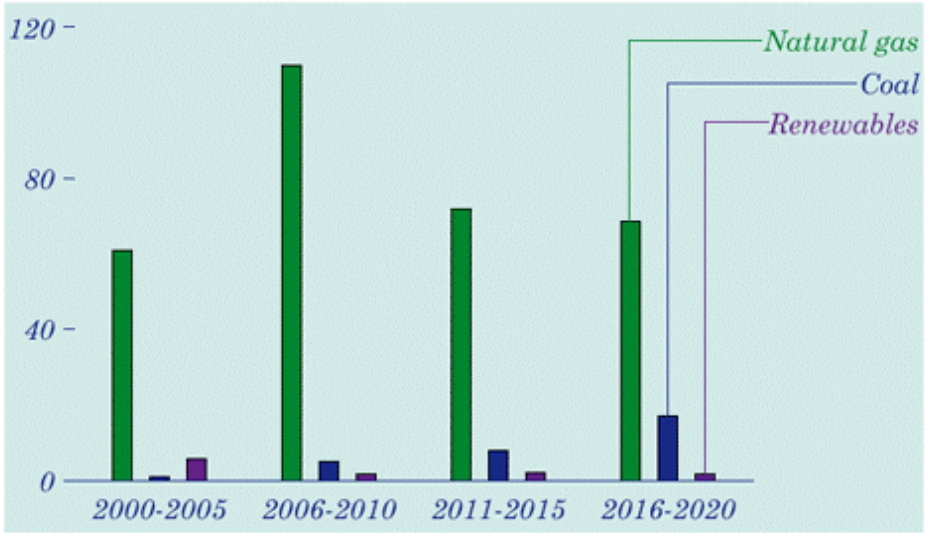


Table A9.

Figure 52. Projected electricity generation by fuel, 2000 and 2020 (billion kilowatthours)

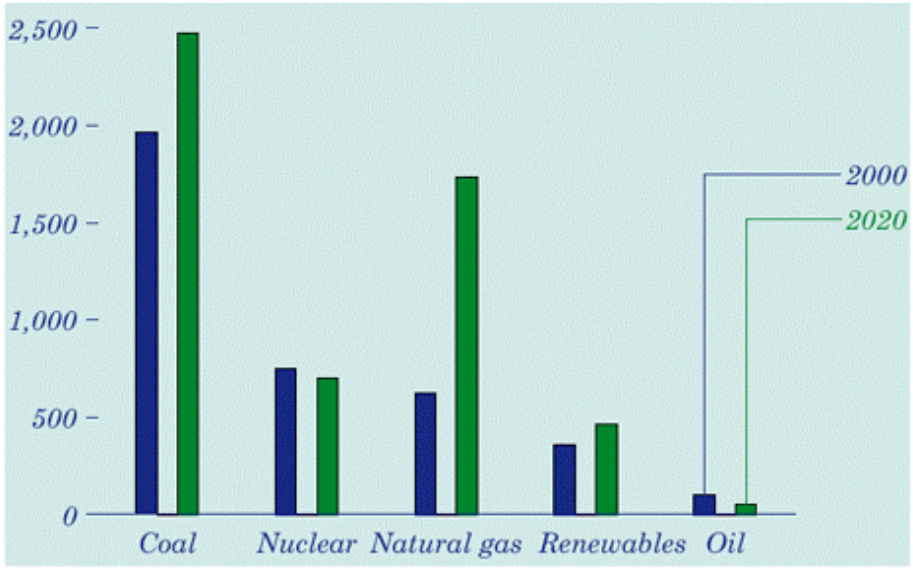


Table A8.

Source: Figures from EIA Annual Energy Outlook 2002 with comments by SFA Pacific, Inc.

Energy Efficiency

Energy efficiency is the **"win-win"** approach as this reduces energy end-use, costs & increases economic growth

Two ideologically opposing approaches to higher efficiency

- Advanced central power plants - favored by regulated electric utilities
- Cogeneration - favored by deregulation & private energy companies

Utilities should upgrade existing old inefficient coal plants

Cogeneration is the big energy efficiency gain for new plants

Clearly favors gas turbines & cogeneration once deregulated

- Natural gas for new NGCC, GT-repowering & especially maximum power cogeneration - assuming NG is available at moderate prices
- Gasification of coal & oil residues for: NG replacement, stringent emissions, existing coal power plant repowering & polygeneration

Existing Power Plant Repowering

Defined as adding new gas turbines to existing steam plants

- Usually best to let the GT determine the size & add a new steam system

Many advantages to repowering existing steam cycle plants

- Large capacity increase, up to 3 times the original power plant capacity
- Large efficiency increase, usually from about 30-35% to 45-55% if NGCC or about 40-42% if CGCC ("real" HHV efficiency)

Great potential due to location of old existing power plants

- Strategically located in existing grid system with significantly less siting or permitting problems relative to a new "green field" power plant
- NGCC repowering of NG & oil boilers now & later CGCC repowering of coal boilers depending on future of: NG prices,"grandfathering" & CO_2

Why Traditional Power Generators Are Skeptical of Coal Gasification Combined Cycle

Successful CGCC requires chemical process expertise

- Little or no chemical process expertise at most coal utilities & will usually not pay the price required to attract personnel with essential oil & chemical industry gasification expertise even if considering CGCC
- Embarrassingly poor history with the simplest chemical process - wet limestone SO_2 scrubber FGD - why FGD costs have dropped in half due to outrageously poor starting baseline costs & performance

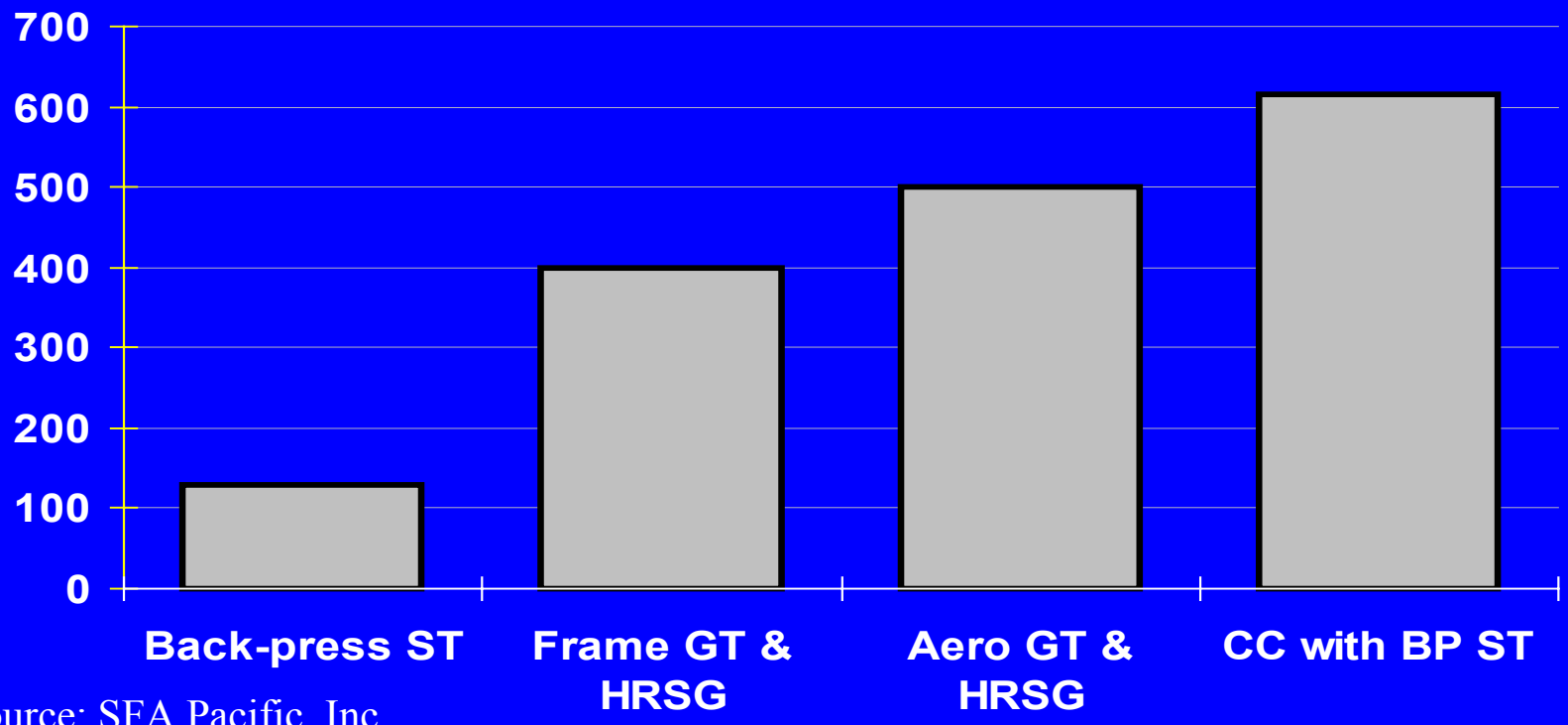
Any risk is a "lose-lose" for traditional regulated power generators & CGCC is clearly a much greater risk than PC

- If it does not work well, will not get all the costs covered by rate payers
- If it works quite well & greatly reduces costs, most of the savings are passed on to the rate payers

Maximum Power in Total Cogeneration Clearly Favors Gas Turbines Over Steam Turbines

For a given heat host, 3-5 times more power with GT vs ST
This is the key issue as true cogeneration is heat host limited

Power-to-Steam ratio: kWe per ton/hr 150 psig cogen steam (no steam to condenser)



Source: SFA Pacific, Inc.

Energy Efficiency - Large Cogen Potential

The European cogen experience clearly shows there is significantly more cogen potential than many believed

- The Netherlands is delaying large cogen projects due to excess power
- New cogen application like gas turbine exhaust for crude oil heaters

There is still large potential for additional cogen in North America once full deregulation & start replacing old coal units

The Japanese Gas Association 1991 Industrial Repowering Analysis showed big potential (17,500 MW_e), large power efficiency gain (16%), & major CO_2 reduction (50 MM t/yr)

Major cogen opportunities in China once deregulation

- It is not in a regulated electric utility's best interest to buy cogen power
- 50 % of China's total coal use is in small inefficient industrial boilers

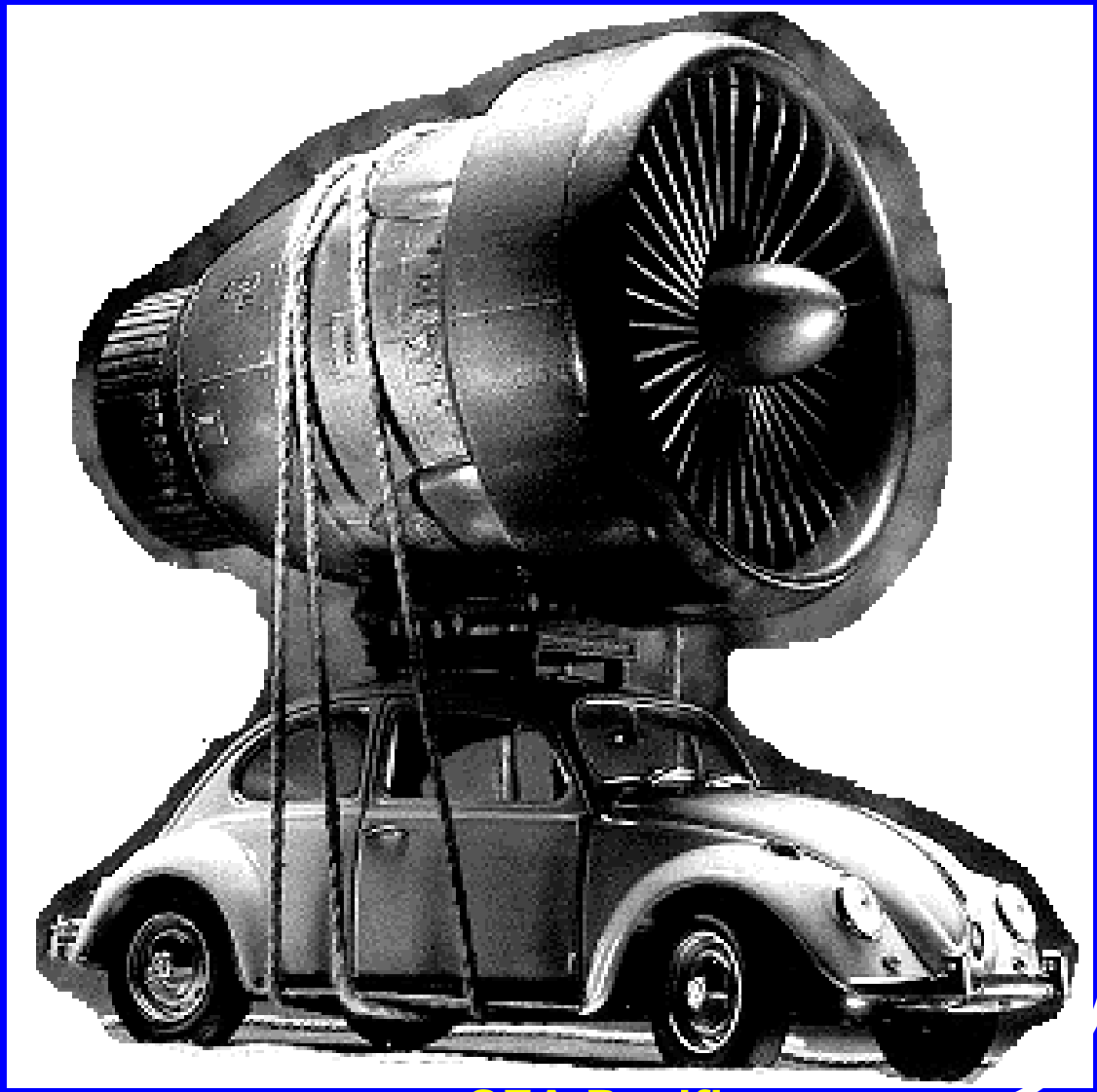
The Future of Distributed Generation?

Which is likely to have the best economy of scale or the lowest unit costs ($/kW & $/kWh) for: permitting, fuel, capital, O&M, & project development costs?

50,000 kW → aeroderivative gas turbine

or

50 kW microturbine, → fuel cell or RE



Hubbert Gas & Oil Peak Curves

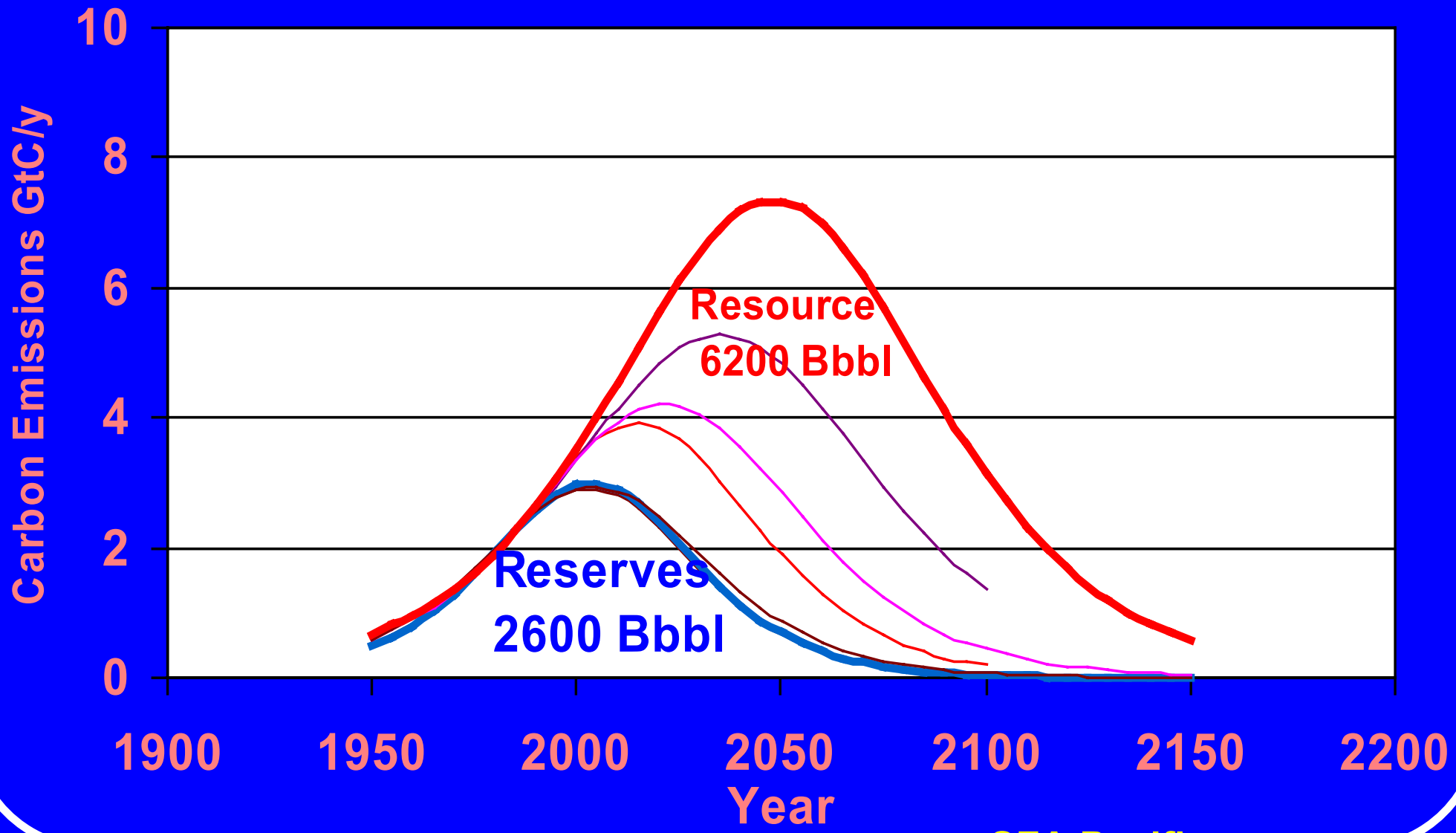
In 1956 M. King Hubbert, a Shell Oil geologist, predicted U.S. domestic oil production would peak in the early 1970s

- In spite of much ridicule from his peers, he was correct
- He also predicted that U.S. NG would also peak the same time + drop quickly & world fossil energy would peak in 1995, both wrong
- Hubbert peak curve analysis continues today primarily by fossil peak doomsayers & renewable advocates

Hubbert peak curve analysis is based on a bell curve analysis with the key input being a fixed recoverable resource

- Great debate about fixing the total recoverable resource based on our poor ability to predict future technology, knowledge & prices
- Nevertheless, a useful tool to bracket fossil fuel peak extremes

Key to Oil Peak is Heavy Oil & EOR



SFA Pacific, Inc.

Trends in Oil

The lifeblood of modern transportation

- Principal growth is developing nations for shipping goods & more importantly, great desire for personal transportation (freedom)
- Also reduced efficiency due to consumers preference for large & heavier vehicles like Sport Utility Vehicles (SUV) & vans

Large oil price & supply volatility due to major reserves in the unstable Middle East - the only fuel that causes wars

High quality transportation fuel mandates to reduce emissions

- Less SOx, NOx & especially fine particulates (soot)
- Requires fuels with increasingly lower S, N & aromatics (less aromatics - means less byproduct H_2 & octane barrels from naphtha reforming)
- Thus large increases in hydrogen for hydrotreating & hydrocracking

Trends in Oil

Oxygenates (ethanol) in gasoline is a bad joke

- Mandated in the U.S. to help farmers, but really makes ADM quite rich
- MTBE is better & cheaper but has ground water contamination issues
- Reformulated gasoline & diesel in with no oxygen (demonstrated in California) are even better & cheaper than MTBE & especially ethanol
  - See the prestigious U.S. National Research Council May 1999 Study

Increased heavy oil production & upgrading of residual

- Increasing supplies of lower quality & heavier crude oils
- Limited markets for low quality heavy fuel oils
- Deregulation allows refiners to convert bottoms to electricity for sales to the grid at higher energy value than selling heavy fuel oil

Technology Trends in Oil Utilization

Improved vehicle efficiency & lower emissions

- Clean direct injection turbocharged diesel with tail pipe clean-up
- Hybrid electric/gasoline engine vehicles
- Fuel cell vehicle testing, but big problems - H_2 & infrastructure costs

Large increases in refinery hydrogen for cleaner transportation fuels from the distillate portion of crude oil

Large increases in "bottom-of-the-barrel" (non-distillate) conversion or upgrading to more distillates

- Both hydrogen addition & carbon rejection
- Rejected carbon from upgrading (pitch or petroleum coke) conversion to syngas (H_2 & CO) for polygeneration

Heavy Oil Resources

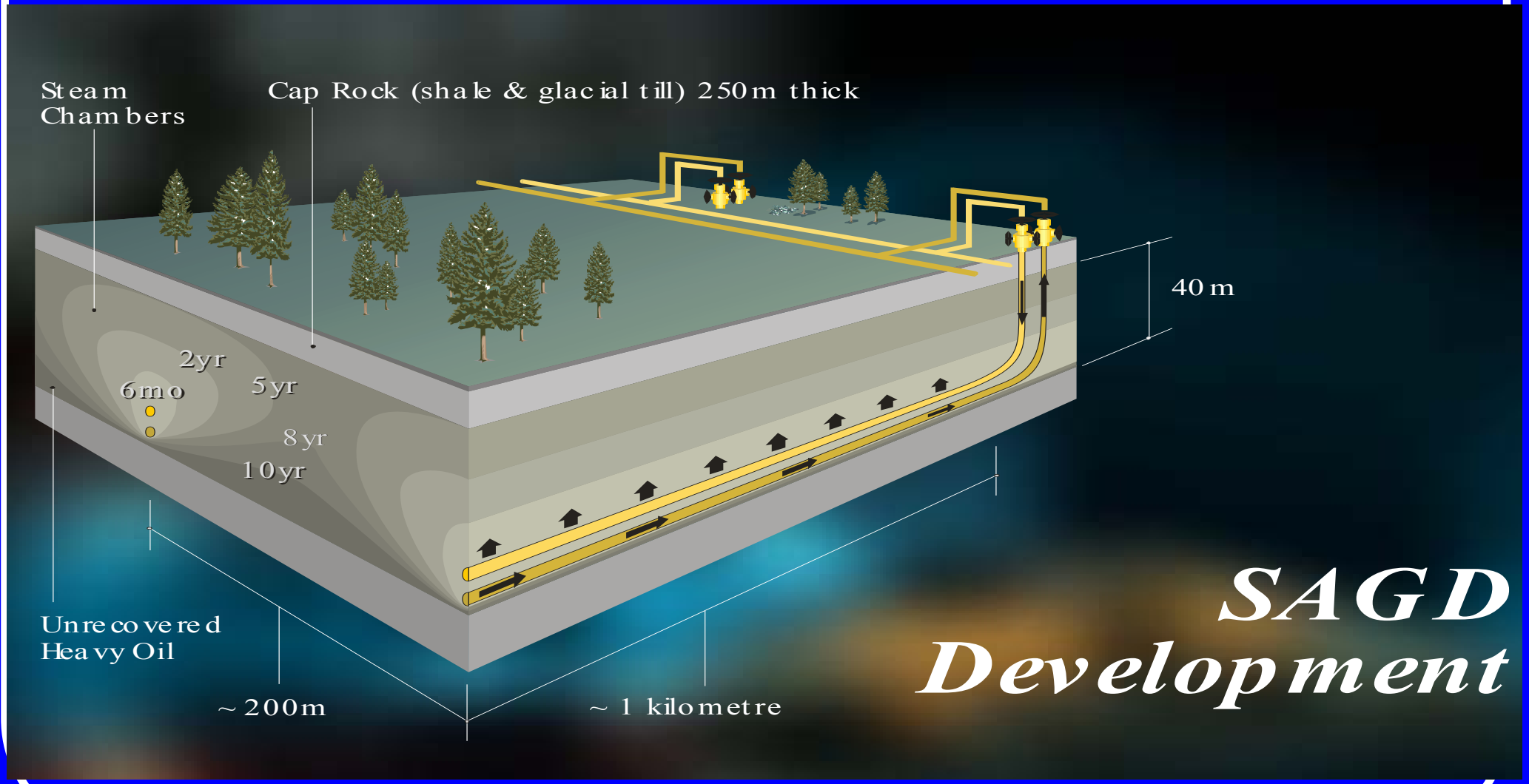
Alberta, Canada - mostly “oil sands”

- Recoverable resource now estimated at 180 billion bbl mostly due to the development of Steam Assisted Gravity Drainage - SAGD
- Current total production approaching 1.75 million bbl/d with >0.5 MM bbl/d from oil sands growing to @>1.0 MM bb/d by 2012
- Total resource is 1,600 billion bbl

Venezuela - mostly Orinoco “extra heavy crude”

- Recovery resource now estimated at 272 billion bbl
- Current production approaching 3.5 million bbl/d with 0.5 million bbl/d from Orinoco but political instability hurting growth
- Total resource is 1,900 billion bbl

Steam Assisted Gravity Drainage



Source: Suncor

Polygeneration

Defined as gasification to synthesis gas (H_2 & CO) for GT-based cogen steam/power + syngas chemicals & premium fuels

Shell Oil Pernis oil refinery in Holland is a good example: no subsidies & high availability without a spare gasifier

- Pitch gasification - 3 units total 640 MW_{th} with 2 gasifiers for oil refinery H_2 & 1 gasifier for GCC cogeneration with NG as GT back-up

Great potential for polygeneration in the future due to ongoing deregulation of electric power generation

- Low value feedstock, thereby ultra-low marginal load dispatch costs
- Offers greater flexibility than traditional power plants relative to fuels, products, revenues, emissions, efficiency & annual load factors
- Low marginal costs for CO_2 capture (will likely be added at Pernis)

Gasification Projects Without Subsidies

Chemicals from coal or pet coke	MW_{th} syngas
• Ube Ammonia - Japan	294
• Farmland - Kansas, USA	293
• Eastman Chemicals - Tennessee, USA	219

Oil refinery polygeneration from pitch or pet coke	
• Port Arthur*, Texas - USA	2,029
• Repsol* - Spain	1,654
• Lake Charles*, Louisiana - USA	1,407
• Deer Park*, Texas - USA	1,400
• Total/EdF/Texaco - France	1,043
• Nippon Oil - Japan	793
• Exxon - Texas, USA & Singapore	711
• Shell - the Netherlands	637

* Planned

Feedstock Issues for Gasification

Solids fuels - coal or pet coke?

- Most newer solid fuel units are water slurry feeding Texaco designs
  - Allows higher pressure operations and improved feeding control at the expense of poor oxygen utilization (yield of syngas, H_2 & CO, per unit O_2)
- Fuel grade pet coke - similar to coal except lower ash and near zero or even negative fuel value due to much higher sulfur and heavy metal
  - Relative to coal water slurry feeding of Texaco, capital saving of about 5 -10% due lower ash and 10-15% higher syngas yield per ton O_2

Residue - Hot liquid hydrocarbon feeding significantly reduces capital costs and improves availability relative to solid (coal or coke) feeding

- Relative to coke water slurry feeding of Texaco, capital saving of about 20% due to 30-35% higher syngas yield per ton O_2
- Pitch from a severe visbreaker or SDA is like a "liquid coke" with low fuel value unless ocean port for distillate blending into bunker fuel markets

Status of CO_2 Capture & Storage via EOR

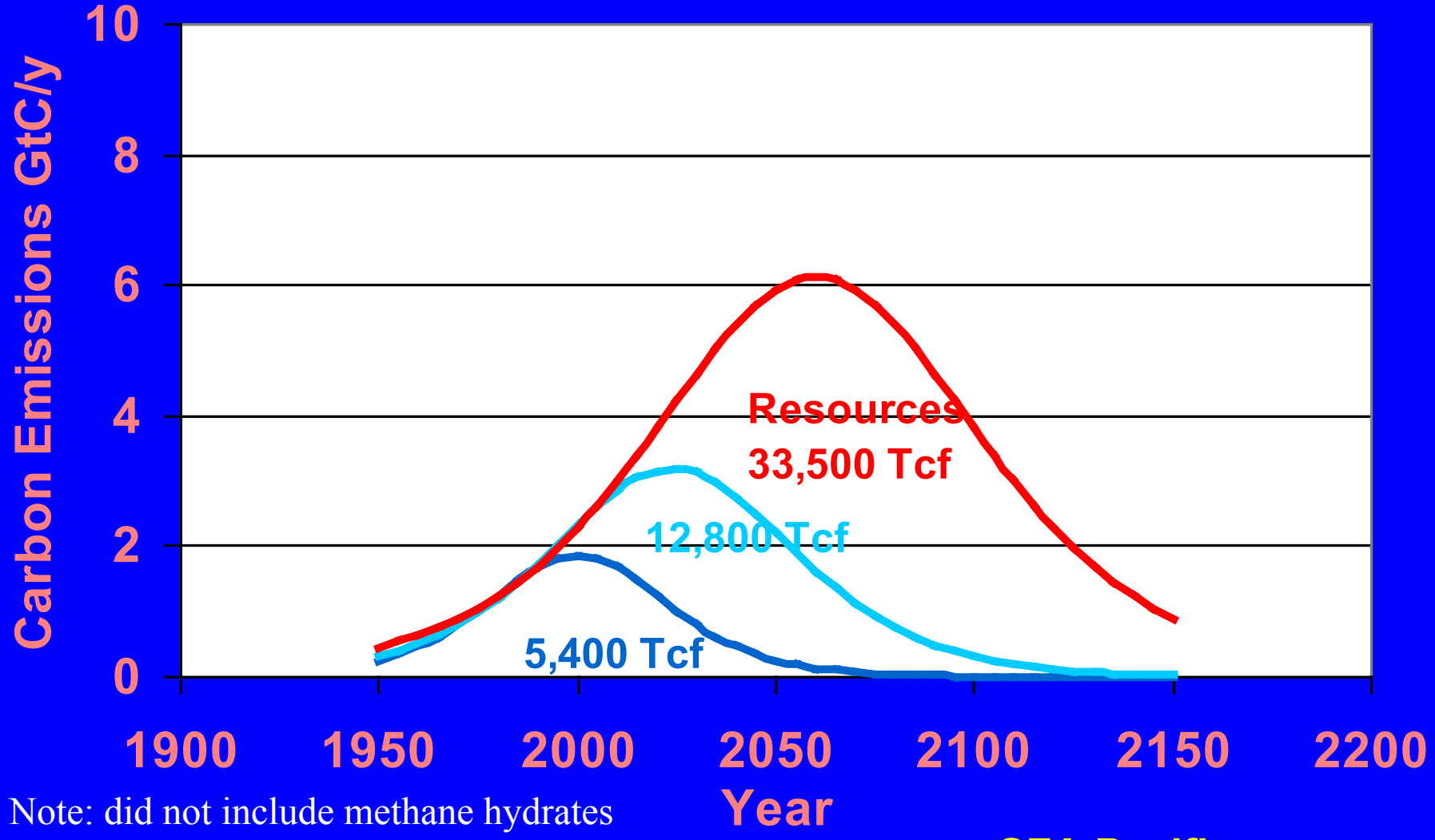
Already over 30 million metric tons per year (mt/yr) of CO_2 storage in enhanced oil recovery (EOR) in North America

- Six projects totaling 6 million mt/yr CO_2 were recovered from process plants that would otherwise vent this CO_2 to the atmosphere
- Already 2 CO_2 emission credit trades of CO_2 EOR from process plants
- Typical EOR uses 6,000 scf (or 0.3 mt) CO_2 per incremental bbl (0.14 mt) crude oil production at a CO_2 price of $0.60/1,000 scf (or $11/mt)
  - At 8,500 scf CO_2 per incremental bbl oil, the oil produced is carbon neutral

Expect large growth in CO_2 storage for EOR & CBM recovery

- Current wind turbine subsidy of $18/MWh when replacing NGCC @ 0.36 tons CO_2/MWh is a CO_2 avoidance subsidy equivalent of $50/ton, at that same subsidy for man-made CO_2 into EOR & CBM is a "win-win"

Key to Gas Peak Is Remote Gas to LNG or GTL & Non Conventional Gas - Coal Bed Methane



Note: did not include methane hydrates

SFA Pacific, Inc.

Trends in Natural Gas

Large growth due to large supplies & improving delivery options: super pipelines, LNG & gas to liquids (GTL)

Over 5,000 quads of known reserves - half is "stranded gas"

- 16 quads/yr currently being flared, vended or re-injected, if recovered or GTL converted would be about 10% of current world oil use

High LNG & LPG growth of Developing Asia has Japan looking at alternatives for traditional LNG/LPG uses (like MeOH/DME)

NG markets are expanding into transportation fuels via LPG, compressed NG, GTL & potentially H_2

Natural gas is key to distributed power or energy generation

- Few appreciate the economic & market impacts of size & load factor

Technology Trends in Natural Gas Utilization

Super pipelines will create more competition & supplies of NG

LNG & GTL competition will bring "stranded gas" to market

Closely follow the new Sasol/Chevron 35,000 bbl/d Fischer Tropsch (F-T) GTL project at Escavos, Nigeria

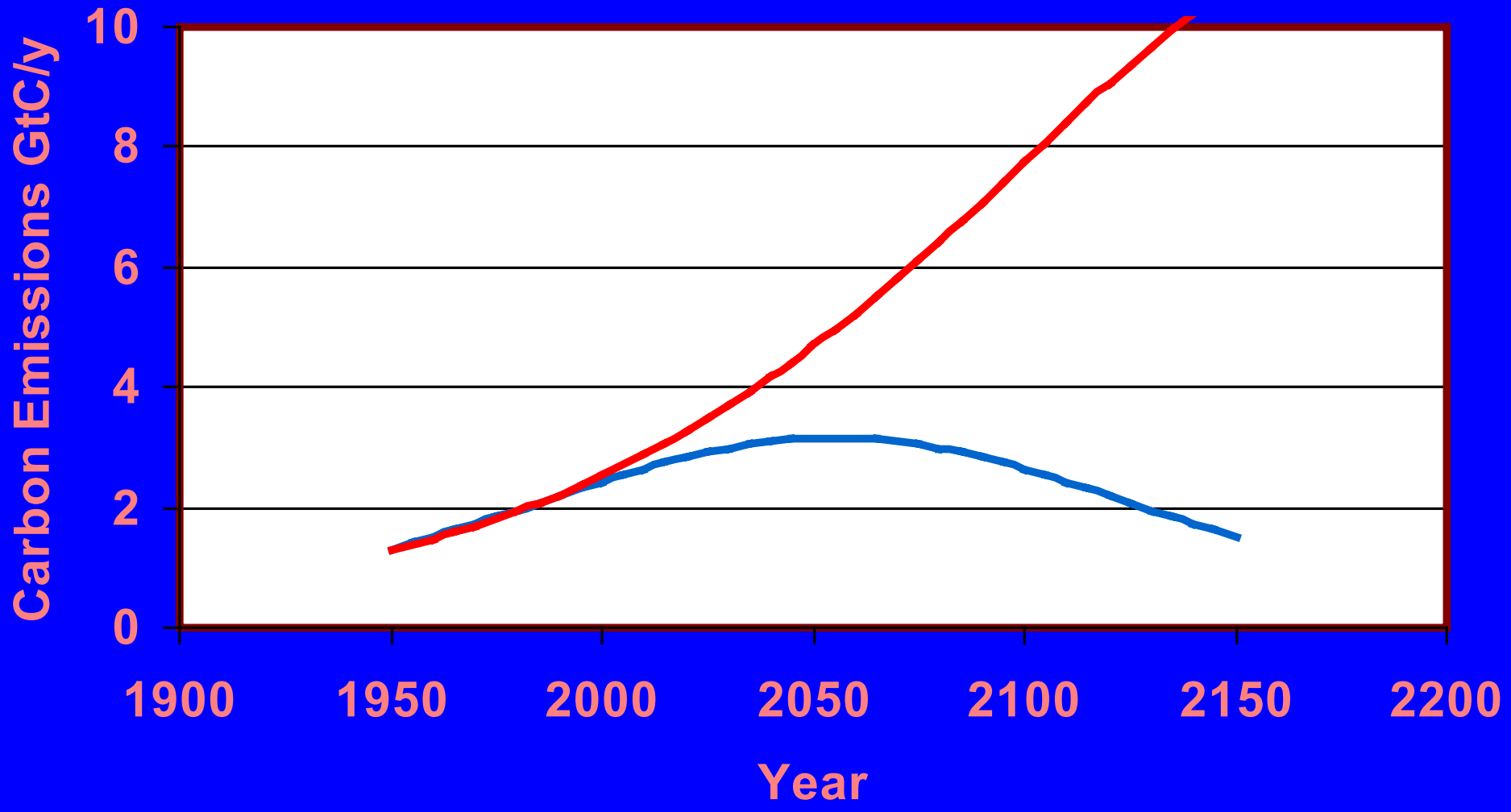
- BP, Exxon Mobil, Shell & others also promoting their versions of GTL

GTL via methanol is interesting for CC power generation & potentially direct fuel cells vehicles longer-term

GTL via di-methyl ether (DME) also has potential as a LPG alternative depending on future LPG costs/demand

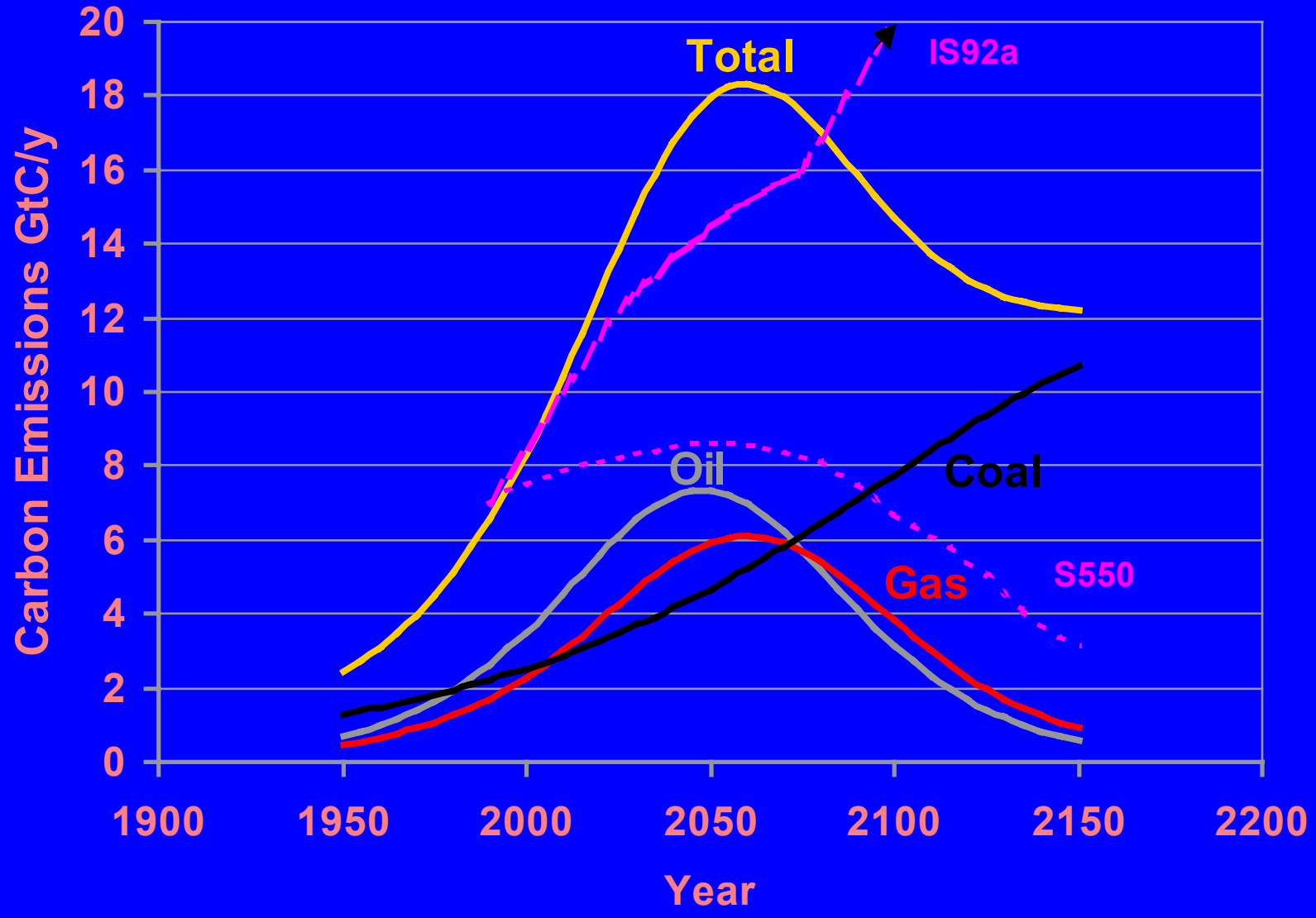
Methane hydrates, biogenic methane or a modern version of town gas (50% NG & 50% H_2) could be interesting

Coal is the Wildcard Due to Large Resource Plus Does Not Fit the Hubbert Analysis Well



SFA Pacific, Inc.

SFA Pacific's Projection of the Fossil Age Peak



SFA Pacific, Inc.

Hydrogen is Already a Large, Commercially Well Proven Industry

World commercial H_2 production is currently >40 billion scf/d

- Equivalent to 133,000 MW_{th} or 75,000 MW_e if converted to electricity

Most H_2 is made from natural gas via steam methane reforming (SMR) yet 15% is made from oil residue or coal gasification

H_2 transportation & storage depends on amount & distance

- Pipelines for big users - worldwide over 10,000 miles with many in Texas, longest is 250 miles from Antwerp to Normandy @ 100 atm.
- Liquid hydrogen for moderate users - used through out California
- High pressure tube trailers for small users - used through out the world

Many H_2 advocates are unaware of this impressive experience

Status of Gasification & H_2 + CO_2 Generation

Worldwide commercial gasification capacity

- Almost 50,000 MW_{th} (syngas) operating & growing at 5,000 MW_{th}/yr
- New projects are mostly petroleum coke or pitch gasification in oil refineries for export power + cogen steam & syngas - polygeneration

Extensive successful commercial experience with coal & heavy oil gasification producing pure H_2 & CO_2 streams

- Over 15 solid & 40 liquid fuel gasification plants making pure H_2
- Mostly for ammonia fertilizer plus some for oil refinery H_2
- Most are in China, some in USA, Germany, Japan, India & Brazil

General Electric has tested & will give commercial performance guarantees for H_2- fired "F" type gas turbines

Farmland in Kansas - Commercial (no subsidies) Coke to H_2 Gasification Plant for Ammonia & CO_2

H_2 based Power Generation with CO_2 Storage

This is the easier application to start using hydrogen because

- It can develop without any changes in existing energy infrastructure & does not have to wait for advanced fuel cells to commercially develop
- Large existing coal-fired power plants are most interesting due their old age, high emissions & low efficiency

Gasification repowering old coal units with H_2-CC is best

- Can increase both capacity & efficiency while at the same time reducing all existing traditional emissions plus Hg & CO_2 to near zero
- This is perhaps the only major CO_2 capture & storage application that can make this important claim
- This is quite important as this helps obtain critical public, NGO & environmentalist support required for H_2 infrastructure to develop

Hydrogen based Transportation

This is a much bigger challenge than H_2 based electricity

- Requires major changes in existing energy infrastructure & likely delayed until mass production commercialization of fuel cell vehicles
- The "big bang" or ramp-up problem
  - Before the first mass-produced fuel cell vehicles roll off the assembly line, most of the H_2 infrastructure must be in place, faced with poor capital utilization for 10-15 yrs of ramp-up

SFA Pacific recently did a H_2 supply costs scoping study with the final report published July 2002 - NREL/SR-540-32525

SFA Pacific is currently supplying technical & economic assistance to the National Academies Hydrogen Committee

- Objective, simple & transparent cost & performance model of H2

Conclusions

Aggressive resource recovery assumptions show gas & oil production may still start to peak with in only 50-60 years

Can greatly improve gas & oil supplies with simple market-based competition among energy & CO_2 mitigation options

- Cogeneration - limited by cheap paid-off old coal power plants & regulated electric utilities with little benefit reselling power by others
- Heavy oil production with residue gasification for polygeneration
- Current wind turbine subsidy of $18/MWh when replacing NGCC @ 0.36 tons CO_2/MWh is a CO_2 avoidance subsidy equivalent of $50/ton, at that same subsidy for man-made CO_2 into EOR & CBM is a "win-win"
- Effective remote gas utilization (LNG or GTL) & non-conventional gas
- CO_2 capture with gasification of residues, coal, & biomass into syngas products & H_2 can greatly increase gas/oil with low CO_2 emissions