Approved: May 1, 2003 Carl Dean Holmes
Date

MINUTES OF THE HOUSE COMMITTEE ON UTILITIES.

The meeting was called to order by Chairman Carl D. Holmes at 9:10 a.m. on March 13, 2003 in Room 526-S of the Capitol.

All members were present except: Representative Jerry Williams

Committee staff present: Mary Galligan, Legislative Research
Dennis Hodgins, Legislative Research
Mary Torrence, Revisor of Statutes
Jo Cook, Administrative Assistant

Conferees appearing before the committee: M. Lee Allison, Kansas Geological Survey

Others attending: See Attached List

Chairman Holmes welcomed Dr. M. Lee Allison, State Geologist and Director for the Kansas Geological Survey and the Chair of the State Energy Resources Coordination Council (SERCC). Dr. Allison spoke to the committee about the 2003 State Energy Plan (Attachment 1) and energy forecasts. He provided details on the state's energy balance with projections to 2007 and the state's consumption of energy, by fuel source. He also addressed concerns on the state's energy production potential and how it declining to the point of Kansas being a net importer of energy. Dr. Allison also explained the SERCC goals and requested legislative actions. Dr. Allison responded to questions from the committee.

Dr. Allison then addressed the committee on the issue of "Coalbed Methane in Kansas" (Attachment 2). Dr. Allison provided a power point presentation that detailed the areas of potential coalbed methane development in the state. He told the committee that the keys to success were: good petroleum transportation infrastructure, sufficient price to spur drilling, thicker coals, high gas content of coals and access to pipelines. Dr. Allison also distributed two documents to the committee: Kansas Geological Survey Public Information Circular 19 "Natural Gas from Coal in Eastern Kansas" (Attachment 3) and an article from the Oil & Gas Journal titled "Coalbed gas play emerges in eastern Kansas basins"(Attachment 4).

Dr. Allison, again, responded to questions from the committee.

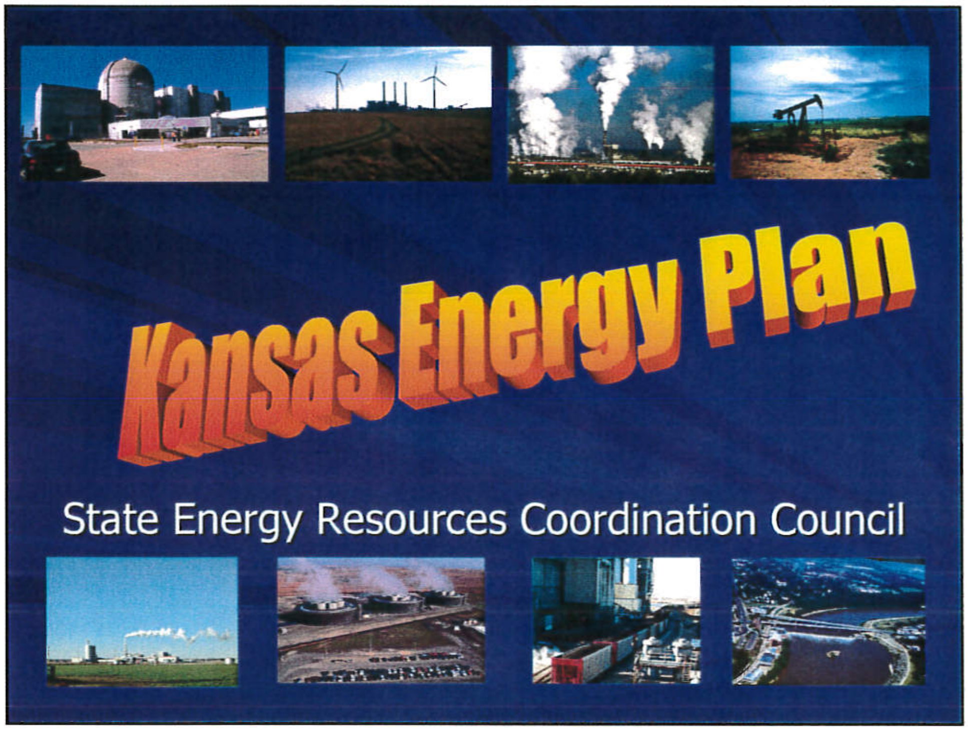
The meeting adjourned at 10:47 a.m.

The next meeting will be Friday, March 14, 2003 at 9:00 a.m.

# HOUSE UTILITIES COMMITTEE GUEST LIST

DATE: March 13, 2003

| NAME | REPRESENTING |
|---|---|
| Joe Dick | KCBPU |
| Lee Allison | KGS-KU |
| Liz Brosius | KGS |
| Larry Brady | KGS |
| K. Dave Newell | KGS |
| Scott Schneider | GBBA |
| Bob Krehbiel | KIOGA |
| Charles Benjamin | Sierra Club |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |




SERCC www.kansasenergy.org

Tasks

- Energy production and consumption forecasts
- Annual comprehensive energy plan

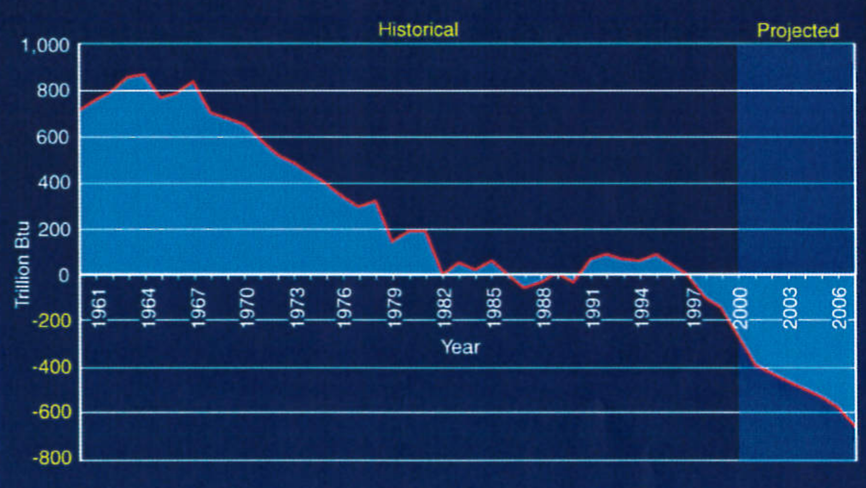
HOUSE UTILITIES
DATE: 3-13-03
ATTACHMENT 1

## SERCC

- Kansas Energy Plan (January 13, 2003)
- Kansas Energy Abstract (March, 2003)
- Kansas Energy Atlas (online)

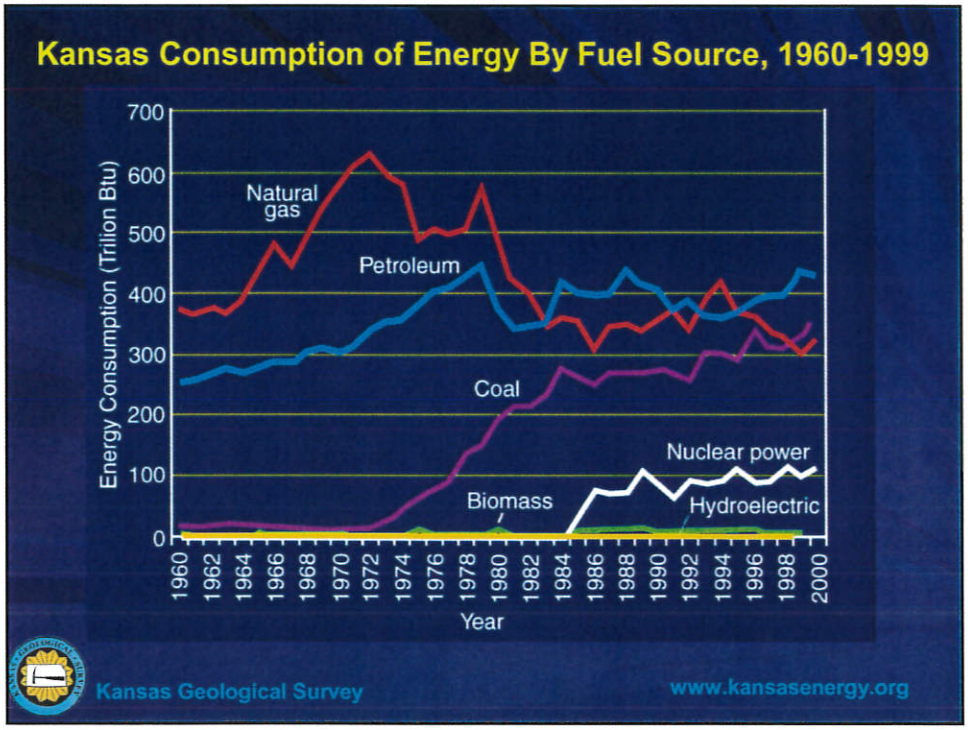
  http://neutrino.kgs.ku.edu/website/energy_atlas/

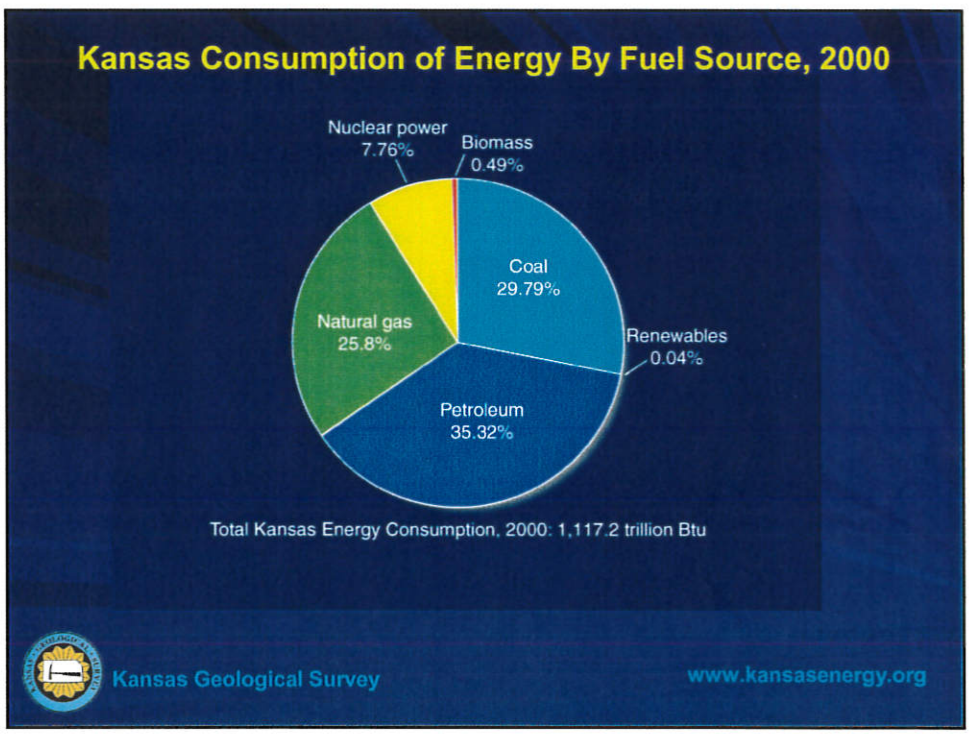
## Kansas Energy Balance, 1960-1999, with Projections to 2007

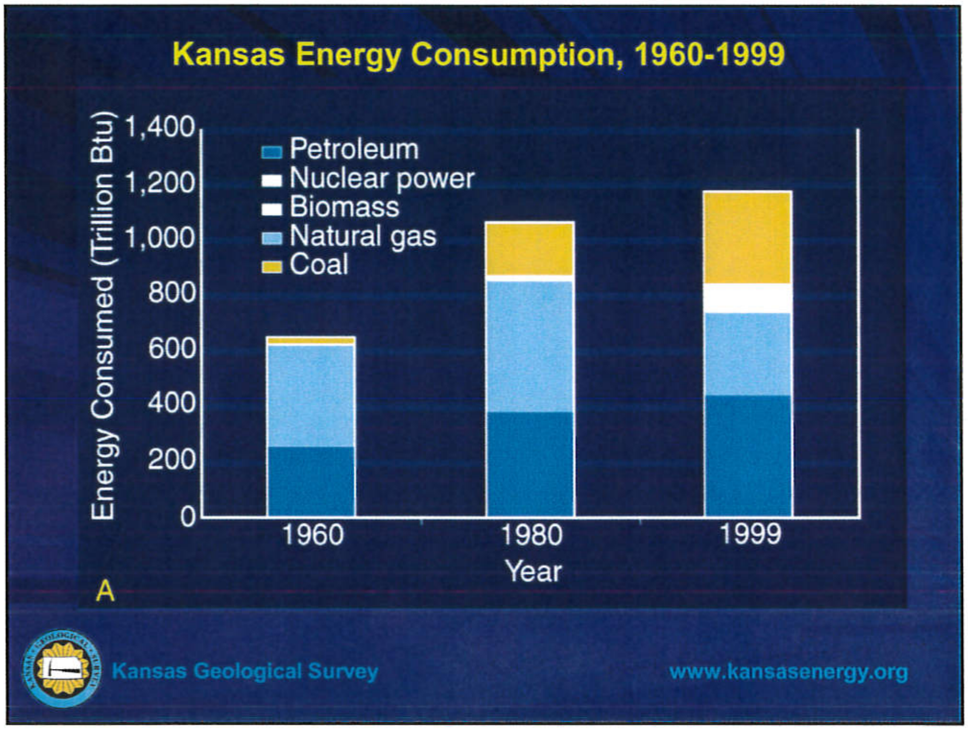


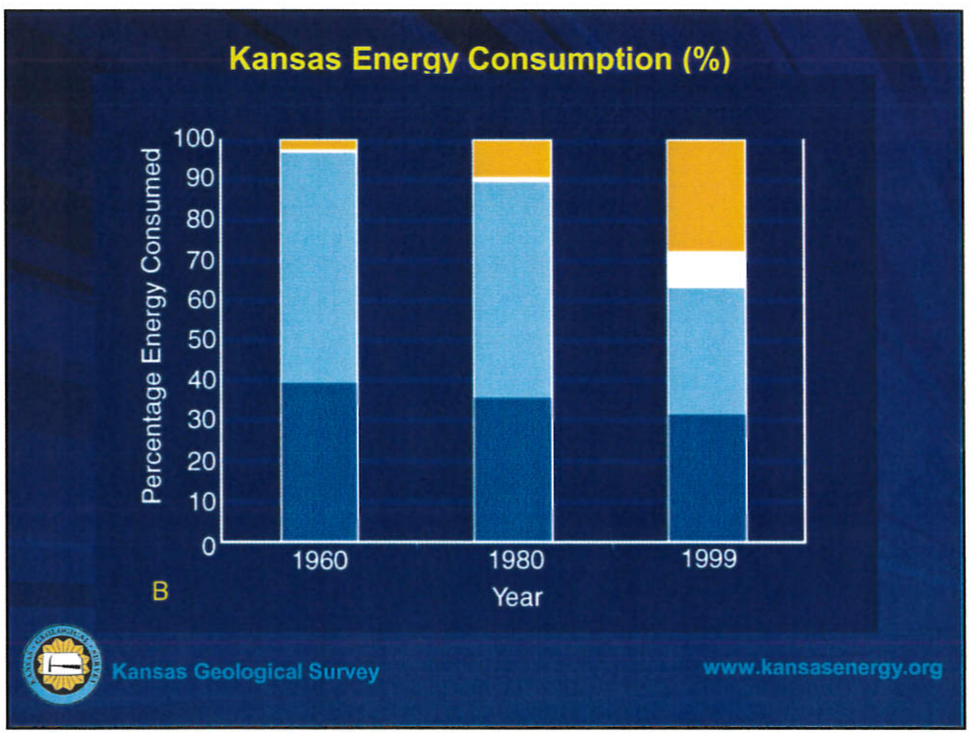

Kansas Geological Survey

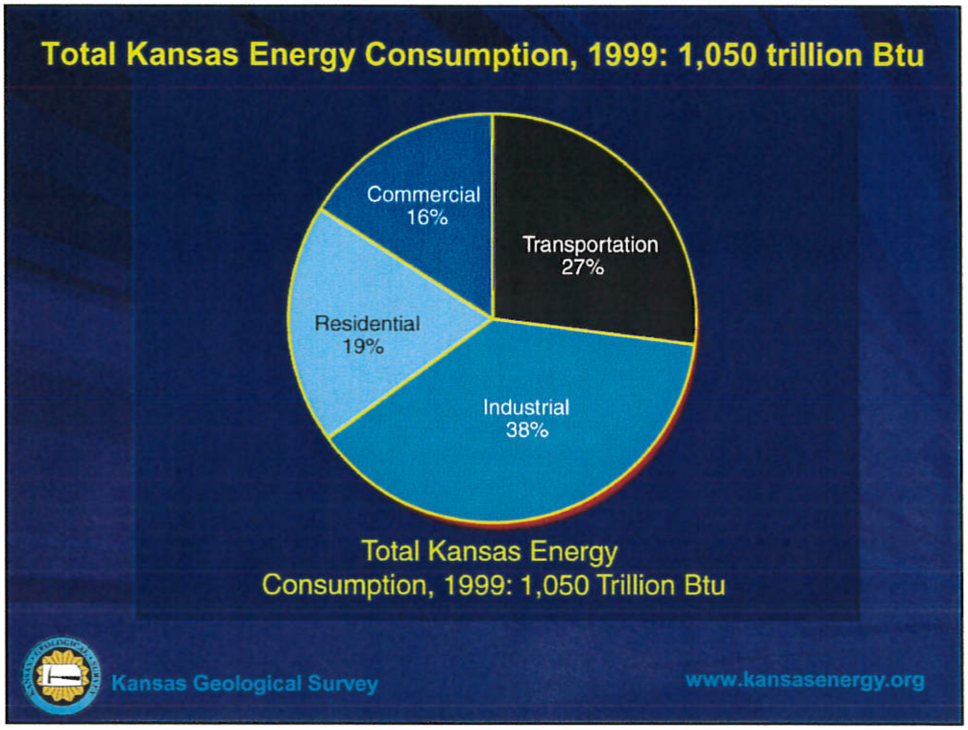
www.kansasenergy.org

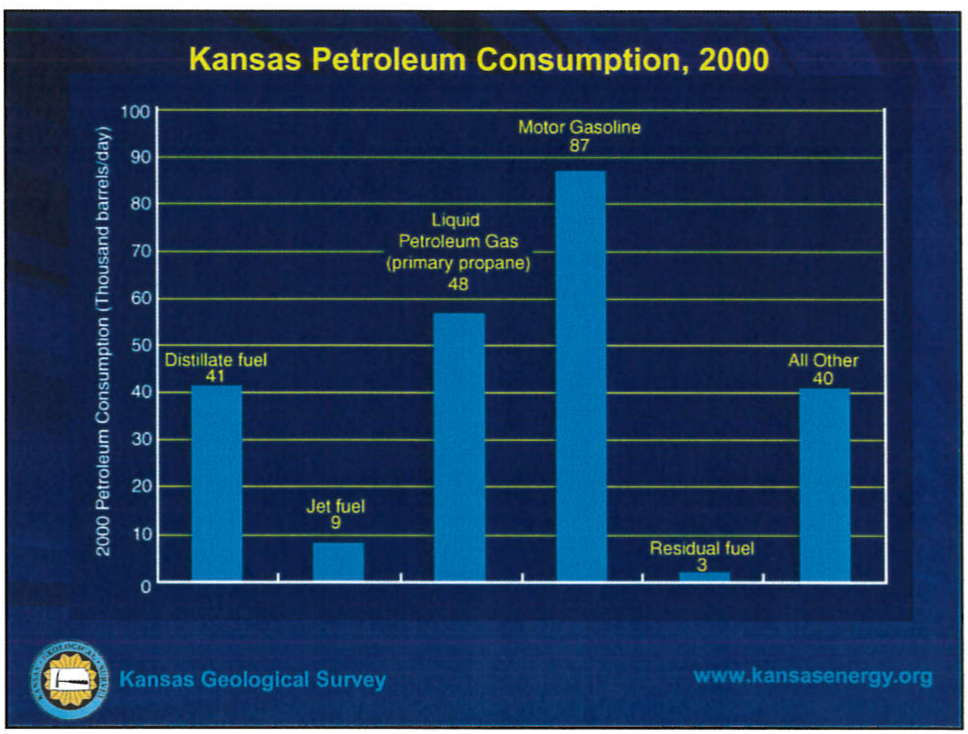

Kansas Consumption of Energy By Fuel Source, 1960-1999
Energy Consumption (Trilion Btu)
700
600
500
400
300
200
100
0
Natural gas
Petroleum
Coal
Nuclear power
Biomass
Hydroelectric
1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000
Year
Kansas Geological Survey
www.kansasenergy.org

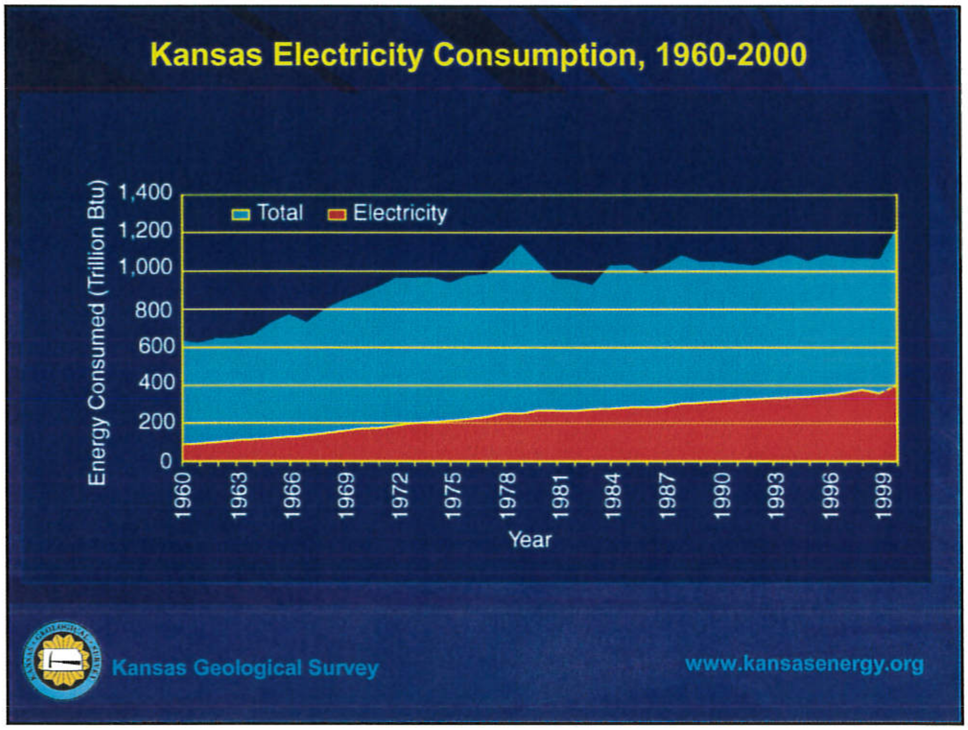

Kansas Consumption of Energy By Fuel Source, 2000
Nuclear power 7.76%
Biomass 0.49%
Coal 29.79%
Renewables 0.04%
Natural gas 25.8%
Petroleum 35.32%
Total Kansas Energy Consumption, 2000: 1,117.2 trillion Btu
Kansas Geological Survey
www.kansasenergy.org

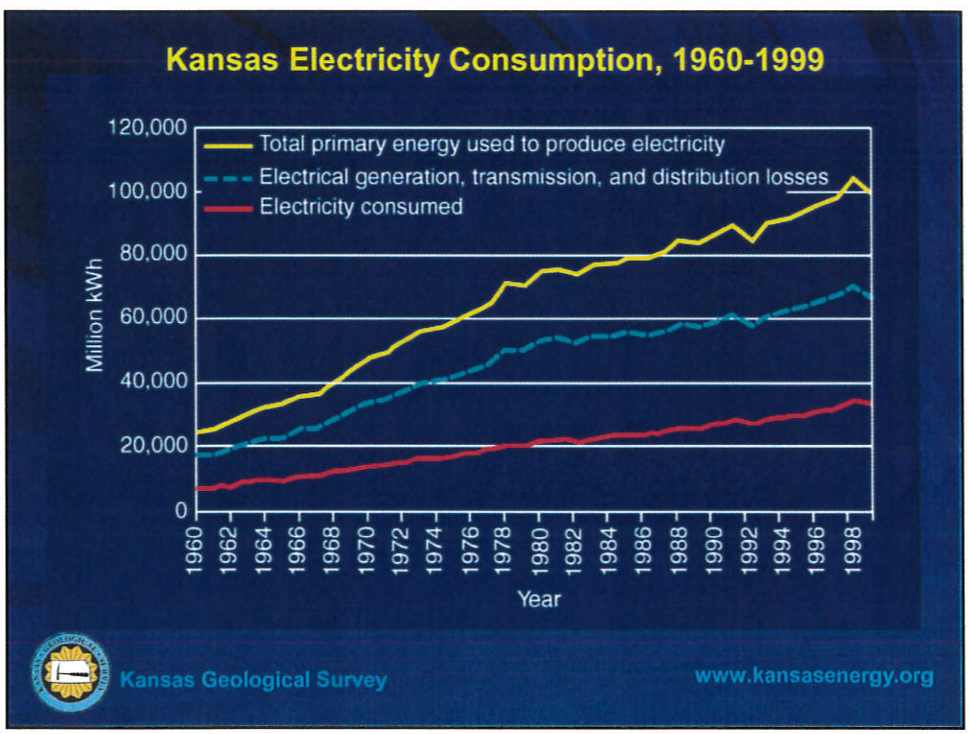

Kansas Energy Consumption, 1960-1999
Energy Consumed (Trillion Btu)
1,400
1,200
1,000
800
600
400
200
0
Petroleum
Nuclear power
Biomass
Natural gas
Coal
1960
1980
1999
Year
A
Kansas Geological Survey
www.kansasenergy.org


Kansas Energy Consumption (%)
Percentage Energy Consumed
100
90
80
70
60
50
40
30
20
10
0
1960
1980
1999
Year
B
Kansas Geological Survey
www.kansasenergy.org

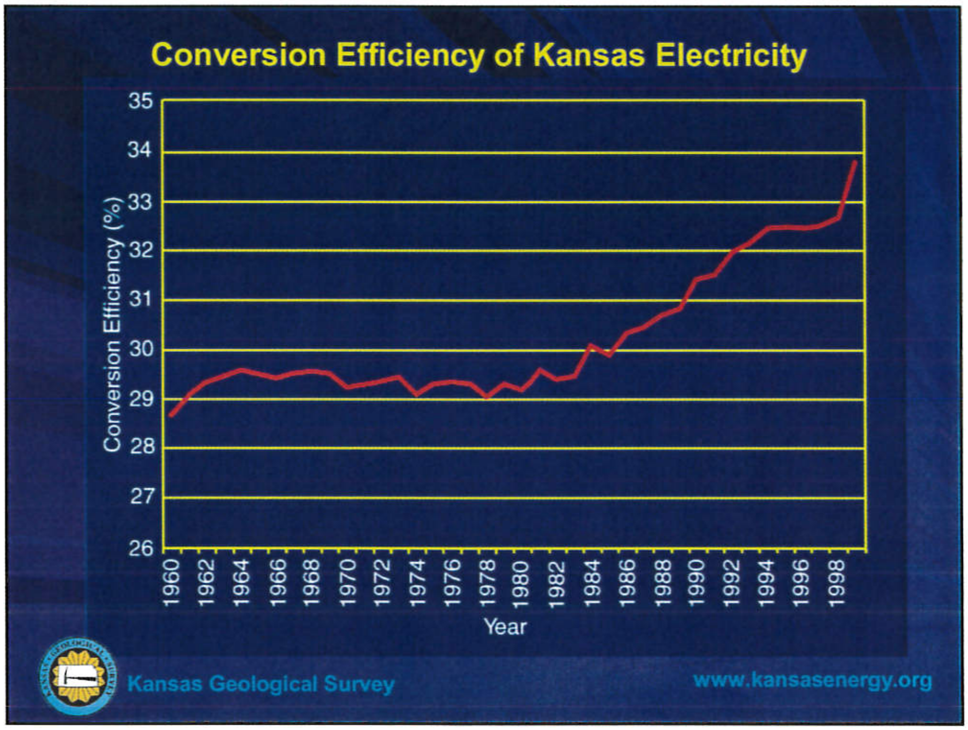

Total Kansas Energy Consumption, 1999: 1,050 trillion Btu
Commercial 16%
Transportation 27%
Residential 19%
Industrial 38%
Total Kansas Energy Consumption, 1999: 1,050 Trillion Btu
Kansas Geological Survey
www.kansasenergy.org

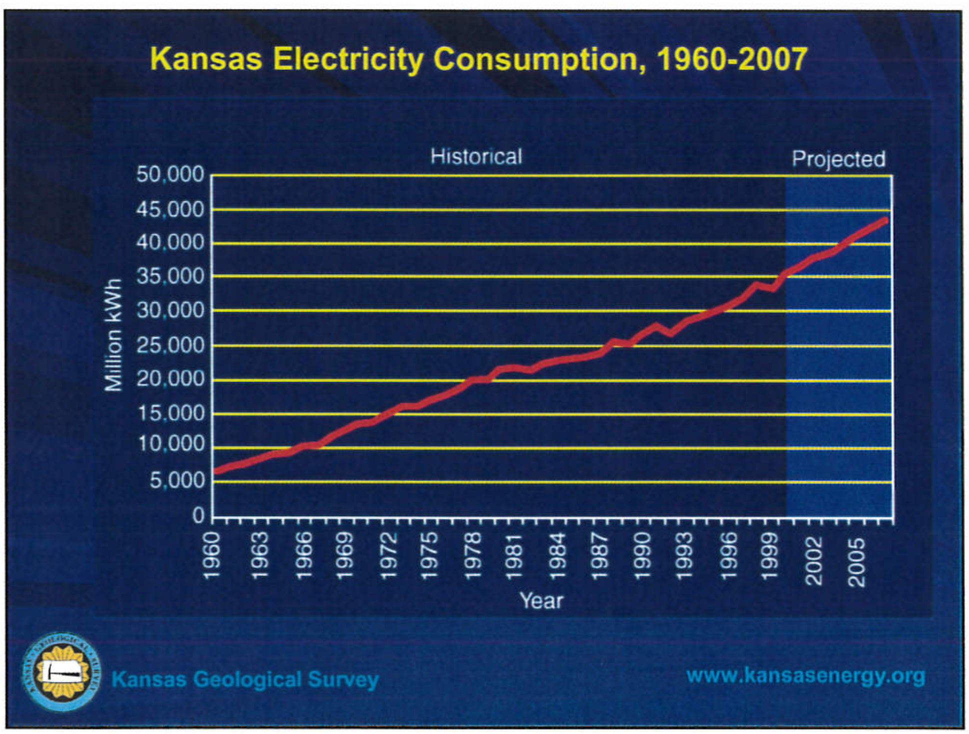

Kansas Petroleum Consumption, 2000
2000 Petroleum Consumption (Thousand barrels/day)
0
10
20
30
40
50
60
70
80
90
100
Distillate fuel 41
Jet fuel 9
Liquid Petroleum Gas (primary propane) 48
Motor Gasoline 87
Residual fuel 3
All Other 40
Kansas Geological Survey
www.kansasenergy.org


Kansas Electricity Consumption, 1960-2000
Total
Electricity
Energy Consumed (Trillion Btu)
1,400
1,200
1,000
800
600
400
200
0
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
Year
Kansas Geological Survey
www.kansasenergy.org

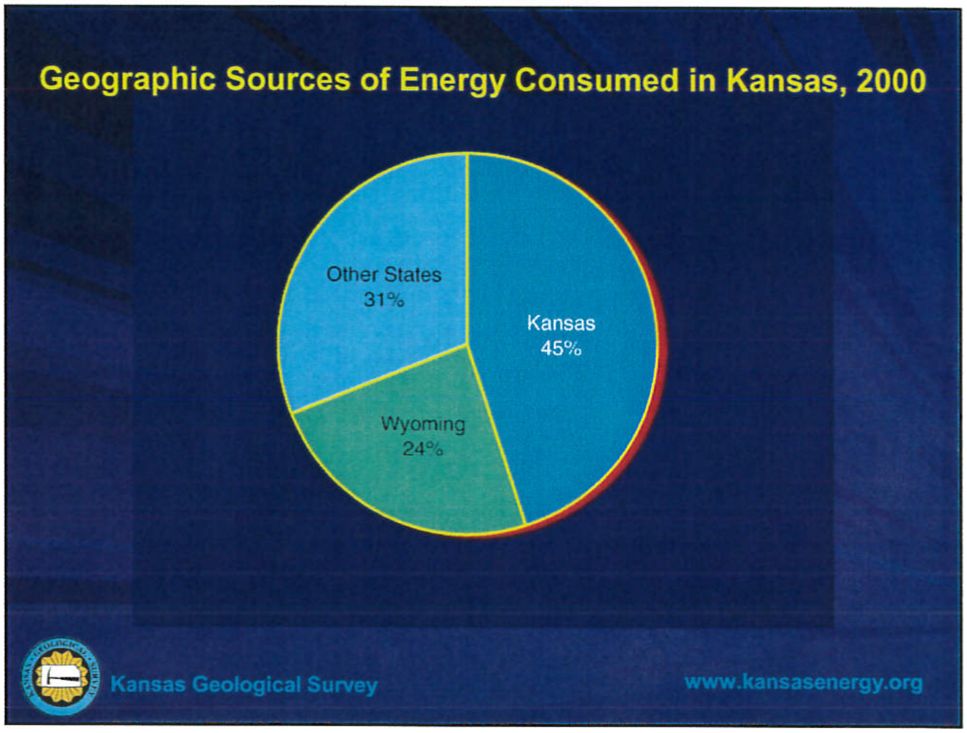

Kansas Electricity Consumption, 1960-1999
Total primary energy used to produce electricity
Electrical generation, transmission, and distribution losses
Electricity consumed
Million kWh
120,000
100,000
80,000
60,000
40,000
20,000
0
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
Year
Kansas Geological Survey
www.kansasenergy.org

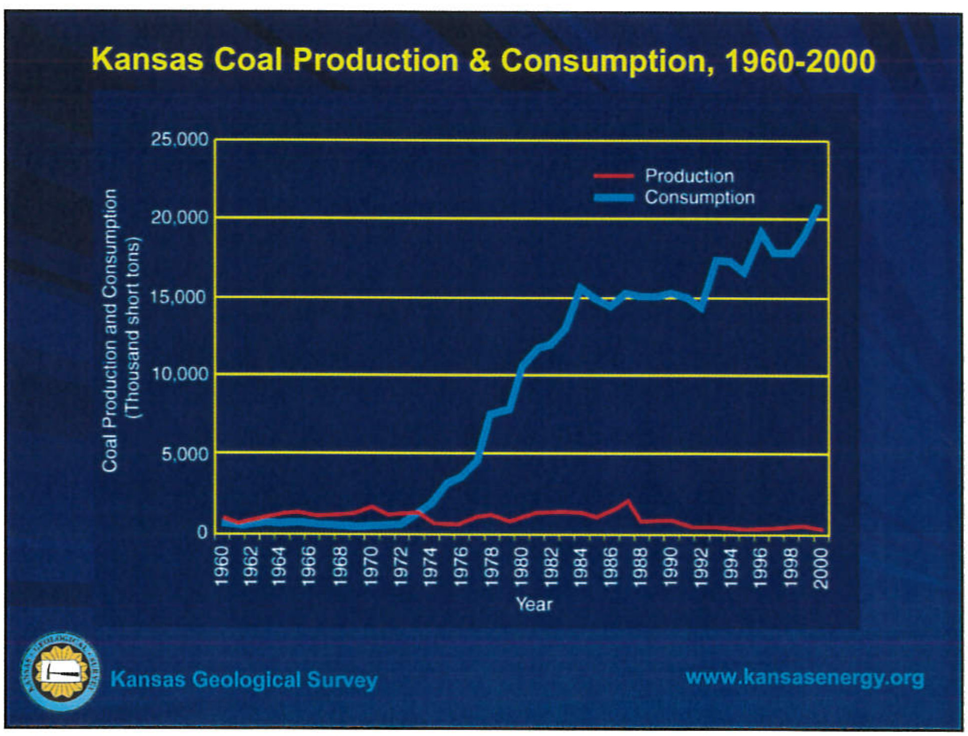
1-6


Conversion Efficiency of Kansas Electricity
35
34
33
32
31
30
29
28
27
26
Conversion Efficiency (%)
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
Year
Kansas Geological Survey
www.kansasenergy.org

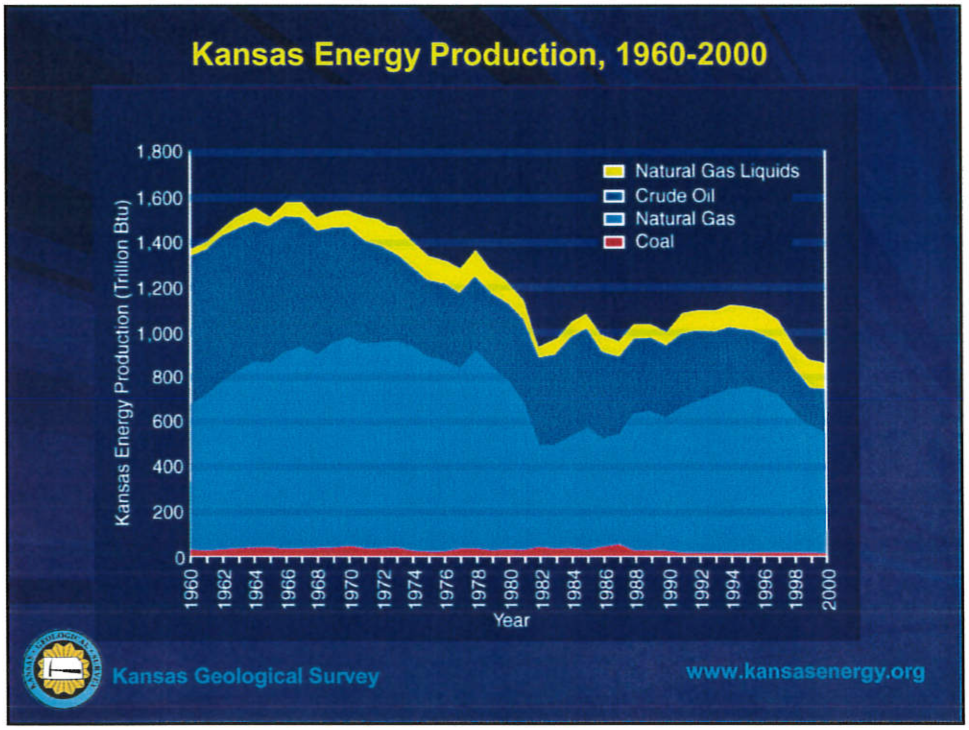

Kansas Electricity Consumption, 1960-2007
Historical
Projected
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Million kWh
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
Year
Kansas Geological Survey
www.kansasenergy.org

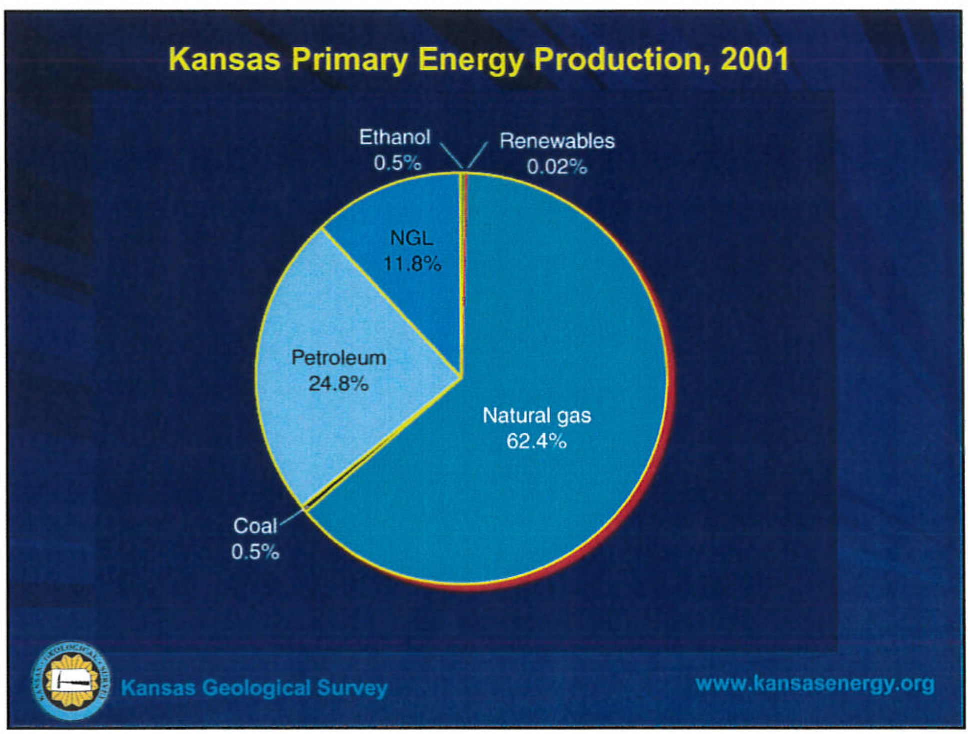
1-7


Geographic Sources of Energy Consumed in Kansas, 2000
Other States 31%
Kansas 45%
Wyoming 24%
Kansas Geological Survey
www.kansasenergy.org

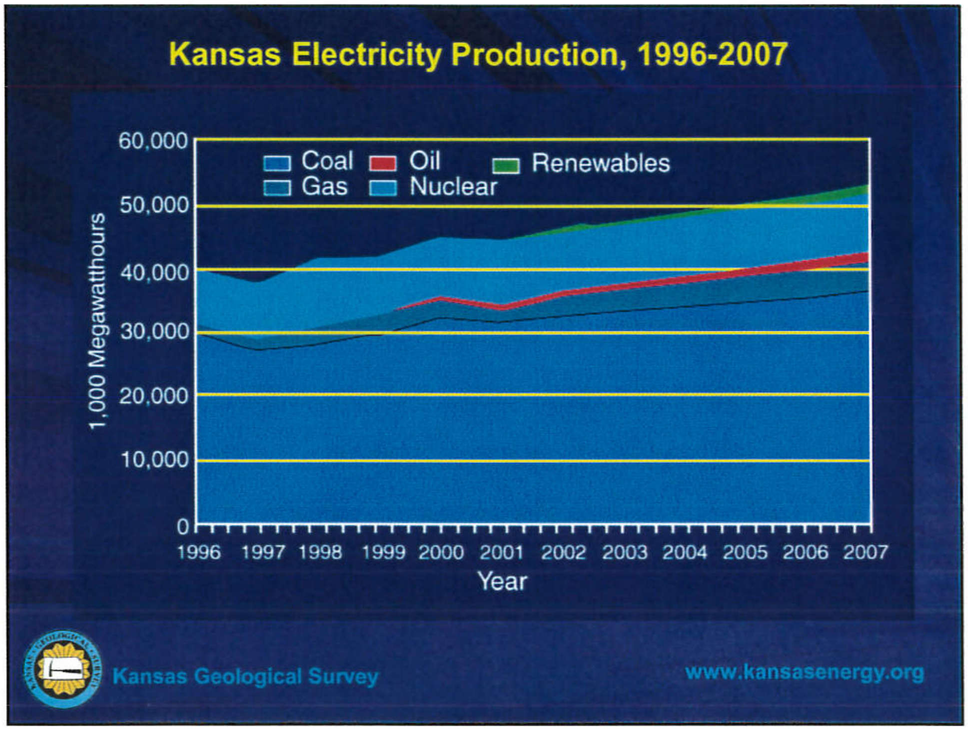

Kansas Coal Production & Consumption, 1960-2000
Production
Consumption
Coal Production and Consumption (Thousand short tons)
25,000
20,000
15,000
10,000
5,000
0
1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000
Year
Kansas Geological Survey
www.kansasenergy.org

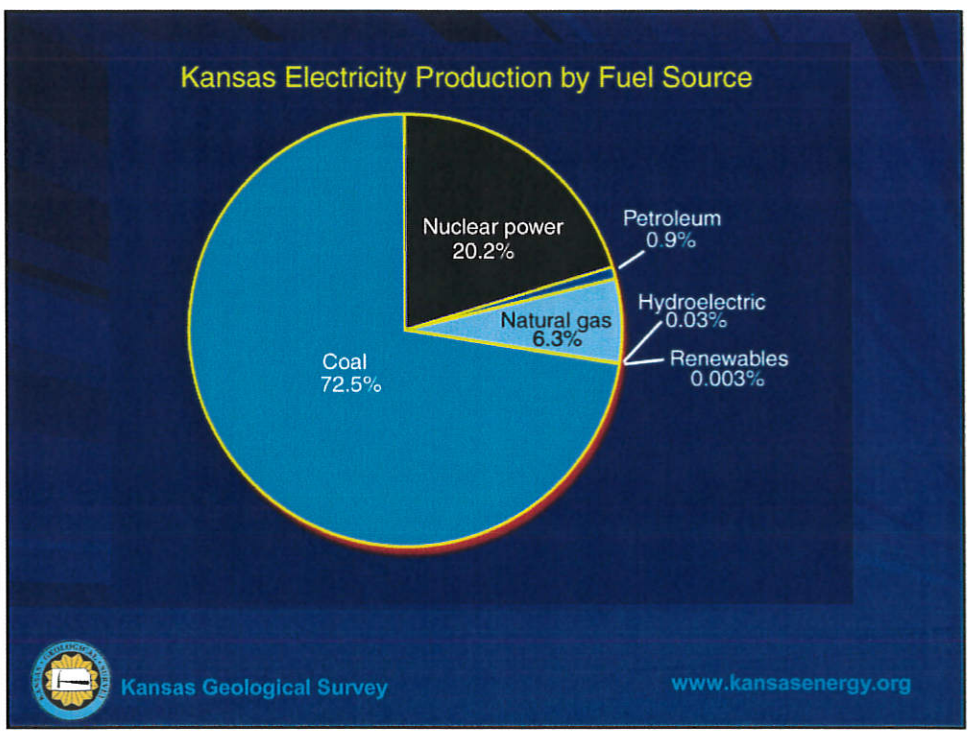
1-8


Kansas Energy Production, 1960-2000
Natural Gas Liquids
Crude Oil
Natural Gas
Coal
Kansas Energy Production (Trillion Btu)
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000
Year
Kansas Geological Survey
www.kansasenergy.org

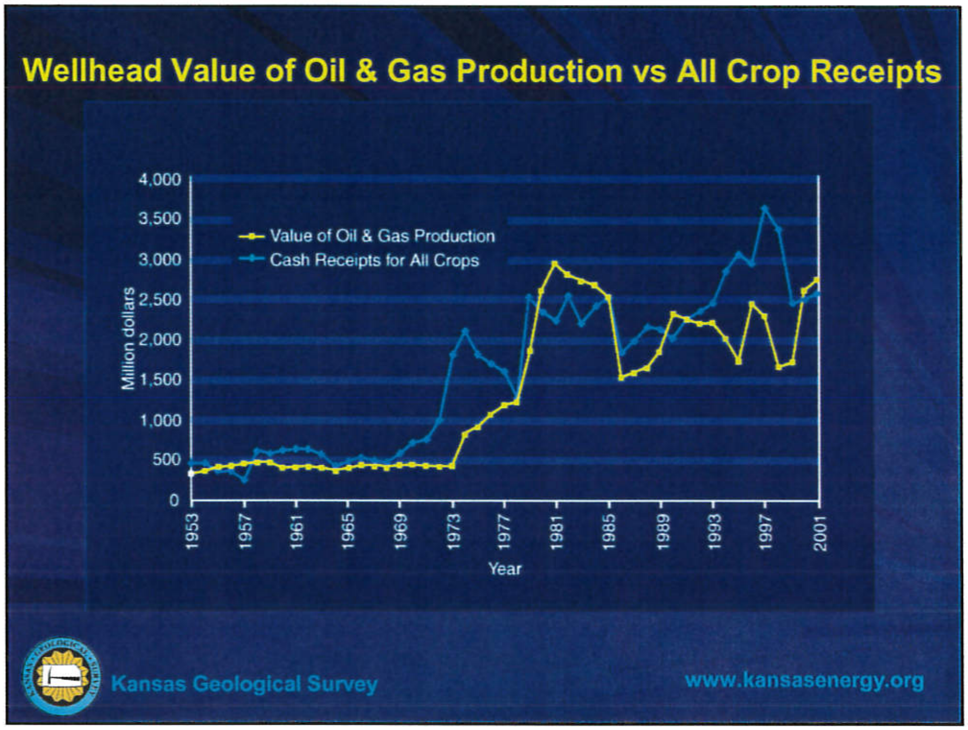

Kansas Primary Energy Production, 2001
Ethanol 0.5%
Renewables 0.02%
NGL 11.8%
Petroleum 24.8%
Natural gas 62.4%
Coal 0.5%
Kansas Geological Survey
www.kansasenergy.org

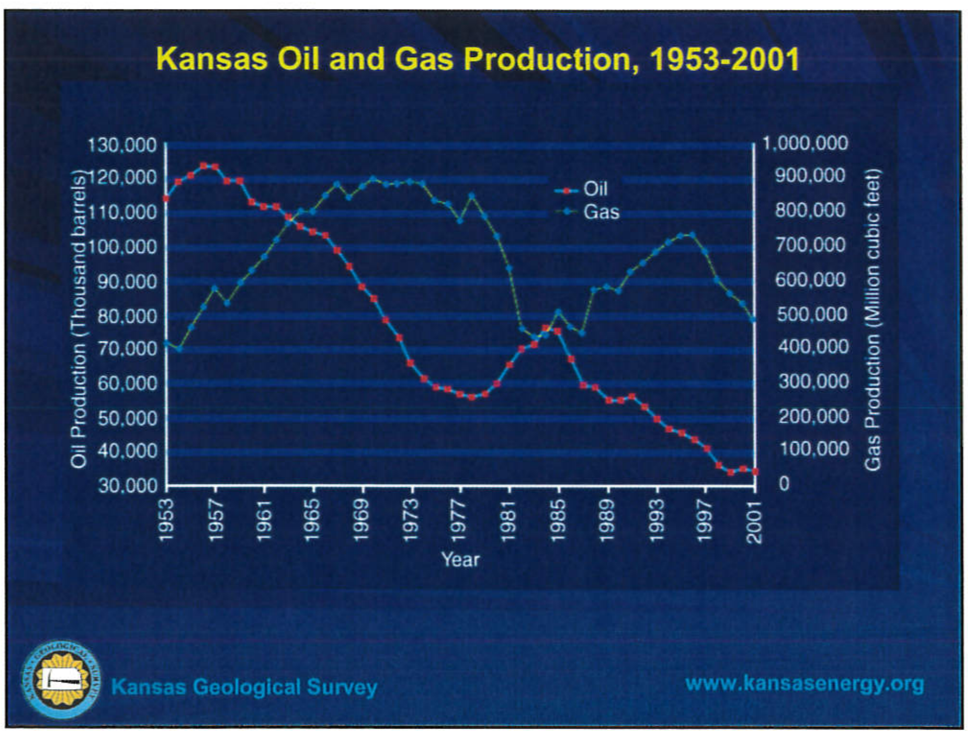
1-9


Kansas Electricity Production, 1996-2007
60,000
50,000
40,000
30,000
20,000
10,000
0
1,000 Megawatthours
Coal
Oil
Renewables
Gas
Nuclear
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
Year
Kansas Geological Survey
www.kansasenergy.org

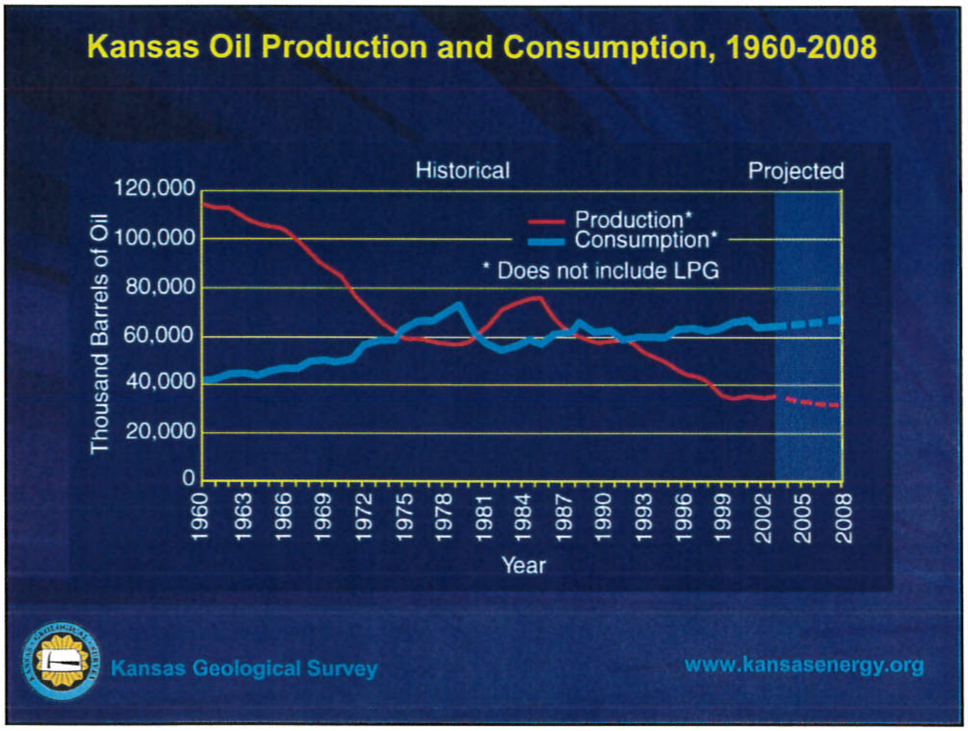

Kansas Electricity Production by Fuel Source
Nuclear power 20.2%
Petroleum 0.9%
Hydroelectric 0.03%
Natural gas 6.3%
Renewables 0.003%
Coal 72.5%
Kansas Geological Survey
www.kansasenergy.org

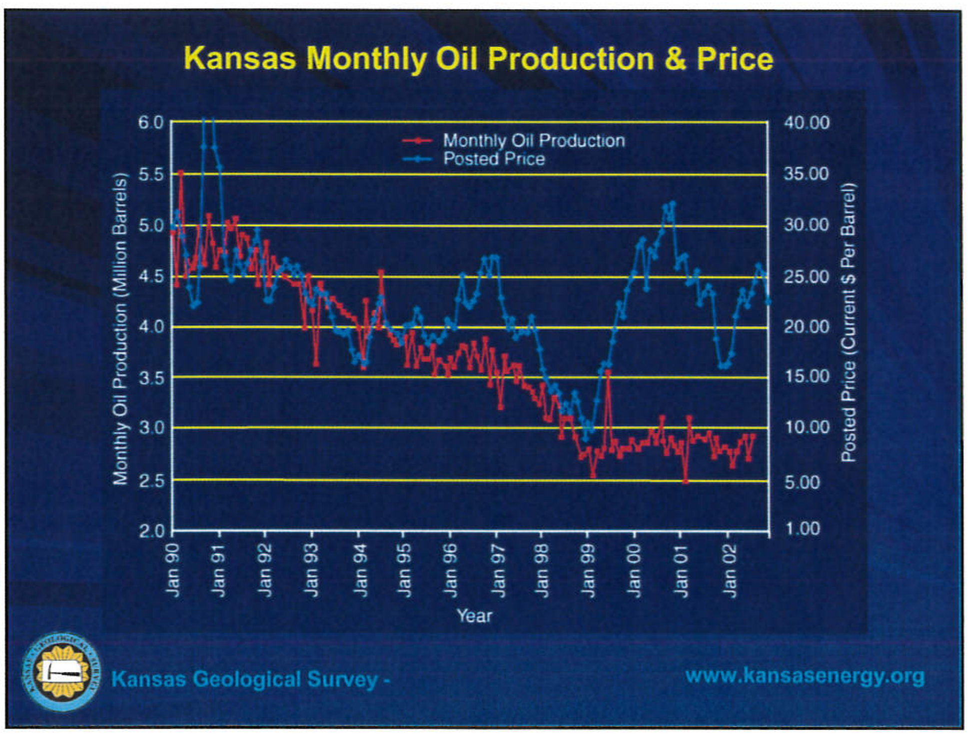
1-10


Wellhead Value of Oil & Gas Production vs All Crop Receipts
Value of Oil & Gas Production
Cash Receipts for All Crops
Million dollars
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001
Year
Kansas Geological Survey
www.kansasenergy.org

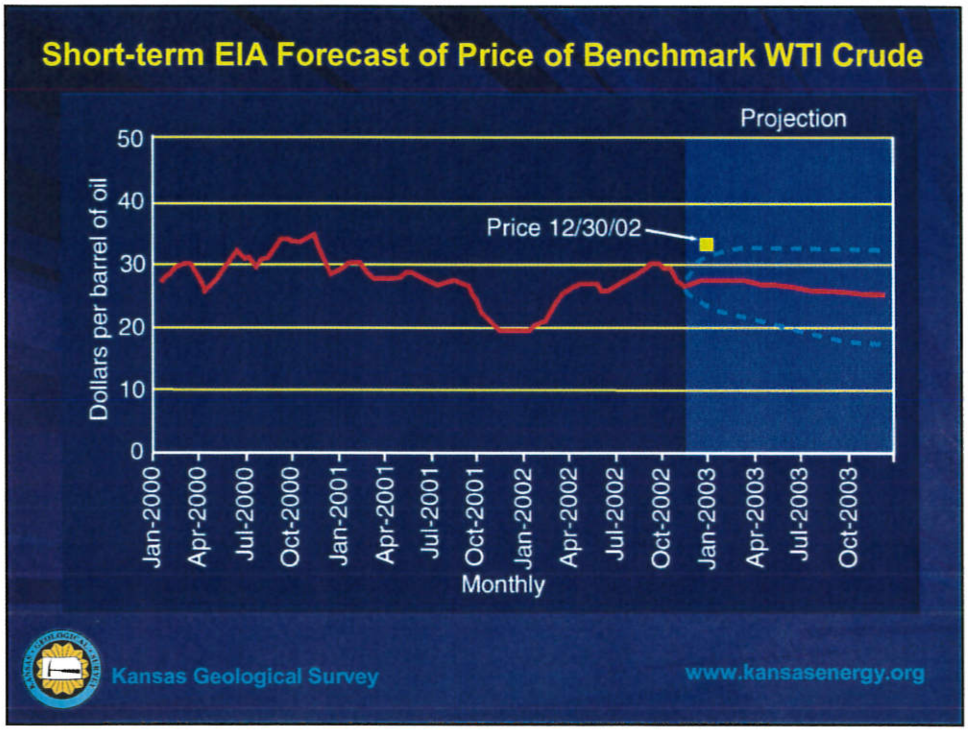

Kansas Oil and Gas Production, 1953-2001
Oil
Gas
Oil Production (Thousand barrels)
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
Gas Production (Million cubic feet)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001
Year
Kansas Geological Survey
www.kansasenergy.org

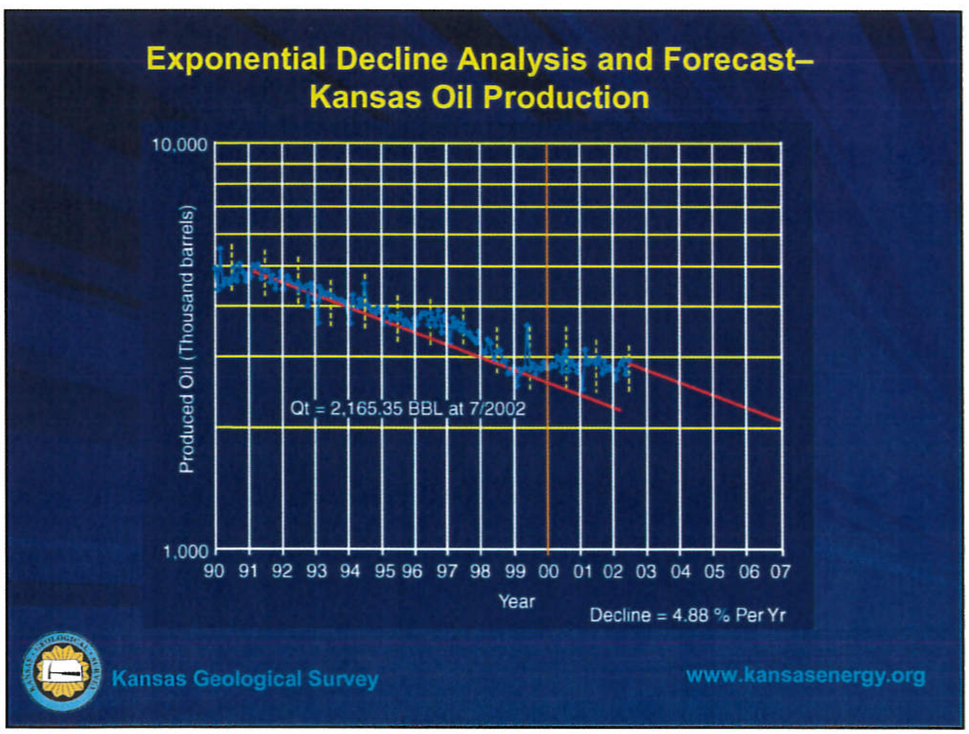
1 - 11


Kansas Oil Production and Consumption, 1960-2008
Historical
Projected
Production*
Consumption*
* Does not include LPG
Thousand Barrels of Oil
120,000
100,000
80,000
60,000
40,000
20,000
0
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
Year
Kansas Geological Survey
www.kansasenergy.org

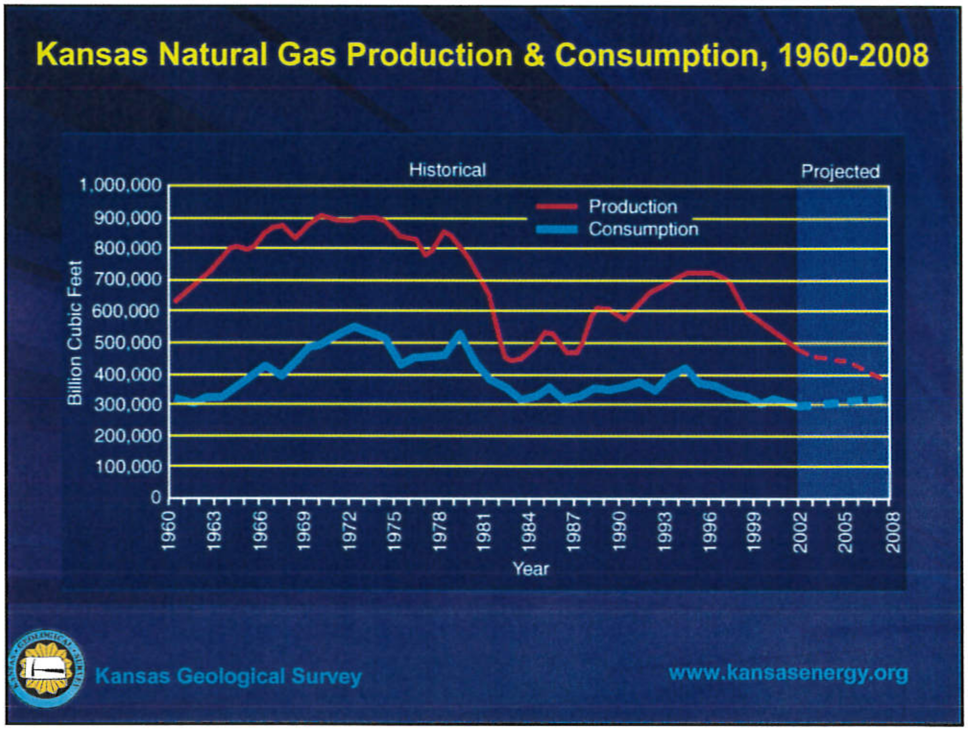

Kansas Monthly Oil Production & Price
Monthly Oil Production
Posted Price
Monthly Oil Production (Million Barrels)
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Posted Price (Current $ Per Barrel)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
1.00
Jan 90
Jan 91
Jan 92
Jan 93
Jan 94
Jan 95
Jan 96
Jan 97
Jan 98
Jan 99
Jan 00
Jan 01
Jan 02
Year
Kansas Geological Survey -
www.kansasenergy.org

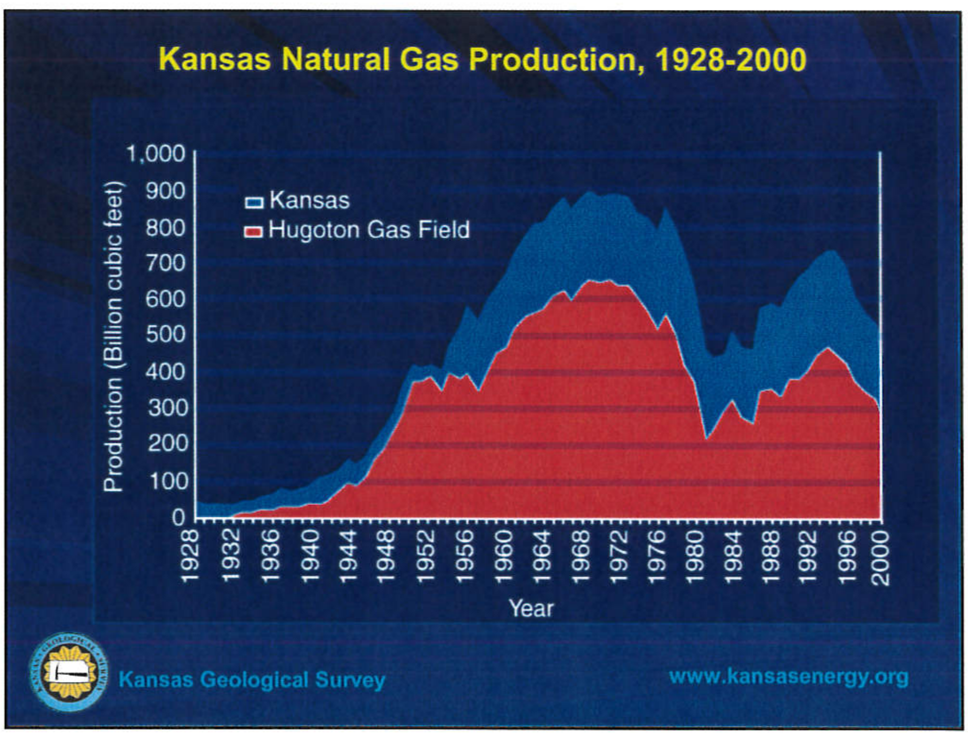
1-12


Short-term EIA Forecast of Price of Benchmark WTI Crude
Projection
Price 12/30/02
Dollars per barrel of oil
50
40
30
20
10
0
Jan-2000
Apr-2000
Jul-2000
Oct-2000
Jan-2001
Apr-2001
Jul-2001
Oct-2001
Jan-2002
Apr-2002
Jul-2002
Oct-2002
Jan-2003
Apr-2003
Jul-2003
Oct-2003
Monthly
Kansas Geological Survey
www.kansasenergy.org

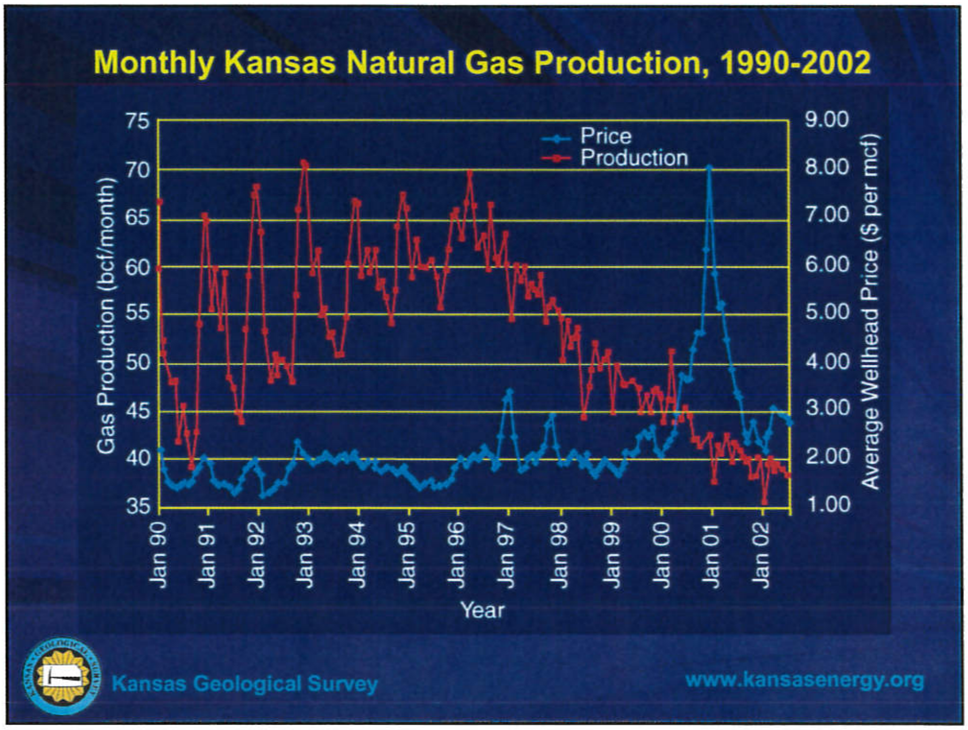

Exponential Decline Analysis and Forecast–
Kansas Oil Production
10,000
1,000
Produced Oil (Thousand barrels)
Qt = 2,165.35 BBL at 7/2002
90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07
Year
Decline = 4.88 % Per Yr
Kansas Geological Survey
www.kansasenergy.org

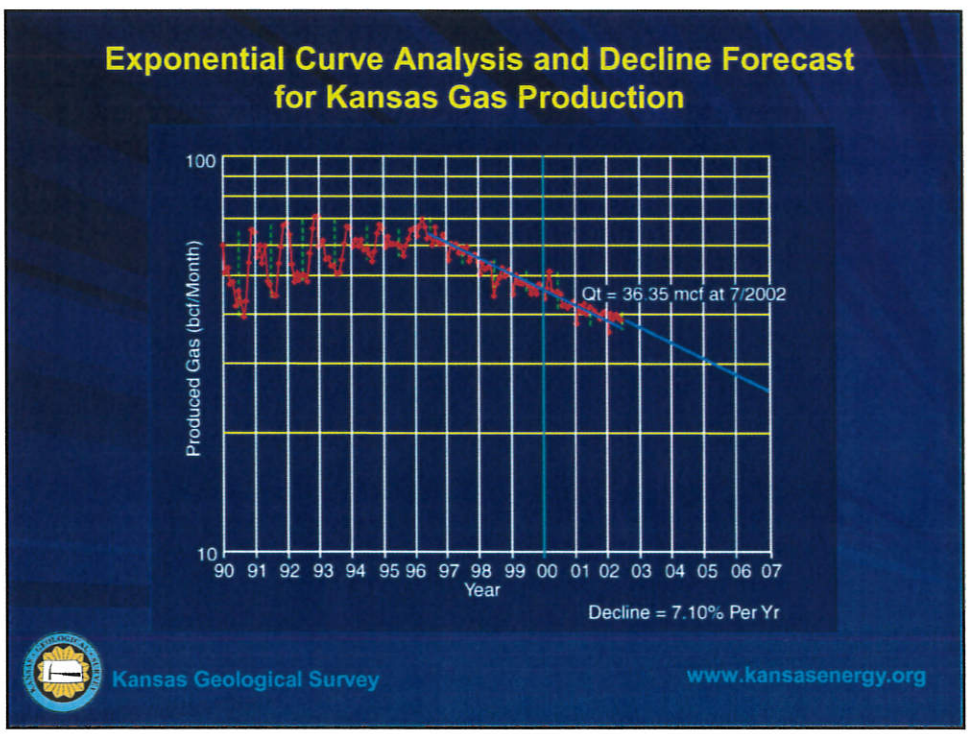
1-13


Kansas Natural Gas Production & Consumption, 1960-2008
Historical
Projected
Production
Consumption
Billion Cubic Feet
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
Year
Kansas Geological Survey
www.kansasenergy.org


Kansas Natural Gas Production, 1928-2000
Kansas
Hugoton Gas Field
Production (Billion cubic feet)
1,000
900
800
700
600
500
400
300
200
100
0
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
Year
Kansas Geological Survey
www.kansasenergy.org

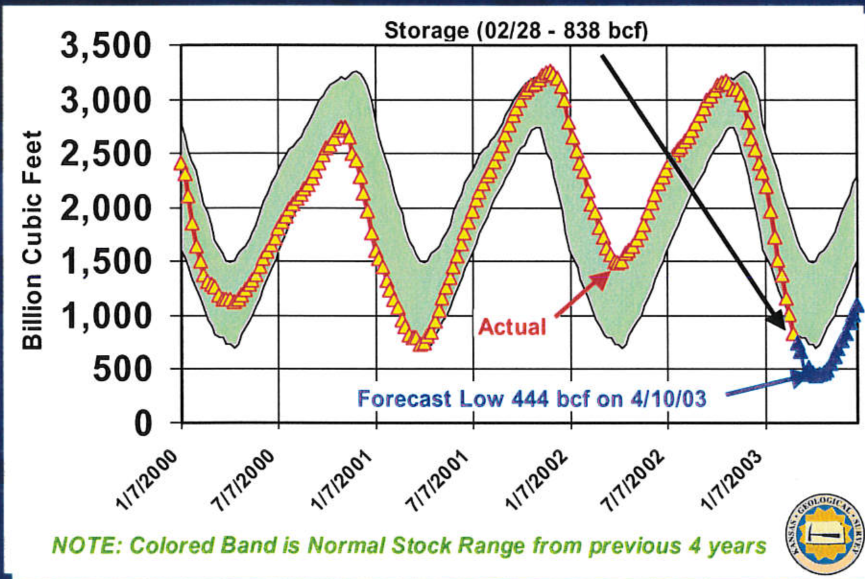
1-14


Monthly Kansas Natural Gas Production, 1990-2002
Price
Production
Gas Production (bcf/month)
Average Wellhead Price ($ per mcf)
75
70
65
60
55
50
45
40
35
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
Jan 90
Jan 91
Jan 92
Jan 93
Jan 94
Jan 95
Jan 96
Jan 97
Jan 98
Jan 99
Jan 00
Jan 01
Jan 02
Year
Kansas Geological Survey
www.kansasenergy.org


Exponential Curve Analysis and Decline Forecast for Kansas Gas Production
Produced Gas (bcf/Month)
100
10
Qt = 36.35 mcf at 7/2002
90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07
Year
Decline = 7.10% Per Yr
Kansas Geological Survey
www.kansasenergy.org

1-15

## Natural Gas Storage




## SERCC

### Goals

- Energy self-reliance
- Restore Kansas energy exports

# SERCC Legislative actions

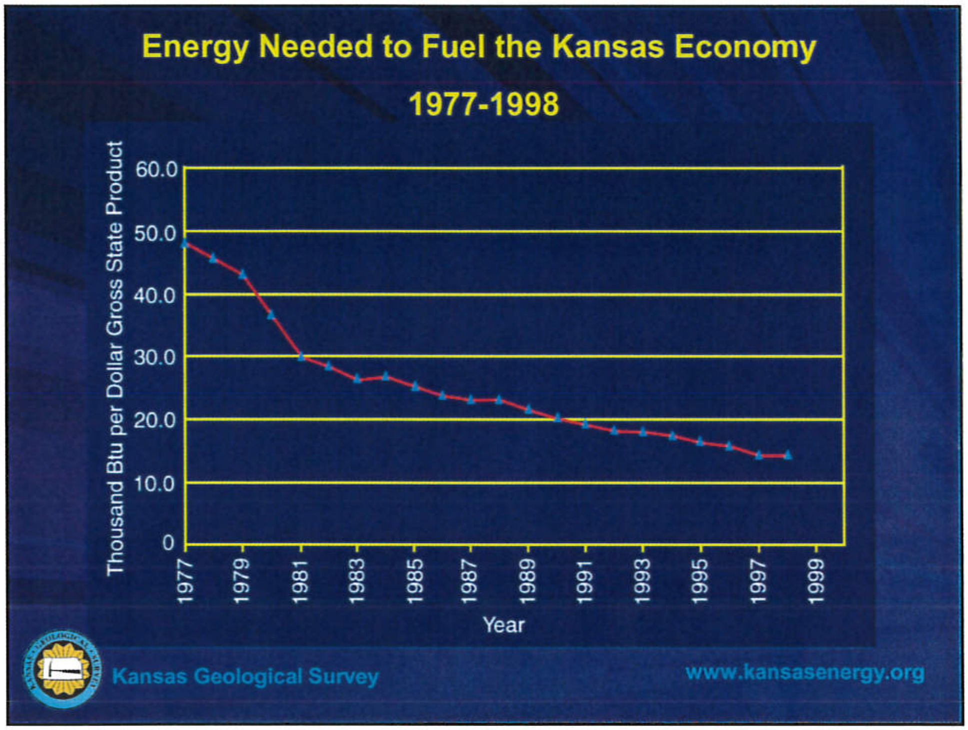
- Energy performance contracts for state buildings HCR-5015
- Update 1989 energy efficiency standards with ASHRAE 1999 standards HB-2131
- Alleviate punitive liabilities for compliance with regulations HB-2282

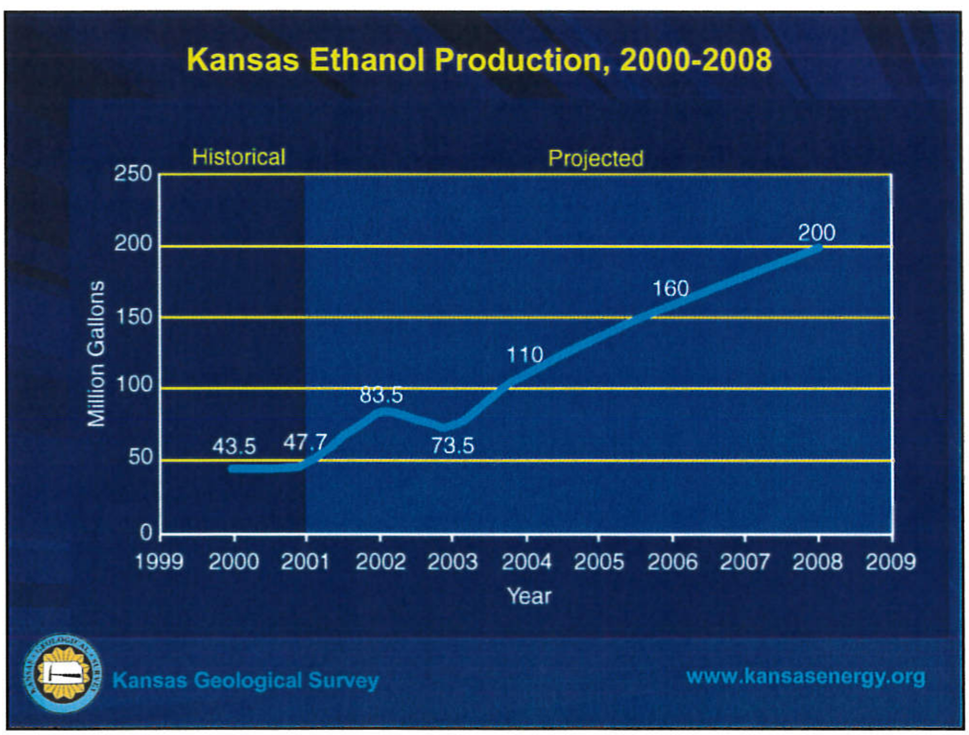
## SERCC

Self-reliance in energy:

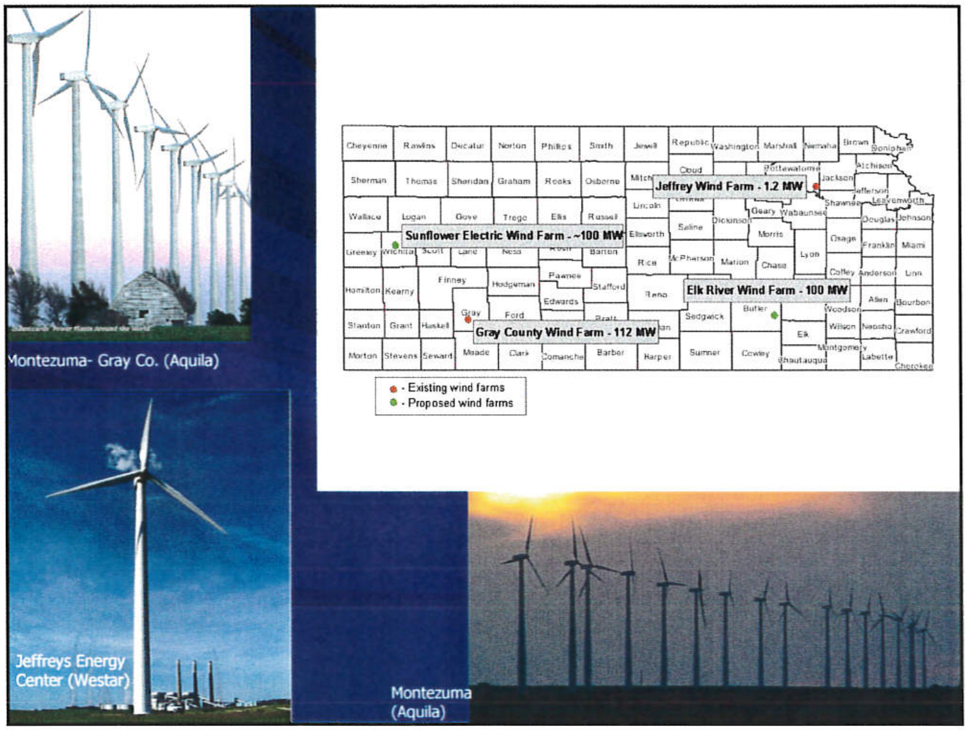
- Extend the life of existing energy sources (oil and gas fields)
- Increased conservation and efficiency
- Develop new energy sources (e.g. wind, ethanol, coalbed methane

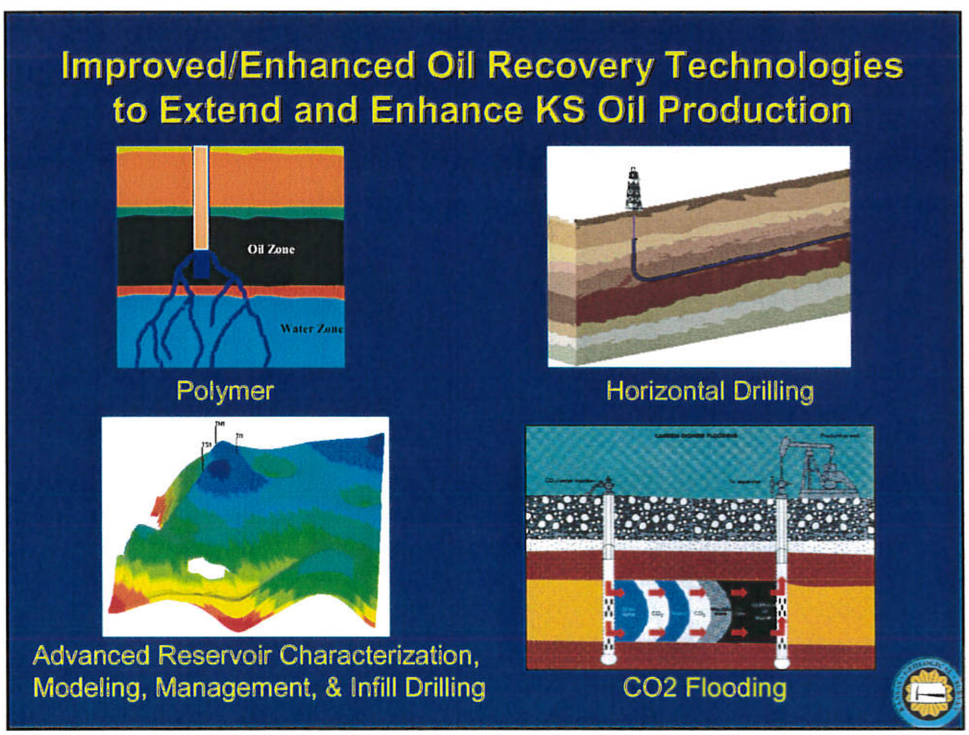
1-17


Energy Needed to Fuel the Kansas Economy
1977-1998
Thousand Btu per Dollar Gross State Product
60.0
50.0
40.0
30.0
20.0
10.0
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
Year
Kansas Geological Survey
www.kansasenergy.org

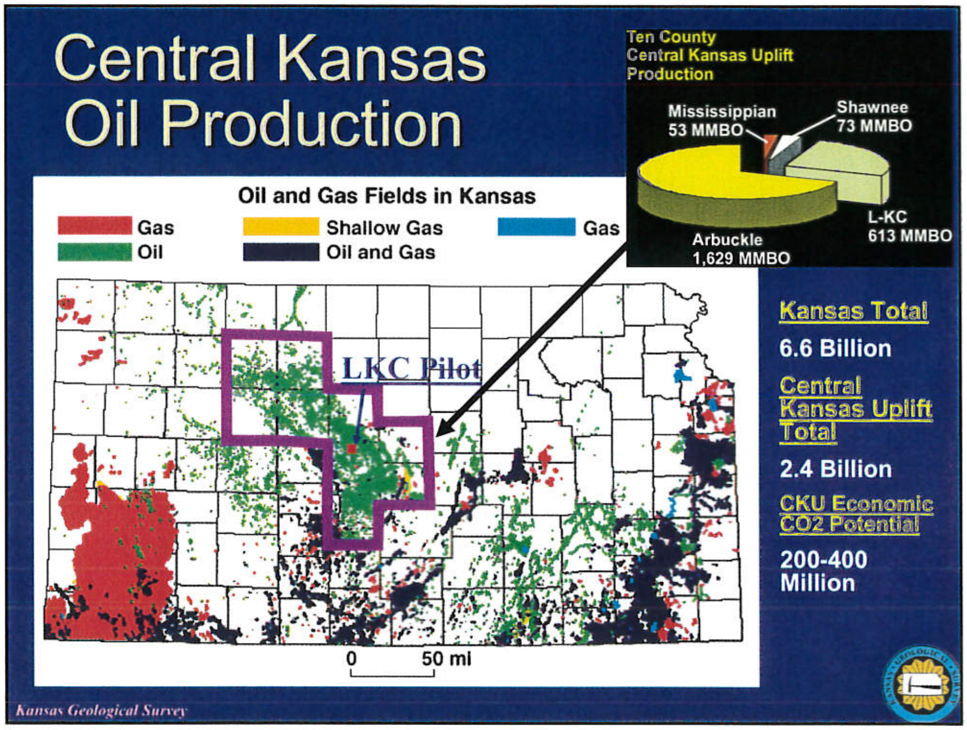

Kansas Ethanol Production, 2000-2008
Historical
Projected
Million Gallons
250
200
150
100
50
0
200
160
110
83.5
73.5
43.5
47.7
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year
Kansas Geological Survey
www.kansasenergy.org

1-18


Montezuma- Gray Co. (Aquila)
Jeffreys Energy Center (Westar)
Montezuma (Aquila)
Jeffrey Wind Farm - 1.2 MW
Sunflower Electric Wind Farm - ~100 MW
Elk River Wind Farm - 100 MW
Gray County Wind Farm - 112 MW
- Existing wind farms
- Proposed wind farms


Improved/Enhanced Oil Recovery Technologies to Extend and Enhance KS Oil Production
Oil Zone
Water Zone
Polymer
Horizontal Drilling
Advanced Reservoir Characterization, Modeling, Management, & Infill Drilling
CO2 Flooding

1-19


Central Kansas Oil Production
Ten County Central Kansas Uplift Production
Mississippian 53 MMBO
Shawnee 73 MMBO
Arbuckle 1,629 MMBO
L-KC 613 MMBO
Oil and Gas Fields in Kansas
Gas
Oil
Shallow Gas
Oil and Gas
Gas
LKC Pilot
0 50 mi
Kansas Total
6.6 Billion
Central Kansas Uplift Total
2.4 Billion
CKU Economic CO2 Potential
200-400 Million
Kansas Geological Survey


State Energy Resources Coordination Council
Kansas Geological Survey
University of Kansas

1-20

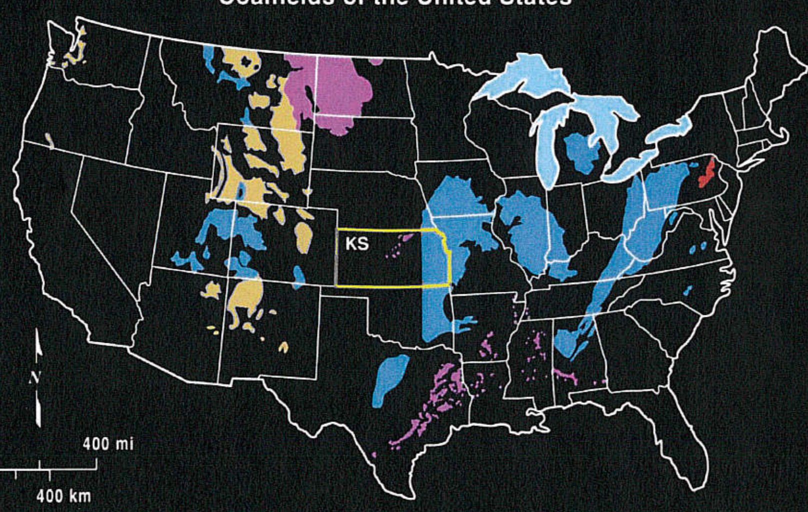
# Kansas Coalbed Methane Potential

Kansas Geological Survey
University of Kansas

http://www.kgs.ku.edu

University of Kansas March 13, 2003

## Coalfields of the United States




anthracite | bituminous coal | subbituminous coal | lignite

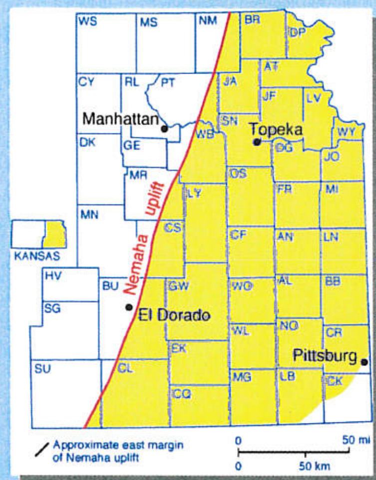
*modified from Trumbull, 1960 (USGS)*

*HOUSE UTILITIES*

DATE: 3-13-03

ATTACHMENT 2

## Area of Potential Coalbed Methane Development




http://www.kgs.ku.edu

University of Kansas

March 13, 2003

## Keys to success

- Good petroleum infrastructure
- Sufficient price to spur drilling
- Thicker coals
- High gas content of coals
- Access to pipelines

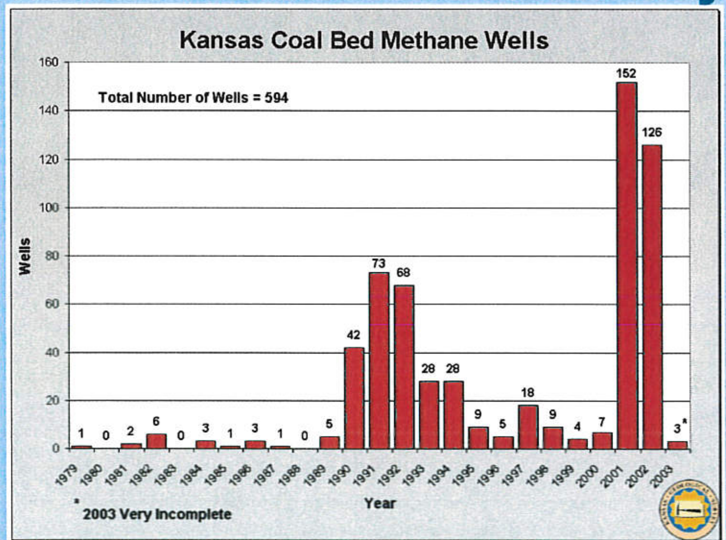
http://www.kgs.ku.edu

University of Kansas

March 13, 2003

2-2

## Coalbed Methane Activity

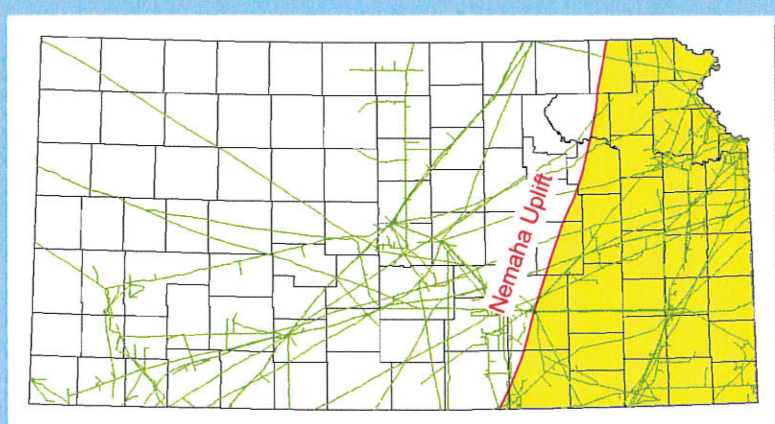



http://www.kgs.ku.edu

March 13, 2003

University of Kansas

## Kansas Major Pipelines

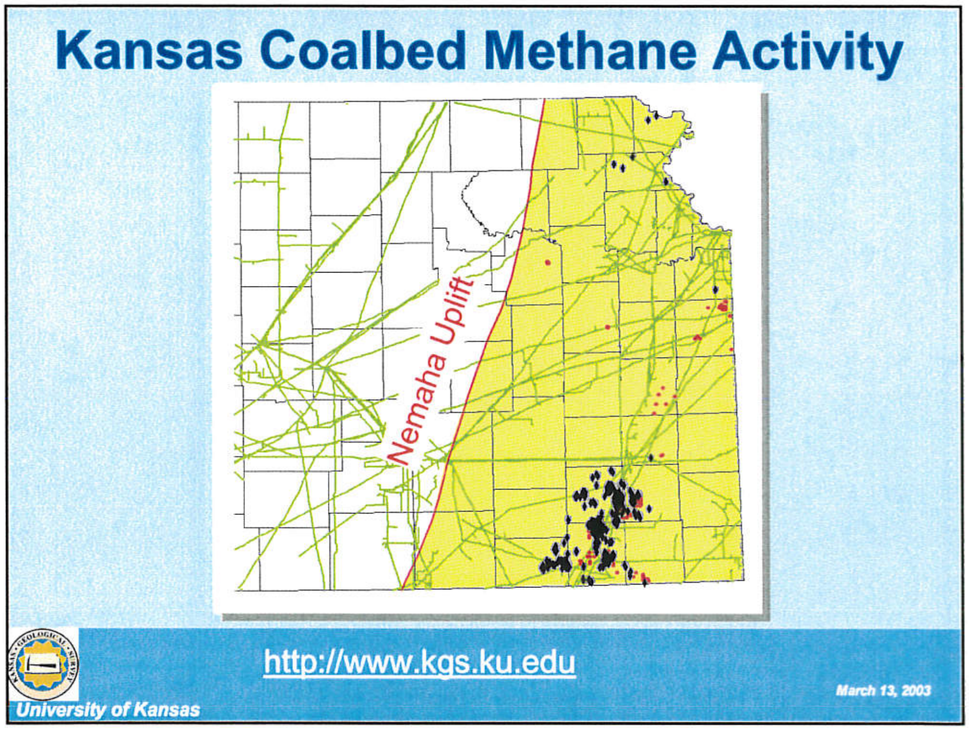


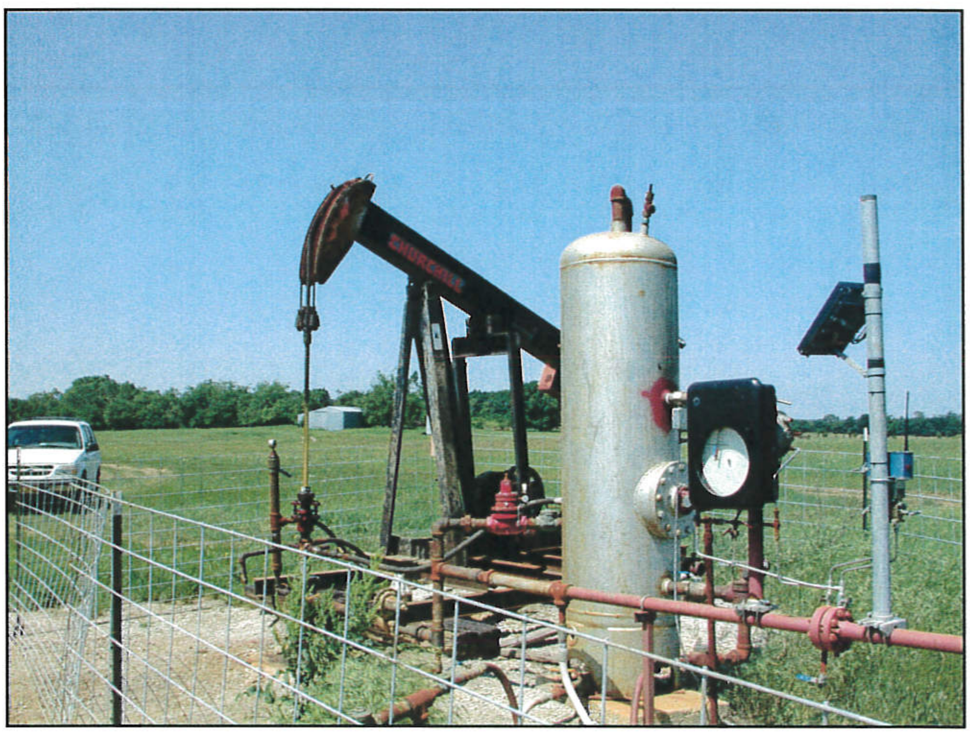

Excellent Pipeline Infrastructure

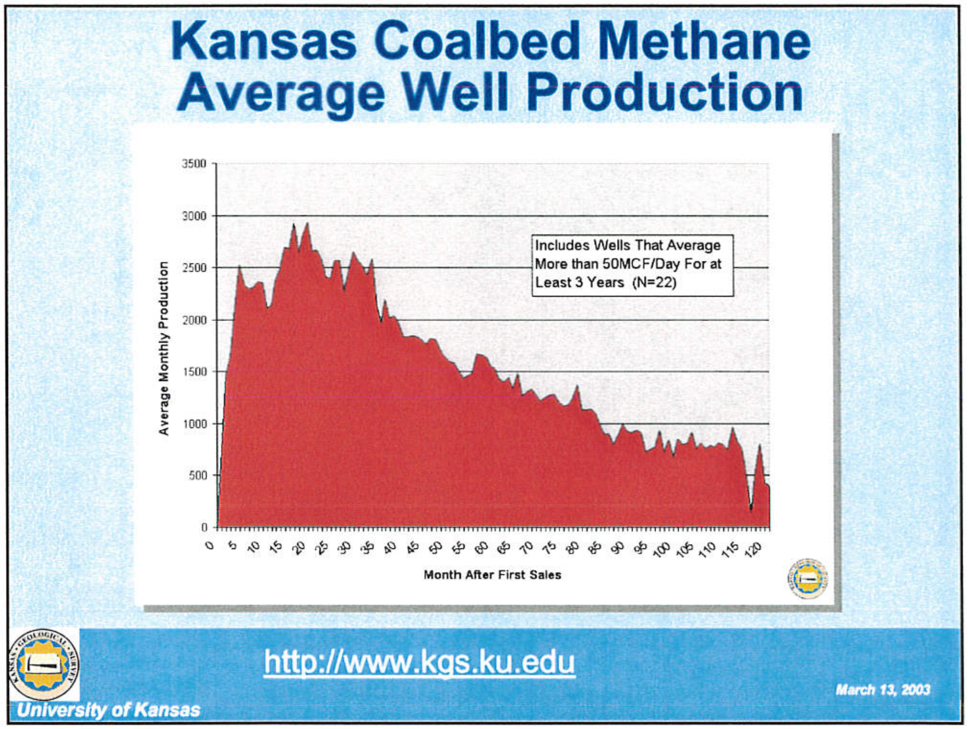
http://www.kgs.ku.edu

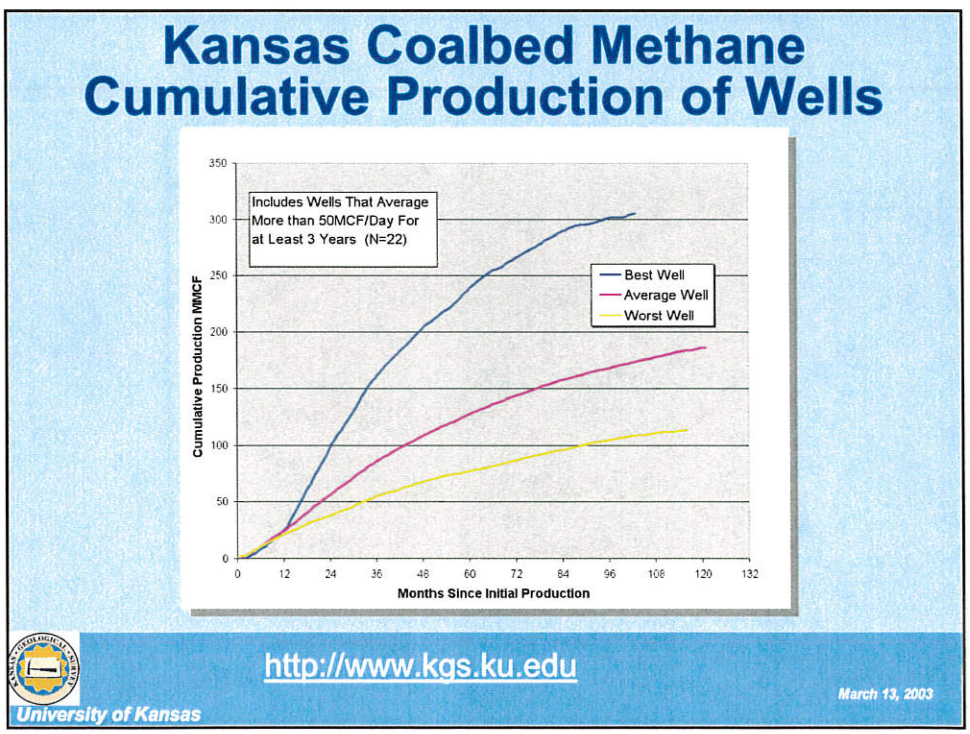
March 13, 2003

University of Kansas

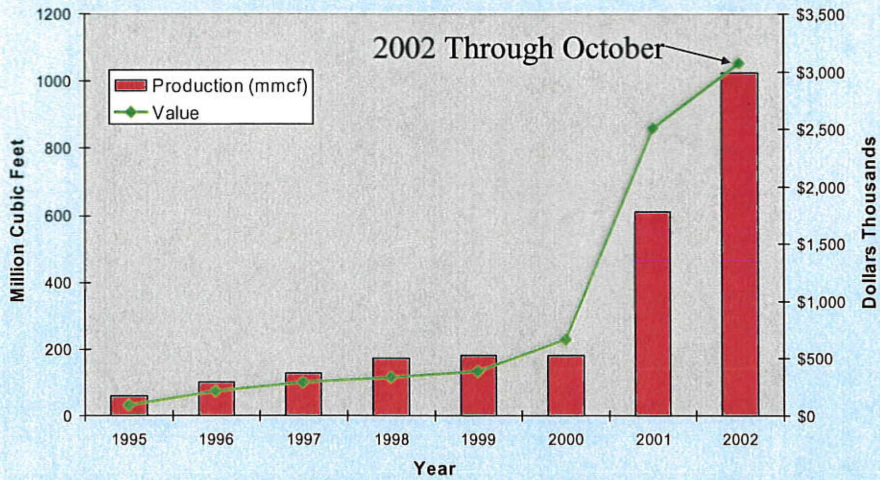

Kansas Coalbed Methane Activity
Nemaha Uplift
http://www.kgs.ku.edu
University of Kansas
March 13, 2003




Kansas Coalbed Methane
Average Well Production
Includes Wells That Average More than 50MCF/Day For at Least 3 Years (N=22)
Average Monthly Production
3500
3000
2500
2000
1500
1000
500
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
Month After First Sales
http://www.kgs.ku.edu
March 13, 2003
University of Kansas


Kansas Coalbed Methane
Cumulative Production of Wells
Includes Wells That Average More than 50MCF/Day For at Least 3 Years (N=22)
Best Well
Average Well
Worst Well
Cumulative Production MMCF
350
300
250
200
150
100
50
0
0 12 24 36 48 60 72 84 96 108 120 132
Months Since Initial Production
http://www.kgs.ku.edu
March 13, 2003
University of Kansas

# Neosho County Gas Production

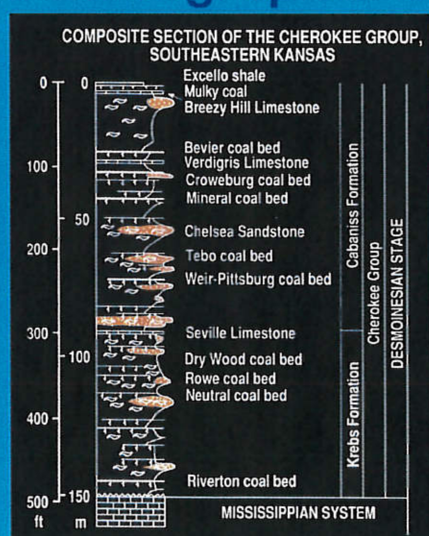



http://www.kgs.ku.edu

University of Kansas

March 13, 2003

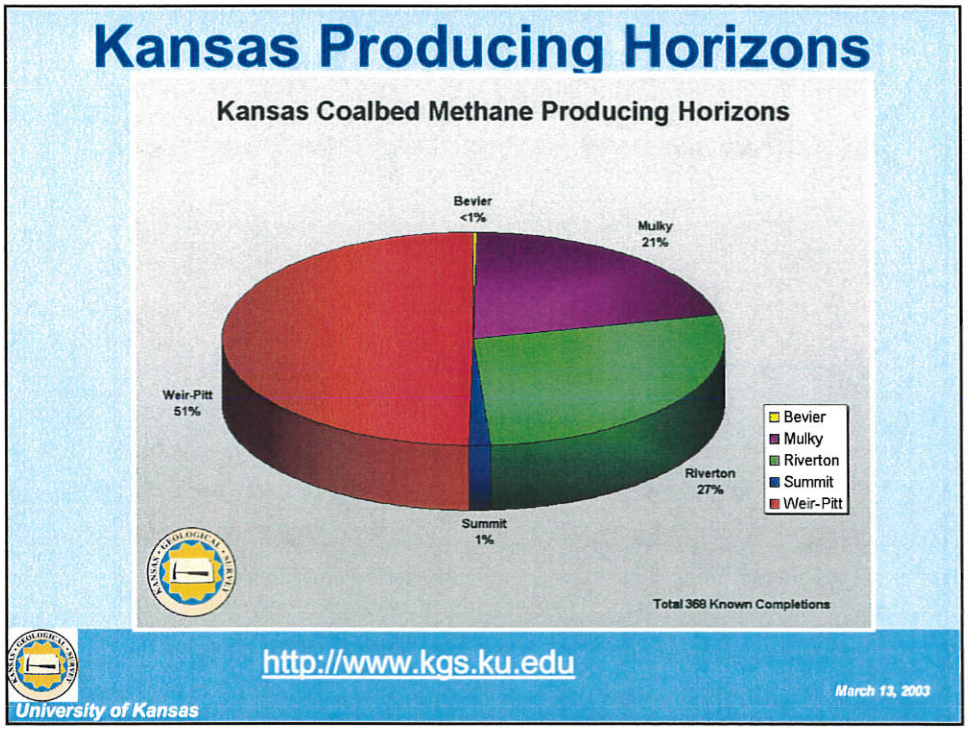
# Kansas Stratigraphic Column



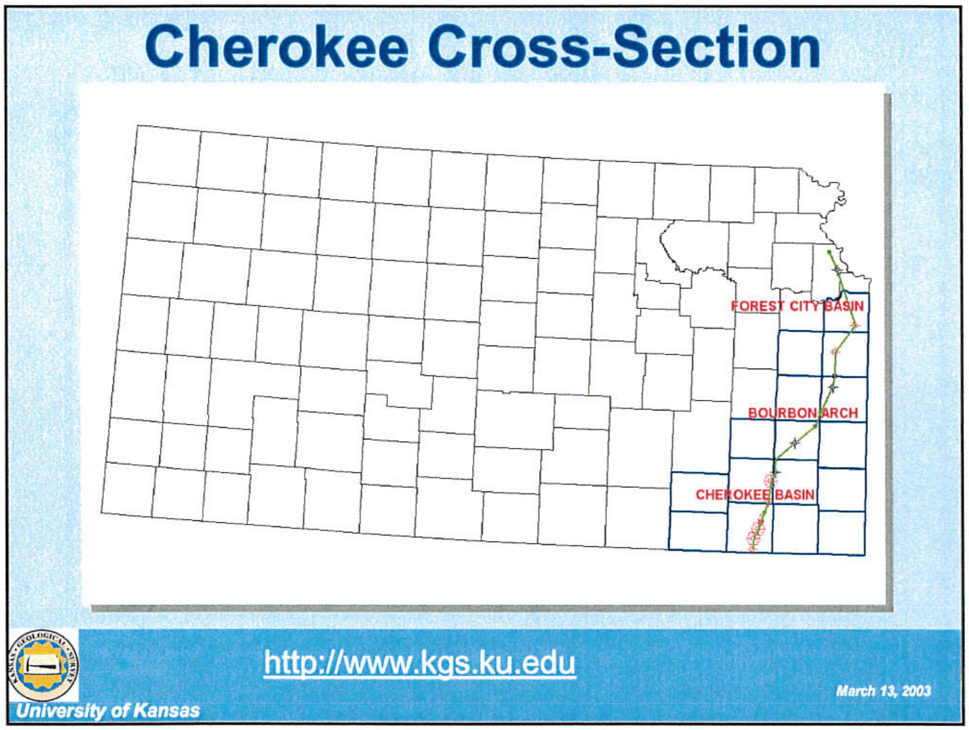

http://www.kgs.ku.edu

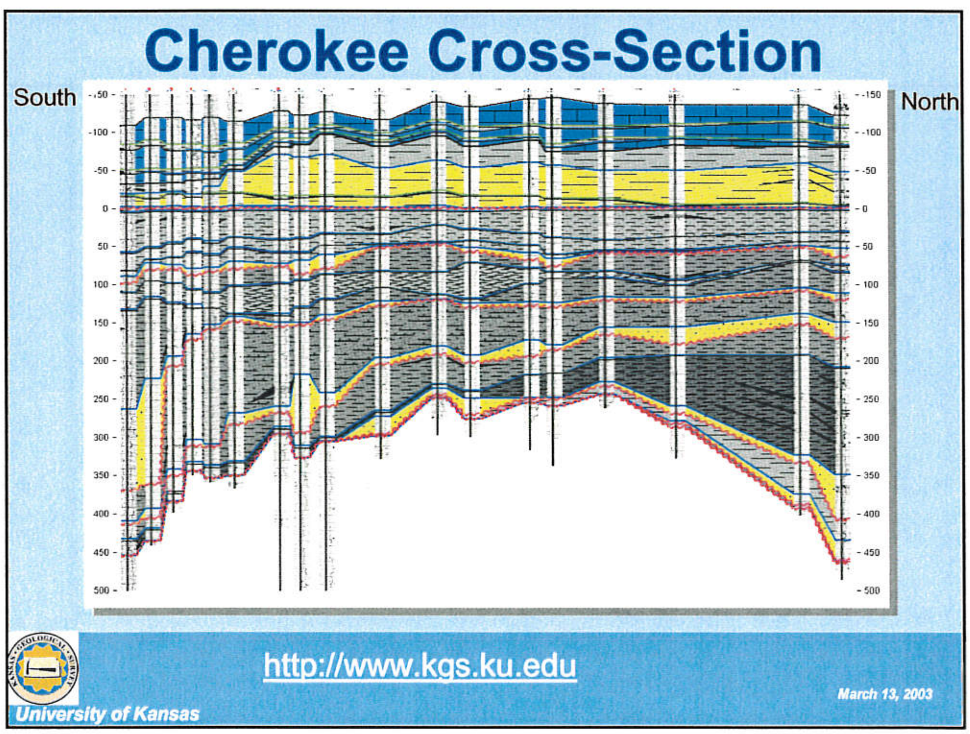
University of Kansas

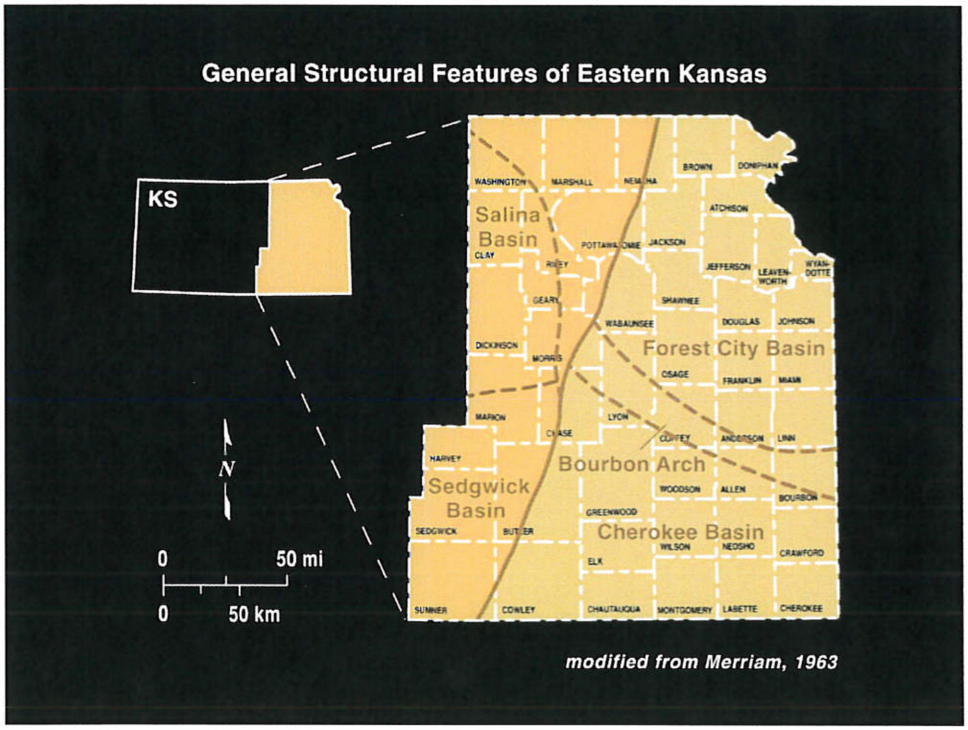
March 13, 2003

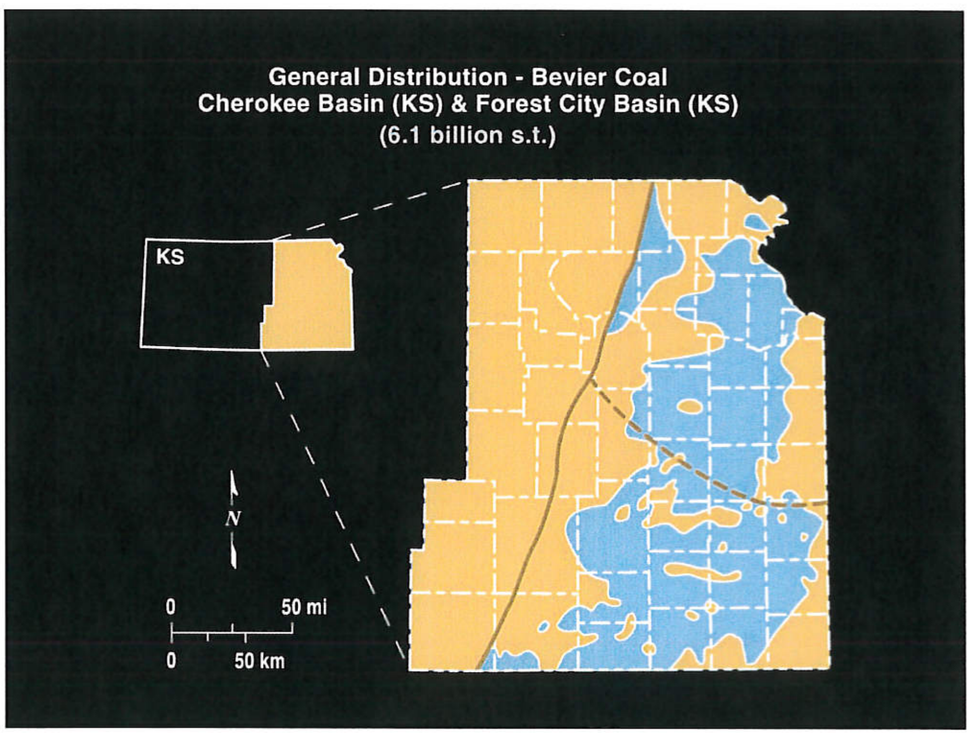

Kansas Producing Horizons
Kansas Coalbed Methane Producing Horizons
Bevier
<1%
Mulky
21%
Weir-Pitt
51%
Riverton
27%
Summit
1%
Bevier
Mulky
Riverton
Summit
Weir-Pitt
Total 368 Known Completions
http://www.kgs.ku.edu
March 13, 2003
University of Kansas


Mineral Coal

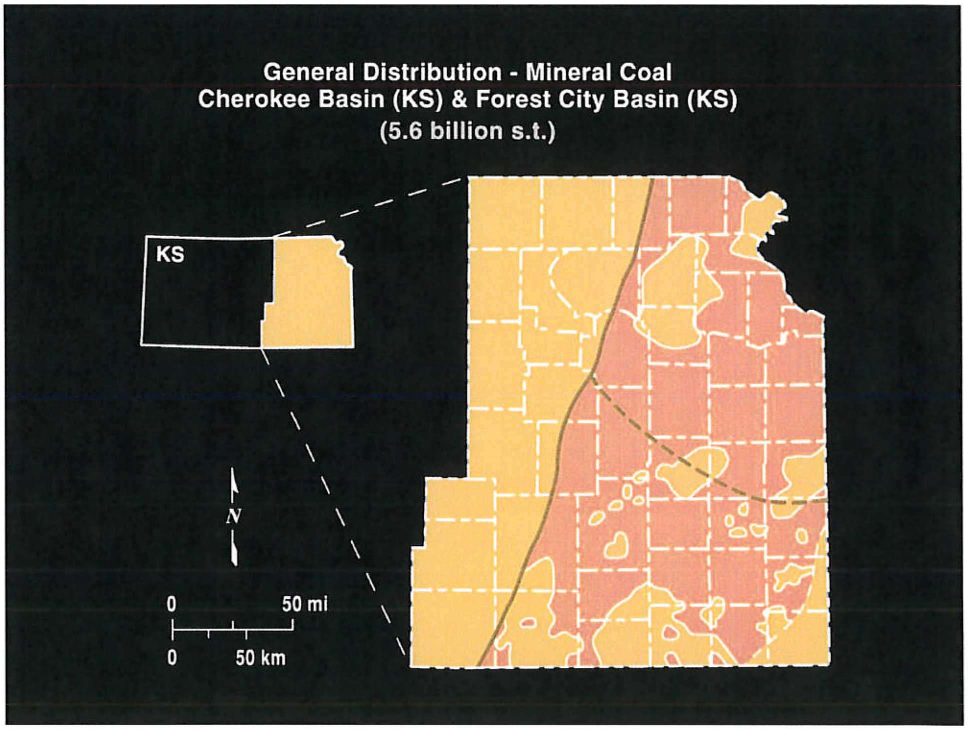

Cherokee Cross-Section
FOREST CITY BASIN
BOURBON ARCH
CHEROKEE BASIN
http://www.kgs.ku.edu
March 13, 2003
University of Kansas

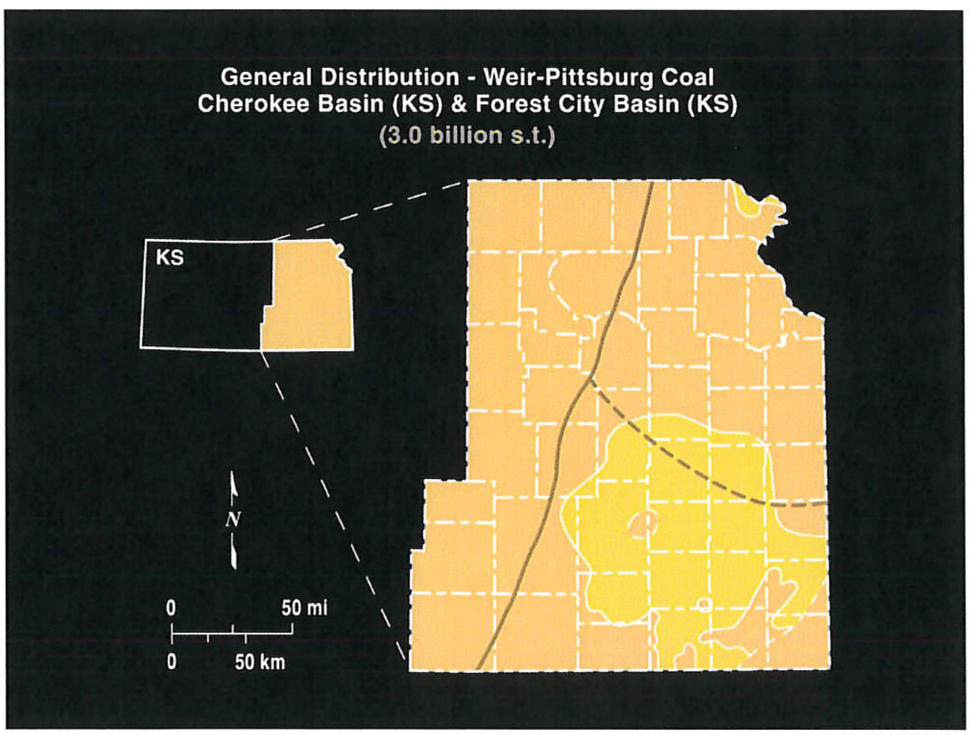

Cherokee Cross-Section
South
North
http://www.kgs.ku.edu
March 13, 2003
University of Kansas


General Structural Features of Eastern Kansas
KS
Salina Basin
Forest City Basin
Bourbon Arch
Sedgwick Basin
Cherokee Basin
N
0 50 mi
0 50 km
modified from Merriam, 1963

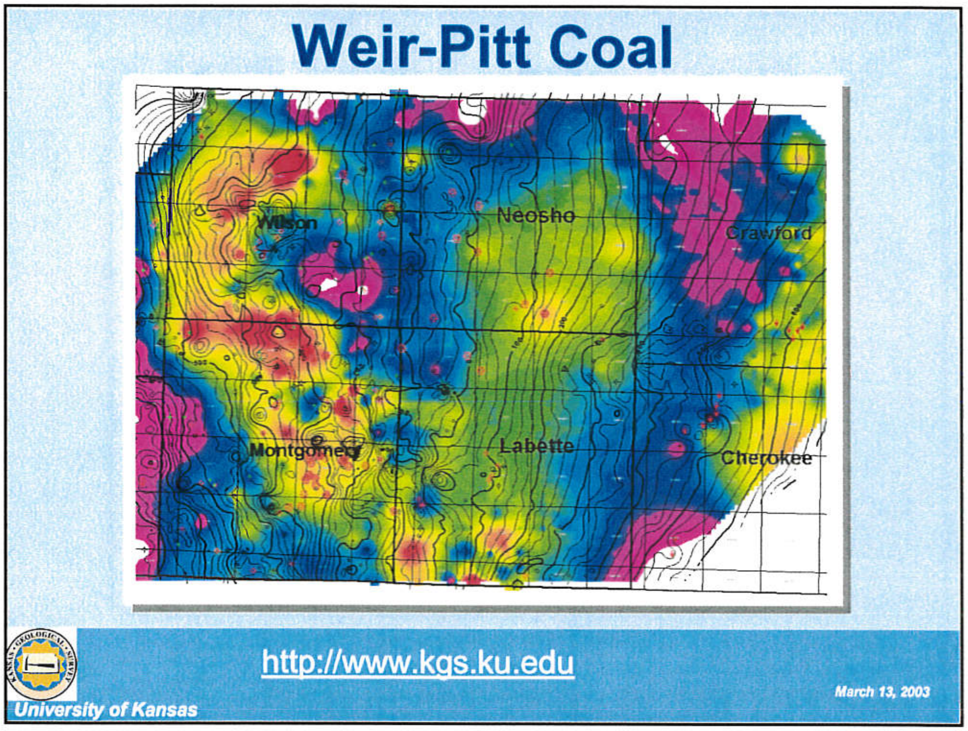

General Distribution - Bevier Coal
Cherokee Basin (KS) & Forest City Basin (KS)
(6.1 billion s.t.)
KS
N
0 50 mi
0 50 km

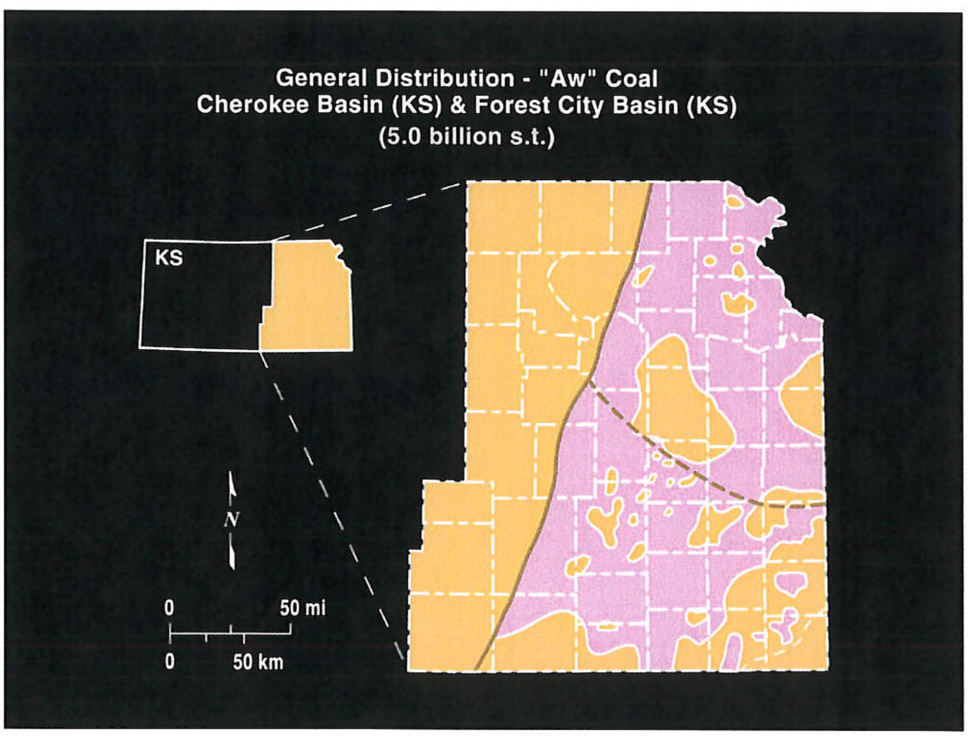
29


General Distribution - Mineral Coal
Cherokee Basin (KS) & Forest City Basin (KS)
(5.6 billion s.t.)
KS
N
0 50 mi
0 50 km

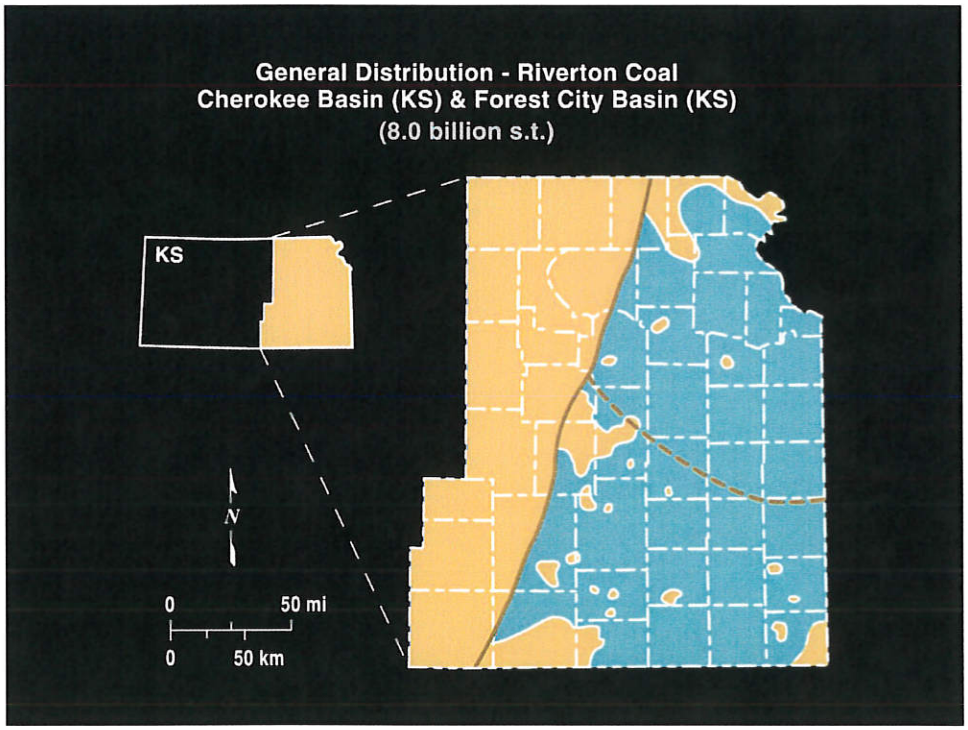

General Distribution - Weir-Pittsburg Coal
Cherokee Basin (KS) & Forest City Basin (KS)
(3.0 billion s.t.)
KS
N
0 50 mi
0 50 km

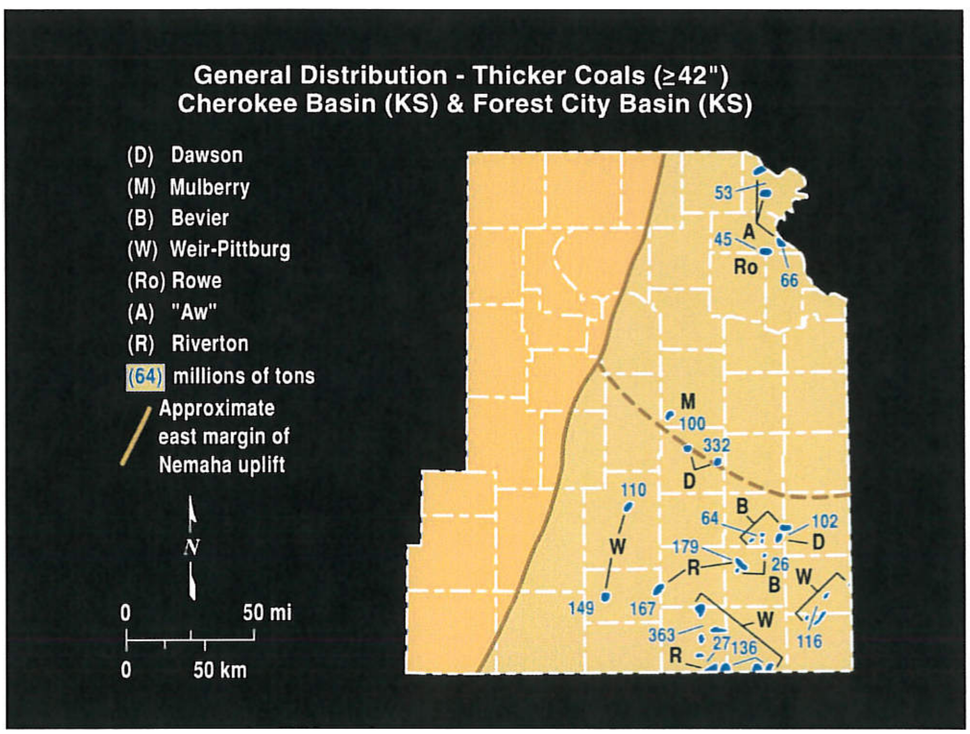
2-10


Weir-Pitt Coal
Wilson
Neosho
Crawford
Montgomery
Labette
Cherokee
http://www.kgs.ku.edu
University of Kansas
March 13, 2003


General Distribution - "Aw" Coal
Cherokee Basin (KS) & Forest City Basin (KS)
(5.0 billion s.t.)
KS
N
0
50 mi
0
50 km

2-11


General Distribution - Riverton Coal
Cherokee Basin (KS) & Forest City Basin (KS)
(8.0 billion s.t.)
KS
N
0 50 mi
0 50 km


General Distribution - Thicker Coals (≥42")
Cherokee Basin (KS) & Forest City Basin (KS)
(D) Dawson
(M) Mulberry
(B) Bevier
(W) Weir-Pittburg
(Ro) Rowe
(A) "Aw"
(R) Riverton
(64) millions of tons
Approximate east margin of Nemaha uplift
N
0 50 mi
0 50 km

2-12

## Coalbed Methane Program

University of Kansas

http://www.kgs.ku.edu

March 13, 2003

## Coalbed Methane Program


University of Kansas

http://www.kgs.ku.edu

March 13, 2003

2-13

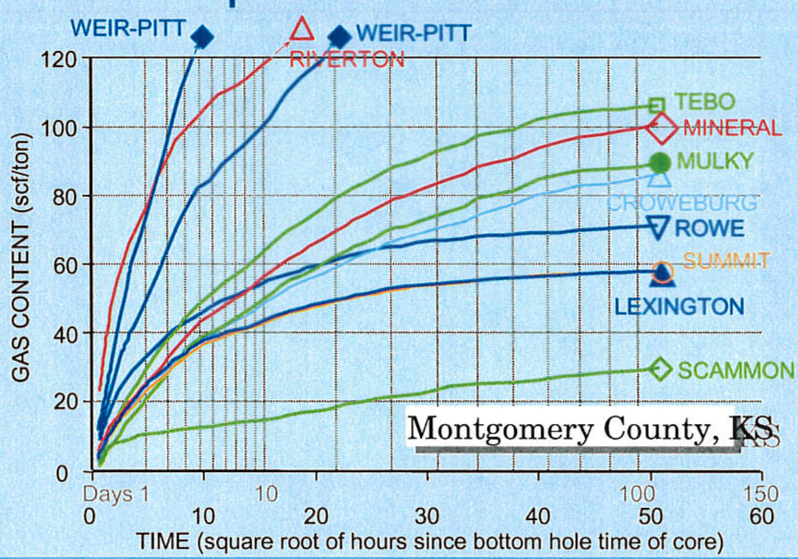
# Coalbed Methane Program

http://www.kgs.ku.edu

University of Kansas

March 13, 2003

# Desorption Characteristics



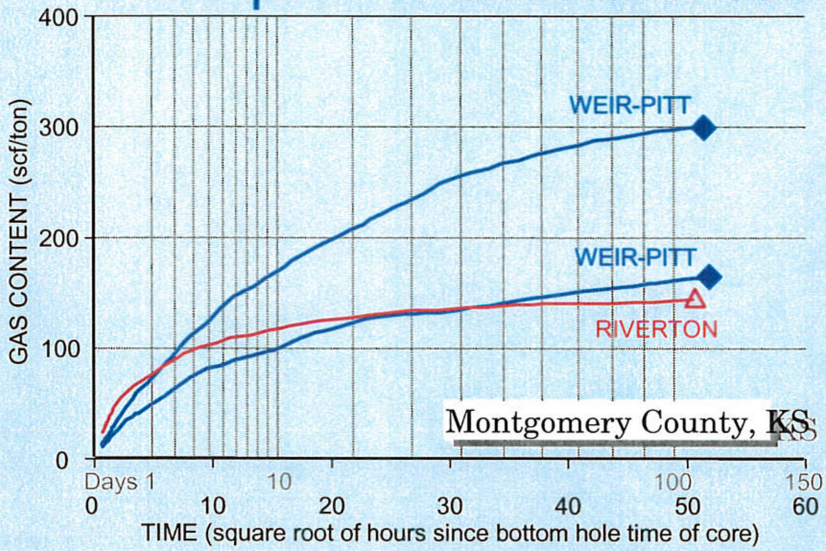

http://www.kgs.ku.edu

University of Kansas

March 13, 2003

2-14

# Desorption Characteristics




http://www.kgs.ku.edu

University of Kansas

March 13, 2003

# Coal resources in eastern Kansas

| Coal thickness | Billions of tons |
|---|---|
| 14-28" | 45.3 |
| 28-42" | 6.2 |
| 42-56" | 1.9 |
| >56" | 0.1 |
| Total | 53.5 |

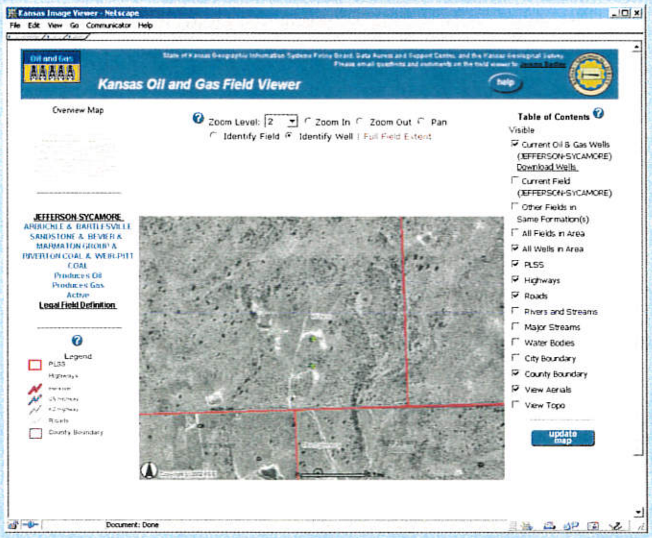
http://www.kgs.ku.edu

University of Kansas

March 13, 2003

2-15

# Well and Production Data

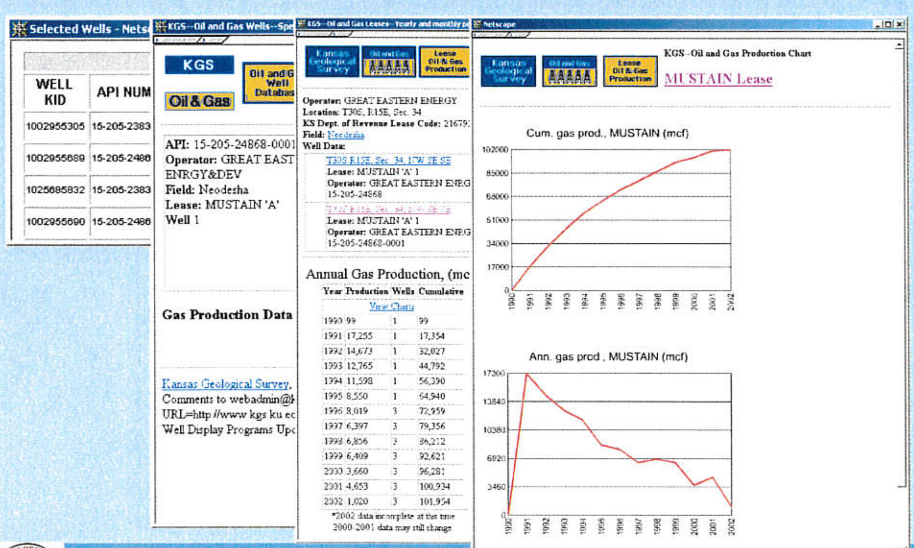



http://www.kgs.ku.edu

University of Kansas

March 13, 2003

# Well and Production Data

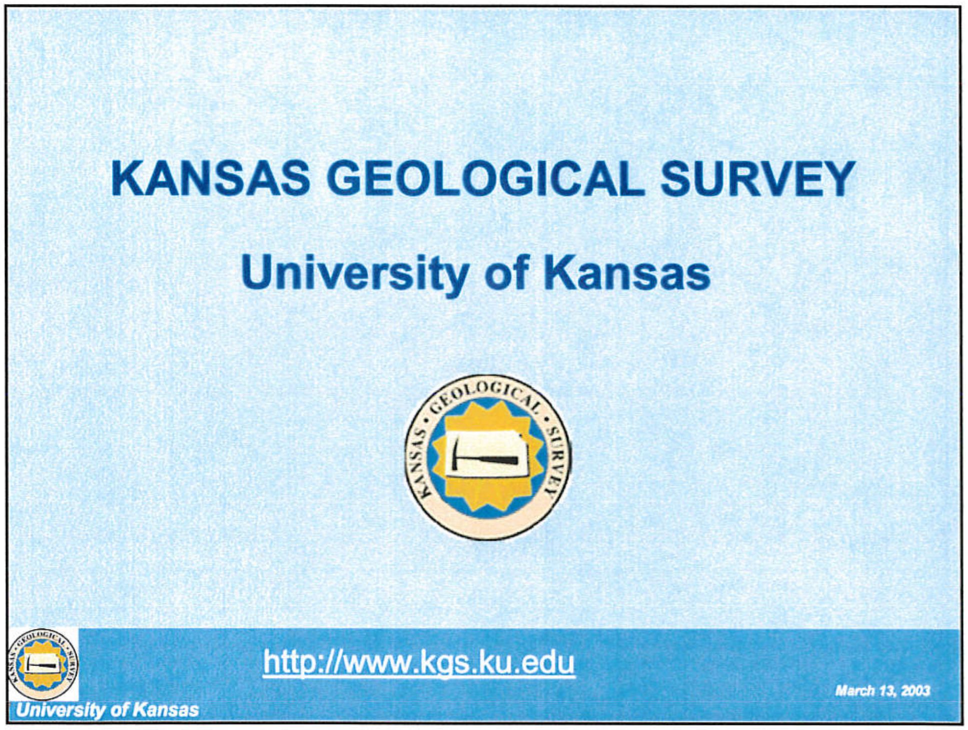



http://www.kgs.ku.edu

University of Kansas

March 13, 2003

2-16


KANSAS GEOLOGICAL SURVEY
University of Kansas
KANSAS GEOLOGICAL SURVEY
http://www.kgs.ku.edu
University of Kansas
March 13, 2003

2-17

Kansas Geological Survey
Public Information Circular 19 December 2001

# Natural Gas from Coal in Eastern Kansas

**Robert S. Sawin**
Public Outreach, Kansas Geological Survey

**Lawrence L. Brady**
Geologic Investigations, Kansas Geological Survey

*Coalbed methane now accounts for about 7 percent of the total annual gas production in the United States*

## Introduction

Methane, the main component of natural gas, has been a product of the petroleum industry for years. Many of us use natural gas in our homes—in our furnaces, water heaters, and stoves. Now, a relatively new and unconventional source of natural gas—methane from coal beds—has generated interest in eastern Kansas.

Coalbed methane is natural gas that occurs in coal beds. The geological process that turns plant material into coal generates methane gas. This gas was a deadly nuisance that produced explosions in underground coal mines, so the mines had to be ventilated to remove the gas. In the early 1980's, the mining industry began to capture and sell this gas rather than release it to the atmosphere. Thus, a new industry was created—the commercial production of methane from subsurface coal beds.

Coalbed methane now accounts for about 7 percent of the total annual gas production in the United States. In areas of the San Juan basin in New Mexico and Colorado, parts of the Black Warrior basin in Alabama, and basins in the central Appalachians, large quantities of methane are being developed from coal beds. This gas is now being exploited in other areas of thick, coal-bearing rocks such as the Powder River basin in Wyoming and Montana.

In Kansas, most of the activity has been in the southeastern part of the state, primarily Montgomery, Wilson, western Labette, and eastern Chautauqua counties; however, other parts of eastern Kansas that are underlain by coal beds also have potential for coalbed methane production (fig. 1). Coal beds that have potential to produce methane occur in eastern Kansas east of the Nemaha uplift, a subsurface geologic structure that runs from Oklahoma City, Oklahoma, north through El Dorado, Kansas, and just east of Manhattan, Kansas.

This circular describes coal and coalbed methane, gas production from coal, leasing and landowner mineral rights, and the potential for coalbed methane production in Kansas.

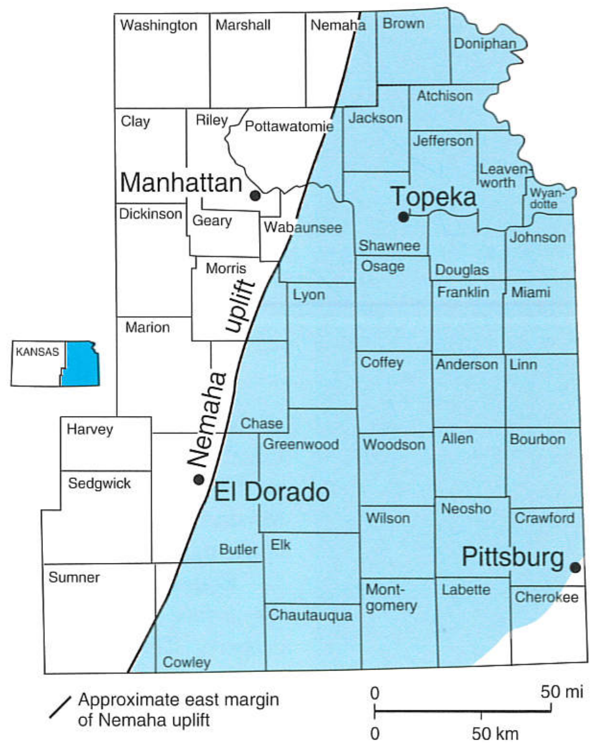



Figure 1—*Portion of Kansas with potential for coalbed methane development.*

## Coal and Coal Gas

Coal is the most abundant energy source in the world. Coal deposits have been mined in Kansas for nearly 150 years, mostly in southeastern Kansas, where surface and subsurface mines have produced over 300 million tons of coal. Bituminous (soft grade) coal resources of Pennsylvanian age, deposited about 300 million years ago, are widespread in eastern Kansas and constitute nearly all the coal resources in the state. Coal production in Kansas peaked during World Wars I and II. Today, however, only one small mine operates in Kansas, near Prescott, in Linn County

HOUSE UTILITIES
DATE: 3-13-03
ATTACHMENT 3

Coal forms from plant material that was accumulated in ancient swamps and bogs at rates fast enough to prevent decay. Upon burial, the material is first converted to peat. Through time, as temperature and pressure increase with further burial, peat is converted to coal (it takes about 10 feet of peat to make 1 foot of coal). During this process, large quantities of methane-rich gas are generated and stored within the coal. Coal can store surprisingly large volumes of gas, up to six or seven times as much gas as a conventional gas reservoir (typically sandstone or limestone) of equal rock volume. The amount of gas in coal depends on the degree of alteration the coal has undergone in the burial process, the depth below the surface, and the pressure of the reservoir.

Coalbed gas is mainly composed of methane ($CH_4$), the principal constituent of natural gas. Coalbed methane is what geologists call a sweet gas because it typically contains very few impurities such as hydrogen sulfide, nitrogen, or carbon dioxide, all normally found in natural gas. Coalbed methane, when burned, generates as much heat as petroleum-based natural gas.

***An increasing level of interest in coalbed methane has spurred activity in eastern Kansas***

## Producing Gas from Coal

Coal contains gas and large amounts of water. Once the confining pressure on the coal is relieved (for example, by drilling and pumping), the gas is slowly released from the coal. Naturally occurring fractures, called cleats, provide the plumbing system within the coal that allows water and gas to travel through the coal to the well. For gas to be released from the coal, the pressure must be reduced by removing water from the coalbed, a process called dewatering. Dewatering brings large quantities of water (usually saltwater in Kansas) to the surface, which is reinjected deep underground.

Initial development of coalbed methane wells can take several months because of the large quantities of water that need to be pumped from the coal bed. In general, coalbed methane wells go through three stages during their production history (fig. 2). During the dewatering stage, water production initially exceeds that of methane, but as production continues, the volume of water decreases as the volume of methane increases. A stable production stage is reached when methane production reaches its maximum and water production levels off. During the decline stage, water production remains low and the amount of methane declines until methane becomes uneconomical to produce.

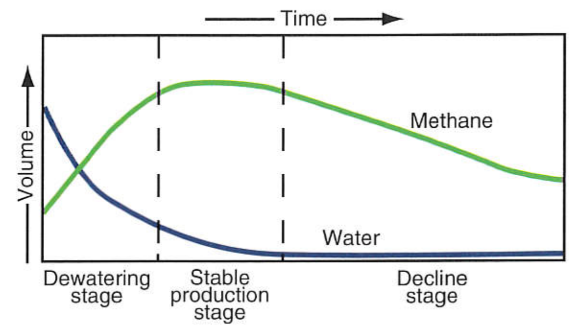



Figure 2—*Production stages of a coalbed methane well (adapted from Rice, 1997).*

## Mineral Rights and Leases

An increasing level of interest in coalbed methane has spurred activity in eastern Kansas. Local landowners may benefit economically if they own the mineral rights beneath their property. Mineral rights are defined as the right of ownership of the mineral resources that underlie a tract of land.

Both the land surface and the resources below the surface can be owned and are considered property. The mineral rights can be owned in total or can be owned by the specific mineral commodity; for example, one company can own the mineral rights to the coal, while another company owns the oil and gas rights. Coalbed methane is natural gas and is considered part of the oil and gas minerals.

The owner of the mineral rights can be different than the surface owner. In Kansas, the landowner usually owns the subsurface rights, but sometimes these rights have been severed, or separated from the surface ownership. Severance of mineral rights occurs when the owner of both the surface and mineral rights sells or grants by deed the mineral rights underlying their property. The landowner may also reserve, or retain, all or a portion of the mineral rights upon sale of the property. Mineral deeds and mineral reservations are recorded with the county register of deeds and are included in any abstract of title to the land involved.

Mineral owners have the right to access and develop their minerals. Landowner rights are preserved, whether or not they participate in development of the mineral rights. Regulations are in place to stop operators if their activities are irresponsible or damaging to the surface. Landowners are entitled to compensation for loss of use or damage to their land. Most operators are willing to work with the landowner to reach a fair settlement for damages, but if this fails, state and federal regulations protect the landowner.

re companies can begin an exploration and development program, they must obtain a lease to the mineral rights (in the case of coalbed methane, an oil and gas lease). An oil and gas lease is a legal agreement between the mineral-rights owner (the lessor) and the oil and gas operator (the lessee) that grants the operator the right to explore and develop the oil and gas resources which may underlie the area described in the lease. Some general stipulations that are usually part of a lease agreement are lisited below:

- A legal description of the area and the number of acres.
- The primary term of the lease. This can be for any period of time, but is usually five or ten years.
- A provision for lease rental payments (usually annual) by the operator to the mineral-rights owner. Rental payments maintain the lease in effect throughout the primary term. If oil or gas is found, the lease will remain in effect as long as production continues, even beyond the primary term of the lease.
- A royalty clause that stipulates the mineral-rights owner's share of the oil or gas production. The royalty may be any amount mutually agreed to by the operator and the mineral rights owner, but is usually one-eighth (12.5 percent) of the oil or gas produced from the lease. Usually the operator sells the oil or gas to a refiner and the mineral-rights owners receive payment for their share from the operator.

## Coalbed Methane Potential in Kansas

The bituminous coals of eastern Kansas have great potential for large quantities of methane. In areas where the coals are deeper than 500 feet, and the gas has been trapped in the coals by thick overlying shales, economic quantities of methane gas may exist. Many other factors, such as the market price for natural gas, also determine the economic feasibility of exploring for coalbed methane in eastern Kansas.

Although the coal beds in eastern Kansas tend to be widely distributed, and several beds (up to 14) could be encountered in a well, the primary concern is the thinness of most of the coal beds and the correspondingly smaller volumes of gas. Evaluation of approximately 600 geophysical logs in eastern Kansas indicates that about 96 percent of the coal occurs in beds 14 to 42 inches thick (fig. 3) and only about 4 percent occurs in beds greater than 42 inches. The main strategy for exploring for coalbed methane in eastern Kansas will be to locate thicker coals or multiple coal beds to warrant viable economic development (fig. 4).

Most of the coals in eastern Kansas are less than 2,500 feet deep, so drilling costs should be relatively low. Many gas pipeline networks already exist, and Kansas has recognized disposal zones for the water that is produced with the methane. All these factors suggest that eastern Kansas is an important area for potential development of coalbed methane.

*The bituminous coals of eastern Kansas have great potential for large quantities of methane*

Photo: Robert S. Savin

Figure 3—*Outcrop of a thin coal bed in Cherokee County.*

# Agencies to Contact About Coalbed Methane

**Kansas Corporation Commission**
Conservation Division
Finney State Office Building
130 S. Market, Room 2078
Wichita, KS 67202-3802
316-337-6200
**www.kcc.state.ks.us**

**Kansas Geological Survey**
1930 Constant Ave.
Lawrence, KS 66047-3726
785-864-3965
**www.kgs.ku.edu**

## Sources


Baars, D. L., Watney, W. L., Steeples, D. W., and Brostuen, E. A., 1989 (revised 1993), Petroleum—A primer for Kansas: Kansas Geological Survey, Educational Series 7, 40 p.

Brady, L. L., 1997, Kansas coal resources and their potential for coalbed methane; *in*, Transactions of the 1997 American Association of Petroleum Geologists Mid-continent Meeting, September 14–16, G. McMahan, ed. and compl.: Oklahoma City, Oklahoma, American Association of Petroleum Geologists, p. 150–163.

Clough, J. G., 2001, Coalbed methane—Potential energy source for rural Alaska: Alaska Geological Survey, Alaska GeoSurvey News, 5, no. 2, 3 p.

De Bruin, R. H., Lyman, R. M., Jones, R. W., and Cook, L. W., 2001, Coalbed methane in Wyoming: Wyoming State Geological Survey, Information Pamphlet 7 (revised), 19 p.

Nuccio, V., 2000, Coal-bed methane—Potential and concerns: U.S. Geological Survey, Fact Sheet FS-123-00, 2 p.

Rice, D., 1997, Coalbed methane—An untapped energy resource and an environmental concern: U.S. Geological Survey, Fact Sheet FS-019-97, http://energy.usgs.gov/factsheets/Coalbed/coalmeth.html (July 16, 2001).

U.S. Department of Energy, 2000, U.S. crude oil, natural gas, and natural gas liquids reserves, 1999 Annual Report: Energy Information Administration, U.S. Department of Energy, DOE/EIA-0216(99), 156 p.



Figure 4—*Coalbed methane well in Montgomery County, Kansas.*

The mission of the Kansas Geological Survey, operated by the University of Kansas in connection with its research and service program, is to conduct geological studies and research and to collect, correlate, preserve, and disseminate information leading to a better understanding of the geology of Kansas, with special emphasis on natural resources of economic value, water quality and quantity, and geologic hazards.

The Geology Extension program furthers the mission of the KGS by developing materials, projects, and services that communicate information about the geology of Kansas, the state's earth resources, and the products of the Kansas Geological Survey to the people of the state.


**Public Information Circular 19**
***December 2001***



**Kansas Geological Survey**
**Geology Extension**
**The University of Kansas**
**1930 Constant Avenue**
**Lawrence, Kansas**
**66047–3726**
**(785) 864–3965**
**http://www.kgs.ku.edu**



**Printed on recycled paper with soy ink by The University of Kansas Printing Services**




3-4

OIL&GAS JOURNAL

# Coalbed gas play emerges in eastern Kansas basins

K. David Newell
Lawrence L. Brady
Jonathan P. Lange
Timothy R. Carr
Kansas Geological Survey
Lawrence, Kan.

The Cherokee and Forest City basins in eastern Kansas and western Missouri, which comprise part of the Western region of the Interior Coal Province, are venerable energy-producing basins (Fig. 1). Coalbed gas represents a new potential resource that could revitalize this region.

Higher gas prices, increasing demand for natural gas, and new technologies have turned coalbed gas into an active energy play. Coalbed gas represents approximately 7% of total dry gas production and 9% of dry-gas proved reserves of the US.[1,2] These values are expected to increase in the future.

In the last two decades, the total coalbed methane gas production in the US is in excess of 7 tcf, a value of $156.1 billion, at a price of $2.23/Mcf.[3]

## Brief history

The history of petroleum production in eastern Kansas started over a century ago.

In 1860, as soon as one year after Col. Drake's historic well first produced oil near Titusville, Pa., drilling for petroleum reportedly commenced near the town of Paola, in eastern Kansas.[4] Oil and gas production started in the late 1800s and most of the larger fields were discovered and delineated by 1930.

Conventional petroleum production continues to the present, but it has been in decline for several decades. Virtually all of it is now stripper production.

Most drilling activity for both conventional reserves and coalbed gas is in the Cherokee basin and Bourbon arch (Fig. 1A), with considerably less activity in the Forest City basin.

Coals also have been produced from surface and subsurface mines in eastern Kansas since the mid-1800s. Peak production was during World War I and production from only strip mines continues to present time, but these operations are very small and are carried out by only local companies. Surface and subsurface mines have produced over 300 million tons of coal in Kansas.[5]

Coalbed gas production began in Kansas in the mid-1980s. No systematic compilation of coalbed gas fields in Kansas exists, but a regional map is presented (Fig. 1A). At least 232 wells were completed for coalbed gas in Kansas by 1993,[6] and total completions have more than doubled since then, with a virtual explosion in drilling in 2001 and 2002 (Table 1). The Cherokee basin in the southeastern part of the state hosts the majority of these wells.

## Present resource

Coal beds in eastern Kansas tend to be widely distributed, but the primary concerns are their thinness and their correspondingly smaller volumes of gas.

Evaluation of 600 geophysical logs from eastern Kansas indicates that 85% of the coal occurs in beds 14-28 in. thick, 11% occurs in beds 28-42 in. thick, and 4% occurs in beds thicker than 42 in.[7] The main strategy for exploring for coalbed gas will thus be to locate thicker coals or multiple coal beds.

Thirty-two coal beds, with thickness in excess of 14 in., are identified in the Middle Pennsylvanian stratigraphic column in eastern Kansas (Fig. 2). Most of these are in the Desmoinesian Cherokee Group, which is a cyclothemic unit mostly composed of marine and terrestrial sandstones and shales, marine carbonates, and minor coals.

Up to 14 coal beds can be encountered in a typical well,[7] so a strategy for production from several zones in a single well may be a good option for economically viable resource development.

Resource assessment places the amount of deep coal in eastern Kansas (i.e., >100 ft depth) at 53 billion tons.[5,7] This assessment includes all the coals in the Cherokee Group and six Pennsylvanian coals stratigraphically higher.

Of this deep coal, approximately 70% resides in the Cherokee basin and Bourbon arch and 30% in the Forest City basin. Coals having the largest deep resources include the Bevier, Min-

### COALBED GAS WELL COMPLETIONS, EASTERN KANSAS — Table 1

| | Completions |
|---|---|
| 1981 | 2 |
| 1982 | 5 |
| 1983 | 0 |
| 1984 | 0 |
| 1985 | 1 |
| 1986 | 2 |
| 1987 | 0 |
| 1988 | 0 |
| 1989 | 5 |
| 1990 | 28 |
| 1991 | 69 |
| 1992 | 63 |
| 1993 | 27 |
| 1994 | 25 |
| 1995 | 9 |
| 1996 | 4 |
| 1997 | 18 |
| 1998 | 4 |
| 1999 | 3 |
| 2000 | 1 |
| 2001 | 89 |
| 2002 | *33 |

*Through March.

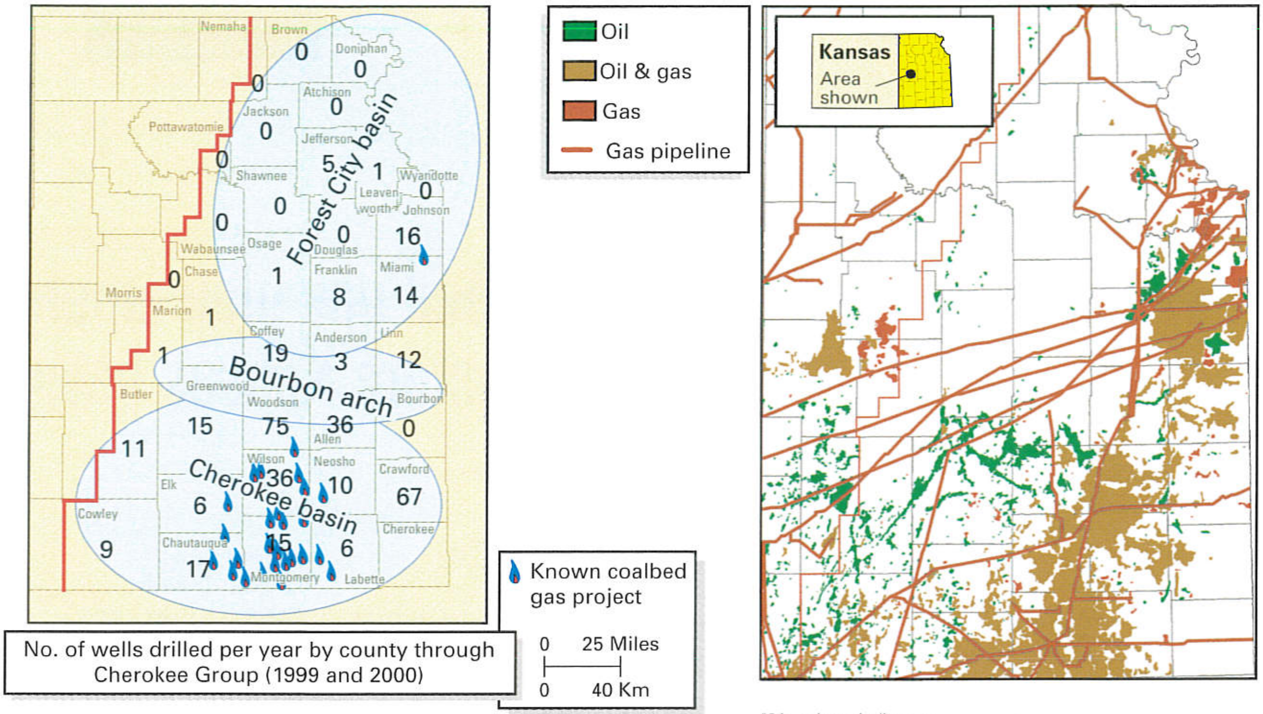
HOUSE UTILITIES
DATE: 3-13-03
ATTACHMENT 4

## THE EASTERN KANSAS COALBED METHANE SCENE

Fig. 1

Fig. 1a
**Coalbed methane project sites and wells**

Fig. 1b
**Oil and gas fields and main gas pipelines***




*8 in. or larger in diameter.

eral, Weir-Pittsburg, Rowe, Riverton, and two informally named coals ("Aw" and "Cw") between the Rowe and Riverton (Fig. 2 and 3).

Most of the coals in eastern Kansas are less than 2,500 ft deep, so drilling and development expenditures are relatively modest. Major pipelines traverse the region (Fig. 1B), and large urban markets are nearby. Because a local petroleum industry exists, infrastructure necessary for energy development is largely in place, and landowners have a relatively benign rapport with this industry.

Water disposal is no great problem, with most brines being readily pumped into permeable zones at the top of the Cambrian-Ordovician Arbuckle limestone, present 200 to 400 ft below the base of Pennsylvanian strata in the Cherokee basin. This zone is deeper in the Forest City basin (up to 1,300 ft below the Pennsylvanian), but other lower Paleozoic limestones can also be utilized for this purpose.

### *Development considerations*

Although several coalbed gas operations have been started in the last 15 years in southeastern Kansas (Fig. 1A), exploration and development programs for coalbed gas in this region are hindered by limited data. Large areas remain unevaluated.

More detailed work on the extent and thickness of the coals is required for better resource evaluations. The gas quality and gas content of individual coals also remain largely untested. In general, coals in the Cherokee Group in the Cherokee basin are of high-volatile A bituminous rank. Shallow coals in the Forest City basin have been rated as slightly less-mature high-volatile B bituminous in rank,[7-10] but deeper coals are high-volatile A bituminous in rank.[11]

The gas storage capacity of a coal is a complex function of reservoir temperature and pressure, composition, micropore structure, and molecular properties of its adsorbed gas. In addition to these parameters, the geology of the coal deposit and the surrounding strata also can affect gas content.

Desorption tests published for the Cherokee basin[8,12] report gas contents from a core sample of Weir-Pittsburg coal in Montgomery County as being as high as 220 scf/ton and Riverton coal as high as 239 scf/ton. Gas contents reported for a cored well in the Forest City basin are less—94 scf/ton for Riverton coal in Leavenworth County and lower volumes for coals higher in the section.[11] Additional desorption work is necessary to more fully understand the potential of both basins.

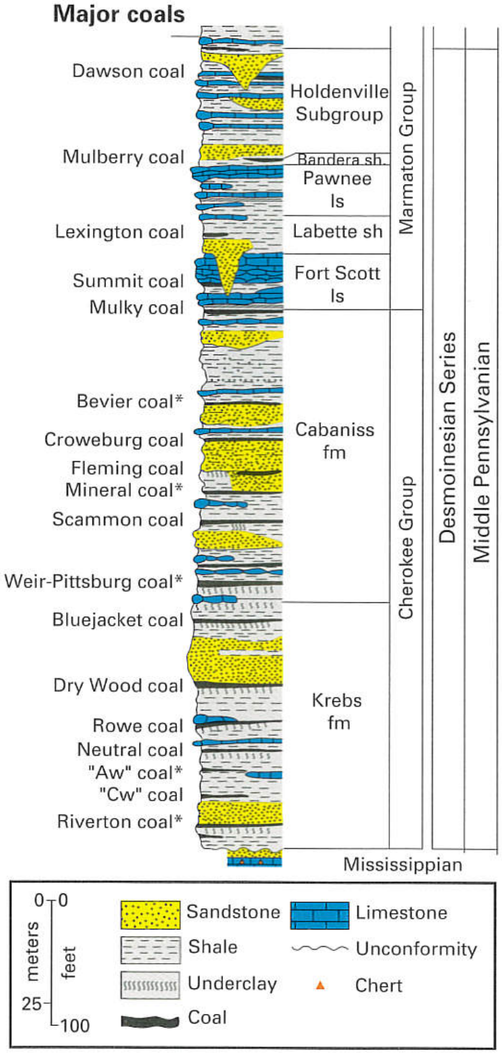
Even though coalbed gas is often termed "coalbed methane," other gases are produced such as nitrogen, carbon dioxide, and other hydrocarbon gases. Coalbed hydrocarbon gases have been attributed to both biogenic and thermogenic processes.[13]

Biogenic gas is generated by bacterial degradation of the coal. This gas largely is composed of methane that typically is isotopically light (i.e., relatively enriched in $C_{12}$). Thermogenic gas can contain greater proportions of higher-molecular-weight hydrocarbons

4-2

## Desmoinesian Series in Eastern Kansas

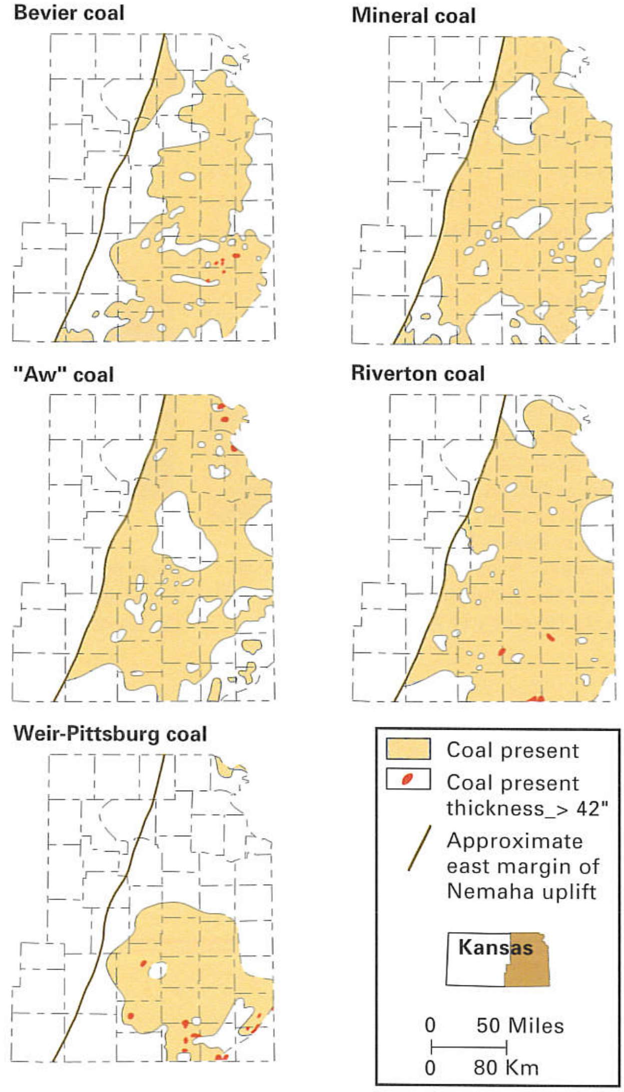
Fig. 2




*Distribution shown in Fig. 4

## Five Important Deep Coals in Eastern Kansas

Fig. 3




and its methane carbon is isotopically heavier than biogenic gas. Thermogenic gas is generated from the high temperature and pressure of deep burial over time, a process that roughly begins at a rank of high-volatile C bituminous and increases at higher ranks.

Kansas coals are slightly higher rank than this (i.e., high-volatile A and B bituminous) and thus may have both biogenic and thermogenic contributions. Both biogenic and thermogenic methane have been documented in Pennsylvanian sandstone reservoirs in eastern Kansas,[14] but differentiation of these gas sources in Kansas coals is yet to be determined.

Coalbed gases desorbed from a well in the southern end of the Forest City basin in eastern Kansas[11] yield calculated heating values ranging from 860 to 1,079 BTU/scf. This range is comparable to that produced by traditional Cherokee Group gas wells (Fig. 4).

Whether coal gases will also mimic the regional trends in BTU content for nearby conventional gas reservoirs has yet to be determined, but at least some of the gas in conventional gas fields has been sourced by coals. Recent work by Stoeckinger[15] documented that channel sandstones truncating coals in southeastern Kansas can be charged with gas generated by these coals, and vice versa.

A group of relatively higher-BTU gases in the tier of counties along the Oklahoma state line (Fig. 4) indicates these gases have a greater proportion of heavier hydrocarbon gases (i.e., wet gas), such as ethane, propane, and butane. This may be caused by greater thermal maturity of Pennsylvanian strata in this area[16] and also possibly by wet gases that may have migrated northward out of deeper strata in Oklahoma.

Coalbed gases, because they are also subject to these geological conditions in this region, may also have greater BTU content relative to production farther north. Coals farther upsection from the Cherokee Group may contain gases having lower BTU content, for this pattern appears to be the case for

ern Kansas," abs., in "Finding and Producing Cherokee Reservoirs in the Southern Midcontinent—A Workshop," May 14-15, 2002, Oklahoma City, Oklahoma Geological Survey and US Department of Energy, p. 30.

16. Hatch, J.R., and Newell, K.D., "Geochemistry of oils and hydrocarbon source rocks from the Forest City basin, northeastern Kansas, northwestern Missouri, southwestern Iowa, and southeastern Nebraska," Kansas Geological Survey Technical Series 13, 1999, 32 pp.

17. Lange, J.P., "Stratigraphy, depositional environments and coalbed methane resources of Cherokee Group coals (Middle Pennsylvanian)-southeastern Kansas," unpub. MS thesis, University of Kansas, Lawrence, Kan., in prep.

*Jonathan Lange is a graduate research assistant with the KGS, where he is working towards an MS in geology from the University of Kansas. He is researching the stratigraphy and depositional environments of the Cherokee Group coals in southeastern Kansas. He has a BS in geology from Kansas State University.*

**The authors**

*Dave Newell (dnewell@kgs.ukans.edu) has researched stratigraphy, diagenesis, and petroleum geochemistry at the Kansas Geological Survey since 1982. Before this, he worked 6 years in exploration with Mobil Oil in Dallas and Aramco in London. He has a BS in geology from Indiana State University, an MS from the University of Wisconsin, and a PhD from the University of Kansas.*

*Lawrence L. Brady is a senior scientist with the KGS, where he has worked for 31 years in geologic research. His professional experience also includes teaching as an assistant professor of geology at Oklahoma State University and as an engineering geologist with the US Army Corps of Engineers. Brady holds a BS in geology from Kansas State University and an MS and PhD in geology from the University of Kansas.*

*Tim Carr worked for 13 years at ARCO Oil & Gas Co. in research and exploration. Since 1991, he has been chief of petroleum research at the KGS, co-director of the Energy Research Center, and adjunct professor of geology at the University of Kansas. He has a BS in economics and a PhD in geology from the University of Wisconsin and an MS in geology from Texas Tech University.*

4-4

conventional reservoirs (Fig. 4).

Detailed mapping and stratigraphic interpretations of individual coals will be critical in any exploration program. The Weir-Pittsburg coal, for example (Fig. 5), markedly changes thickness over distances of just a few miles, whereas Riverton coal in the same area is thinner but more consistent. Through such detailed mapping, depositional trends and related production fairways can be determined and factored into leasing and resource evaluation.

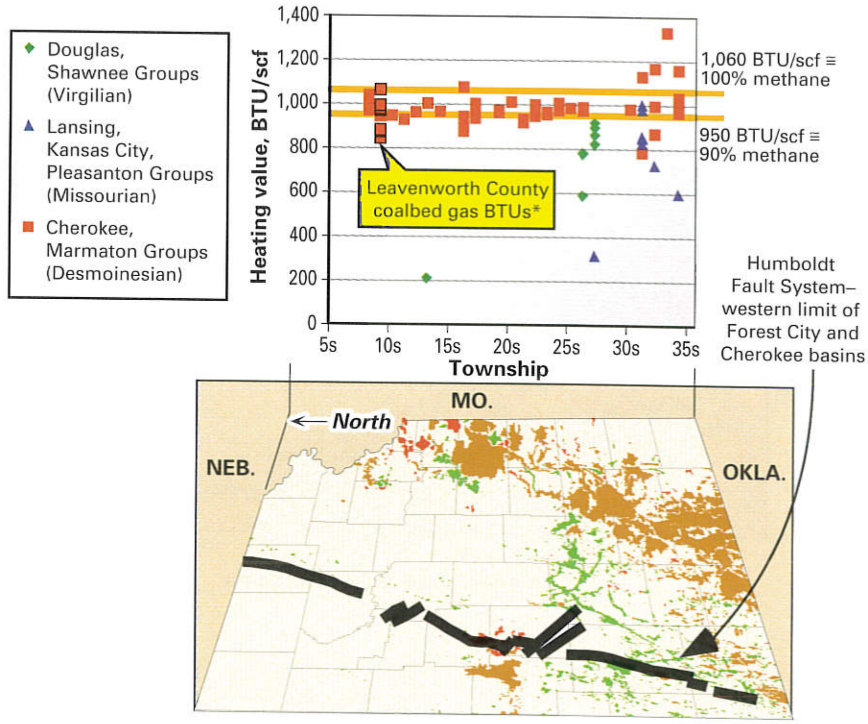
Variations in coal quality, thickness, and lateral distribution will be better understood by placing Cherokee Group coals within a sequence-stratigraphic framework. Lange[17] (in progress) notes that these coals accumulated in a variety of depositional settings such as marsh, back-barrier marine, fluvial floodbasin, and interdistributary deltaic environments.

Gas production data in Kansas for coalbed gas leases to date are only cursorily compiled, as the type of gas production (i.e., traditional or coalbed gas) for any well permit or lease was not originally required of operators. However, monthly production figures for single-well leases (Fig. 6) reveals the presence of coalbed gas production because peak production for these wells typically occurs several months after initial production (as opposed to peak production with conventional wells, which occurs almost immediately after production begins).

Production in coalbed gas wells typically peaks in 1-3 years after start and slowly declines for years. The rate of production can greatly vary from well to well, but the best wells may produce 350 Mcfd at their peak. Average daily production during peak time for all wells considered (minimum 50 Mcfd for at least 3 years) is about 90 Mcfd (Fig. 6). The systematic classification and analysis of these data according to location, depth, and stratigraphic horizon may reveal production fairways and

## North-south distribution of gas BTU content

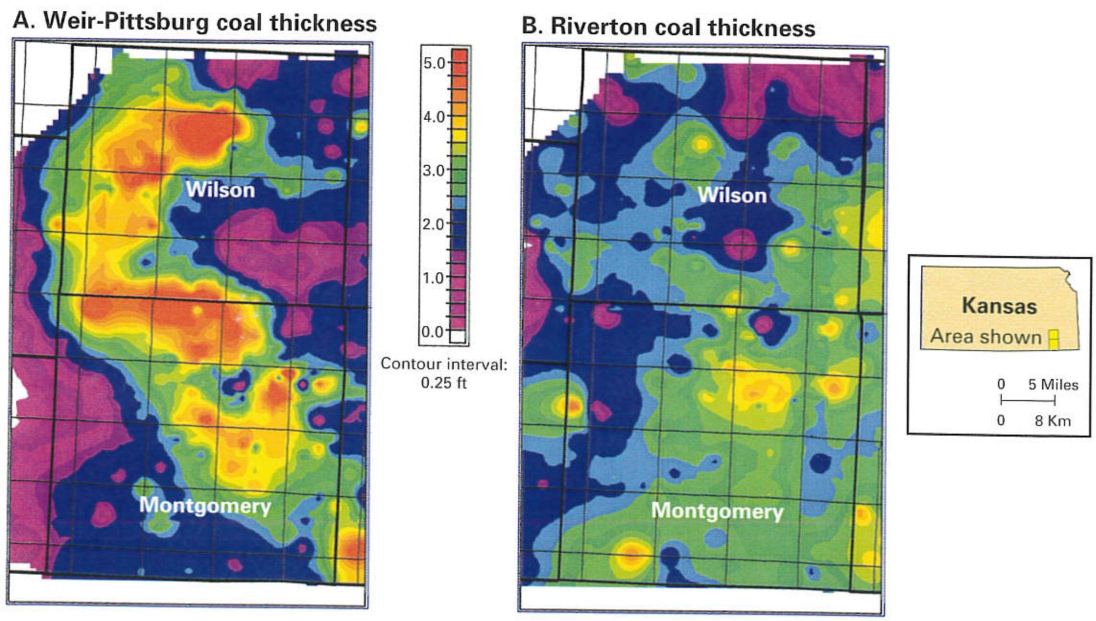
Fig. 4




Source: *After Bostic and others, 1993

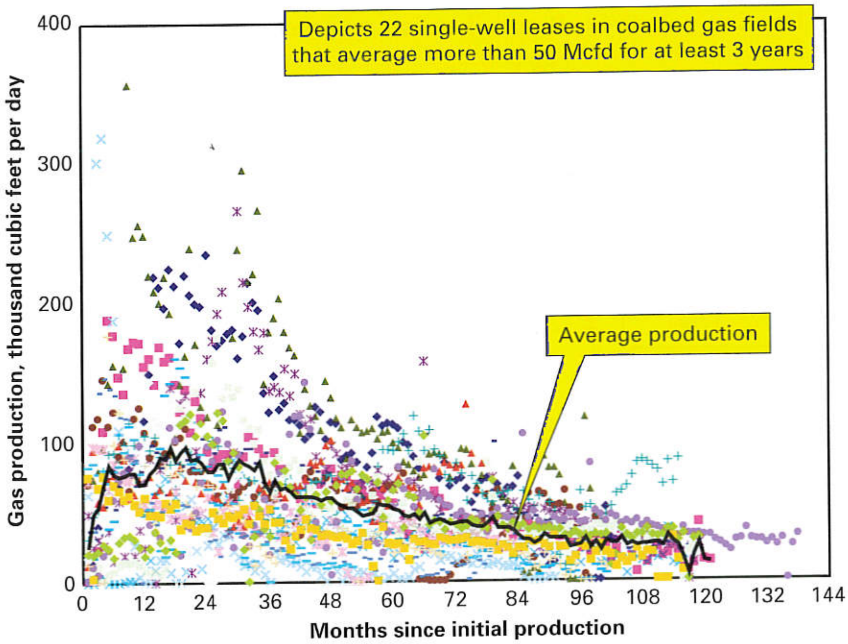
## Two coals in two counties

Fig. 5



## EASTERN KANSAS COALBED GAS PRODUCTION

Fig. 6




sweet spots that have hitherto gone unnoticed.

### Data sources

Data available from years of oil and gas drilling can be utilized to provide reliable regional correlation of major coal beds and discern their thickness, depth, and structural deformation, as well as ancillary information on bottom-hole temperatures and pressure tests.

Wireline logs, drillers logs, and scout cards, archived at the Kansas Geological Survey in Lawrence, Kan., and Kansas Geological Society in Wichita are good data sources. Cores and well cuttings are also archived at Kansas Geological Survey facilities in Lawrence and Wichita. Drilling permit information is readily available online from the Kansas Corporation Commission. Many consultants have extensive personal data collections, born of years of local petroleum experience.

### Summary

Coalbed gas from Middle Pennsylvanian rocks in eastern Kansas is an emerging new energy play.

Many of the critical geological parameters that will prove to be the major controls on the production fairways of this potential new resource have yet to be determined. Nevertheless, preliminary analyses indicate that recent leasing and exploration may translate into long-term production of new gas resources in what was hitherto considered a supermature petroleum province.

### Acknowledgments

The authors are grateful to Jennifer Sims and Patricia Acker for graphics arts and file formatting support for illustrations in this article. ✦

### References


1. Energy Information Administration (http://www.eia.doe/gov/oil-gas/fwd/cr2000.html), "U.S. crude oil, natural gas, and natural gas liquids reserves 2000 Annual Report," 2000 (accessed 1/2002).

2. Scott, A.R., "Coalbed exploration strategies; where is the next play?," Kansas Geological Society Bull., Vol. 76, No. 5, 2001, p. 9.

3. Nelson, C.R., "Changing perceptions regarding the size and production potential of coalbed methane resources," Gas Research Institute, Gas Tips, Vol. 5, No. 2, summer 1999, pp. 4-11.

4. Haworth, E., "Special report on oil and gas," University Geological Survey of Kansas, Vol. 9, 1908, 586 pp.

5. Brady, L.L, "Eastern Kansas- some considerations for coalbed methane," Proceedings of the Rocky Mountain Association of Geologists Coalbed Methane Symposium, June 19, 2002, Denver, 5 pp.

6. Stevens, S.H., and Sheehy, L.D., "Western Interior Coal Region (Arkoma, Cherokee, and Forest City basins)," in "Coalbed methane—state of the industry," Gas Research Institute, Quarterly Review of Methane from Coal Seams, Vol. 11, No. 1, 1993, pp. 43-48.

7. Brady, L.L., "Kansas coal resources and their potential for coalbed methane," in McMahan, G., ed., Transactions of the AAPG Mid-Continent Section Meeting, Sept. 14-16, 1997, Oklahoma City, pp. 150-163.

8. Stoeckinger, W.T., "Kansas coalbed methane comes on stream," OGJ, June 4, 1990, pp. 88-90.

9. Tedesco, S.A., "Coalbed methane potential assessed in Forest City basin," OGJ, Feb. 10, 1992, pp. 68-72.

10. Brady, L.L., and Guy, W.J., "Coal resources and coalbed methane potential in the Kansas portion of the Forest City basin," abs., AAPG Bull., Vol. 83, No. 7, 1999, pp. 1,193-94.

11. Bostic, J., Brady, L., Howes, M., Burchett, R., and Pierce, B.S., "Investigation of the coal properties and the potential for coal-bed methane in the Forest City basin," U.S. Geological Survey, Open-File Report 93-576, 1993, 44 pp.

12. Stoeckinger, W.T., "Methane from coal in southeast Kansas; the rebirth of an old industry," proceedings of the 1989 Coalbed Methane Symposium at University of Alabama, Tuscaloosa, 1989, pp. 211-217.

13. Rice, D.D., "Composition and origin of coalbed gas," in Law, B.E., and Rice, D.D., "Hydrocarbons from Coal," AAPG Studies in Geology No. 38, 1993, pp. 159-184.

14. Jenden, P.D., Newell, K.D., Kaplan, I.R., and Watney, W.L., "Composition and stable isotope geochemistry of natural gases from Kansas, Midcontinent, USA," Chemical Geology, Vol. 71, No. 1-3, 1988, pp. 117-147.

15. Stoeckinger, W.T., "Gas in an incised valley, Upper Cherokee age, east-


4-6