NATURAL GAS INFRASTRUCTURE MODELING:
FROM LOCAL DISTRIBUTION TO
TRANSBOUNDARY NETWORKS

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1. THE U.S. NATURAL GAS INDUSTRY
   1.1. OVERVIEW
   1.2. TRANSMISSION
   1.3. IMPORTS/EXPORTS
   1.4. UNDERGROUND STORAGE
   1.5. GAS DISTRIBUTION

2. LITERATURE ON NATURAL GAS MODELING
   2.1. GAS DISTRIBUTION STATISTICAL MODELING
   2.2. LDC/PIPELINE OPTIMIZATION MODELING
   2.3. REGIONAL MODELING
   2.4. NATIONAL/TRANSBOUNDARY MODELING

3. ISSUES AND FURTHER RESEARCH
   3.1. DATA AVAILABILITY
   3.2. DISTRIBUTION COSTS AND GEOGRAPHICAL FACTORS
   3.3. COMPANY-LEVEL UNCERTAINTY
   3.4. GLOBAL UNCERTAINTY
1. THE U.S. NATURAL GAS INDUSTRY

1.1. OVERVIEW
Natural Gas Supply and Disposition in the U.S., 2006

Gross Withdrawals from Gas and Oil Wells: 29.6

Reservoir Repressing: 3.3

Vented/Flared: 0.1

Nonhydrocarbon Gases Removed: 6.7

Dry Gas Production: 18.6

Extraction Loss: 0.9

Dry Gas Production: 18.6

Natural Gas Storage Facilities:
- Canada: 0.341
- Mexico: 0.322
- Japan: 0.081

Natural Gas Withdrawals: 2.6

Additions: 3.0

Gross Withdrawals

- Canada: 3.660
- Trinidad and Tobago: 0.262
- Egypt: 0.171
- Nigeria: 0.057
- Algeria: 0.017
- Mexico: 0.013

Natural Gas Use:
- Gas Industry: 1.7
- Residential: 4.4
- Commercial: 2.8
- Industrial: 0.5
- Vehicle Fuel: 0.02
- Electric Power: 0.2
Generalized Natural Gas Pipeline Capacity Design Schematic

Supply Sources
- Gathering Systems
- Gas Processing Plant
- Imports

Long Distance Trunkline
- 500 MMcf/d

Market Area
- Underground Natural Gas Storage
- 100 MMcf/d
- Local Distribution Service Load
- 600 MMcf/d
- 620 MMcf/d
- Consumers

LNG Peaking Facility
- 70 MMcf/d
- 50 MMcf/d (Generation)
- 40 MMcf/d (Reprocessing)

Legend:
- Black = Year round design capacity
- Red = Non-heating season (spring-summer need)
- Blue = Heating Season (winter or peak period need)

Note: MMcf/d = million cubic feet per day. Areas shown are not proportional to capacity volumes indicated. Other natural gas transmission pipelines may interconnect with and supplement the supplies of the mainline transmission or local distribution company in the market area to meet peak period demands.

Source: Energy Information Administration, Office of Oil and Gas
Gas Demand Varies Seasonally During the Year
(Billion Cubic Feet per Month)

Source: Monthly Energy Review, August 2007
1.2. TRANSMISSION

- INTERSTATE PIPELINES: 120 - 213,409 MILES
- INTRASTATE PIPELINES: 90 - 86,882 MILES
- TOTAL: 210 PIPELINES – 300,291 MILES
- 1400 COMPRESSOR STATIONS
- 11,000 DELIVERY POINTS
- 5,000 RECEIPT POINTS
- 1,400 INTERCONNECTION POINTS
- 20 HUBS OR MARKET CENTERS
- LONG-DISTANCE TRUNKLINES VS. REGIONAL GRID SYSTEMS
- TRADE-OFF BETWEEN PIPE SIZE AND COMPRESSION
- MUST MEET PEAK DEMAND OF FIRM SERVICE SHIPPERS
- 6800 OIL/GAS PRODUCING COMPANIES
- 300,000 WELLS
- 130+ GATHERING SYSTEMS
- REGULATION: FERC AND STATE REGULATORY COMMISSIONS
- 300 MARKETERS
Texas Intrastate Natural Gas Pipeline
(over 43,000 miles)
Interstate Natural Gas System Mainline Compressor Stations - 2006

Legend
- Interstate Pipeline
- Compressor Station

Note: EIA has determined that publication of this figure does not raise security concerns, based on the application of Federal Geographic Data Committee’s Guidelines for Providing Appropriate Access to Geospatial Data in Response to Security Concerns.
Source: Energy Information Administration, Natural Gas Division, Natural Gas Transportation Information System, Compressor Station Database.
Producing Basins and Regional Natural Gas Flows
Region-to-Region Natural Gas Pipeline Capacity, 2004

Legend
NN = Estimated Capacity on December 31, 2004
(NN%) = Percentage increase in Capacity since 2000

* Export capacity was not in place in 2000
Source: Energy Information Administration, Gas Transportation Information System, Natural Gas Pipeline Capacity Database
Gas Pipeline Capacity Into and Out of the Midwest Region

Note: MMcf/d = million cubic feet per day.
Source: Energy Information Administration, Office of Oil and Gas, Natural Gas Pipeline Capacity Database.
Areas with Major Natural Gas Pipeline Capacity Additions in 2003

Northwest PL Evergreen Expansion (268 MMcf/d)
Northwest PL Rockies Expansion (175 MMcf/d)
Grasslands Project Phase I (80 MMcf/d)
Guestar Overthrust Tie Line '12 (217 MMcf/d)
Fina/dal/Jonah System Expansion (360 MMcf/d)

Martimes & Northeast: Phase III (255 MMcf/d) and Algonquin HubLine (255 MMcf/d)

Kern River Transmission Expansion (900 MMcf/d)

East Tennessee Patriot Pipeline (316 MMcf/d)
Transco Momentum Phase I (262 MMcf/d)

Kinder Morgan Texas Pipeline Expansion (375 MMcf/d)

Okeanos Deepwater PL Phase I (1,200 MMcf/d)
Triton Pipeline System (275 MMcf/d)
Canyon Chief Pipeline (350 MMcf/d)

Note: MMcf/d = million cubic feet per day.
Source: Energy Information Administration, Office of Oil and Gas, Natural Gas Pipeline Capacity and Construction Databases, as of December 2003.
1.3. IMPORTS/EXPORTS

- 24 IMPORT LOCATIONS
- 19 EXPORT LOCATIONS
- 12 IMPORT/EXPORT LOCATIONS
- 5 LNG (LIQUEFIED NATURAL GAS) IMPORT TERMINALS
- IMPORTS IN 2006 = 17% OF GAS CONSUMED (11% 10 YEARS AGO)
- CANADA PROVIDES 99.8% OF PIPELINE-IMPORTED GAS
LNG LINKS MARKETS GLOBALLY

The maps show the projected growth in global LNG trade, with the arrows depicting supply flows exceeding 1 billion cubic feet a day.
LNG TANKER AND TERMINAL FACILITY
U.S. Liquefied Natural Gas Facilities - 2004
Proposed LNG Marine Terminals in the Gulf of Mexico - 2005

Sources: Map locations are based on company announcements and trade publications.
1.4. UNDERGROUND STORAGE

- 394 UNDERGROUND NATURAL GAS STORAGE FACILITIES
- 133 UNDERGROUND STORAGE OPERATORS
- 100 LNG STORAGE FACILITIES
- 71 LNG STORAGE OPERATORS
Storage Reservoirs by Type

Underground Storage:
A. Salt Caverns
B. Mines
C. Aquifers
D. Depleted Reservoirs
E. Hard-rock Caverns

Source: PB-KBB Inc
Natural Gas Storage Role

- Critical supply component during heating season
- Smoothes domestic production of gas throughout the year by enabling storage refill during periods of low demand
- Withdrawals help satisfy sudden increases in demand or supply declines caused by weather or other factors
- Support pipeline and hub operations—e.g., peak day service and load balancing
Monthly Consumption, Production and Net Imports

Source: EIA, Short-Term Energy Outlook, August 2007
Major Underground Gas Storage Additions in 2003

2 Storage Field Expansions - 1,008 MMcf additional Working Gas Capacity, 45 MMcf/d additional Daily Withdrawal capability

1 Storage Field Expansion - 5,000 MMcf additional Working Gas Capacity, 300 MMcf/d additional Daily Withdrawal capability

1 Storage Field Expansion - 1,000 MMcf Working Gas Capacity, 200 MMcf/d Daily Withdrawal capability

1 Storage Field Expansion - 3,910 MMcf additional Working Gas Capacity, 870 MMcf/d additional Daily Withdrawal capability

2 Storage Field Expansions - 3,568 MMcf additional Working Gas Capacity, 200 MMcf/d additional Daily Withdrawal Capability

1 New Storage Field - 4,100 MMcf Working Gas Capacity, 400 MMcf/d Daily Withdrawal capability

Note: MMcf/d = million cubic feet per day.
Source: Energy Information Administration, Office of Oil and Gas, Natural Gas Storage Projects Database.
1.5. GAS DISTRIBUTION AND CONSUMPTION

- 1500 LOCAL GAS DISTRIBUTION COMPANIES (LDCs)
- TOTAL CONSUMPTION: 22.2 TCF (2006)
- RESIDENTIAL: 21.6%
- COMMERCIAL: 14.0%
- INDUSTRIAL: 30.3%
- ELECTRIC POWER: 26.4%
- PIPELINE FUEL: 2.6%
- VEHICLE FUEL: 0.1%
Natural Gas Distribution Schematic
Natural Gas Distribution Network – Township of Wilson, Niagara County, N.Y.
2. LITERATURE ON NATURAL GAS MODELING

2.1. GAS DISTRIBUTION STATISTICAL MODELING
2.2. LDC/PIPELINE OPTIMIZATION MODELING
2.3. REGIONAL SIMULATION/OPTIMIZATION MODELING
2.4. NATIONAL/TRANSBOUNDARY MODELING
2.1. GAS DISTRIBUTION STATISTICAL MODELING

- DATA CHARACTERIZE (1) PLANT/CAPITAL COSTS AT THE LOAD CENTER/CITY LEVEL, AND (2) TOTAL COSTS AT THE COMPANY LEVEL.

- ECONOMIC THEORY OF FIRM BEHAVIOR: COST MINIMIZATION

- PRODUCTION FUNCTION VS. COST FUNCTION

- COST = F(OUTPUTS, INPUT PRICES, HEDONIC VARIABLES)

- ECONOMETRIC TECHNIQUES FOR ESTIMATION
S1, N1: sales to/numbers of residential customers
S2, N2: sales to/numbers of non-residential customers
D: population density
LILCO: 58 cities; EOGC: 43 cities

**LILCO**

\[
C = 68.001 + 3.519S_1 + 0.19N_1 + 1.473S_2 + 738.98N_2 - 8002.8D,
\]

\[
\begin{align*}
t & (0.67) & (12.98) & (0.005) & (3.21) & (1.50) & (-0.99) \\
\text{prob} > |t| & (0.5056) & (0.0001) & (0.9958) & (0.0023) & (0.1396) & (0.3266) \\
R^2 & = 0.993, & F= 1483, & ADRSQ = 19.08, & (10)
\end{align*}
\]

\[
\ln C = 5.542 + 0.503 \ln S_1 + 0.176 \ln N_1 - 0.016 \ln S_2 + 0.279 \ln N_2 - 0.250 \ln D,
\]

\[
\begin{align*}
t & (8.45) & (4.75) & (1.26) & (-0.29) & (2.64) & (-4.00) \\
\text{prob} > |t| & (0.0001) & (0.0001) & (0.2148) & (0.7695) & (0.0110) & (0.0002) \\
R^2 & = 0.952, & F= 206, & ADRSQ = 5.90, & (11)
\end{align*}
\]

**EOGC**

\[
C = 527,797 + 0.899S_1 + 82.50N_1 + 0.093S_2 + 2226.53N_2 - 72,031.4D,
\]

\[
\begin{align*}
t & (3.74) & (1.75) & (0.91) & (2.68) & (2.93) & (-1.90) \\
\text{prob} > |t| & (0.0006) & (0.0875) & (0.3677) & (0.0110) & (0.0057) & (0.0647) \\
R^2 & = 0.996, & F= 1873, & ADRSQ = 1.40, & (12)
\end{align*}
\]

\[
\ln C = 5.675 + 0.245 \ln S_1 + 0.504 \ln N_1 + 0.065 \ln S_2 + 0.099 \ln N_2 - 0.067 \ln D
\]

\[
\begin{align*}
t & (4.82) & (1.04) & (2.01) & (2.37) & (1.79) & (-1.57) \\
\text{prob} > |t| & (0.0001) & (0.3029) & (0.0522) & (0.0233) & (0.0808) & (0.1239) \\
R^2 & = 0.981, & F= 374, & ADRSQ = 0.73, & (13)
\end{align*}
\]
## MARGINAL COSTS ESTIMATED AT SAMPLE MEANS

<table>
<thead>
<tr>
<th>Company</th>
<th>LILCO</th>
<th>EOGC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total cost $C ($)</strong></td>
<td>1,963,391</td>
<td>3,753,481</td>
</tr>
<tr>
<td><strong>Residential marginal costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity ($/MCF)</td>
<td>2.332</td>
<td>0.656</td>
</tr>
<tr>
<td>Customer ($/customer)</td>
<td>69.37</td>
<td>238.92</td>
</tr>
<tr>
<td><strong>Non-residential marginal costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity ($/MCF)</td>
<td>0.000</td>
<td>0.114</td>
</tr>
<tr>
<td>Customer ($/customer)</td>
<td>1065.96</td>
<td>711.87</td>
</tr>
<tr>
<td><strong>Density marginal costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$/(people/acre)</td>
<td>-49,619</td>
<td>-60,077</td>
</tr>
</tbody>
</table>

6 companies: LILCO, EOGC, CGO, PNG (Iowa), PG&E
240 cities
K = replacement value of distribution plant in city
S1 = annual sales to residential sector
S2 = annual sales to non-residential sector
N1 = number of residential customers
N2 = number of non-residential customers
D = population density
L = load factor (weather)
W = wage rate

Estimation method: Box-Cox non-linear

\[
K = \left[ -5.1251 + 1.1173S_1^{0.057} + 0.0041S_2^{0.191} + 0.9282N_1^{0.065} \\
+ 0.1869N_2^{0.133} - 0.0964D^{0.099} - 0.9028L^{1.504} + 2.2868W^{0.079} \right]^{10.974}
\]
ECONOMIES OF SCALE AND DENSITY

- There are always economies of density: market expansion without territorial expansion
- Market and territorial expansion at the urban fringe: both economies and diseconomies of scale, depending upon market size and mix, density, and load factor.

Fig. 1 Ray Expansion of Output Bundle
SAMPLE OF ADDITIONAL ECONOMETRIC RESEARCH

- 65 communities, Peoples Natural Gas Company, Iowa
- Patterns of price discrimination and cross-subsidization
- Small communities subsidize large ones; commercial/industrial customers subsidize residential customers

P. Fabri, G. Fraquelli, R. Giandrone – Costs, Technology and Ownership of Gas Distribution in Italy – Managerial and Decision Economics – 2000
- 31 companies; low economies of scale, high economies of density
- Significant role of morphological (topography) and demographic variables

- 131 natural gas extension projects; use Box-Cox estimation
- Cost = f(peak daily demand, pipe length, dummy variables)
- Conclusion: too large a share of capital costs assigned to use relative to access

- 46 gas distributors
- Economies of scale only for smallest units, constant return to scale for most.
2.2. LDC/PIPELINE OPTIMIZATION MODELING

H.B. CHENERY – ENGINEERING PRODUCTION FUNCTIONS – QUARTERLY JOURNAL OF ECONOMICS, 1949
- Derivation of production function for pipeline gas transportation
- Pipe link between two points; capacity flow as a function of pipe diameter and pressures at the inlet and outlet points
- Cost = f(pipe diameter and thickness, compression ratio)

J. TZOANNOS – AN EMPIRICAL STUDY OF PEAK-LOAD PRICING AND INVESTMENT POLICIES FOR THE DOMESTIC MARKET OF GAS IN GREAT BRITAIN – APPLIED ECONOMICS, 1977
- Four seasons; price-sensitive demands; cost functions for energy, capacity, and customers; capacity constraint
- Marginal cost pricing; equilibrium.

- Hypothetical LDC; Rate Design submodel
- Tests different rate structures, including based on MCs
- Simplified storage modeling; Iterative procedure, until equilibrium
Monthly loads = f(heating degree-days - HDD); HDD=random variable
- Trade-offs between purchases, storage operations/expansion, reliability
- Use of CCP with 2 linear decision rules – LP deterministic-equivalent
- Expected cost minimization subject to maximum monthly supply and storage deliveries and withdrawals constraints
Maximize $E(cx)$

$P(Ax \leq b) \geq \alpha,$

$x = (x_1, x_2, \ldots, x_i, \ldots, x_m),$
- LP structure; 12 months; several suppliers; marginal cost calculations
- Price-sensitive monthly residential, commercial, and industrial demands
- Optimization of supply mix and transmission/storage capacity expansion
- Revenue requirements and rates calculations; price equilibrium
### Table II
Evaluation Criteria for the Average- and Marginal-Cost Pricing Policies

<table>
<thead>
<tr>
<th></th>
<th>Average-Cost Pricing Policy (ACPP)</th>
<th>Marginal-Cost Pricing Policy (MCPP)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Load Related Criteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual residential sales (MMCF)</td>
<td>287,817</td>
<td>287,246</td>
</tr>
<tr>
<td>Annual commercial sales (MMCF)</td>
<td>115,445</td>
<td>115,524</td>
</tr>
<tr>
<td>Annual industrial sales (MMCF)</td>
<td>198,195</td>
<td>206,333</td>
</tr>
<tr>
<td>Total annual sales (MMCF)</td>
<td>601,457</td>
<td>609,103</td>
</tr>
<tr>
<td>Peak sales month</td>
<td>January</td>
<td>December–February</td>
</tr>
<tr>
<td>Monthly peak sales (MMCF)</td>
<td>88,186</td>
<td>78,378</td>
</tr>
<tr>
<td>Monthly load factor (%)</td>
<td>56.84</td>
<td>64.76</td>
</tr>
<tr>
<td><strong>Supply-Related Criteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consolidated's contract demand (MMCF)</td>
<td>2081.34</td>
<td>1816.33</td>
</tr>
<tr>
<td>Panhandle's contract demand (MMCF)</td>
<td>325.20</td>
<td>325.20</td>
</tr>
<tr>
<td>Production capacity expansion (MMCF)</td>
<td>723.05</td>
<td>744.29</td>
</tr>
<tr>
<td>Storage capacity expansion (MMCF)</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Transmission T₁ capacity expansion (MMCF)</td>
<td>20,867</td>
<td>12,938</td>
</tr>
<tr>
<td>Total commodity charges ($)</td>
<td>650,908,870</td>
<td>659,794,973</td>
</tr>
<tr>
<td>Total demand charges ($)</td>
<td>31,735,110</td>
<td>28,618,556</td>
</tr>
<tr>
<td>Total winter requirement charges ($)</td>
<td>24,402,531</td>
<td>23,622,563</td>
</tr>
<tr>
<td><strong>Investment and Financial Criteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment in transmission T₁ ($)</td>
<td>58,254,409</td>
<td>36,119,018</td>
</tr>
<tr>
<td>Investment in transmission T₂ ($)</td>
<td>116,159,936</td>
<td>77,628,752</td>
</tr>
<tr>
<td>Investment in distribution D₁ ($)</td>
<td>93,253,360</td>
<td>62,320,464</td>
</tr>
<tr>
<td>Total new investment ($)</td>
<td>851,344,896</td>
<td>763,344,384</td>
</tr>
<tr>
<td>Rate base ($)</td>
<td>1,230,205,700</td>
<td>1,144,359,710</td>
</tr>
<tr>
<td>Revenue requirement ($)</td>
<td>1,063,837,737</td>
<td>1,065,953,979</td>
</tr>
<tr>
<td><strong>Surplus Differentials ($)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential market</td>
<td>0</td>
<td>-9,524,313</td>
</tr>
<tr>
<td>Commercial market</td>
<td>0</td>
<td>-2,761,881</td>
</tr>
<tr>
<td>Industrial market</td>
<td>0</td>
<td>+17,723,082</td>
</tr>
<tr>
<td>Total market</td>
<td>0</td>
<td>+5,436,888</td>
</tr>
<tr>
<td>Total producer's and consumer's surplus</td>
<td>0</td>
<td>+13,248,850</td>
</tr>
</tbody>
</table>
2.3. REGIONAL MODELING

- OPTIMIZATION
- SIMULATION
- Detailed network representation; LP structure; multi-period; deterministic
- Minimize costs of supply (commodity/demand), transportation (firm/interruptible), and storage injections, withdrawals, and capacity
- Applications to Questar Pipeline Corporation and Southwest Gas Corporation

Figure 3. Questar Pipeline transmission system. Producers and other pipelines supply natural gas which is stored or distributed to the local distribution company, Mountain Fuel.
New England historically handicapped by lack of gas infrastructure

Simulation, costing, and cost allocation model

Four markets: A=connected customers converting from oil to gas heating → D=new gas loads in communities without access

Eight expansion scenarios
Interstate Pipelines Feeding Into New England

FIGURE 14 Diagrammatic Representation of Tenneco, Texas Eastern, and Algonquin

FIGURE 15 Iroquois Pipeline Layout (Source: FERC 1988b)
2.4. NATIONAL/TRANSBOUNDARY MODELING

- United States Energy Information Administration – Department of Energy
  - Project Independence Evaluation System (PIES) – 1970’s
  - Gas Analysis Modeling System (GAMS) – 1984
  - Natural Gas Transmission and Distribution Model (NGTDM) of the National Energy Modeling System (NEMS) – 2000
  - Equilibrium submodels of larger energy models
    - Fixed point/Gauss-Seidel iterative equilibration procedures

  - Non-linear constraints linearized; 25 intrastate companies (Louisiana); priority allocations.

  - Nonlinearities; optimal reinforcement of the Belgian gas network.
NEW APPROACHES TO LARGE-SCALE GAS MODELS

- Separate, explicit optimization models for (1) pipeline operators, (2) production operators, (3) marketers/shippers, (4) reservoir operators, and (5) peak gas operators
- The equilibrium is an instance of mixed nonlinear complementarity (NCP) problem, where the Kuhn-Tucker multipliers and optimality conditions for each category of market participants provide the pricing linkages

- GASTALE: Gas Market System for Trade Analysis in a Liberalising Europe
- No storage, peak gas, and pipeline operator models
3. ISSUES AND FURTHER RESEARCH

• 3.1. DATA AVAILABILITY
• 3.2. DISTRIBUTION COSTS AND GEOGRAPHICAL FACTORS
• 3.3. COMPANY-LEVEL UNCERTAINTY
• 3.4. GLOBAL UNCERTAINTY
3.1. DATA AVAILABILITY

• MAJOR GOVERNMENTAL DATA SOURCES
  – Ferc 2/2A (pipeline financial/operating data)
  – Ferc11 (pipeline monthly data)
  – Ferc 567 (pipeline system flow diagram)
  – Ferc 537 (pipeline certificate report – new projects)
  – EIA Form 176 9gas supply/disposition: all companies)
  – State Public Utilities Commissions: Annual Reports

• EIAGIS-NG

• ARGONNE NATIONAL LABORATORY: GASMAP

• COMMERCIAL PROVIDERS: MAPSEARCH, etc.
<table>
<thead>
<tr>
<th>LOCATION NAME</th>
<th>1998 ANNUAL AVERAGE DAY (Mcf)</th>
<th>COINCIDENTIAL MAX DAY 01/05/99 HEATING SEASON 11/98 - 3/99 (Mcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANR EAST TEXAS COUNTY INTERCONNECTION</td>
<td>7,731</td>
<td>7,429</td>
</tr>
<tr>
<td>ANR/FS INT-TRUNK 485/489</td>
<td>13,185</td>
<td>0</td>
</tr>
<tr>
<td>ANR/GPM INT-HAMMER RAY</td>
<td>2,020</td>
<td>2,162</td>
</tr>
<tr>
<td>ANR/GPM INT-KORFMANY</td>
<td>2,284</td>
<td>919</td>
</tr>
<tr>
<td>ANR/GPM INT-LAVERNE</td>
<td>50,233</td>
<td>76,512</td>
</tr>
<tr>
<td>ANR/GPM INT-LOVEDALE</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ANR/GPM INT-N LOVEDALE</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>ANR/GPM INT-WOODWARD</td>
<td>23,648</td>
<td>18,722</td>
</tr>
<tr>
<td>BEAVERPLANT (CNG)</td>
<td>10,533</td>
<td>0</td>
</tr>
<tr>
<td>BEAVER-CIG</td>
<td>77,306</td>
<td>48,730</td>
</tr>
<tr>
<td>BERLIN INTERCONNECT (TRANSOK)</td>
<td>40,176</td>
<td>71,979</td>
</tr>
<tr>
<td>CIMARRON INTERCONNECT</td>
<td>1,310</td>
<td>5,111</td>
</tr>
<tr>
<td>CUSTER CITY</td>
<td>16,764</td>
<td>16,051</td>
</tr>
<tr>
<td>DELHI PANTHER CREEK INTERCONNECT</td>
<td>19,307</td>
<td>31,682</td>
</tr>
<tr>
<td>DELHI SWEETWATER</td>
<td>12,237</td>
<td>22,856</td>
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<tr>
<td>GREEN STATION</td>
<td>16,817</td>
<td>14,436</td>
</tr>
<tr>
<td>GREENSBURG</td>
<td>8,555</td>
<td>0</td>
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</table>
## ANR Pipeline Company
1998 Format No. F.E.R.C.567
System Deliveries - Diagram 2

<table>
<thead>
<tr>
<th>Location Name</th>
<th>1998 Annual Average Day (Mcf)</th>
<th>Coincidental Max Day 01/05/99 Heating Season 11/98 - 3/99 (Mcf)</th>
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<tr>
<td>ALDEN (MCMC)</td>
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<tr>
<td>ALBANY</td>
<td>(287)</td>
<td>(855)</td>
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<td>ALEDO</td>
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<td>(2,111)</td>
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<td>ALLERTON</td>
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<td>(887)</td>
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<td>ALTA VISTA</td>
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<td>ANDOVER</td>
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<td>(400)</td>
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<td>CENTERVILLE</td>
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<td>CINCINNATI</td>
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<td>CORYDON</td>
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<td>CRAIG</td>
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<td>DANVILLE</td>
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<td>STATION NAME</td>
<td>WILLIAM G. WOOLFOLK</td>
<td>REED CITY</td>
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<td>1-4000 H.P.RECP.</td>
<td>2-2000 H.P.RECP.</td>
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<td>2-4500 H.P.RECP.</td>
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<td>4-12500 H.P.RECP.</td>
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<td>FUEL MMCF/D</td>
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The data currently within EIAGIS is organized into four main categories. These categories and a partial list of the data files assigned to each of them are presented below.

1. Natural Gas Pipelines
   - Interstate
   - Intrastate

2. Pipeline Related Points
   - Compressor Stations
   - Delivery Points
   - Receipt Points
   - Major Interstate Pipeline Interconnections
   - State Border Crossings

3. Associated Energy Data
   - Underground Storage
   - Proposed Underground Storage
   - Abandoned Storage
   - Oil Tank Farms
   - Oil Import Points
   - Cogeneration Plants
   - Electric Power Plants

4. Other Display Data
   - Counties
   - Cities
   - LDC Service Areas
   - Canada
   - Mexico
   - Highways
   - Rivers
   - Railroads
GASMPAP - U.S./CANADA PIPELINES
GASMAP – OHIO PIPELINES
GASMAP - PIPELINE LINK INFORMATION
3.2. DISTRIBUTION COSTS AND GEOGRAPHICAL FACTORS

- EXPAND ECONOMETRIC MODELS OF GAS DISTRIBUTION COSTS TO INCLUDE, AS EXPLANATORY VARIABLES:
  - Population and employment distribution
  - Land-use structure
  - Street pattern
  - Soil characteristics
  - Underground aquifers
  - Topography
  - Weather (peak demand)

- THRESHOLDS FOR ECONOMIES OF SCALE AND DENSITY
  - Role of geographical factors in determining thresholds
  - Implications for marginal/spatial pricing

- NATURAL MONOPOLY AND ECONOMIES OF SCOPE
  - Geographical factors and economies of scope
3.3. COMPANY-LEVEL UNCERTAINTY

- OPTIMAL GAS SUPPLY MIX (LDCs)
  - LONG-TERM (FIRM) VS. SHORT-TERM (SPOT) CONTRACTING
  - CONTRACT CLAUSES (TAKE-OR-PAY)

- OPTIMAL PIPELINE AND STORAGE CAPACITY RESERVATION (LDCs)

- OWN CAPACITY EXPANSION (LDCs and Pipelines)

- ASSESSING A CHANGING MARKET

- METHODS:
  Simulation - Scenarios
  Optimization:
  - Multi-stage LP under uncertainty
  - Chance-constrained and reliability programming
3.4. GLOBAL UNCERTAINTY

- AGGREGATION VS. DISAGGREGATION OF NATIONAL GAS NETWORKS
  
  IS THERE A LOSS OF INFORMATION/PRECISION WHEN USING MAJOR
  
  CORRIDORS INSTEAD OF INDIVIDUAL PIPELINES?

- IMPACTS OF RENEWABLES (SOLAR, WIND, BIOFUELS) ON THE GAS
  INDUSTRY

- IMPACTS OF LNG SHIPPING: PORT FACILITIES, TRANSPORT OF LNG
  INLAND, STORAGE, REGASIFICATION

- INTERDEPENDENCIES BETWEEN THE ELECTRICITY AND NATURAL GAS
  INDUSTRIES

- IMPACT OF CLIMATE CHANGE: CO2 CAPTURE/STORAGE, ENERGY
  CONSERVATION
THANK YOU