ATLANTIC COUNCIL

IDEAS. INFLUENCE. IMPACT.

A Realistic Balanced Perspective on European Unconventional Gas Developments A North American Perspective

Investments and Surface Impacts Associated with Infrastructure Requirements

Michael E. Moore

Vice President External Affairs and Business Development Blue Source LLC

Executive Director – NACCSA

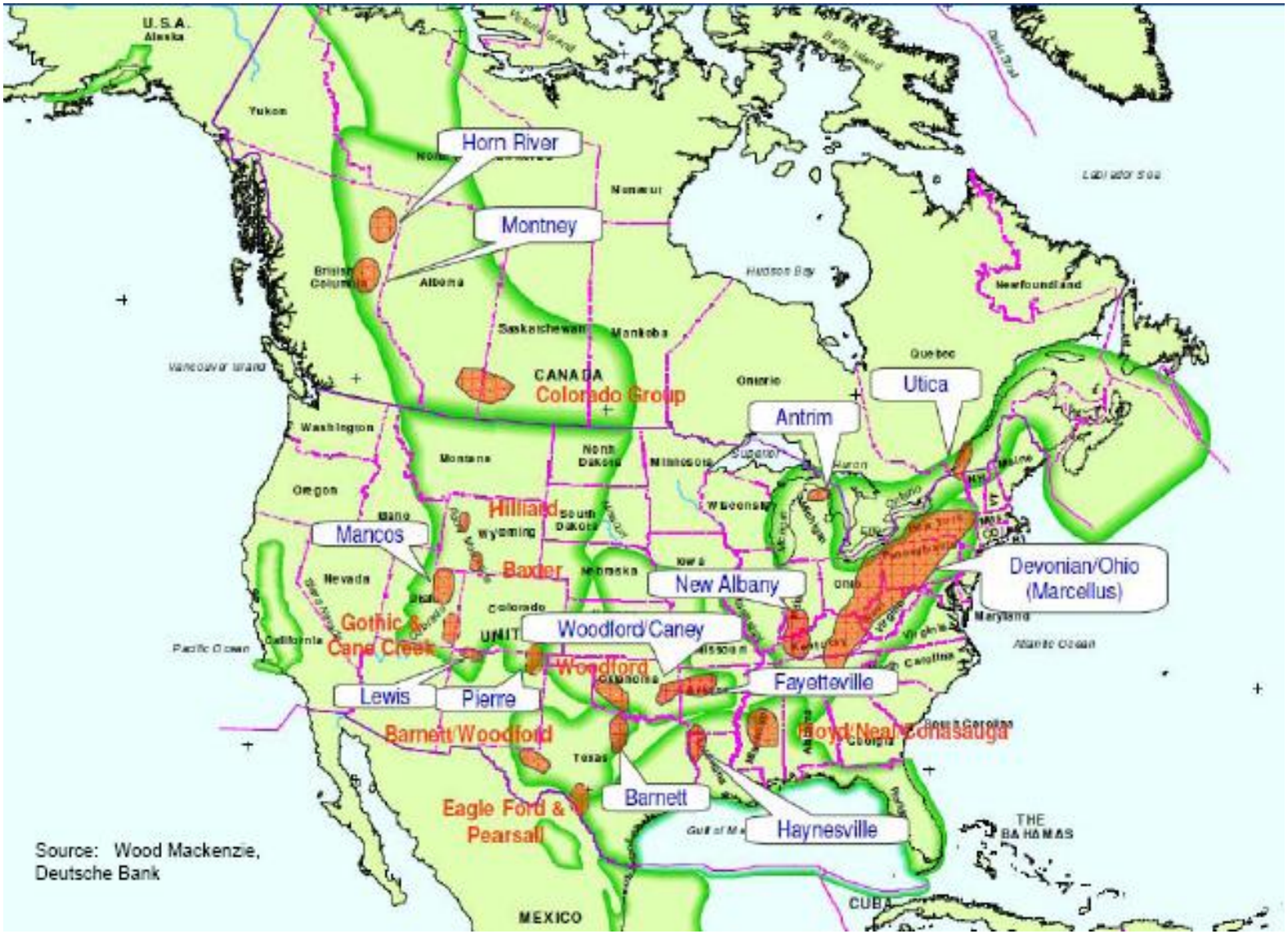
Washington, DC January 25th, 2011

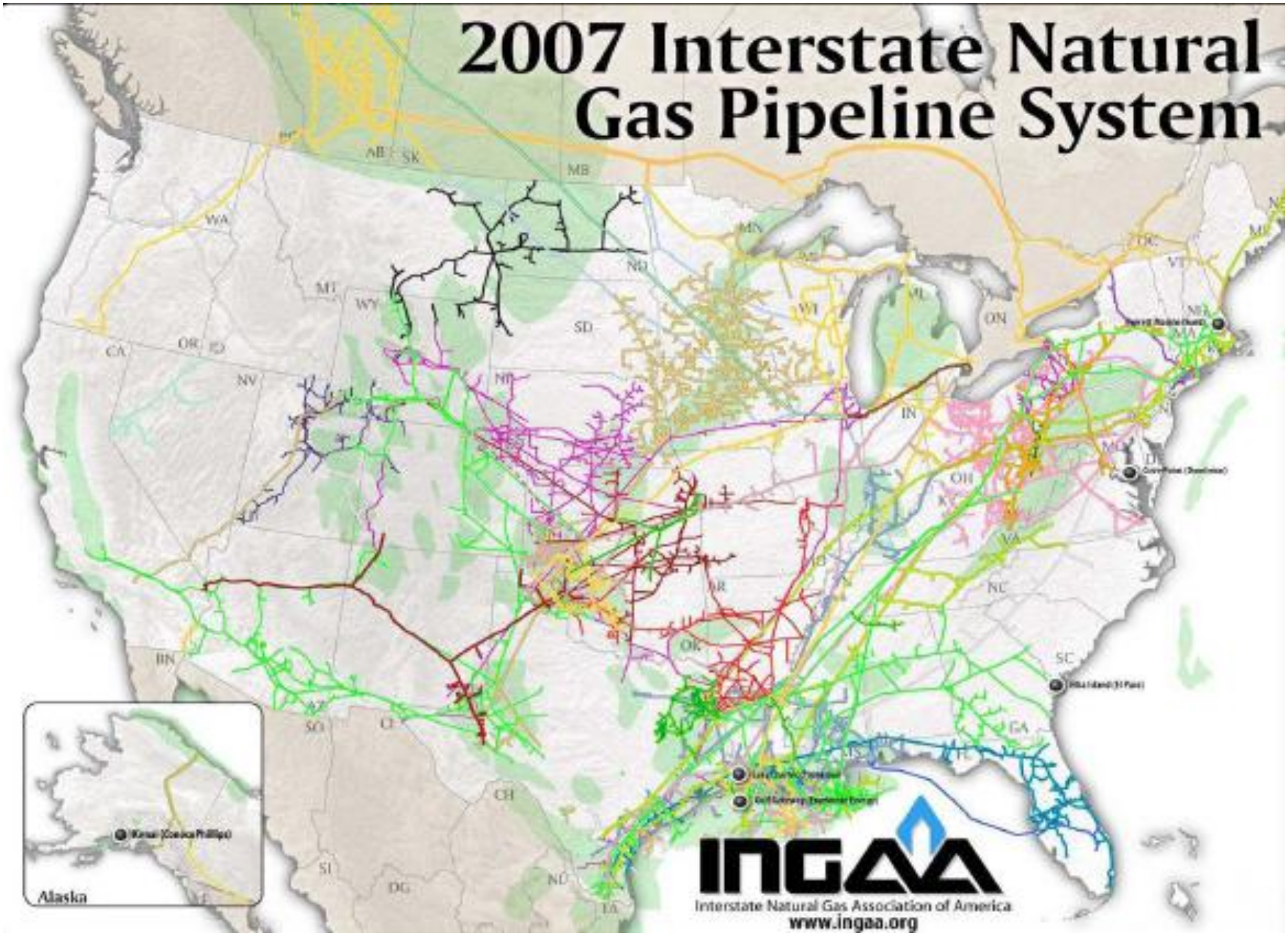
The US and Natural Gas

Source: API, etc

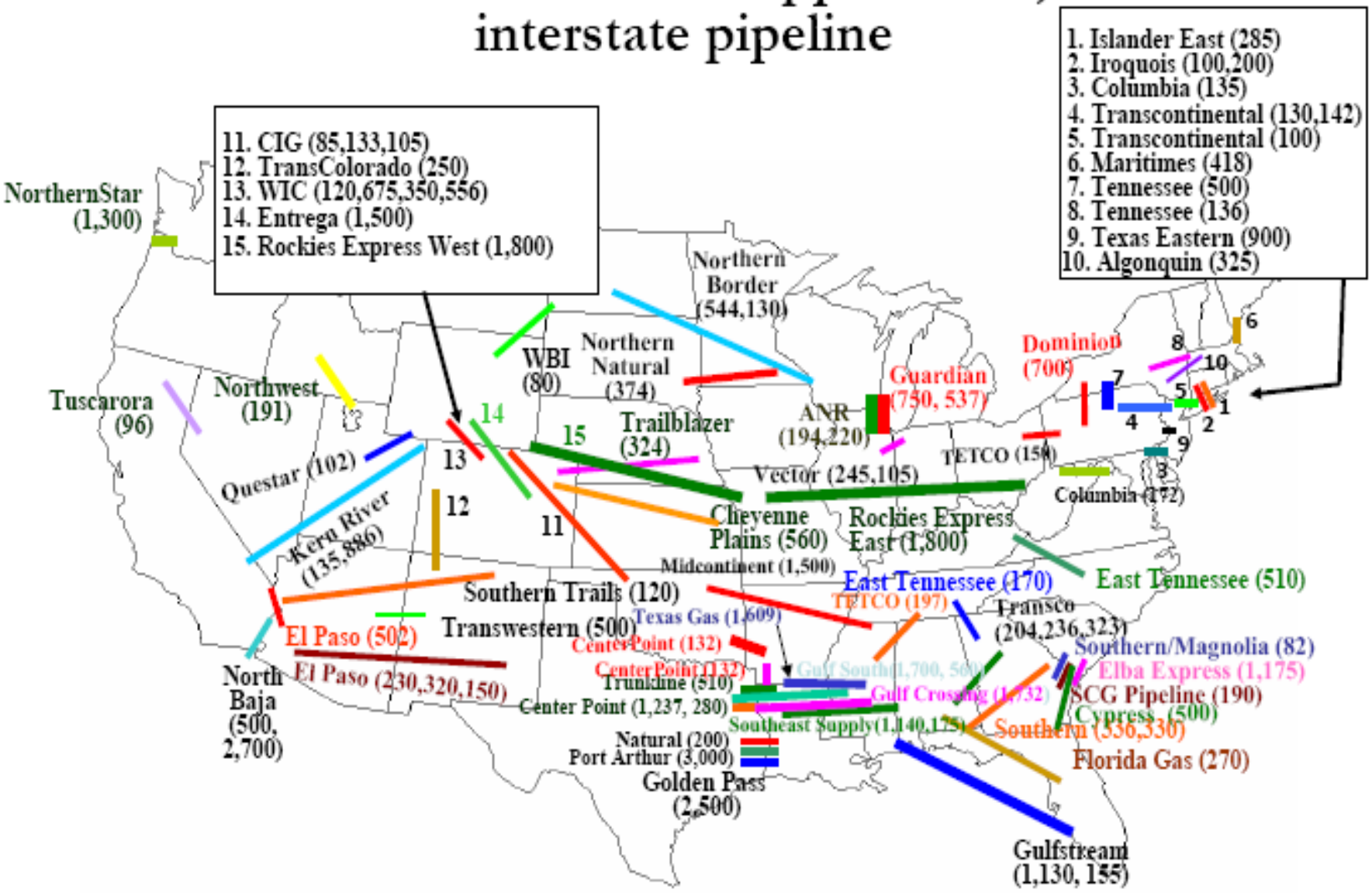
- **America's oil and natural gas industry supports 9.2 million jobs throughout the economy and by 2007, the industry supported a total value added to the national economy of more than $1 trillion or 7.5 percent of GDP.**
- ***Of this The natural gas industry supports nearly 4 million jobs and adds more than $385 billion to the national economy.***
- This industry provides higher-than-average wages and contributes to our nation's energy security:
- The national average annual salary for oil and gas exploration and production is $96,844 or about $47 per hour – more than double the average annual salary of all occupations.
- From 2004-2007, the oil and natural gas industry was responsible for creating nearly 2 million additional domestic jobs
- Adding the coalbed methane, tight sands and the shale gas formations the US now has enough natural gas for the next 90-100 yrs. Additionally there are the deep waters of the Gulf of Mexico, to the vast potential of the Arctic and other offshore resources,
- **The areal extent of the Marcellus Shale underlying the states of New York, Pennsylvania, West Virginia, and eastern Ohio ranges from 48,000 to 54,000 square miles (roughly 31million acres), but when including its full area nearly 95,000 square miles.**

Scope of North American Shale Gas




2007 Interstate Natural Gas Pipeline System
Alaska
INGAA
Interstate Natural Gas Association of America
www.ingaa.org

Between 2000 and 2009 FERC approved 15,000 miles of interstate pipeline



Source: FERC

INGAA Gas Infrastructure Study 2009

Source: http://www.ingaa.org/File.aspx?id=10509

- The U.S. and Canada will need 28,900 to 61,900 miles of additional natural gas pipeline by 2030..
- Between 2009 and 2030, the U.S. and Canada will need 371 to 598 bcf of additional gas storage capacity. Total expenditures range from $2 to $5 billion.
- From 2009 to 2030, a total of $133 to $210 billion must be spent on all types of midstream natural gas infrastructure, ~$6.0 and $10.0 billion per year.
- ~ 80% of this for natural gas transmission pipelines ($108 to $163 billion--- $5.0 and $7.5 billion per year).
- Gas processing investments will account for 8 to 10% of the investment in midstream assets.

Scope of North American Gas Infrastructure

Source: http://www.ingaa.org/File.aspx?id=10509

- Sufficient midstream natural gas assets, such as gathering systems, processing plants, transmission pipelines, storage fields are crucial for an efficient natural gas market.
- In the U.S. and Canada, there are roughly 38,000 miles of gathering pipeline, 85 bcf/d of natural gas processing capacity, 350,000 miles of transmission pipeline and 4.5 Tcf of natural gas storage capacity.

Pipeline Costs

Source: http://www.ingaa.org/File.aspx?id=10509

- Building natural gas pipeline ran between $30,000 and $100,000 per inch-mile from 1993 to 2007
- Pipeline construction costs are divided roughly equally between materials, labor, and miscellaneous.
- In 2007, materials costs accounted for over 35 percent of total costs.
- The miscellaneous category includes engineering, surveying, administration, and environmental costs.
- Costs for rights-of-way account for 8 to 9 percent of total construction costs.
- Note: skilled labor remains a premium commodity and pipeline permitting and siting continue to increase in complexity.

Compression Costs

- Between 1999 and 2007, the cost of building pipeline compression ranged from $1,400 to $1,800 per horsepower.
- Materials costs are one half of this
- Labor costs and the miscellaneous component, which includes engineering and environmental compliance, account for roughly one-fourth each.
- Costs in more densely populated regions tend to be more expensive than in less populated regions--increased costs of permitting, safety, and environmental compliance.

Gathering Lines

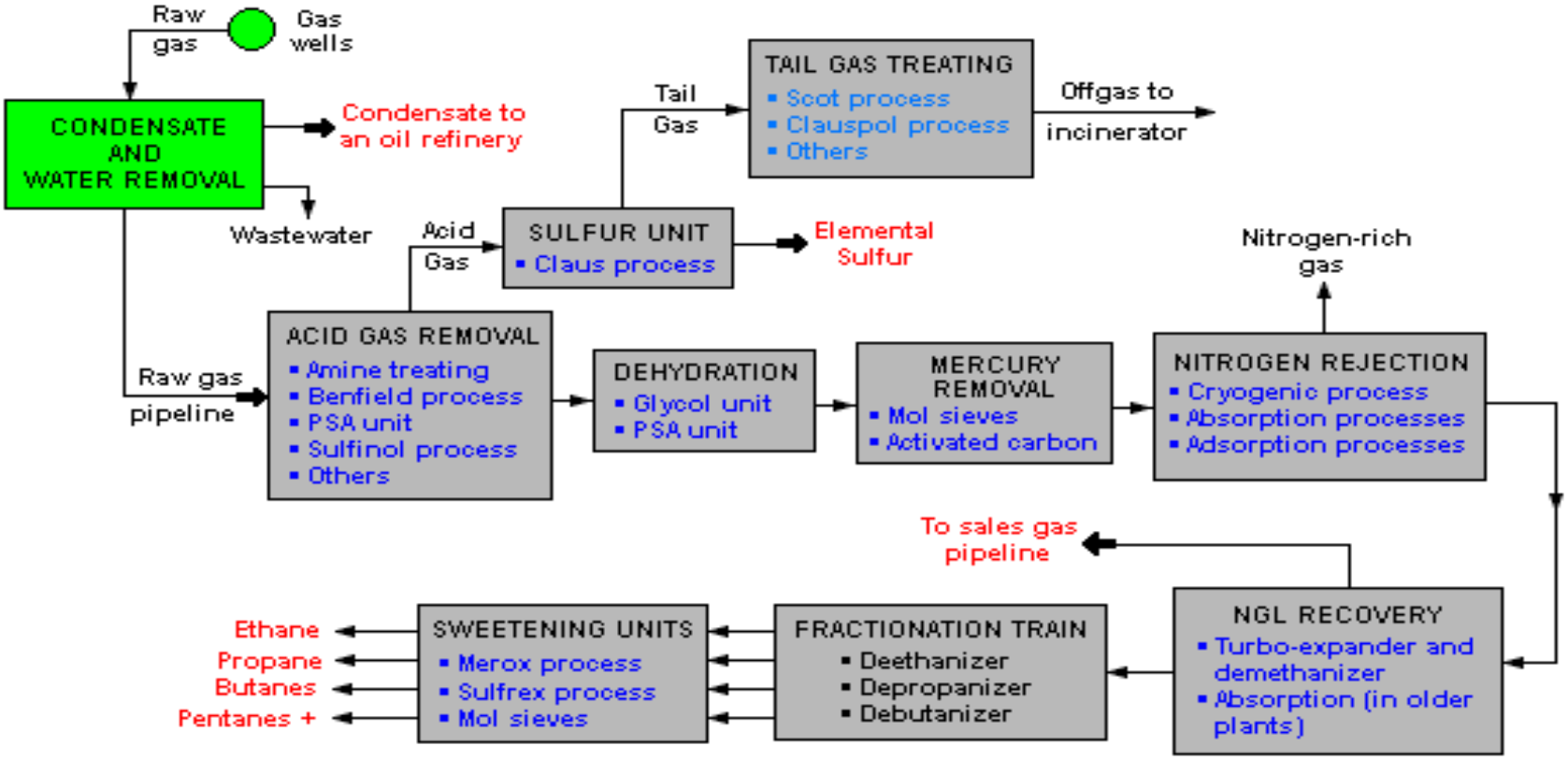
Source: http://www.ingaa.org/File.aspx?id=10509

- As of 2008, there are over 450,000 producing natural gas wells in the U.S.
- Excluding individual natural gas well connections, nearly 20,000 miles of mainline gathering pipeline is necessary to connect domestic natural gas production to the U.S. transmission system.
- Approximately two-thirds of this pipeline mileage is onshore and the remainder is offshore.
- From 2009 to 2030, expenditures on gathering mainlines are projected to range from $9 to $18 billion, equating to $500 million to $1 billion per year

Gas Processing

- 2008 to 2030, net U.S. and Canadian natural gas production is projected to increase by 11 to 24 bcf/d.
- Between 2009 and 2030, the U.S. and Canada will have to invest between $11 and $22 billion in new natural gas processing infrastructure
- Conventional areas declining in production/NGLs, shale gas areas increasing
- Existing facilities not near most shale gas production/NGL's
- Estimated that a min. of 20 bcf/d of new natural gas processing capacity will be needed for this dislocation

Gas Processing



LEGEND:

- Located at gas wells / Located in gas processing plant
  Red Indicates final sales products Blue Indicates optional unit processes available
- Condensate is also called natural gasoline or casinghead gasoline
- Pentanes + are pentanes plus heavier hydrocarbons and also called natural gasoline
- Acid gases are hydrogen sulfide and carbon dioxide
- Sweetening processes remove mercaptans from the NGL products
- PSA is Pressure Swing Adsorption
- NGL is Natural Gas Liquids

Regulatory

- The siting and permitting process for pipeline, storage, and other midstream natural gas infrastructure can be both time consuming and expensive.
- The Federal Energy Regulatory Commission (FERC) is responsible for the review and authorization of interstate natural gas transmission facilities in the US.
- Other federal statutes that affect the construction of interstate natural gas pipelines include the:
- Clean Air Act,
- Clean Water Act,
- Endangered Species Act,
- Coastal Zone Management Act,
- Fish and Wildlife Coordination Act,
- Historic Preservation Act,
- Rivers and Harbors Act,
- Mineral Leasing Act,
- Federal Land Policy Management Act, and
- Wild and Scenic Rivers Act.40
- Additional state and local agency approvals may be necessary before pipeline construction can begin. Each agency has its own forms, processes, and data requirements.
- Pipeline projects, by their nature, can be disruptive during construction. Both the temporary effects of construction and permanent environmental effects along the pipeline right-of-way. Need to be addressed.
- Routes must be selected to avoid both environmentally sensitive areas and urban areas.

CO_2, Renewables & Electric Transmission

- New electric transmission lines and potential CO_2 pipelines used for carbon capture and storage (CCS) will have to compete for rights-of-way, especially in highly populated areas.
- A recent INGAA Foundation study focused on the pipeline infrastructure requirements for CCS. It forecasts that between 15,000 and 66,000 miles of pipeline will be needed in the U.S. by 2030, depending on how much CO_2 could be sequestered, and the use of CO_2 for enhanced oil recovery (EOE).
- CO_2 pipelines also may compete with natural gas pipelines for labor and materials. According to some studies, cumulative CO_2 pipeline costs through 2030, including pumps and compressors, could range from $25 to $100 billion.
- Also the siting of renewables (solar/wind) and related transmission lines could compete with natural gas infrastructure for rights-of-way and materials.

Developing Unconventional Gas in the Marcellus Shale

Steps for Unconventional Gas Development

- Prospects defined
- Land/mineral rights aggregated
- Seismic and related geophysical studies done
- Permitting
- Road access, water resources, road building, site prepping
- Equipment moved in and drilling-then removed
- Hydraulic fracturing and related equipment moved in-then removed
- Production well head and related equipment set
- Site remediation
- Long term maintenance
- Plugging, abandonment and reclamation

Marcellus Shale Drilling Site

Note: Conventional oil and gas wells result in 1-1/2 to 3 acres of disturbance at the drill site, Marcellus well sites are likely to range from 4 to 6 acres. Site prep, drilling, fracturing and production 2-4 months. Site life 20-40 years

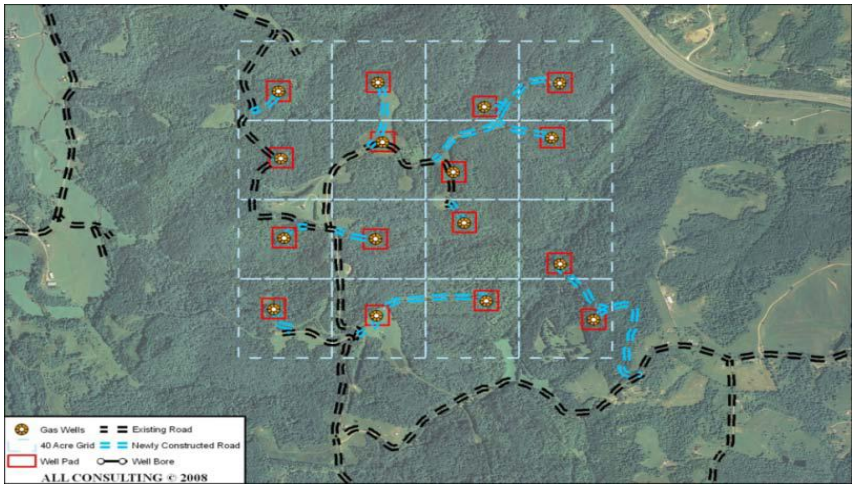
Well Hydraulic Fracturing

Marcellus Drilling/Production/Processing Sites and Access Roads-Allegheny, PA

Vertical vs. Horizontal Wells

Source: http://www.all-llc.com/publicdownloads/AOGR-0810ALLConsulting.pdf

- 16 vertical wells develop 640 acres with approximately 77 ac total disturbance (including proportionate share of roads and utilities)



- 6 to 8 horizontal wells develop 640 acres with approximately 7.4 ac total disturbance –10 times less acreage disturbed

Trucking Requirements & Traffic

Source: Penn State Univ Study-"An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play" 7-24-09

- Many rural roads in the Marcellus Shale occurrence will not meet standards necessary for large trucks that will be used to haul equipment, water, and other supplies to and from drill pad sites. These roads will need to be upgraded through widening, and surfacing; and road curve angles may need to be reduced. If roads are not surfaced or watered regularly, air quality may be degraded by truck traffic related dust, and area residents may be subjected to traffic hazards.

New Well Development

Drill Pad and Road Construction Equipment – 10 to 45 truckloads

Drilling Rig – 30 truckloads

Drilling Fluid and Materials – 25 to 50 truckloads

Drilling Equipment (casing, drill pipe, etc.) 25 to 50 truckloads

Completion Rig - 15 truckloads

Completion Fluid and Materials – 10 to 20 truckloads

Completion Equipment – (pipe, wellhead) 5 truckloads

Fracture Stimulation Fluids and Materials – 100 to 1000 truckloads

Fracture Stimulation Equipment (pump trucks, tanks) – 100 to 150 truckloads

- Oil and gas specialists in the Geologic Resources Division estimate that the "average" oil and gas well requires 320 to 1,365 truckloads of equipment to bring a well into production.

General Well Maintenance

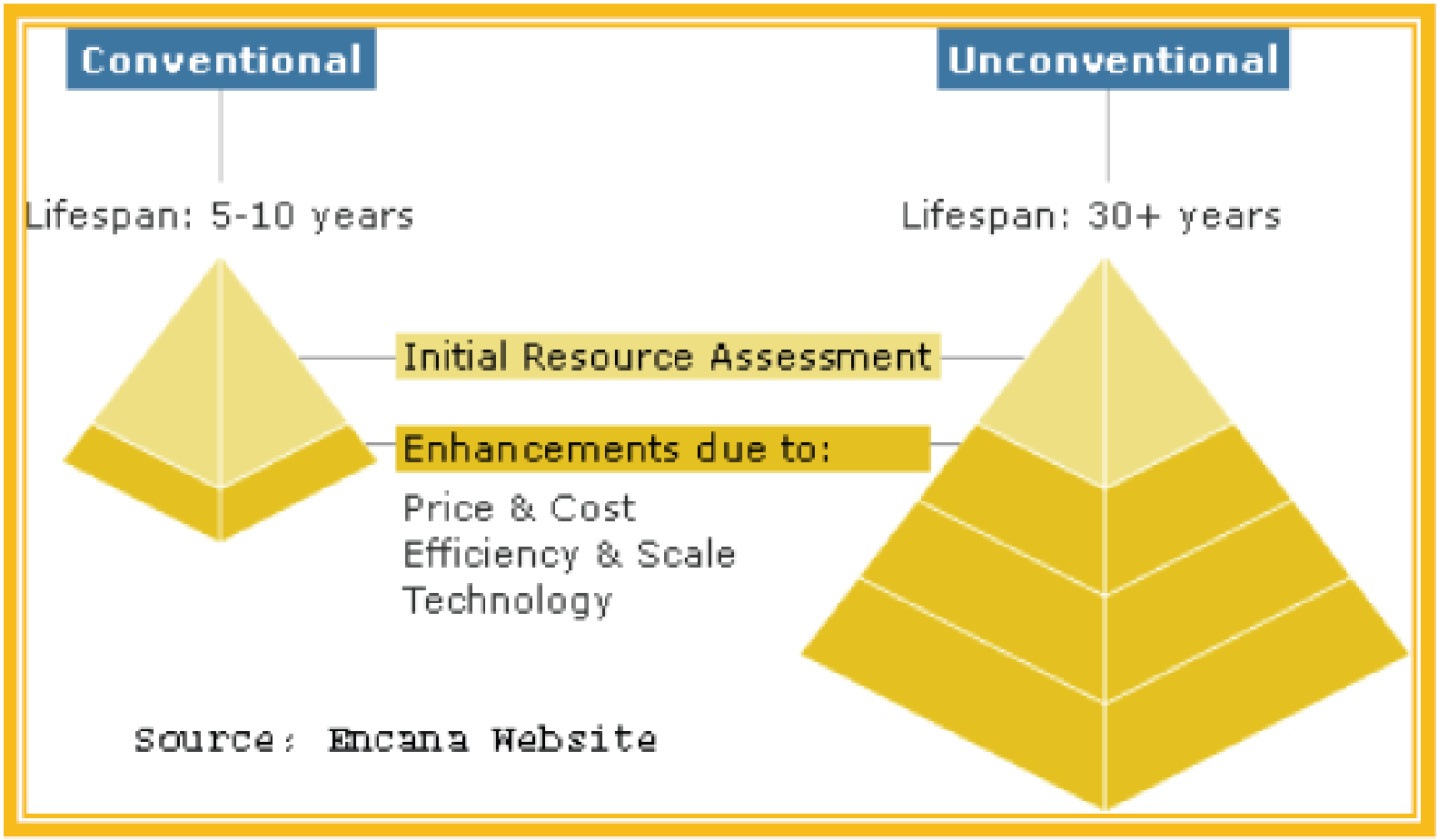
Every 3 to 5 years – 25 to 40 truckloads

Roads Impacted by Marcellus Shale Development in Pennsylvania

Source: Dec 29-2010 Natural gas drillers' damage to roads debated
http://www.pittsburghlive.com/x/pittsburghtrib/news/s_715701.html

- The Marcellus shale gas industry says drilling companies spent about $200 million repairing Pennsylvania roads its trucks damaged during the past year (2010), but a PennDOT official claims the industry owes $35mm more "significant damage" that can't be recovered under agreements with companies, according to a transition report the outgoing administration of Democratic Gov. Ed Rendell prepared for Gov.-elect Tom Corbett.
- More than 2,000 miles of roadway are under agreements requiring drillers to pay for maintenance, the report says. Crews posted those roads with weight restrictions during the past three years.

Well Life-Conventional vs Unconventional



Life span; conventional vs. unconventional shale gas wells

Well Spacing

Source: Penn State Univ Study-"An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play"7-24-09

Sample of Well Spacing Requirements

Gas Shale Name	State(s)	Well Spacing
Barnett Shale	TX	▪ 40- to 160-acre spacing typical ▪ 20-acre spacing being tested
Fayetteville Shale	AR	▪ 40-acre spacing by rule (Arkansas Oil and Gas Commission Rule B-43 ▪ 80- to 160-acre spacing in practice ▪ 60-acre spacing being tested
New Albany Shale	IL, IN, KY	▪ 160-acre spacing initially ▪ 80-acre spacing now common
Antrim Shale	MI	▪ 40- to 80-acre spacing
Ohio Shale	OH	▪ 40- to 160-acre spacing
Woodford Shale	OK	▪ 640-acre spacing initially ▪ 160-acre spacing now common ▪ 80-acre spacing proving effective ▪ 40-acre spacing being tested
Marcellus Shale	NY, PA, OH, WV	▪ 160- to 320-acre spacing initially ▪ 40- to 80-acre spacing can be expected

Gas Processing in the Marcellus

- Typically, gas pipeline specifications for British thermal units (Btu) range from 1,050-1,125Btu/ft³. Natural gas usually ranges from 950-1,150Btu/ft³, while ethane alone has 1,783Btu/ft³. When ethane is mixed with the natural gas stream, it substantially increases the heat content.
- Producers found a 'sweet spot' in the Marcellus play in western Pennsylvania and nearby West Virginia that has higher NGL content. Requiring infrastructure to be built to remove and transport the NGLs. New-build projects [for ethane] will 18-24 months if the dirt was turned tomorrow.
- The NGL's and ethane will need a separate pipeline system to be built plus the natural gas system.

Impacts of Marcellus Shale Gas

Source: http://www.scribd.com/doc/34656839/The-Economic-Impacts-of-the-Marcellus-Shale-Implications-for-New-York-Pennsylvania-West-Virginia

- The economic impact of the Marcellus industry just in West Virginia and Pennsylvania expanded considerably during 2009.
- That 1,121 wells were drilled in these two states during 2009. Output of dry natural gas and petroleum liquids increased to over 600 million cubic feet of gas equivalents during calendar year 2009.
- Total value added or contribution to gross regional product for these two states increased by $4.8 billion as a result of Marcellus production activities.
- This increase in value added is distributed across a broad swath of the economy, generating more than 57,357 jobs and $1.7 billion in local, state, and federal tax collections.
- The gains in value added are broad based, which dispels the notion that natural gas production contributes benefits to only a select few sectors or individuals.
- Leasing, exploring, drilling, and developing these natural gas reserves will directly generate thousands of high-paying jobs and indirectly create many others as employment is stimulated in support industries and as workers spend these wages and households spend royalty income.
- The economic stimulus from natural gas development and production will increase gross regional product, income, and tax receipts.

Questions & Thank You!

Michael E. Moore

- **VP External Affairs and Business Development CCS**
- **Blue Source LLC**
- **WWW.BLUESOURCE.COM**

- **Executive Director and Founding Board of Directors Member**
- **North American Carbon Capture Storage Association**
- **WWW.NACCSA.Org**

- **VP and Founding Board of Directors Member**
- **Texas Carbon Capture Storage Association**
- **WWW.TXCCSA.Org**

- mmoore@bluesource.com

- Tel: 281-668-8475

Blue Source

NACCSA
North American Carbon Capture & Storage Association

Hess Oil Seminole CO_2-EOR Project

Pipelines

- Critical to development of well
- Little high pressure gathering capacity in PA
- No eminent domain for gathering lines
- FERC for interstate transmission lines.
- Placement of lines
- Various impacts & considerations

Example Pennsylvania Shale Gas Permits

- Well Drilling Permit
- Water Management Plan
- Earth Disturbance Permit (>5acres)
- Preparedness, Prevention and Contingency Plan
- Water Withdrawal Permits
- Chapter 105 Obstruction and Encroachment Permit
- Air Quality Permits
- Water Quality Management Plan

Gas Processing

Source: http://www.ingaa.org/File.aspx?id=10509

- The requirements for shale gas can vary from area to area.
- Gas processing removes one or more components from produced gas to prepare it for use. Common components removed to meet pipeline, safety, environmental, and quality specifications include H2S (acid gas), CO2, N2, heavy hydrocarbons, and water. The technique employed to process the gas varies with the components to be removed as well as with the properties of the gas stream (e.g., temperature, pressure, composition, flow rate).
- Acid-gas removal is commonly by absorption of the HS and CO into aqueous amine solutions. This technique works well for high- pressure gas streams and those with moderate to high concentrations of the acid gas component.
- Physical solvents such as methanol or the polymer DEGP, or Selexol may also be used in some cases. And, if the CO2 level is very high, such as in gas from CO2- flooded reservoirs, membrane technology affords bulk CO2 removal in advance of processing with an- other method. For minimal amounts of HS in a gas stream , sc avengers can be a cost effective approach to HS removal.
- Natural gas that becomes saturated with water in the reservoir requires dehydration to increase the heating value of the gas and to prevent pipeline corrosion and formation of solid hydrates.
- In most cases, dehydration with a glycol is employed. The water rich glycol can be regenerated by reducing pressure and applying heat. Another possible dehydration method is use of molecular sieves that contact the gas with a solid adsorbent to remove the water. Molecular sieves can remove the water down to the extremely low levels required for cryogenic separation processes.
- Distillation uses the different boil- ing points of heavier hydrocarbons and nitrogen for separation. Cryogenic temperatures, required for separation of nitrogen and methane, are achieved by refrigeration and expansion of the gas through an expander. Removal of the heavy hydrocarbons is dictated by pipeline quality requirements, while deep removal is based on the economics of NGL production.
- Barnett has liquids and adds 100mmcfd every 3 months and to continue this for the next 10 yrs
- The projected volume of ethane gas production in Marcellus could be as much as 100m bbl/day. More realistically, the production would yield 50m-80m bbl/day when the ability to blend ethane gas into natural gas streams is taken into account, as well as the likelihood of drilling slowing down if natural gas prices don't pick up.
- Typically, gas pipeline specifications for British thermal units (Btu) range from 1,050-1,125Btu/ft^3. Natural gas usually ranges from 950-1,150Btu/ft^3, while ethane alone has 1,783Btu/ft^3. When ethane is mixed with the natural gas stream, it substantially increases the heat content.
- producers found a 'sweet spot' in the Marcellus play in western Pennsylvania and nearby West Virginia that has higher NGL content. There is no infrastructure - such as fractionators or ethane pipelines - in the Northeast to process ethane gas, so producers have nowhere to sell or use the ethane. New-build projects [for ethane] will take 18-24 months if the dirt was turned tomorrow,
- The NGL's and ethane situation call s for a separate pipeline system to be built in addition to the natural gas system and is creating logistical issues due to existing processing capacities in regions experincing decling production with areas of increasing NGL production lacking in processing capacity