



#### Appalachian Storage Hub: What is needed to store and maximize the regional development and use of ethane?



Brian J. Anderson Director, The WVU Energy Institute GE Plastics Material Engineering Professor Chemical Engineering

#### MARCELLUS & MANUFACTURING Development conference

March 23, 2016 Charleston, WV



# **Energy Institute Initiatives**



#### Research

- Fossil
  - Coal, gas, oil
- Renewable
  - Biomass, solar
- Policy
  - Economic, regulatory
- Environment
  - Water, air



### Education

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- Energy graduate programs
- Energy minor and certificate programs
- General Education Curriculum
- Student energy club



### Campus Sustainability

- Building efficiency
- Transportation services

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- Campus energy services
  - Student learning



# **Broad Areas of Energy Research**

• **Fossil Energy**: Promote the efficient use of fossil resources, conversion, extraction, utilization, and environmental management



 Sustainable Energy: Promote energy efficiency, alternative fuels, conservation, renewable energy sources, geothermal, and sustainable and responsible development



• Energy Policy: Analyze energy policies, and their impact on use of these resources, carbon management, environmental, and infrastructure



**Environmental Stewardship**: Ensuring that energy production is balanced with minimizing negative impacts to our air and water resources





# Sustainable Energy

- Sustainable Energy: Promote energy efficiency, alternative fuels, conservation, renewable energy sources, geothermal, and sustainable and responsible development
  - renewable energy; transitions from traditional to renewable energy sources:
  - geothermal energy
  - biomass conversion and utilization
  - biomass/coal conversion and co-firing
  - energy efficiency
  - conservation
  - sustainable design and development







# **Energy Policy**

- Energy Policy: Analyze energy policies, and their impact on use of these resources, carbon management, environmental, and infrastructure
  - analysis and modeling of energy and environmental policy issues
  - analysis for the development of strategies for the management of carbon
  - analysis of energy infrastructure systems
  - data-driven policy assessment
  - community impact evaluation



CARBON DIOXIDE EMISSION REDUCTION OPPORTUNITIES FOR THE WEST VIRGINIA POWER SECTOR

#### DISCUSSION PAPER





James Van Nostrand, Evan Hansen, Beren Argetsinger, Jeff Simcon, Juseph James

# **Environmental Stewardship**

- Environmental Stewardship: Ensuring that energy production is balanced with minimizing negative impacts to our air and water resources
  - developing tools to lower the carbon footprint of our energy portfolio
  - development of efficient water usage methods in energy production
  - evaluation of impacts of energy systems on air and water quality
  - sustainable use of water in energy production
  - life cycle assessment of energy systems





air emissions monitoring CAFEE





# **Fossil Energy**

- **Fossil Energy**: Promote the efficient use of fossil resources, conversion, extraction, utilization, and environmental management
  - carbon capture and geologic storage
  - high-efficiency engine and vehicle technology
  - fuels production
  - clean power generation and distribution
  - extraction technology
  - utilization of coal for clean fuels and chemicals











# Shale Gas: From Supply to Demand

- Research at WVU spans the full range from upstream to downstream
- We have entered a strategic partnership with Ohio State University in five areas of shale-related activities
  - Subsurface
  - Utilization
  - Environment
  - Policy
  - Economics



#### "Father of Geology" Israel C. White.

PO	WERSOURCE	ENERGY NEWS. IN CON Fittsburgh Bost-Go		
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Jobs	Schedule a marrie			
NETL d shale d	eveloping working lab to improve rilling	* *		
By Anya Lit	rak / Pittsburgh Post-Gazette	Most Read		
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### MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY MSEEL

The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term collaborative field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development





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# **MSEEL Vision**

- **S** Demonstrate the Best Approach to Drill, Complete and Produce a New Horizontal Well That Minimizes Any Environmental/Social Costs While Maximizing Economic Productivity
- **S** Monitor and Document Impacts in a Controlled Environment
  - # Greenhouse Gas Emissions
  - Local Air Pollution
  - Water Supply and Quality
  - \* Noise and Activity
  - Societal Impacts

#### **S** Develop New Technologies

- # Microseismic Monitoring
- \* Production Monitoring
- # Advanced Logging

**S** Develop New Scientific and Engineering Approaches to Apply to Multi-disciplinary and Multi-institutional Natural Resource Studies



# Marcellus Shale Energy And Environment Laboratory - MSEEL





# **MSEEL Science Well**





# **MSEEL Research Areas**

- **S** Deep Subsurface Geochemistry
  - \* Characterization of Core, Fluids and Gases
- **S** Database Development and Maintenance
  - \* Data portal will serve as central place to exchange and search for data
- S Surface Environmental
  - ✤ Air Emissions
  - Water Supply and Quality
- **S** Geologic Engineering
  - \* Analysis and Modeling of Well Drilling and Completion
  - Reservoir Simulation
  - \* Production Monitoring
  - # Geostatistical Well Analysis
- **S** Geophysical and Geomechanical
  - # Microseismic Monitoring
- S Economic and Societal



# Marcellus (and Utica) are driving U.S. Gas production

#### Monthly dry shale gas production

billion cubic feet per day



through February 2016 and represent EIA's official shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).



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# WVU Mountain of Excellence in Shale Gas - Opportunities

• WV – a long history in NG to chemicals

- Clendenin, WV: Site of the world's first commercial ethylene plant



#### • Upstream:

- resource evaluation,
- management, and
- production
- Downstream:
  - use as an alternative transportation fuel
  - conversion to liquid fuels or chemicals
  - use in fuel cells



- Union Carbide 10,000 lb/day ethylene plant online in 1921
- Driven by access to raw materials



# Natural gas utilization

The focus is on responsible demand-side research that emphasizes the technology needs to promote responsible growth of the shale gas industry and economic development in the State.

The focus must include economic, legal, and policy needs to inform the State and legislative decision makers.

The emergence of significant national natural gas plays, coupled with thermocatalyic pathways, provides the potential to decrease dependence on conventional petrochemical routes towards a variety of products, including gasoline, diesel, methanol, ethanol, ammonia, hydrogen, and a variety of oligomers and polymers.

Statler Chair Lead Shale Gas Utilization Initiative (focus on STEM)

# Demand & Utilization Finances Stationary & Mobile

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## Natural gas utilization: around to stay?



Source: EIA

## Natural gas utilization: around to stay?



Source: EIA The "true" BTU ratio of WTI crude to natural gas of 5.8 MMBtu/Bbl

### Natural gas utilization: many options



# Natural gas utilization: pathway toward a natural gas economy?

Significant R&D needs remain:

- Process Synthesis:
  - development and utilization of advanced algorithms to synthesize and model processes tailored for a specific characteristic
- Reaction Engineering:
  - leveraging scientific innovation, leveraged by technology pull and push, to develop processes (thermal, catalytic, photo, etc.) tailored for natural gas feeds.
- Grand Challenges:
  - exploit advances in fundamental computational and experimental sciences to rapidly identify optimum structure-function relationships
  - overcoming grand challenges associated with natural gas utilization (C1 activation, H-cleavage, coking, etc.).



# Natural gas utilization at WVU

#### <u>Topic areas</u>

- Gas to liquids (GTL)
  - Catalytic approaches
  - Non-catalytic approaches
- Direct-use NG fuel cells (FC)
- NG combustion (NGC)
  - Stationary
  - Vehicular
- Gas to chemicals (CTC)
  - Alkanes
  - Aromatics

- Basic science needs
  - Catalyst and chemical pathway development (GTL, GTC)
  - Fundamental SOFC material development (FC)
  - Reactive CFD modeling (NGC, FC)
  - Computational chemistry (GTL,GTC,NGC,FC)



# Potential lifetime of North American Gas



# New Fractionation Capacity in the U.S.



Map data generated by PennWeil MAPSnarch, Houston

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# The U.S. has become long on ethane



Average monthly ethylene spot price spreads over ethane and naphtha spot prices January 2010-November 2014 dollars per pound 2011 2012 2013 2014 -U.S. Gulf Coast ethylene-naphtha spread ——Japan ethylene-Singapore naphtha spread ——U.S. Gulf Coast ethylene-ethane spread

# Why focus on ethane?

Purity product	Conversion factor (Mcf/bbl)	Application	End-use product	Primary sector
Ethane	1.558	Ethylene for plastics production, petrochemical feedstock	Plastic bags, plastics, antifreeze, detergent	Industrial
Propane	1.499	Propylene for plastics/solvents/ petrochemicals, residential/ commercial heating, cooking	Plastics, solvents, LPG for home heating, stoves, BBQ, engines	Industrial, residential, commercial
Normal butane	1.288	Petrochemical feedstock, gasoline blendstock	LPG, synthetic rubber for tires, lighter fuel	Industrial, transportation
Isobutane	1.245	Petrochemical feedstock, gasoline blendstock	Alkylate for gasoline, aerosols, refrigerants	Transportation
Natural gasoline	0.940	Gasoline blendstock, ethanol denaturant, diluent for bitumen	Motor gasoline, Canadian crude oil imports	Transportation

Source: U.S. Energy Information Administration.



# Why focus on ethane?

#### Intermediates







# **Regional Advantage**

Product	Price Unit	Gulf of Mexico	Europe	Asia	Appalachian Basin
natural gas	\$/MMBtu	2.50	6.30	8.20	0.87
ethane	\$/gal	0.19	0.49	0.60	0.04
propane	\$/gal	0.41	0.72	0.87	0.10
isobutane	\$/gal	0.66	0.64	0.93	0.40
n-butane	\$/gal	0.66	0.64	0.93	0.25
gas condensate	\$/gal	1.06	1.25		0.90



# Estimated Ethane Supply and Announced Demand



August 2015 it is estimated that 350 MBPD was rejected — the announced demands/off takes will provide a relevant "frac" spread for the Appalachian Basin with the majority of ethane leaving the region (Europe, Texas, Canada)

### Appalachia to Texas (ATEX) Express Pipeline



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### Utica Marcellus Texas Pipeline (UMTP)



![](_page_29_Picture_2.jpeg)

# New Outlets Needed for Appalachian NGLs

- Appalachian growth projections exceed planned local fractionation capacity by 2016
- Achieving MTBV pricing, liquidity, and connectivity for all products can only be achieved on UMTP

C3+ Available			12	43	92	128	161
Fractionation	300	300	320	335	335	335	335
Supply	169	263	332	378	427	463	496
C3+ Analysis	2014	2015	2016	2017	2018	2019	2020

- Producers will only recover ethane to the extent they:
  - Reach the ethane spec limits on the gas pipelines
  - Achieve value higher than gas price (rejection economics)
  - Have contractual obligations to ethane pipes
- Appalachian producers can only achieve Mont Belvieu pricing for ethane via ATEX, UMTP

C2 Analysis	2014	2015	2016	2017	2018	2019	2020
Supply	177	278	350	400	452	490	525
Takeaway	118	131	154	236	301	301	301
C2 Rejection	59	147	196	164	151	189	224

![](_page_30_Picture_10.jpeg)

From: Kinder Morgan

# U.S. NGL Supply Potential Assuming Sufficient Markets (MBPD)

![](_page_31_Figure_1.jpeg)

\* Current is increased by 200-250 MBPD for estimated ethane rejection

Source: EPD Fundamentals

# **Tri-State Shale Summit**

#### • WV, PA, and OH

- Governors signed collaboration agreement

- Infrastructure
- Research
- Workforce Development
- Publicity and Marketing
- http://www.tristateshalesummit.com/

![](_page_32_Picture_8.jpeg)

![](_page_32_Picture_9.jpeg)

![](_page_32_Picture_10.jpeg)

October 13, 2015

![](_page_32_Picture_12.jpeg)

#### Petrochemical & Downstream Manufacturers within 400 Miles: <u>17,477</u> Companies

![](_page_33_Figure_2.jpeg)

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# Existing and proposed supply and demand for NGLs

#### Shell Chemical Co.

Youngstown

![](_page_34_Figure_2.jpeg)

![](_page_34_Picture_3.jpeg)

![](_page_35_Figure_0.jpeg)

![](_page_35_Picture_1.jpeg)

# Operating underground and aboveground U.S. HGL storage facilities

![](_page_36_Figure_1.jpeg)

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Source: U.S. Energy Information Administration, compiled from Sulpetro LPG Almanac and U.S. Department of Energy, National Energy Technology Laboratory, <u>Cavern Roof Stability for Natural Gas</u> <u>Storage in Bedded Salt</u>, with permission.

# The Appalachian Basin Ethane Storage Study

A Project of the Appalachian Basin Oil & Natural Gas Research Consortium

National Research Center for Coal & Energy, West Virginia University State Geological Surveys in Ohio, Pennsylvania and West Virginia

CLAUDE WORTHINGTON BENEDUM FOUNDATION

With thanks to the conditional support from the Claude Worthington Benedum Foundation

![](_page_37_Picture_5.jpeg)

# Appalachian Basin Ethane Storage Study

- Geologic investigation of potential subsurface storage options for liquid ethane in a broad geographic area
- Study area is essentially along the Ohio River, starting in Pennsylvania and ending in southern West Virginia and eastern Kentucky
- Proposed project is a critical step in the overall process to build a subsurface storage facility adjacent to a "6-pack" pipeline, one to transport liquid ethane

![](_page_38_Figure_4.jpeg)

The goal of this project is to provide essential data to support of the development the chemical manufacturing industry, promoting economic development

![](_page_38_Picture_6.jpeg)

#### Stratigraphic Units to be Investige lifton Forge Ss Heiderberg West Virginia Keyser Fm Бген

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- Greenbrier Limestone •
- Salina salt beds
- Mississippian sandstones • (Keener to Berea)
- Upper Devonian sandstones (Bradford, Venango, Elk)
- **Oriskany Sandstone**
- Clinton Medina through • **Tuscarora Sandstone**
- Upper Sandy Member of the **Gatesburg Formation**
- Rose Run Sandstone

![](_page_39_Figure_9.jpeg)

Tonoloway Ls

Wills Creek Fm

Newburg Ss

cefer Sandstone

Cacapon 5s

Tuscarora

Sandstone

Chambersburg

Group

nesburg Statio

Fm

Rockdale Run Fm

Stonehenge Ls

Stouffentown Group

![](_page_39_Picture_10.jpeg)

# **Types of Potential Ethane Storage**

- Solution mining to create large cavities in Salina salt beds
- Subsurface excavation to create large mines in Greenbrier Limestone
- Injection into depleted gas fields with good porosity & permeability
- Vertical & lateral seals essential for each option

![](_page_40_Figure_5.jpeg)

Schematic Illustration of a Solution-Mined Storage Cavern in Bedded Salt

![](_page_40_Picture_7.jpeg)

# Appalachian Storage Hub Work Plan

- Data collection (well logs & cores); database creation
- Stratigraphic correlation of key lithologic units
- Map the thickness, extent & structure of key lithologic units
- Conduct studies of reservoir character and storage potential of key lithologic units
- Develop ranking criteria for potential storage zones
- Make final recommendations for the ethane storage hub location

![](_page_41_Figure_7.jpeg)

Generalized distribution and thickness of Salina salt beds (modified in part from Fergusson and Prather, 1968; Griggs, 1958; Sanford, 1965; and Rickard, 1969

# Conclusion

- There is an abundance of natural gas (containing NGLs) in the shales of WV, PA, and OH
- The Appalachian Basin provides 1) access to markets, and 2) a competitive pricing advantage due to the abundance of valuable (yet currently underpriced) hydrocarbons
- Ethane storage is key to the development of a robust NGLs trading post, i.e. a spot market essential to further development of the chemical manufacturing industry in this region
- Businesses developing Marcellus, Utica, Rogersville will benefit from significant infrastructure investments in the region
- A storage facility will be tied into the overall play via massive piping infrastructure
- Would tie Monaca, PA, through the Ohio River valley, to Catlettsburg's refinery, with a tee to the Kanawha Valley
- Would include main trunks for methane, ethane, ethylene, propane, propylene, and chlorine
- The region would benefit from infrastructure development to satisfy the feedstock and offtake requirements for world scale and/or distributed manufacturing elements

![](_page_42_Picture_9.jpeg)

![](_page_43_Picture_0.jpeg)

![](_page_43_Picture_1.jpeg)

### The WVU Energy Institute

The Institute's mission is to coordinate and promote University-wide energy research in engineering, science, technology, and policy.

With an emphasis on Fossil Energy Coal, Oil, and Natural Gas Sustainable Energy Biomass, Geothermal, Wind, and Solar Energy Policy Energy and Environmental Policy Environmental Stewardship Protecting our Air and Water Resources

![](_page_43_Picture_5.jpeg)

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