Project Closeout
Demonstration of Gas-Powered Drilling Operations for Economically Challenged Wellhead Gas and Evaluation of Complementary Platforms

Industrial Commission of North Dakota
Oil and Gas Research Council

Oil and Gas Research Council Meeting

August 20, 2013

Chad Wocken

Project Sponsors:
ND Industrial Commission Oil and Gas Research Council, U.S. Department of Energy, National Energy Technology Laboratory and Continental Resources

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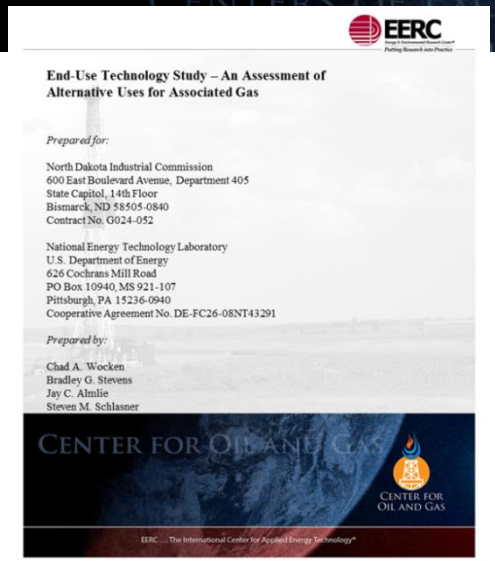
Evaluation of Associated Gas Use


EERC

End-Use Technology Study – An Assessment of Alternative Uses for Associated Gas

Prepared for:

North Dakota Industrial Commission
600 East Boulevard Avenue, Department 405
State Capitol, 14th Floor
Bismarck, ND 58505-0840
Contract No. G024-052

National Energy Technology Laboratory
U.S. Department of Energy
626 Cochrans Mill Road
PO Box 10940, MS 921-107
Pittsburgh, PA 15236-0940
Cooperative Agreement No. DE-FC26-08NT43291

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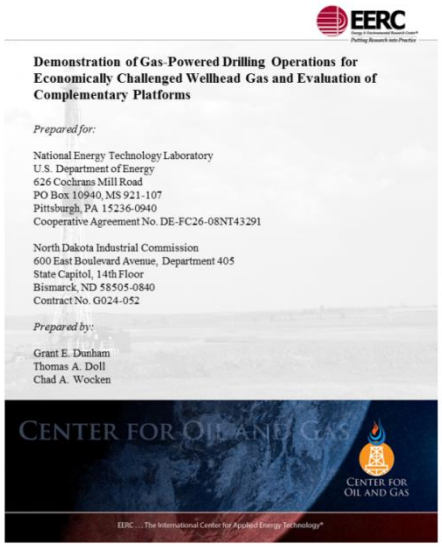
CENTER FOR OIL AND GAS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Prepared by:

Grant E. Dunham
Thomas A. Doll
Chad A. Wocken

CENTER FOR OIL AND GAS

1. Associated Gas Alternative Use Study – analysis of gas use options upstream of gas-processing plants
   - Small-scale gas processing
   - CNG/LNG for vehicles
   - Electric power production
   - Chemical production
2. Bifuel Rig Demonstration – assessment of fuel savings and operational impacts of associated gas–diesel mix

EERC Study and Final Project Report
www.undeerc.org/Bakken/researchstudies.aspx

Total Project Expenditures

Sponsor	Contribution	% of Total
North Dakota Industrial Commission Oil and Gas Research Council	$750,000	49.5
U.S. Department of Energy National Energy Technology Laboratory	$400,000	26.4
Continental Resources	$364,794	24.1
Total	$1,514,794	100.0

Time Line

Associated gas alternative use study:
September 2011 – September 2012

Testing of Bi-Fuel technology at EERC pilot:
November 2011 – May 2012

Field demonstration of Bi-Fuel at Continental drilling location: July 2012 – October 2012

Final report preparation and presentation at Williston Basin Petroleum Conference:
November 2012 – April 2013

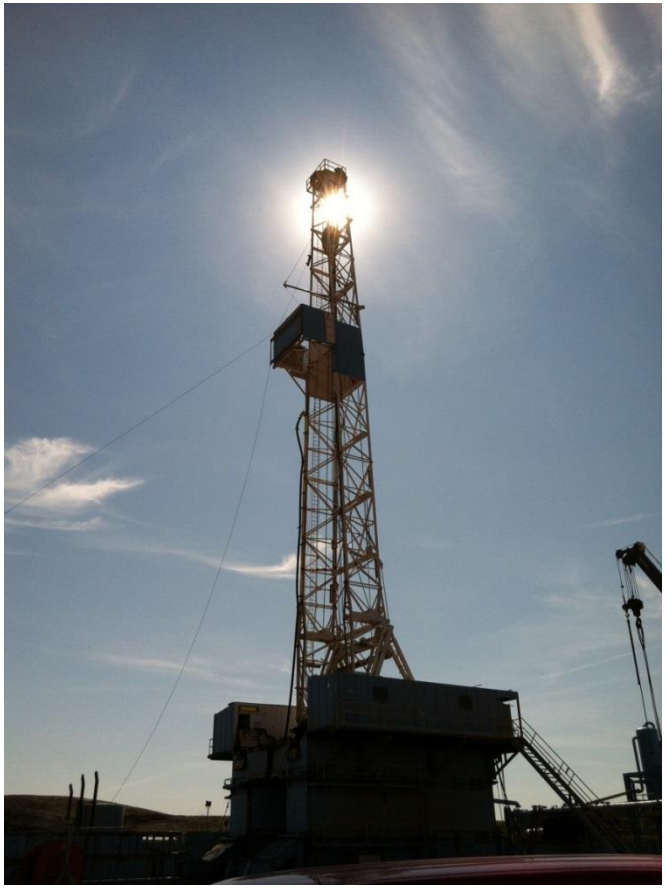
Project Partners

Funding Partners:

North Dakota Industrial Commission Oil and Gas Research Council, U.S. Department of Energy National Energy Technology Laboratory, and Continental Resources

Project Participation:

North Dakota Pipeline Authority
Cyclone Drilling
ECO-Alternative Fuel Systems
Altronic
Butler Machinery Co.

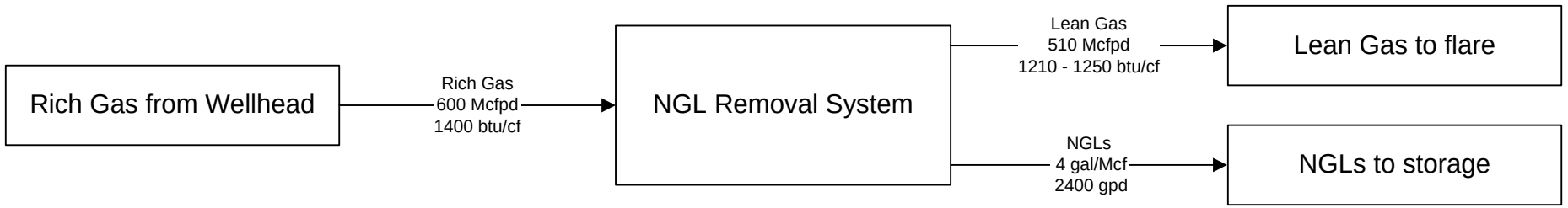


Background
Gas Utilization Study

- The focus of the study was on flared associated gas in the Williston Basin (primarily produced from the Bakken Formation).
- The intent of the study was to assess the technical viability of technologies utilizing associated gas at locations upstream of traditional gas-processing plants and define economic conditions that would enable commercial deployment.
  - Define unutilized gas resource in the Williston Basin
  - Identify natural gas use options that match quality and quantity of gas
  - Identify distributed-scale gas cleanup technologies
  - Find uses tolerant of moisture or NGLs
  - Assess economic conditions that could lead to viable uses

Small-Scale NGL Recovery

- Rich-gas flow rate from wellhead; average = 300 Mcf/day
- Rich-gas flow rate from wellhead; economic cutoff = 600 Mcf/day
- Rich-gas flow rate from wellhead; design flow = 1000 Mcf/day
- Rich-gas heat content = 1400 Btu/cf (10–12 gallons of NGLs)
- Lean-gas flow rate = 85% of rich-gas flow rate
- Lean-gas heat content = 1210–1250 Btu/cf
- NGL recovery rate = 4 gallons/Mcf



Small-Scale NGL Economics

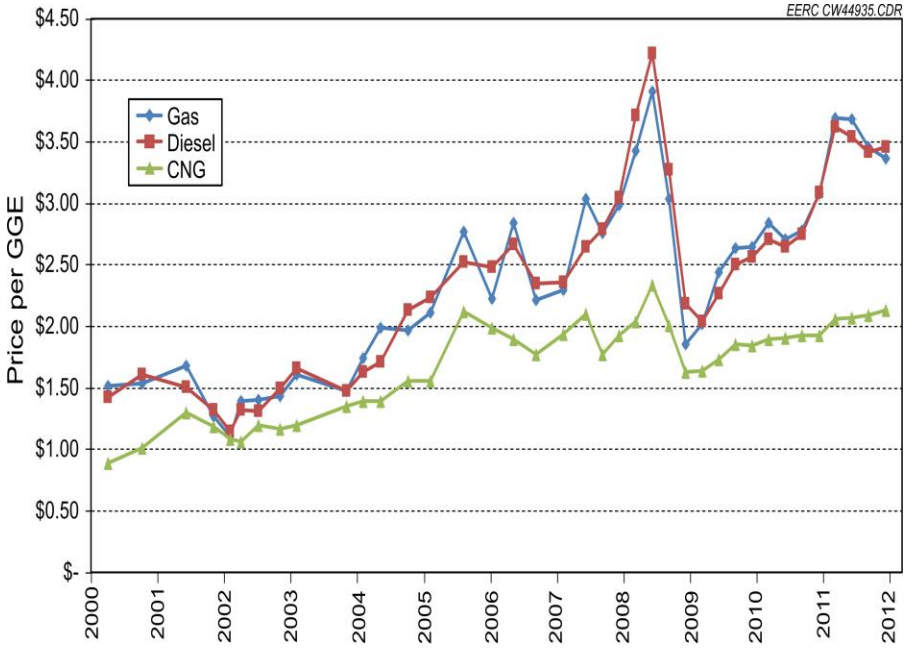
- Assumptions
  - Value (cost) of rich gas at the wellhead = $0.00/Mcf
  - Value of lean gas = flared
  - Value of NGLs = $1.00/gallon
  - Annual O&M = 10% of CAPEX
- Results
  - CAPEX = $2,500,000
  - Annual O&M = $250,000
  - Annual revenue (NGL only)

    $700,800 (600 Mcf/day rich-gas flow rate)

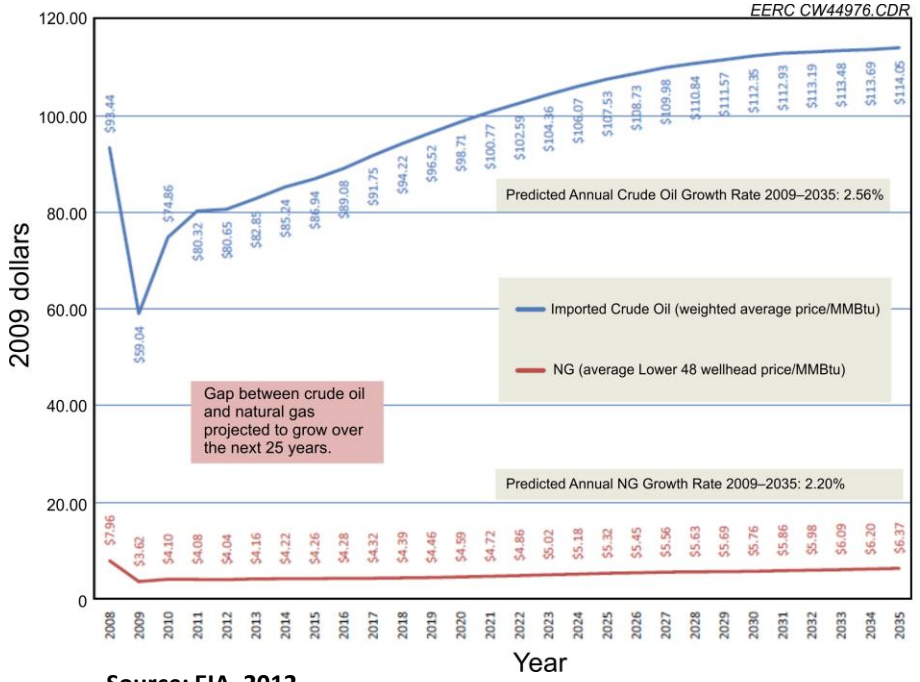
    $1,168,000 (1000 Mcf/day rich-gas flow rate)

CNG/LNG for Vehicles

- A disconnect exists between pipeline gas quality and required CNG fuel quality standards.
- The opportunity for CNG exists as a diesel displacement fuel because of the price differential between natural gas and diesel fuel.



Source: Alternative Fuels and Advanced Vehicles Data Center, 2012



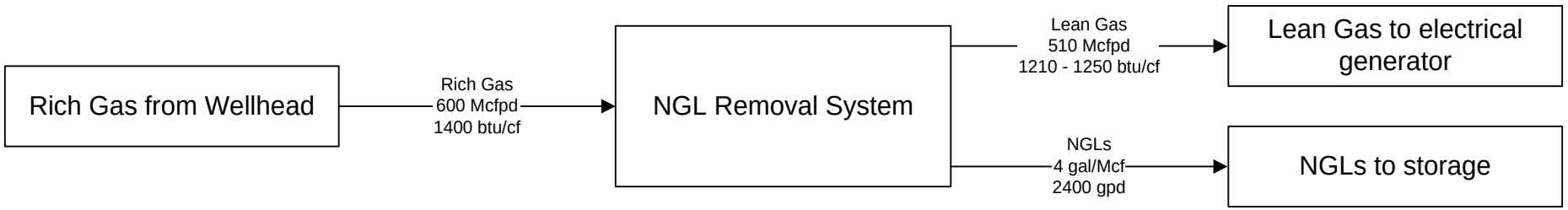
Source: EIA, 2012

CNG Economics
Heavy-Duty Scenario

- Assumptions
  - Value (cost) of rich gas at the wellhead = $0.00/Mcf
  - Value of lean gas (CNG quality) = $1.89 GGE
  - Price of diesel = $3.65 GGE
  - Value of NGLs = $1.00/gallon
  - Annual O&M = 10% of CAPEX
- Results
  - CAPEX = $3,900,000
  - Annual O&M = $390,000
  - Annual NGL revenue $700,800 (600 Mcf/day rich-gas flow rate)
  - Annual fuel savings versus diesel $306,000 (1-million mile/yr fleet, 15% lean gas use)

Electric Power Generation

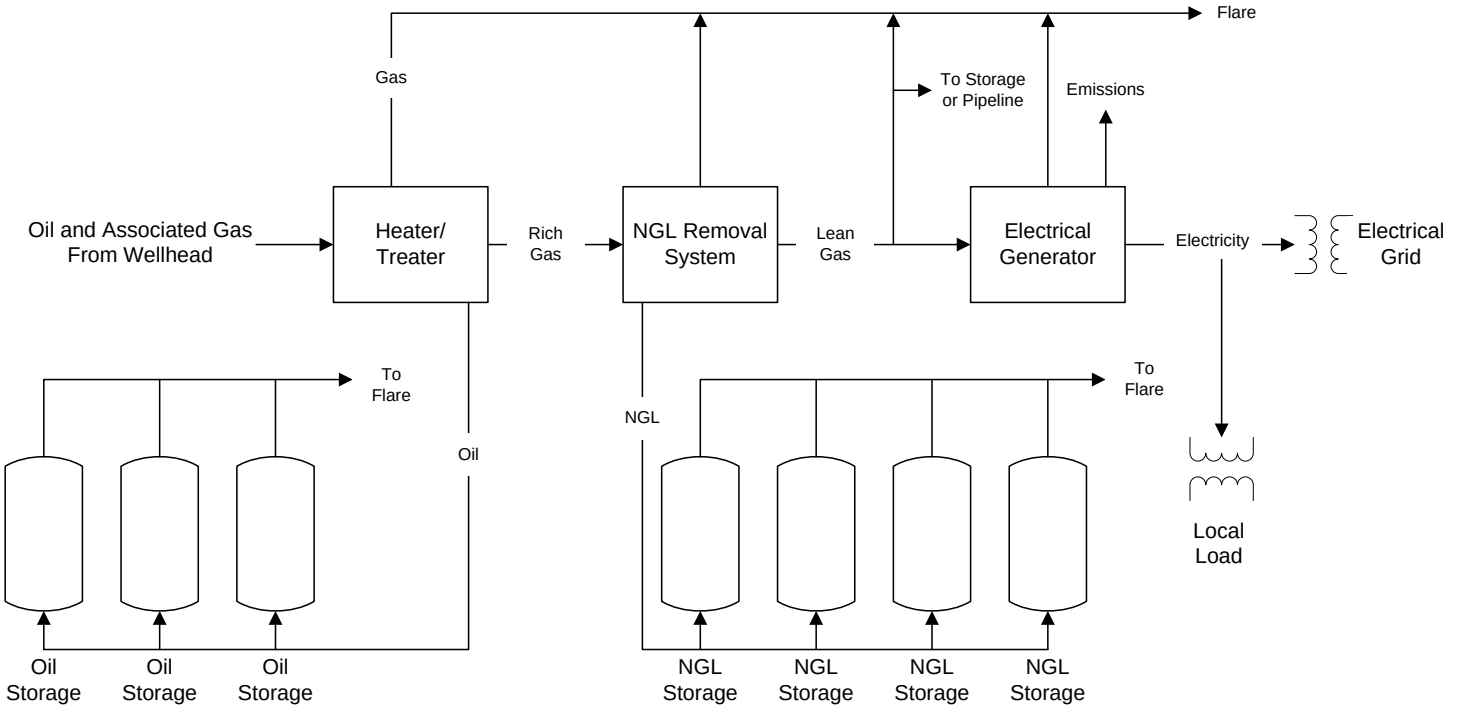
Scenario	Rich-Gas Flow, Mcf/day	NGLs Produced, gallons/day	Lean-Gas Produced, Mcf/day
Grid Support – Reciprocating Engine	1000	4000	850
Grid Support – Gas Turbine	1800	7200	1530
Local Power – Reciprocating Engine	600	2400	510
Local Power – Microturbine	600	2400	510



Electric Power Generation Economics

Scenario	Capital Cost	Annual O&M Cost	NGL Revenue[1]	Electricity Revenue[1]	Lean-Gas Revenue[1]	Annual Revenue[1]
Grid Support – Reciprocating Engine	$7,500,000	$650,000	$1,168,000	$1,664,400	$0	$2,832,400
Grid Support – Gas Turbine	$9,900,000	$890,000	$2,102,400	$2,049,840	$0	$4,152,240
Local Power – Reciprocating Engine	$3,200,000	$270,000	$700,800	$157,680	$291,416	$1,149,896
Local Power – Microturbine	$3,383,200	$283,640	$700,800	$122,932	$269,224	$1,092,956

[1] Assumes 80% annual system availability.



Chemicals

- North American petrochemical industry is located in areas with:
  - Large gas reserves
  - Geologic storage
  - Manufacturing facilities to produce chemical intermediates and finished products
  - Export terminals
- Chemical processes to make nitrogen-based fertilizer may have promise
  - Large agricultural base
  - Stranded gas

Small-Scale Fertilizer Economics

Ammonia Production Cost Estimate at Different Scales and Rates

	Large Unit	Small Unit
NG Feed Rate, Mcfd	2000	320
Capacity, ton/day	90.1	14.4
Production, ton/year	31,227	4,996
Utilization Rate, %	95	95
Fixed Capital Investment, $	52,389,617	17,385,099
Product Cost ($0 rich gas), $/ton	305.71	517.56
Product Cost ($4 rich gas), $/ton	395.71	607.56
Product Cost ($8 rich gas), $/ton	485.71	697.56

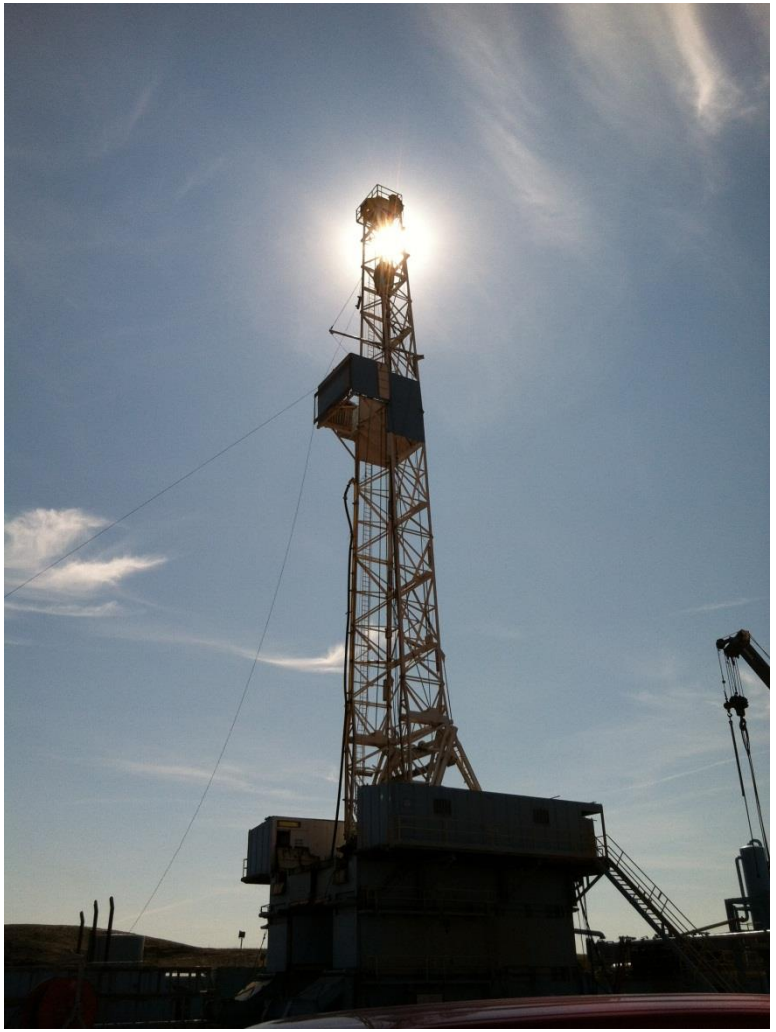
Qualitative Summary of Evaluated Technologies

Technology	Gas Use Range, Mcfd	NGL Removal Requirement	Scalability to Resource	Ease of Mobility	Likelihood of Deployment at Small Scale
Power – Grid Support	1000–1800	Minimal	Very scalable	Very easy	Very likely
Power – Local Load	300–600	Minimal	Very scalable	Very easy	Very likely
CNG	50+	Yes	Scalable	Very easy	Possible
Chemicals	1,000,000*	No	Not scalable	Not mobile	Very unlikely
Fertilizer	300–2000	No	Scalable	Not easy	Possible

* Typical commercial-scale plant.

A Use for Flared Natural Gas

- Power production for drilling rigs using a mixture of associated gas and diesel provides a near-term opportunity for gas use.
- Drill rigs are typically powered by three large diesel generators.
- Diesel engines properly outfitted with bifuel systems can utilize a mixture of diesel and natural gas.
- Significant fuel savings can be achieved because of the price differential between diesel and natural gas.
  - 30%–60% reduced fuel costs
  - Reduced fuel delivery and associated traffic, engine emissions, and fugitive dust



Testing at the EERC Using Simulated Gas Findings

- Testing at the EERC using simulated Bakken gas
  - Diesel replacement rates from 0% to 70%
  - Engine operation at 10%–100% of full load
  - Various amounts and combinations of NGLs
- Diesel engines can run on wellhead gas, but the replacement rate is limited because of the potential for engine knock. Up to 50% diesel replacement achieved.
- Using rich gas at higher diesel replacement rates and heavy load conditions, there was a slight increase in ignition delay and peak cylinder pressure and associated engine vibration.

Summary of Results

- Diesel fuel consumption reduced by 18,000 gallons for two wells. A period of 47 days.
- Fuel-related net cost savings of nearly $60,000.
- Reduced delivery truck traffic.
- Beneficial use of wellhead gas.
- Reduced NO emissions and increased CO and HC emissions compared to diesel-only operation. Mitigation achievable with exhaust gas treatment.
- Seamless engine operation using the GTI Bi-Fuel® system.

Impact of Widespread Use

- Nearly 200 drilling rigs in operation at any given time
- 1,800,000 Mcf of wellhead gas used per year
- 18,000,000 gallons of diesel fuel saved per year
- $72,000,000 diesel fuel cost saved per year
- 3600 fuel deliveries avoided per year

Deliverables

- Topical Reports:
  - Summary of pilot-scale testing of Bi-Fuel technology, May 2012
  - “End-Use Technology Study – An Assessment of Alternative Uses for Associated Gas,” September 2012
- Presentations:
  - NDPA Webinar, November 5, 2012, “EERC Associated Gas Use Study”
  - NDPA Webinar, February 27, 2013, “Use of Associated Gas to Power Drilling Rigs”
  - Williston Basin Petroleum Conference, May 2, 2013, “Utilization of Associated Gas to Power Drilling rigs – A Demonstration in the Bakken”
- Final project report:
  - “Demonstration of Gas-Powered Drilling Operations for Economically Challenged wellhead Gas and Evaluation of Complementary Platforms,” April 2013

Contact Information

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