



EPA Natural Gas STAR Production Workshop
February 11, 2014
Denver, Colorado

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Corporate Environmental Programs



Development Solutions
Balancing Environment, Community & Economy
a division of Southwestern Energy

SWN Geographic Areas of Operation



Exploration and Production Segment

2011:
 5,893 Bcfe of proved reserves
 ~100% natural gas
 500.0 Bcfe of production
 4,552 gross producing wells

2012 est. production:
 560 - 570 Bcfe

Denver Julesburg Basin

Acreage: 290,000 net acres (6/30/12)

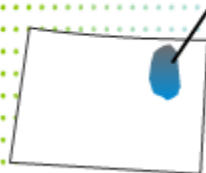
New Brunswick

Acreage: 2.5 million net acres



Fayetteville Shale

Acreage: 925,842 net acres (at 12/31/11)
 2011 Reserves: 5,104 Bcfe (87% of total)
 2011 Production: 436.8 Bcfe (87% of total)

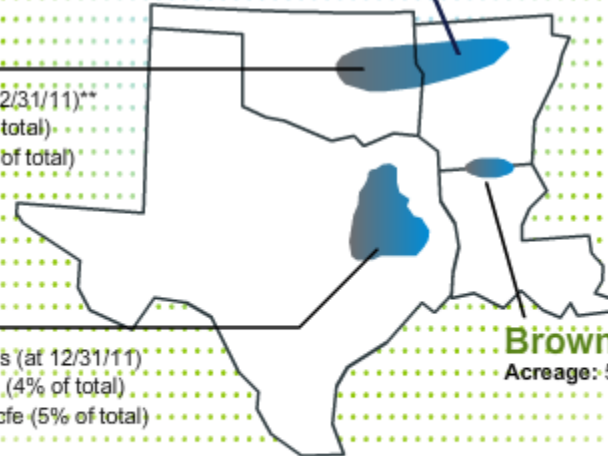


Arkoma Basin

Acreage: 194,494 net acres (at 12/31/11)**
 2011 Reserves: 194 Bcfe (3% of total)
 2011 Production: 16.3 Bcfe (3% of total)

Marcellus Shale

Acreage: 186,893 net acres (at 12/31/11)
 2011 Reserves: 342 Bcfe (6% of total)
 2011 Production: 23.4 Bcfe (5% of total)



East Texas

Acreage: 91,082 net acres (at 12/31/11)
 2011 Reserves: 253 Bcfe (4% of total)
 2011 Production: 23.5 Bcfe (5% of total)

Brown Dense

Acreage: 563,000 net acres (at 6/30/12)

**Conventional Arkoma acreage excludes 125,056 net acres in the conventional Arkoma Basin operating area that are also within the company's Fayetteville Shale focus area.

SWN – Vertically Integrated Company



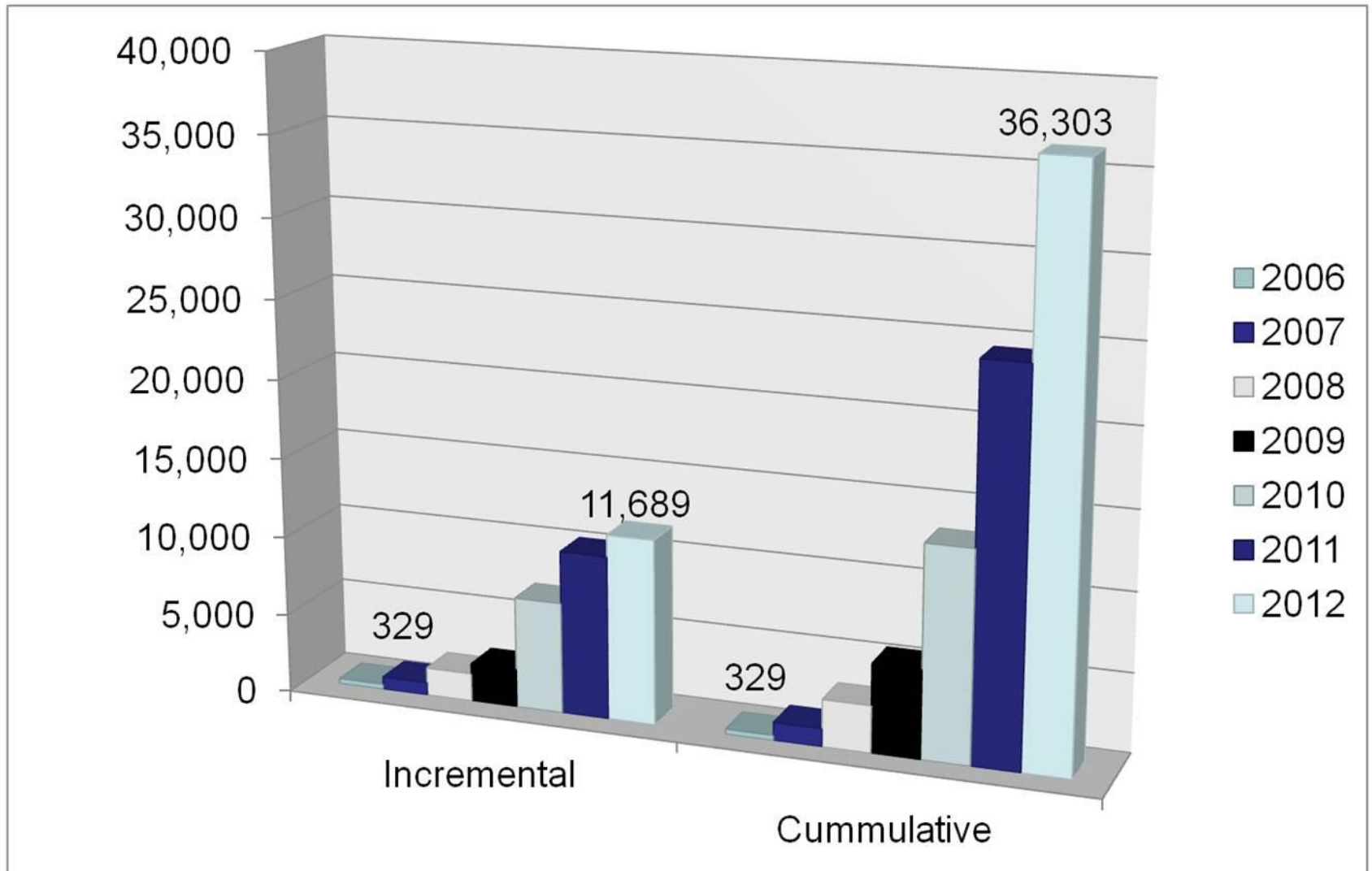
- SEECO
 - Fayetteville and Arkoma (Arkansas)
- Southwestern Energy Production Company
 - Pennsylvania
 - Texas, Louisiana, Oklahoma
 - SWN Drilling Company, Inc.
- SWN E&P Services L.L.C.
 - Desoto Sand L.L.C.
 - SWN Well Services L.L.C.
- SWN Resources Canada Inc.
- Desoto Gathering Company
- Angelina Gathering Company



- 2006 Initial Reporting Year - 329.266 MMSCF
- 2007 “Rookie of the Year”
- 2011 “Production Partner of the Year”
- 2012 Report
 - 11.689 BCF
 - 36.3 BCF Cumulative



SWN EPA Natural Gas STAR Reductions



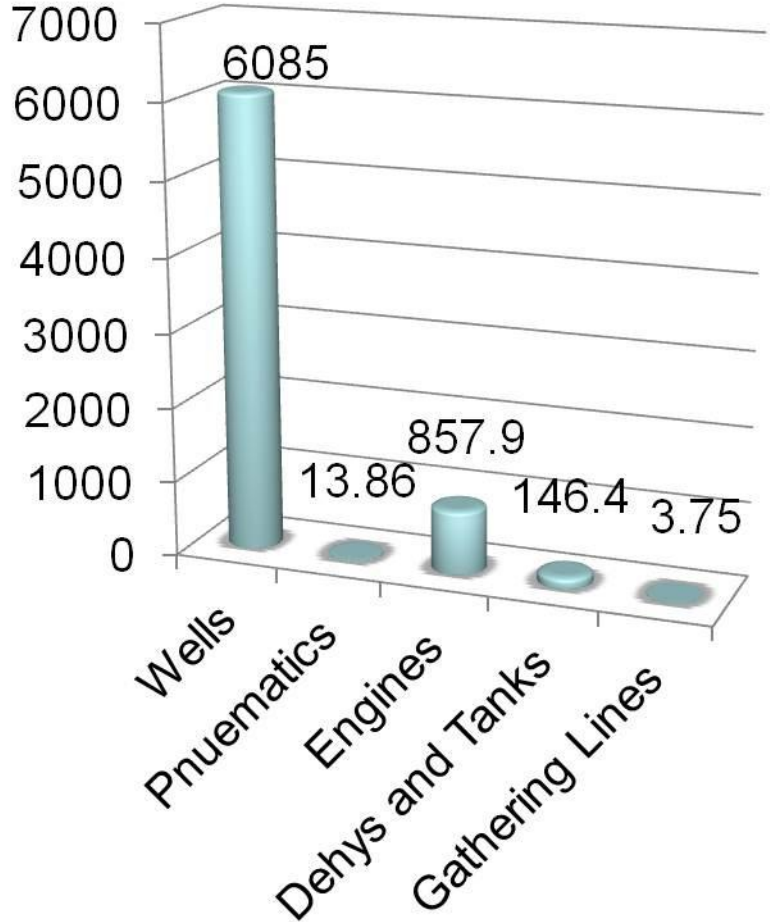


- Regulated by OOOO
 - Hydraulically Fractured Gas Well Completion Flowbacks
 - Hydraulically Fractured Gas Well Recompletion Flowbacks
 - **Continuous Bleed** Pneumatic Controllers
 - Oil, Condensate, and Produced Water Storage Tanks
 - Reciprocating Compressor (not at wellpad)

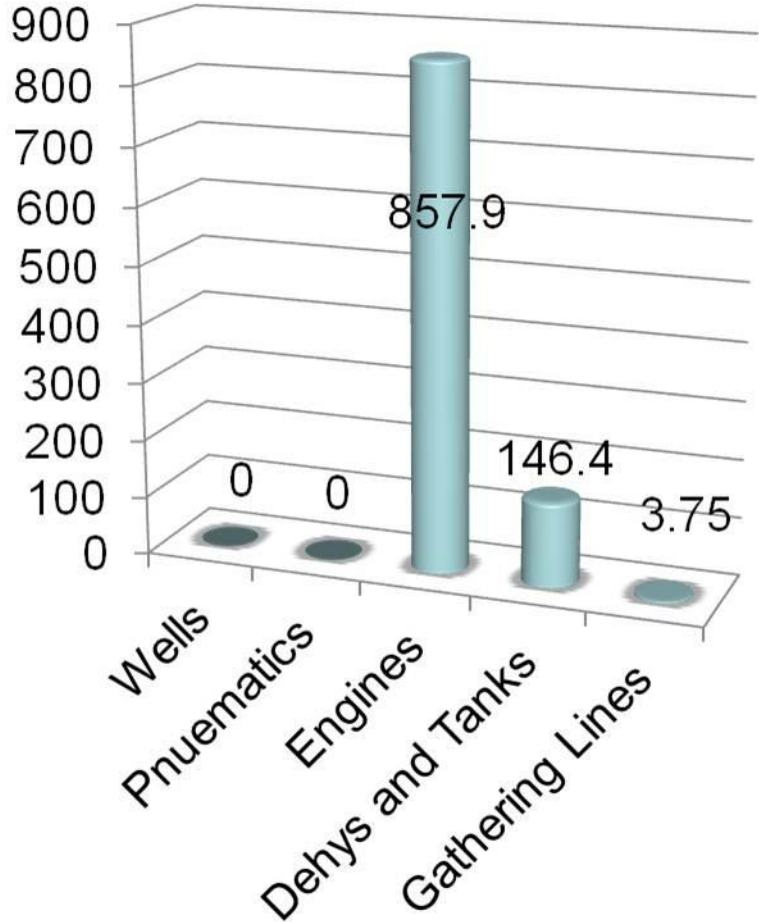
Pre and Post NSPS OOOO



2010 STAR



2010 - OOOO





- **Future Opportunities**

- Reciprocating compressors at well pad
- No bleed pneumatics
- Solar Powered pumps
- Thermostat controllers
- Liquids Unloading
- Storage Tanks < 6 tpy
- Gas capture of blowdowns
- Fleet and vehicle conversions to CNG
- Diesel/Gas Drill Rigs
- Diesel/Gas Frac Spreads (Completions pumps)
- Directed Inspection/Maintenance
- Fuel cells for power generation (air compressors)

SWN Gas Capture



- Since 2009 - 27.562 BCF recovered by Gas Capture and Green Completions



SWN Gas Capture: History - Background



- **Pre 2010**: Wells vented until tubing flow could be established
- **September 2009**: Study concluded **16 MMCF** is vented during an average flowback
- **December 2009**: **Completion program changed. Tubing run immediately after frac plug drill out, no casing flowback**
- **December 2009**: **Flowback scheme “modified”** to allow selling gas via the casing/tubing annulus
- **January 2010**: **Separators upgraded**, allowing for 2000+ bwpd capability, “modified” flowback in full use
- **January 2010**: First “Gas Capture” well was executed
- **April 2010**: Completed 19th full “Gas Capture” operation
- **September 2010**: Completed the 100th full “Gas Capture” operation
- **October Forward**: Expanded “Gas Capture” to recompletions or “Ventless Restoration

SWN "Gas Capture"



SWN Gas Capture - Portable Compressor



- Portable Caterpillar 3406
- 200-300 MCF Gas Compressed
- 8-12 Hours
- Target 2000 psi

SWN Gas Capture -Sand Separator and Sand Box



SWN Gas Capture - Flowback Water to Frac Tank



SWN Gas Capture - Water Recovery/Recycling



SWN Gas Capture - Fat Boy Separators



SWN Gas Capture - Updated Gas Capture Layout



SWN Gas Capture – Fayetteville vs Marcellus



- Fayetteville

- Low pressure reservoir
 - Need for gas compression/injection
- Low sales line pressure ~65 psia



- Marcellus

- High pressure reservoir
- High sale line pressure >500 psi
- Installing additional compression to lower line pressure



- Natural Gas System Methane Emission Measurements
 - Production Sector
 - Gathering & Processing Sector
- SWN Leak Detection and Monitoring
 - SWN SMART LDAR
 - Picarro Monitoring Evaluation
 - Methane Monitoring Projects
- SWN Methane Reduction Projects

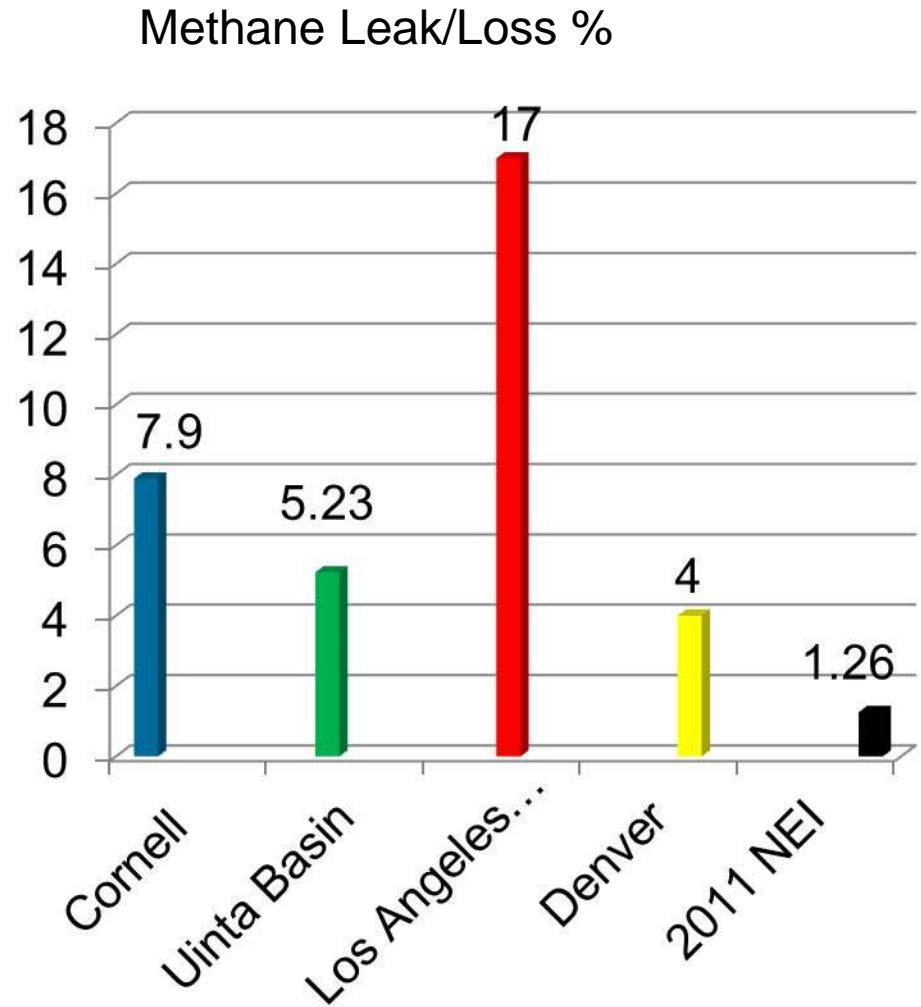
Natural Gas System Methane Emission Measurements



Why?



- Need for more accurate and factual methane emissions data
 - Limited or no methane emissions measurements for industry
 - Outdated emissions factors (GRI 1996).
 - EPA and NEI estimates vary in order of magnitude due to changes in assumptions
- Better understanding of methane emissions and sources
- Demonstrate that natural gas is natural fuel of choice



“Measurements of Methane Emissions at Natural Gas Production Sites in the United States”



- A Unique Partnership
 - Sponsors were an environmental group and nine natural gas producers Environmental Defense Fund (EDF), Anadarko Petroleum Corporation, BG Group plc, Chevron, Encana Oil & Gas (USA) Inc., Pioneer Natural Resources Company, SWEPI LP (Shell), Southwestern Energy, Talisman Energy USA, and XTO Energy, an ExxonMobil subsidiary
 - Study team Led by University of Texas and including URS and Aerodyne Research
 - Scientific Advisory Panel Six university faculty with expertise in air quality and natural gas production



- Direct Measurements
 - “Stack” measurements (flowbacks and unloadings)
 - FLIR Camera (observation of leak)
 - HiFlow (measurement of leak)
- Direct Measurement Sources/Activities
 - Completion Flowbacks
 - Production Sites
 - Chemical Pumps
 - Pneumatic Controllers
 - Equipment Leaks (valves, flanges, open ended lines)
 - Liquids Unloadings (limited)
 - Workovers (limited)

UT Study Results – Phase 1



Source	EPA National Inventory	UT Study Observations
Completion Flowbacks	654 Gg CH ₄	18 Gg CH ₄
Chemical Pumps	34 Gg CH ₄	68 Gg CH ₄
Pneumatic Controllers	355 Gg CH ₄	580 Gg CH ₄
Equipment Leaks	172-211 Gg CH ₄	291 Gg CH ₄
Measured Sources	1215-1254 Gg CH ₄	957 Gg CH ₄
Total Emissions Estimates	2,545 Gg CH ₄	2300 Gg CH ₄

Production Sector Study Methane Measurement Summary



- Direct, on-site measurements of methane emissions from gas production operations were made; for some sources (well completions and unloadings) these are the first measurements reported.
- 67% of the hydraulically fractured well completions sampled during the study had equipment in place that reduces methane emissions by 99%. Because of this equipment, methane emissions from well completions are 97% lower than calendar year 2011 national emission estimates, released by EPA in April 2013.
- Emissions from pneumatic devices are 70% higher than current EPA net emissions estimates, and equipment leaks are 50% higher than current EPA net emission estimates; collectively these emissions account for more than 40% of methane net emissions from natural gas production.
- Methane emissions from gas production, from all sources measured in the study, were comparable (957 Gg \pm 200 Gg) to the most recent EPA estimates (~1200 Gg).
- The 957 Gg in emissions for completion flowbacks, pneumatics and equipment leaks, coupled with EPA national inventory estimates for other categories, leads to an estimated 2300 Gg of methane emissions from natural gas production (0.42% of gross gas production).



- Project Highlights:
 - Successful collaboration between participants resulting in better understanding of emissions
 - Identified the need for additional studies
 - Identified opportunities for SWN to pursue regarding emission reduction/product recovery
 - Catalyst for SWN LDAR initiative
 - One of the pillars for the foundation of SWN's Methane Leadership Initiative

Production Sector Phase 2 Measurements



- Phase II – Emphasis
 - Pneumatic Controllers
 - Liquids Unloading
- Phase II - Participants
 - University of Texas
 - URS
 - Environmental Defense Fund
 - Anadarko
 - British Gas
 - Chevron
 - Conoco Phillips
 - Encana
 - Pioneer
 - Shell
 - Southwestern Energy
 - Statiol
 - XTO-Exxon



Gathering and Processing Methane Measurement



- Colorado State University
 - Aerodyne
 - Carnegie Mellon University
 - Environmental Defense Fund
 - Anadarko
 - Access Midstream
 - Williams
 - SWN
 - Hess
 - DCP (data site)
- Tracer Flux Measurements



SWN Leak Detection and Monitoring





- Company-wide program
 - New wells and compressor stations in Pennsylvania 8/10/2013
 - New wells commencing operation 4th Quarter 2013
 - New and existing wells and compressor stations 2014
- Identify equipment leaks
 - Annual Survey and confirm leak repair
 - Optical Imaging Camera (e.g. FLIR)
 - Primary targets
 - Valves, connectors, open-ended lines
 - Secondary targets
 - Pneumatic Controllers, Storage Tanks, Compressors
- Leak Repairs
 - Repair leaks ASAP but within 15 days (Delay of Repair exemption)
- Track and trend leaking components

- SWN project to compare Picarro monitoring with “direct measurement” (FLIR and HiFlow) to assess viability.
- Field measurements conducted November 4-8, 2013 in Fayetteville operations.



SWN Well Example



PICUBED

Prime User™

Picarro Surveyor™ for Natural Gas Leaks

Mon Nov 04 2013 07:26:46

CH4: 1.996 ppm Wind: 11.04 mph



Survey Mode

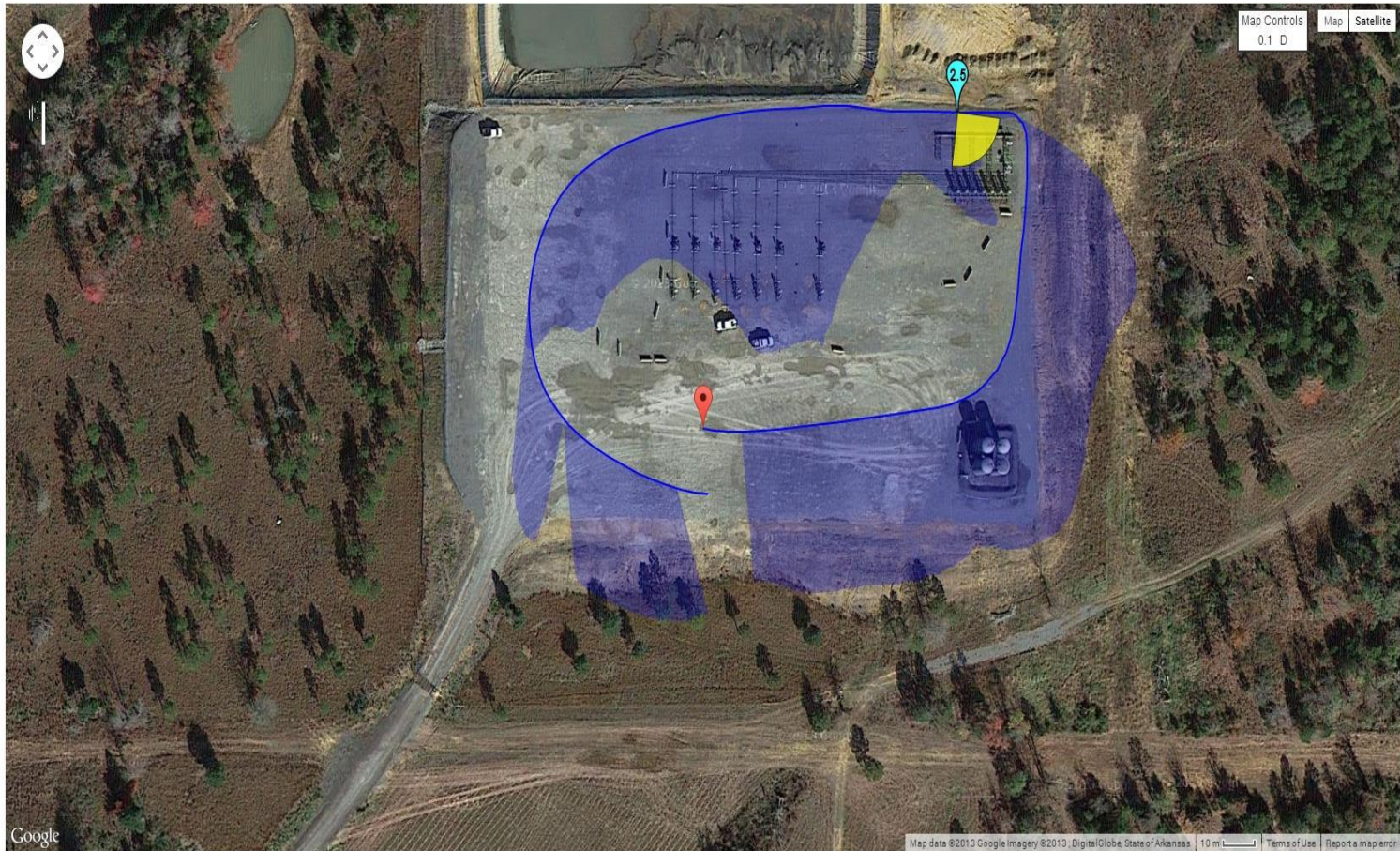
Stop Survey

Start Capture

Surveyor Controls

Select Surveyor

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- 1. Survey ~20 well pads with Picarro Surveyor technology and FLIR camera to determine if the well pads had methane leaks or not**
 - Surveyed 21 wells pads and 3 drill sites in ~17 hrs
- 2. Execute a simulated leak to directly compare the Picarro Scanner and high flow instrument leak measurements**
 - Picarro Scanner and high flow instrument measurements agree
- 3. Quantify the leaks at 5-6 well sites using both the Picarro Scanner technique and high flow instrument operated by Dexter.**
 - Due to limited road access and wind direction, only 2 well pads were measured with the Scanner technique
 - Only 1 well pad leak was measured by both the Plume Scanner (59.8 SCFH) and high flow instrument (79.2 SCFH)
 - We can estimate the leak rates of all pads surveyed using both high flow instrument and Picarro Scanner measurements

Main Results:

- 19% of well pads were *not leaking*
- 77% of leaks rates are less than 10 SCFH (standard cubic feet per hour)
- Direct comparison with a simulated leak show that Picarro Surveyor agree with Dexter's high flow instrument



SWN Methane Emissions Reduction Projects



- Fuel Cell

SWM Methane Reduction Projects



Pressure Actuated Liquids Unloading



Thermostat Actuated Chemical Addition





RIG 26 gets a perfect retrofit



Wellhead

This engine has the capability to run on LNG or CNG. However, we are pulling natural gas straight from the wellhead. This allows us to keep our wellpad footprint small and maintain low-cost rig moves.



Scrubber

Although the Caterpillar Dynamic Gas Blending Engine automatically adjusts to changing gas quality, natural gas flows through a scrubber first to remove dirt, water, foreign matter or undesired liquids.



Piping

Installation of piping needed on location to use this system is just one example of SWN teams working together through vertical integration to utilize and optimize our abilities and efficiencies.



Intake for Natural Gas

Just because this engine runs on natural gas doesn't mean it's short on power. Cranking at 1,200 revolutions per minute (rpm), the Caterpillar Dynamic Gas Blending Engine produces 885 horsepower running at 60 percent of its power-load capacity.

Southwestern Energy is proudly one of the first companies to implement a new natural gas powered engine in our drilling operations; we have successfully been using natural gas from the Fayetteville Shale to drill for gas in the Fayetteville Shale since June.

The recently deployed Dynamic Gas Blending Engine from Caterpillar allows us to generate the power we need to run the Rig 26 engine/generator set with a blend of natural gas and diesel, and seamlessly use traditional diesel methods when natural gas isn't available. At its maximum gas utilization, the engine will run on a 70 percent blend of natural gas and 30 percent diesel. This not only reduces our use of diesel, it lowers the amount of air emissions

we create during the drilling phase of our operations.

"I think it says something about who we are as a company. It makes a statement that we are so passionate about natural gas as a fuel source, that we are using our own product to power our operations," said Marty Carley, Vice President of SWN Drilling Company. "This is definitely SWN doing the Right Thing."

The longer we continue to utilize this technology, it will also provide significant cost savings. We are expecting a five month payback on the investment, and if you look at the current direct-cost comparison of using the two fuels, we are currently saving approximately \$2,000 per day.