

Adapting Low Environmental Impact Technologies from Oil & Gas Development

CONFERENCE

SMU

***Geothermal Energy and Waste Heat to Power:
Utilizing Oil and Gas Plays***

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March 2013

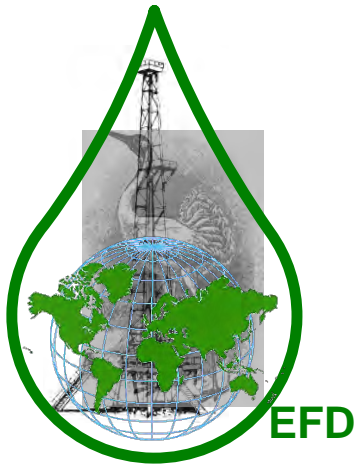


Harold Vance Department of
PETROLEUM ENGINEERING
TEXAS A & M UNIVERSITY

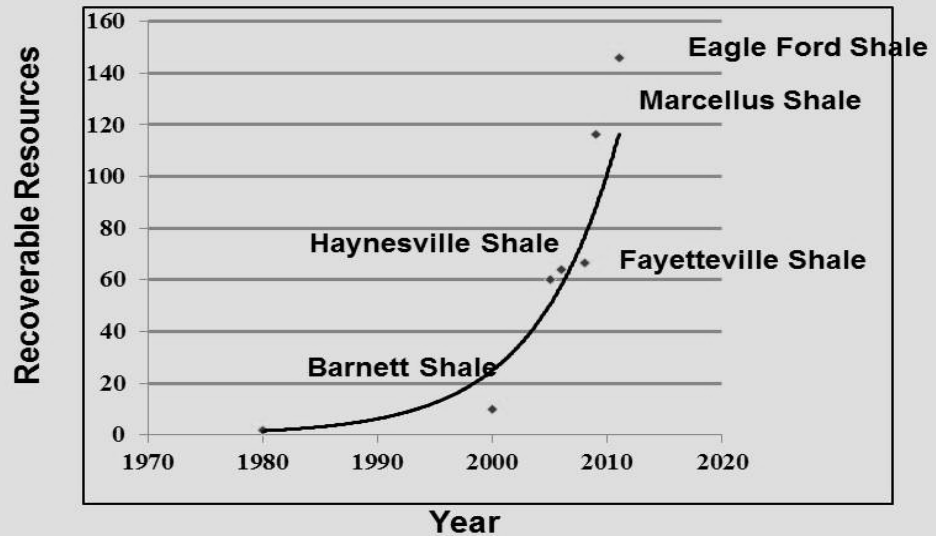
GPRI



How Innovation is Saving America

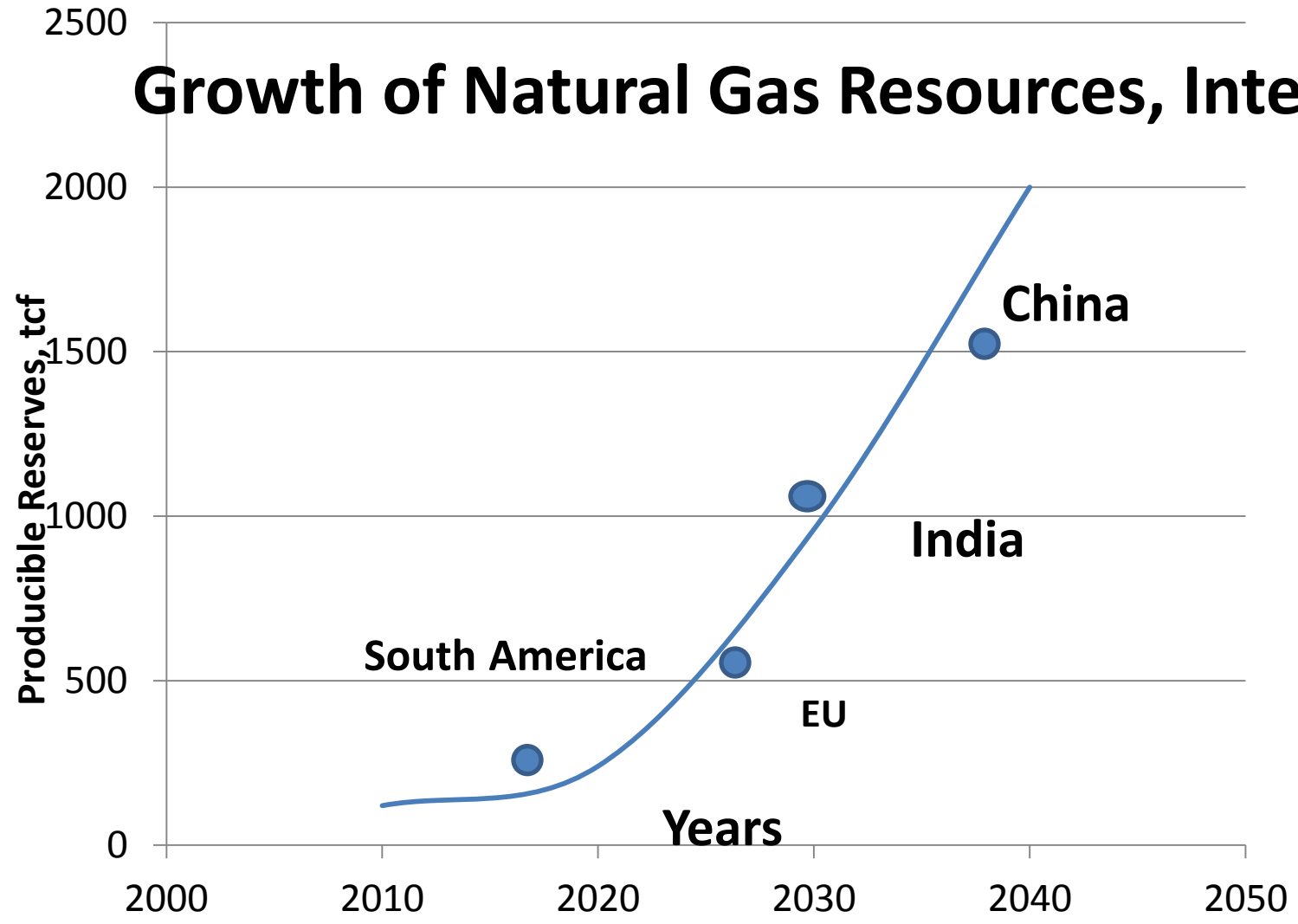


Growth in Shale Gas Reserves



There is Plenty of Energy Available from Natural Gas – a 200 Year Supply

Growth of Natural Gas Resources, International

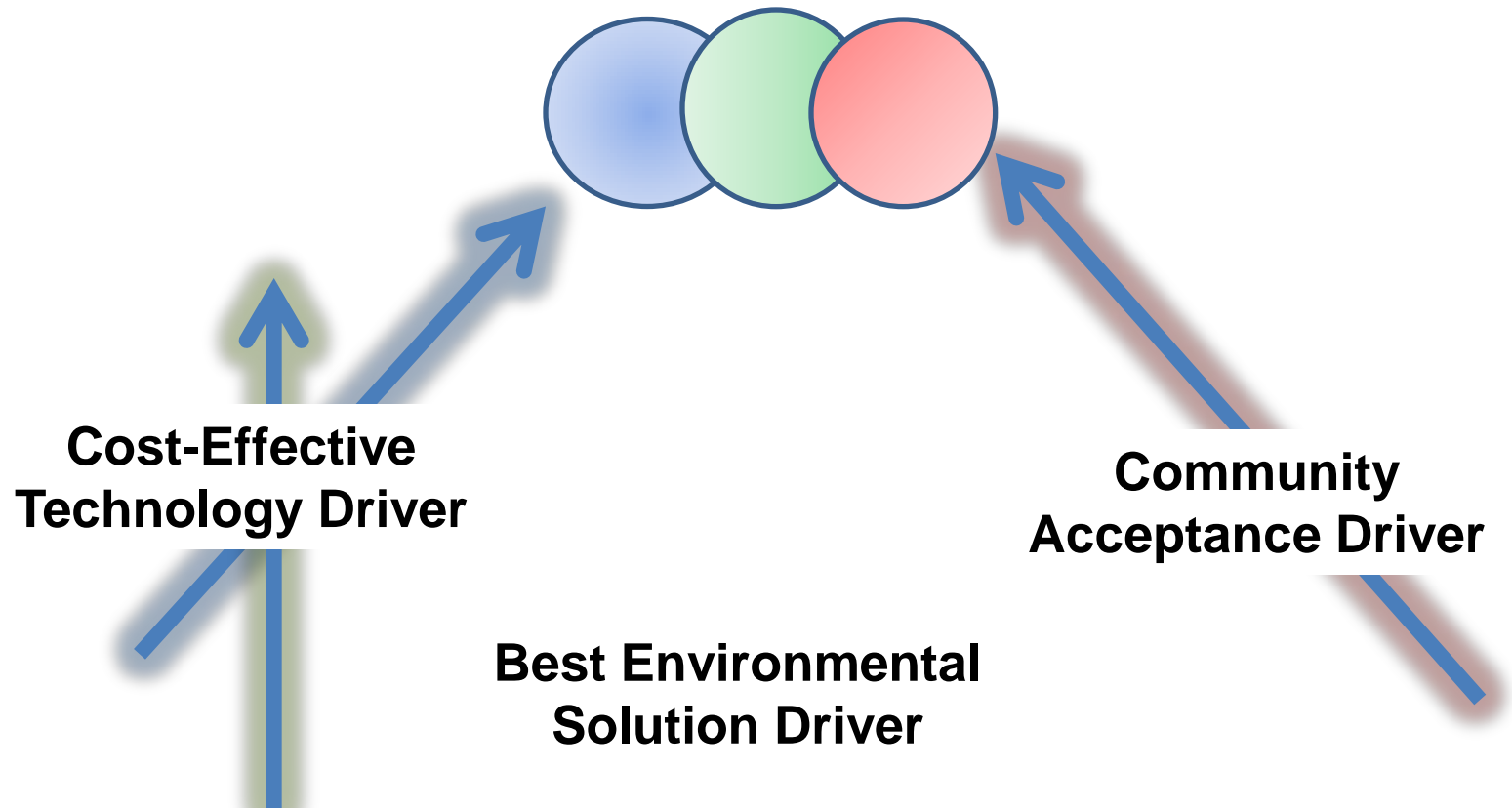


How Innovative Are We?



The gas shale development boom is the biggest thing to happen to the O&G industry since the invention of the rotary drilling rig.

Innovation Needed in More Than “Just” Engineering





Environmental Performance

An Energy Company's License to Operate

Technology is available, but it will be the environmental issues and society's acceptance that slow the development of shale gas resources

The Environmentally Friendly Drilling Systems Program



*Demonstrating
innovative technologies that reduce
environmental footprints*

www.efdsystems.org

www.efd-tip.org



Working to Reduce Impacts

Natural Resources Law Center University of Colorado Law School

Intermountain Oil and Gas BMP Project

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HYDRAULIC FRACTURING

Oil and gas operators have combined hydraulic fracturing, commonly known as "fracking," to over sixty years in either vertical or slant wells (this is often referred to as "conventional drilling"). Within the past decade, the combination of horizontal drilling and hydraulic fracturing has been used with increasing frequency in each of the intermountain states to increase the volume of natural gas that can be extracted from tight sand, coalbed methane and shale formations, and thereby make the extraction process economically feasible (this is often referred to as "unconventional drilling"). The Independent Petroleum Association of America reports that over 90% of vertical and horizontal oil and gas wells nationwide now require some form of hydraulic fracturing.

HYDRAULIC FRACTURING PROCESS

After a well is drilled, a perforated gas well explosive charges to fracture the tight shale reservoir surrounding the well. The fractures are typically located thousands of feet below the water table and extend only hundreds of feet in each direction. Fluid is then injected under high pressure into the well to stimulate the production of natural gas, and in some cases oil. While procedures may differ depending upon the formation, fracturing fluids are generally made up of water and chemical additives designed to enhance the efficacy of the fluid. After injecting the fracturing fluid, producers pump proppants, which is generally either sand, resin-coated sand, or ceramic, to keep the fractures open and allow gas to flow. See a video for an animation of the hydraulic fracturing process created by SMEI Louisiana.

According to the American Petroleum Institute's (API) Hydraulic Fracturing Process, hydraulic fracturing fluids consist of 90% water, 8-5% sand, and 0-5% chemicals. The chemicals are used to enhance fracturing and to protect the

REGULATING FRACING

Oil and gas development is regulated by the federal, state, and local governments. For information about the regulation of oil and gas development generally, see the Law and Policy section.

FEDERAL GOVERNMENT

Environmental Protection Agency

The 2005 Energy Policy Act exempted the regulation of Fracking fluids from the Safe Drinking Water Act's Underground Injection Control Program. (See our Federal Water Quality Laws and Regulations section for more information about this exemption.)

STRONGER

More than Fracking of Oil & Natural Gas Environmental Regulations

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ANNOUNCEMENTS

...other announcements

STRONGER completes review of Hydraulic Fracturing Regulation in Louisiana

- Louisiana Hydraulic Fracturing Review
- Oklahoma Hydraulic Fracturing Review
- Ohio Hydraulic Fracturing Review
- Pennsylvania Hydraulic Fracturing Review
- See all reviews

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Important Documents
State Review Guidelines

State Reviews

What is the State Review Process?

The state review process is a collaborative process by which review teams composed of stakeholders from the oil and gas industry, state environmental regulatory programs, and members of the environmental/public interest communities review state oil and gas waste management programs against a set of Guidelines developed and agreed to by all the participating parties.

Since its initiation, the state review process has completed the reviews of twenty-one state programs responsible for the regulation of over 90% of the domestic offshore production of oil and natural gas.

See a special report about the state review

For more Info see:

<http://www.oilandgasbmps.org/resources/fracing.ph>

<http://www.strongerinc.org/p>

<http://www.efdsystems.org>

Environmentally Friendly Exploration & Production

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What's New:

White Paper on Hydraulic Fracturing - Written by two summer interns the paper reviews technical papers and identifies management practices available to make hydraulic fracturing more environmentally friendly while also being economical and efficient.

EFD response to letter by Mr. Robert Howarth, et al., from Cornell University, published by Climatic Change entitled "Methane and the greenhouse-gas footprint of natural gas from shale formations".

Download presentations from the latest EFD workshop- Managing the Eagle Ford Development

Dr. Richard Haut's editorial in the Houston Chronicle: "We Can Minimize Negative Side-effects of Shale Drilling"

The Houston Advanced Research Center (HARC) and Texas A&M University, along with industry sponsors and stakeholders (NGO's, government agencies, others) operate the **Environmentally Friendly Drilling Systems Program** integrating advanced technologies into systems that significantly reduce the impact of petroleum drilling and production in environmentally sensitive areas. The team focuses on technologies that reduce the environmental and societal tradeoffs associated with the development of energy sources. The objective is to identify, develop and transfer critical, cost effective, new technologies that can provide policy makers and industry with the ability to develop US domestic reserves in a safe and environmentally friendly manner.

Recent Publications:

JIP aims to minimize environmental risks, coastal impact through technology

Dr. Gene Theodoris discusses public perception at expo in East Texas.

AADE-11-NTCE-61 The Impact of Rig Design and Drilling Methods on the Environmental Impact of Drilling Operations

EFD Featured in American Oil & Gas Reporter
The EFD program is featured in an article by Al Pickett, Special Correspondent.

Worldwatch Institute Issues Shale Gas Report
A new independent assessment by the Worldwatch Institute concludes that improved adherence to drilling best practice and better regulatory oversight are essential. [Read letter of announcement.](#)



EFD Program History

- Formed Team in 2005 (6 years)
- Texas A&M University took lead to obtain U.S. Department of Energy Funding
- Formed Joint Industry Partnership to guide and co-fund program
- Engaged Environmental Organizations
- Phase 2 led by HARC with RPSEA funding
- Formed University/National Lab Alliance
- Initiated International outreach program including EFD-EU
- Phase 3, Technology Integration Program co-funded by RPSEA & Industry
- Initiated complementary program funded by U.S. Coastal Impact Assistance Program (CIAP) managed by the Texas General Land Office





The EFD Team

Co-funded by RPSEA, U.S. Fish & Wildlife, Industry, Environmental Organizations

<p>SPONSORS</p>	<p>MANAGEMENT TEAM</p>	<p>ENVIRONMENTAL ORGANIZATIONS</p>
		<p>COLLABORATORS</p>
	<p>ALLIANCE MEMBERS</p>	





Environmental Performance

***Do you think Geothermal Energy will Avoid
the Pushback that Hydraulic Fracturing Has
Caused?***

Better Think Again!

Geothermal Protestors in Hawaii





Water – The Solution

- This technology is mobile, works in remote settings and is dependable
- Acceptable to regulatory agencies
- Turns unusable water into usable water
- Affordable

More water for communities and agriculture!

GPRI Mobile Water Re-use Lab



Mobile Test Unit for Advanced Membrane Testing



Interior of unit, set up for membrane modules



SPE 158396 PP

New York Field Trial of Ultra-High Salinity Brine Pre-treatment: Texas A&M

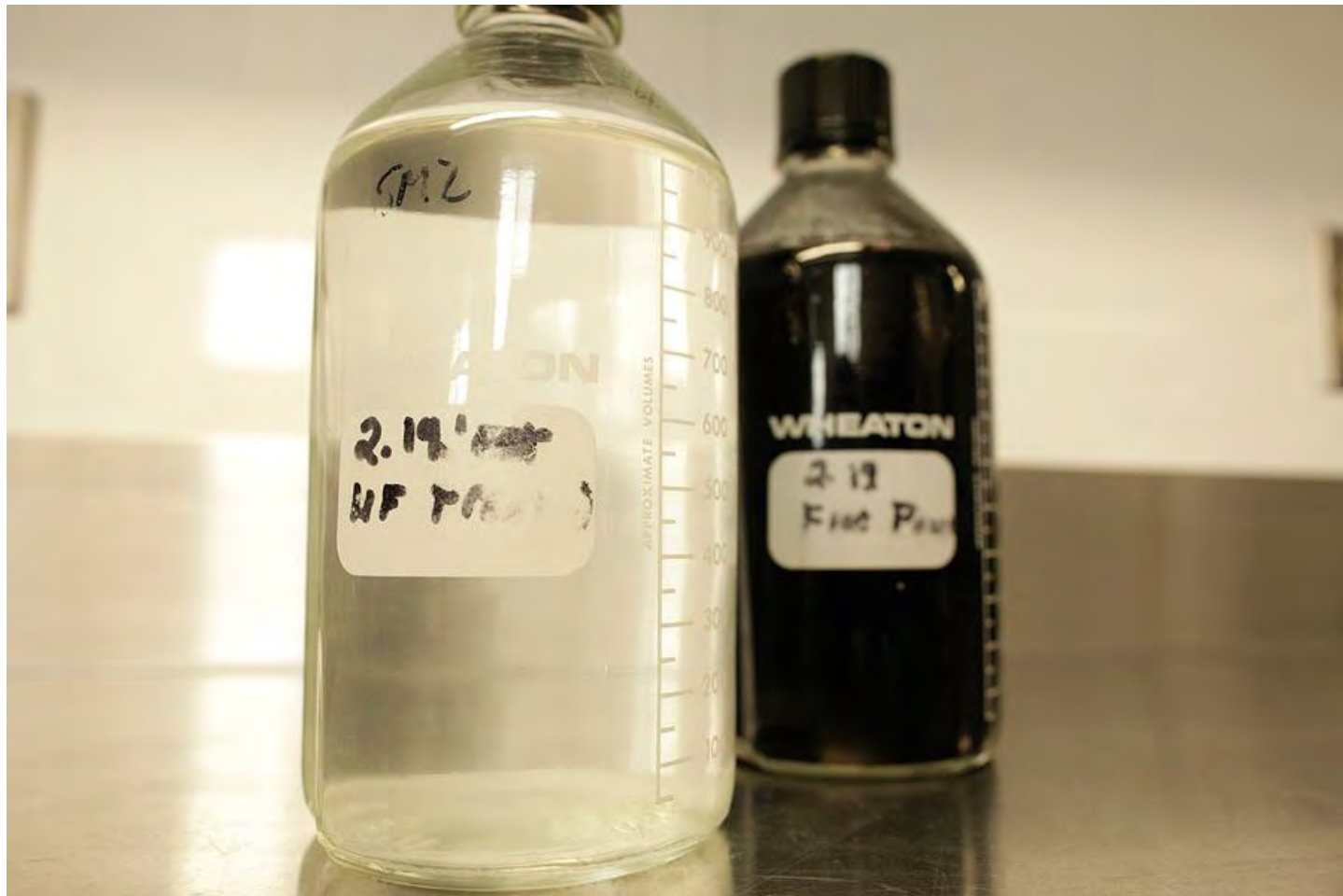
Environmentally Friendly Drilling Technology for the Marcellus Shale



Field Frac Brine after Three Weeks

Treated

Un-Treated



Emissions Reduction in Energy Production



How Rare is Clean Air?

- **Urban Issues**
 - **Non-attainment**
 - **Permit levels**
- **Emissions of Concern**
 - **NOx and VOC's**
 - **Ozone**
 - **Cold-formed Ozone**
 - **Greenhouse Gases**
- **Green Completion Technologies**
- **Regulations/Policies**
 - **Clean Air Act**
 - **Greenhouse Gas Issues**



The EPA estimates that atmospheric emissions of approximately 250 mscf/yr or 100 metric tons of CO₂ equivalent (CO₂e) of methane per year could be avoided for each high-bleed controller converted.



NOx Air Emissions Studies



Develop guidelines concerning the measurement of oxides of nitrogen (NOx) for a drilling site and work with operating company personnel to plan an investigation at a location.

Deliverables

- Plans for an emissions study.
- Guidelines for emissions reduction of large engines.



NOx Reduction Technologies

Exhaust Gas Recirculation (EGR)

- Send up to 30% of the exhaust back into the engine
- Many different options with varying results, broadly applicable
- Limitations: Durability
- 30% to 40% reduction in NOx

Selective Catalytic Reduction (SCR)

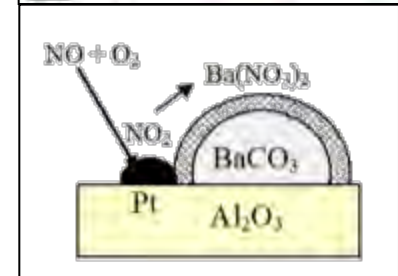
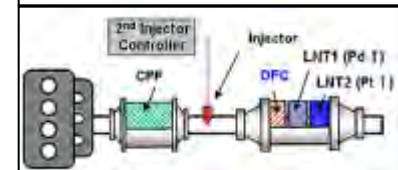
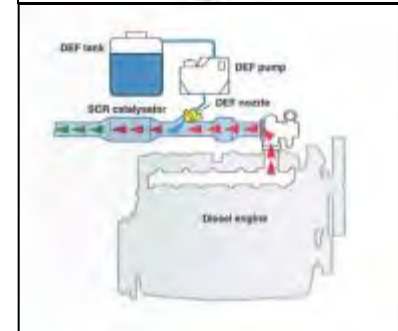
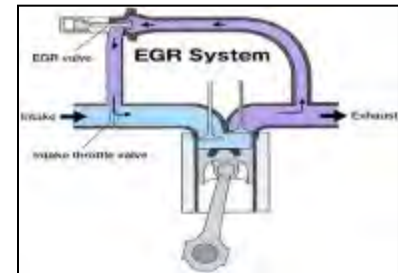
- Requires ammonia to be injected into the exhaust stream
- 3 different technologies functional in different temperature ranges
- Limitations: Requires urea, temperature dependence
- 65% to 90% reduction in NOx

Lean NOx Catalyst (LNC)

- Requires fuel to be injected into the exhaust stream
- Requires at least 260°C for at least 25% of the time
- Limitations: Sulfur sensitive, temperature dependent
- 10% to 50% reduction in NOx

Lean NOx Trap (LNT)

- Chemically absorbs NOx onto a special catalyst
- At set intervals (~60-90 seconds), fuel is injected into the LNT to react with the stored NOx
- Limitations: Requires tight integration with engine management system
- 50% to 80% reduction in NOx





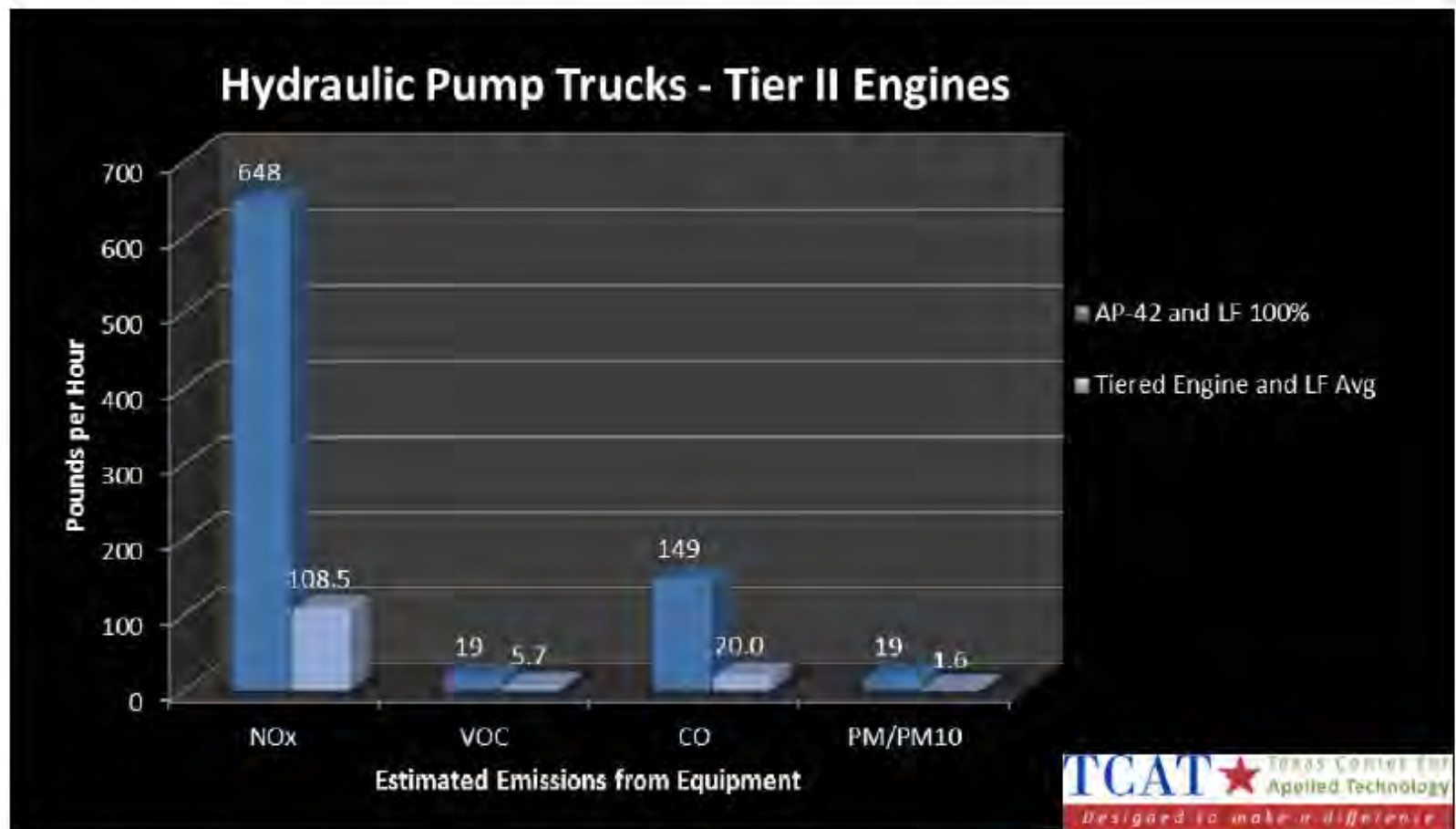
Air Emissions Inventory

Hydraulic Fracturing in the Eagle Ford *How much NOx?*

FRAC PROCESS EQUIPMENT				
Equipment	Make/Model	Fuel	Size	Number
Light Carts	TEREX RL4000	Diesel	13.6 hp	6
Frac Water Pump Engine	Cornell 18F8A Pumps w/Engine-John Deere 6090HF485B	Diesel	384 hp	5
Sand Trucks (Trailer/High Rate Feeder)	APPCO FS-40/Schlumberger SSF-353 Deck Engine	Diesel	78 hp	3
Sand Truck (Cab)	UNKNOWN	Diesel		
Water Tanks (Trailers)	NOT AN EMISSION SOURCE	N/A	N/A	5
Water Tanks (Cab)	UNKNOWN	Diesel		4
Blow Out Control System Engine	Engine - Hatz Diesel-8HZXL.667V83	Diesel	9.4 kW	1
Blow Out Control System Engine	Engine - Hatz Diesel-7HZXL.667V83	Diesel	9.4 kW	1
Telehandler (Forklift)	GRADALL - 534D9-45 w/Engine - John Deere 4045TF275B	Diesel	110 hp	1
Generator (small) -(on fire control trailer)	TITAN 8500 High Performance	Diesel	8500 kW	1
Bulldozer	Angus-Palm TR95 w/Engine-John Deere 4045TF270B	Diesel	99 hp	1
Backhoe	Caterpillar 420D	Diesel	88 hp	1
High Pressure Water Cannon	Twin Disc 1G4539 Model SP211HP3	Diesel		1
Generator - Mobile Office	Terex T70C	Diesel	91 hp	1
Generator - Cooling Room	ATLAS COPCO - Model QAS25	Diesel	29.6 hp	1
Vehicles				
Pump Trucks - Operating Engine	SPF343 - Engine-Caterpillar 3512B	Diesel	2250 hp??	12
Pump Trucks - Cab Engine	Peterbilt	Diesel		
Perf & Plug Truck - Cab Engine	Freightliner Columbia	Diesel		
Perf & Plug Truck - Operating Engine	Caterpillar - 3512B	Diesel	4423 hp	2
Mobile Command Center	SMT 503 Mobile Monitoring Unit/Caterpillar 3176	Diesel	210 hp	1
Crane (small)		Diesel		1
Crane (large) - Operating Engine	ATC3200	Diesel	517 hp	1
Crane (large) - Cab Engine		Diesel		
Large Pickup		Gasoline	250 hp	6
Medium Pickup		Gasoline	350 hp	6
Small Pickup		Gasoline	400 hp	6
Work Truck - GMC	GMC C5500			2
Crew Van	Ford E350	Gasoline	255 hp	1
Cab - 18 Wheeler	Peterbilt	Diesel		3
PRODUCTION PROCESS EQUIPMENT				
Vehicle/Equipment	Make/Model	Fuel		Number
High Pressure Separators		N/A		2
Low Pressure Separators		N/A		2
Condensate Tanks		N/A		8
Test Separator				



Comparison of AP-42 Emission Factors and 100% Load Factor with Tiered Engine Emission Factors and Actual





Air Monitoring Technologies

ORNL Micro-Sensors

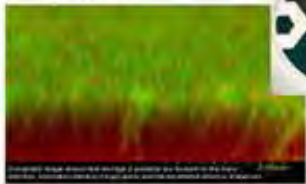


Thermoluminescent Nano-powders



Sensor Design

Material Synthesis



Systems Integration



Packaging

NETL Helicopter

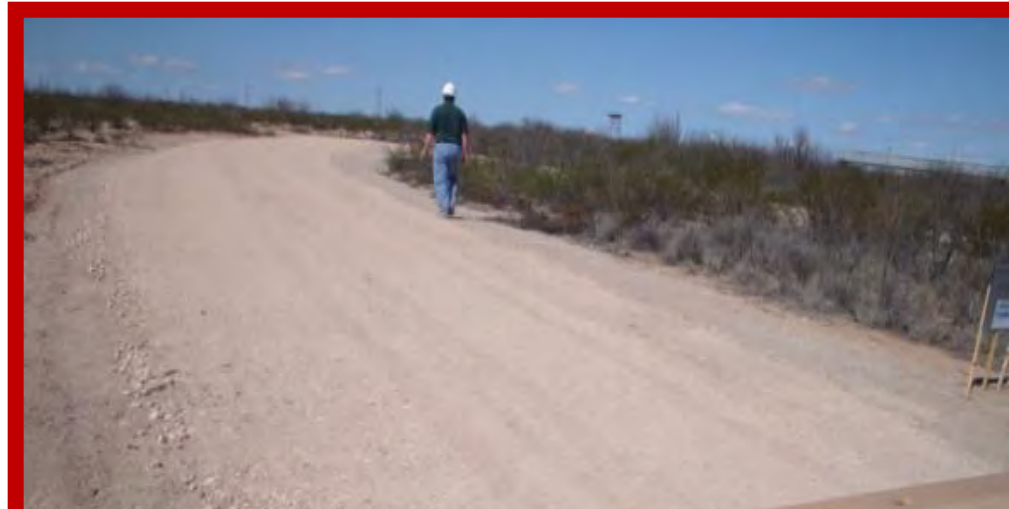
- Can carry 12 lb payload



Reducing Energy Production's Surface Footprint

EFD Projects: Land Use

- Solid Waste Management.
- The University Disappearing Roads Competition.
- RPSEA Low Impact Roads: Storey Ranch
 - Risk Based Assessment of EFD Systems.
 - Analytical Services Roundtable.
 - Land Use Site Selection Information Tool (LUSSIT)



Acknowledging the Role of the Public in Energy Development: Local

Stakeholder Engagement is Important!

Stakeholders are all those who are affected, interested in or have the capacity to influence a project.

Academia

- Texas A&M University College Station
- Texas A&M University Kingsville
- University of New Hampshire
- UT Medical Center
- Mississippi State University
- Sam Houston State
- University of South Alabama
- John Hopkins University
- University of Arizona
- University of Texas
- University of Houston

Environmental Organizations

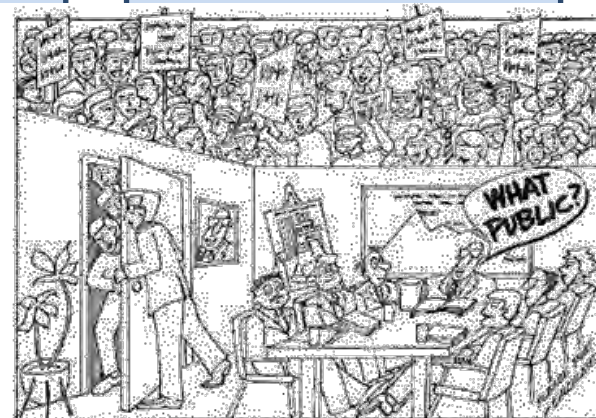
- Natural Resources Defense Council
- Environmental Defense Fund
- The Nature Conservancy
- Conservation International
- Mercer Arboretum
- Bureau of Applied Anthropology/Arizona
- Clinton Climate Initiative
- Rocky Mountain Clean Air
- McFaddin Ranch

Industry

- API
- Ballard Exploration
- BP
- Shell
- Chevron
- StatoilHydro
- ConocoPhillips
- Devon
- King Exploration
- Halliburton
- Huisman
- National Oil Well – Varco
- MI Swaco
- TerraPlatform
- T. Baker Smith
- Weatherford
- Derrick Equipment
- Composite Mats
- Ecology and Environmental Inc.
- PTTC
- IADC

State/Federal Agencies

- US Department of Energy
- Bureau of Land Management
- US Park Service
- Texas Railroad Commission
- Texas General Land Office
- Texas Dept. of Agriculture
- Texas Dept. of Transportation
- US Minerals Management Services
- Texas Parks & Wildlife
- Texas Water Board
- Texas Commission on Env. Quality
- US Environmental Protection Agency
- US Fish and Wildlife
- Argonne National Laboratory
- Big Thicket Preserve
- Idaho National Laboratory



Findings indicate that public will accept and support responsible development

However, the public *will not accept*:
excessive traffic, dust, noise,
pollution of the land and water,
destroying public roads;
poor choices in well sites, roads,
compressor stations,
tank batteries, drilling locations;
and “visitors” who do not
respect their community.

Failure to adequately inform and engage all stakeholders results in poor public perception of the oil and gas industry;

...and because a small percentage of companies do not practice proper environmental safeguards in their operations, the “license to operate” is thus compromised.



Tradeoff Scorecard Development

EFD Facts

Project:

Location:

Ecosystem:

	Max	Score
AIR	10	0
WATER	15	0
SITE	15	0
WASTE MANAGEMENT	20	0
BIODIVERSITY/HABITAT	20	0
SOCIETAL	20	0
	100	0



Environmentally Friendly Drilling Scorecard

Project:
Location:
Ecosystem: Semi-Arid
Date:

Points Achieved Possible Points: 100
 ★ 55 - 64 points ★★ 65 - 74 points ★★★ 75 - 84 points ★★★★ 85 - 94 points ★★★★★ 95 - 100 points

Air			Possible Points: 10		
<input type="checkbox"/>	Prerq 1	Compliance w/Air Quality Regs			
<input type="checkbox"/>	Credit 1	Contractual Obligations for Logistics	2		
<input type="checkbox"/>	Credit 2	Site Emissions	2		
<input type="checkbox"/>	Credit 3	Dust Suppression	2		
<input type="checkbox"/>	Credit 4	Clean Power	3		
<input type="checkbox"/>	Credit 5	Green Completions	1		

Water			Possible Points: 20		
<input type="checkbox"/>	Prerq 1	Stormwater Management Plan			
<input type="checkbox"/>	Prerq 2	Integrity Testing of Surface Casing			
<input type="checkbox"/>	Credit 1	Water Management Plan	9		
<input type="checkbox"/>	Credit 2	Setbacks from Streams/Sources	4		
<input type="checkbox"/>	Credit 3	Mitigation Measures/Protect Waters	4		
<input type="checkbox"/>	Credit 4	Reduce Water Usage	2		
<input type="checkbox"/>	Credit 5	Reuse of Water/Fluids	1		

Site			Possible Points: 20		
<input type="checkbox"/>	Prerq 1	Regulatory Compliance			
<input type="checkbox"/>	Prerq 2	Erosion & Sedimentation Control			
<input type="checkbox"/>	Credit 1	Pre-Existing Site	2		
<input type="checkbox"/>	Credit 2	Pad Drilling	2		
<input type="checkbox"/>	Credit 3	Protect and Restore Habitat	2		
<input type="checkbox"/>	Credit 4	Contractor Guidelines	2		
<input type="checkbox"/>	Credit 5	Site Restoration Plan	2		
<input type="checkbox"/>	Credit 6	Well Design Considerations	2		
<input type="checkbox"/>	Credit 7	Living Quarters and People	2		
<input type="checkbox"/>	Credit 8	Organic Materials	1		
<input type="checkbox"/>	Credit 9	Pre-Plan for Production	2		
<input type="checkbox"/>	Credit 10	Match Site/Access to Topography	1		
<input type="checkbox"/>	Credit 11	Logistics Plan - Offsite Storage	1		
<input type="checkbox"/>	Credit 12	Planting of Native Vegetation	1		

Waste Management			Possible Points: 20		
<input type="checkbox"/>	Prerq 1	Waste Management Plan			
<input type="checkbox"/>	Prerq 2	Pit Design Pre-site Assessment			
<input type="checkbox"/>	Credit 1	Drilling Fluid Handling System	6		
<input type="checkbox"/>	Credit 2	Lubricants, Fluids, Bulk Materials	5		
<input type="checkbox"/>	Credit 4	Spill Prevention System	3		
<input type="checkbox"/>	Credit 5	Cuttings Reuse	3		
<input type="checkbox"/>	Credit 6	Cuttings Reinjection	3		

Biodiversity/Habitat			Possible Points: 15		
<input type="checkbox"/>	Prerq 1	Species Protection			
<input type="checkbox"/>	Prerq 2	Habitat Protection/Enhancement			
<input type="checkbox"/>	Prerq 3	Regulatory Requirements			
<input type="checkbox"/>	Credit 1	Restoration/Interim Reclamation	4		
<input type="checkbox"/>	Credit 2	Reduction of Surface Disturbance	3		
<input type="checkbox"/>	Credit 3	Erosion Prevention	2		
<input type="checkbox"/>	Credit 4	Voluntary Offsite Mitigation	1		
<input type="checkbox"/>	Credit 5	Invasive Species Prevention	1		
<input type="checkbox"/>	Credit 6	Reintroduction of Species, Habitat	1		
<input type="checkbox"/>	Credit 7	Avoidance of High Value Areas	1		
<input type="checkbox"/>	Credit 8	Wildlife and Habitat	2		

Societal			Possible Points: 15		
<input type="checkbox"/>	Prerq 1	Regulatory Compliance			
<input type="checkbox"/>	Prerq 2	Communication Plan			
<input type="checkbox"/>	Credit 1	Public Outreach	3		
<input type="checkbox"/>	Credit 2	Noise and Lighting Control	2		
<input type="checkbox"/>	Credit 3	Training of Local First Responders	2		
<input type="checkbox"/>	Credit 4	Air Quality Monitors	2		
<input type="checkbox"/>	Credit 5	Emergency Response Plan	2		
<input type="checkbox"/>	Credit 6	Dispute Resolution Plan	1		
<input type="checkbox"/>	Credit 7	Surface Use Plan	2		
<input type="checkbox"/>	Credit 8	Unintended Consequences Program	1		

EFD Facts

Project:
Location:
Ecosystem:

	Max	Score
AIR	10	0
WATER	20	0
SITE	20	0
WASTE MANAGEMENT	20	0
BIODIVERSITY/HABITAT	15	0
SOCIETAL	15	0
	100	0





Next Phase

Technology Integration Program

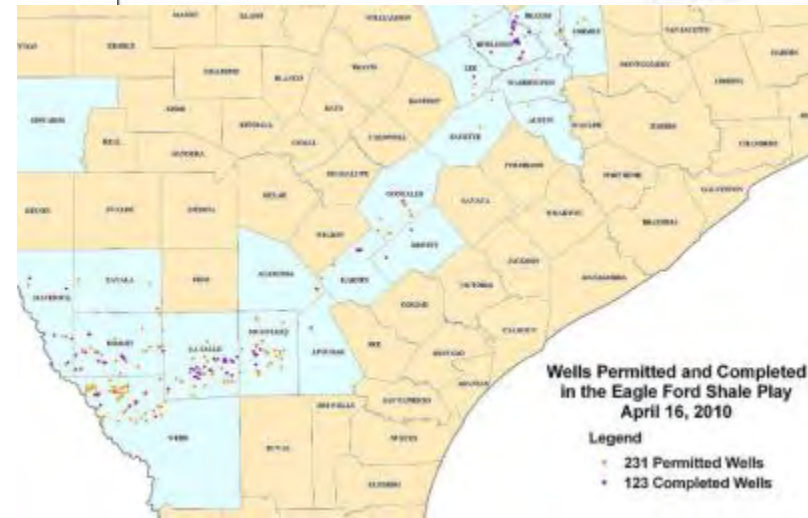
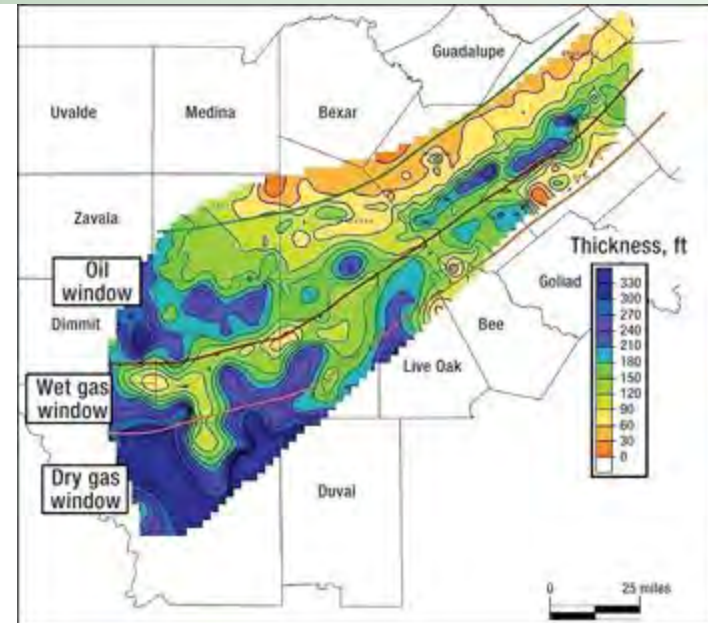
Integrated approach for applying new technologies

Description

- Field Tests in the Eagle Ford, other shales
- Web sites for virtual gas developments
- Outreach/Technology Transfer

Goals

- Speed commercial development
- Create organizational structure to facilitate field deployment
- Perform field trials
- Document and transfer results
- Emphasis on reduced costs and improved performance
- Safety improvements of low impact technologies



Best Management Practices - Sustainability

The third item identified is to develop a set of best management practices (BMP) that can be use for operations, employees and, importantly, for their subcontractors.

- EFD has invested in the development of a Rocky Mountain regional BMP project at the University of Colorado Natural Resources Law School
- Initiated another effort in the Eastern U.S. Marcellus and Utica Play region.
- All documents will be web-based and publicly available. These BMPs could be adapted by any company.



www.oilandgasbmps.org

WWW.efd-aas.org



www.efd-aas.org

And
SPE 158021 PP

EFD Association of Analytical Services

Search this site

▼ A Group of Analytical Services Providers for O&G Operations

- A Primer for Eagle Ford Shale Environmental Research
- Duke University – Nicholas Environmental
- GE Analytical Services
- GSI Environmental
- Hach Company
- Links to Field Trials in New York, Pennsylvania, and West Virginia
- Request for Admission to Roundtable
- Texas A&M School of Rural Public Health (SRPH)

Calendar

Project Documents

Tasks & Actions

Sitemap

Recent site activity

Recent site activity

A Group of Analytical Services Providers for O&G Operations

New. Please review the recent white paper on emissions estimates of fracturing operations in the Eagle Ford. This paper is the basis of a new SPE paper (SPE SPE-158021-PP) --see below

High level comprehensive analytical test programs are being established to address the needs of the upstream oil and gas industry. In cooperation with the [Houston Advanced Research Center](#) and Texas A&M University's [Environmentally Friendly Drilling](#), the association provides specialized analytical techniques needed to monitor and manage oil field waste water systems.

The Association's charter members are

Texas A&M School of Rural Public Health (Analytical Services Section) see the link on the left or go to

<https://sites.google.com/site/efdaas/home/texas-a-m-school-of-rural-public-health-srph>

[Duke University - Nicholas Environmental](#)



Summary

- Public Perception can Make or Break a Project
- Technologies are available to *reduce emissions (water and air)* and new technologies are being developed and tested. Reduction in surface impact should be a paramount research target
- **EFD Program** – Should be Carried over into EGS Planning and Operations

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