Bakken Production Optimization Program

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Dickinson, ND

Bethany Kurz, Senior Research Manager
Energy & Environmental Research Center (EERC)
Grand Forks, North Dakota

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North Dakota oil & gas research program

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Bakken Production Optimization Program Goals

To facilitate ongoing efforts by industry and the state of North Dakota to optimize Bakken/Three Forks production:

- Advanced reservoir characterization and more accurate resource estimates.
- Improved drilling, stimulation, completion, and production techniques and sequences.
- Optimization of wellsite surface operations and reduced surface impacts.

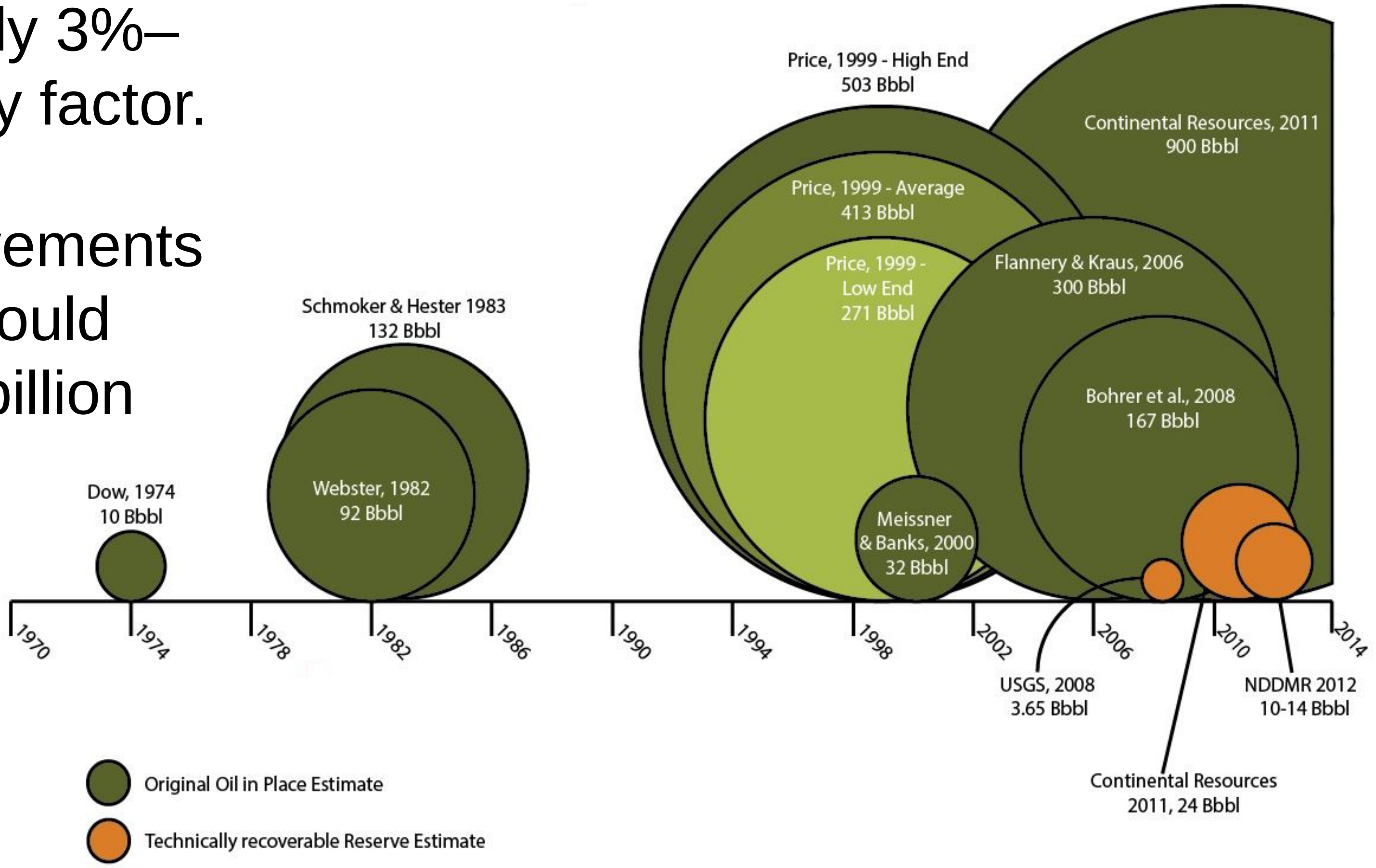
Continental Resources

EERC

Why Optimization Is Important…

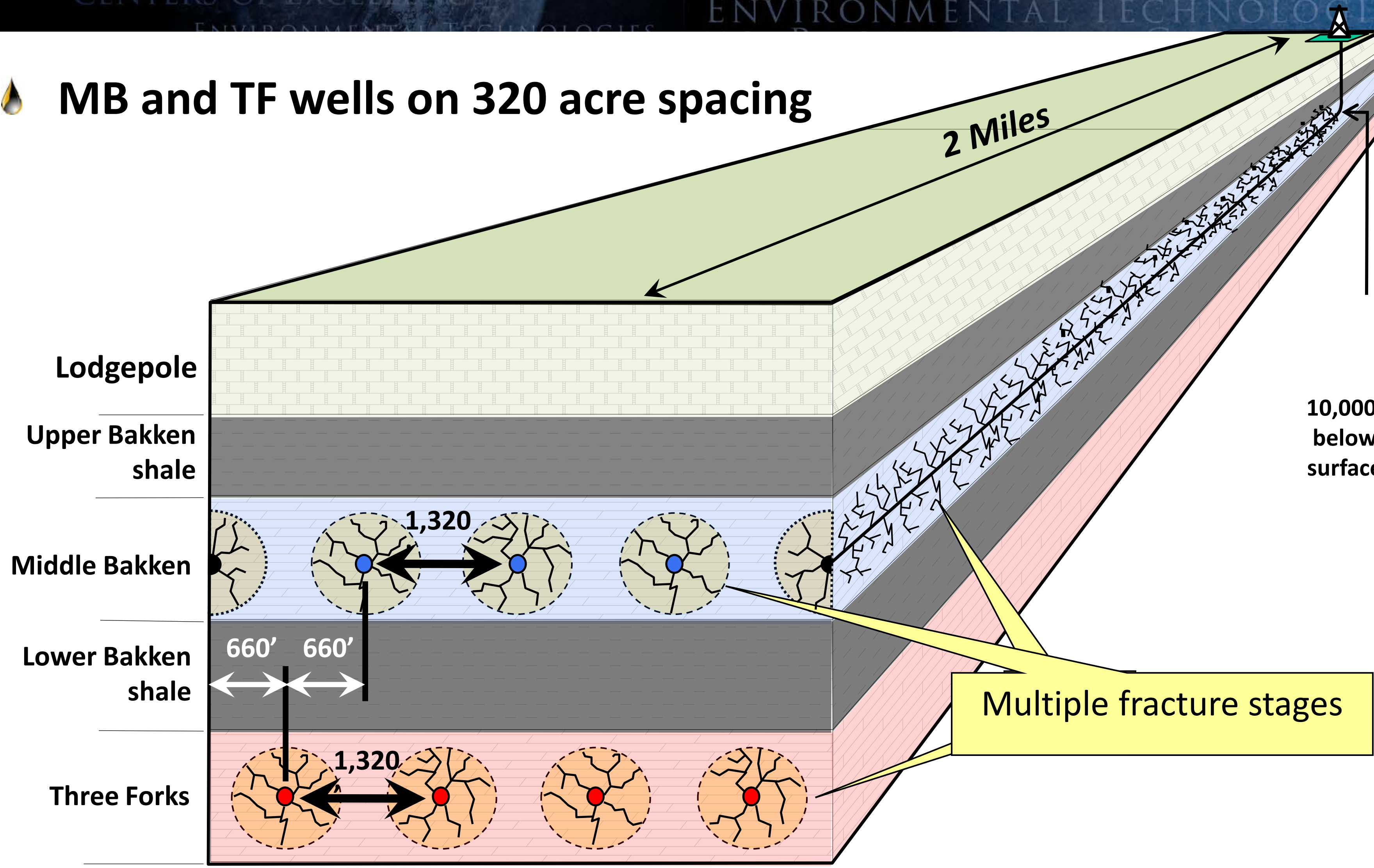
- World-class resource
- Currently, only 3%–10% recovery factor.
- Small improvements in recovery could yield over a billion barrels of oil.

Bakken Petroleum System Total Oil in Place Reserve Estimates



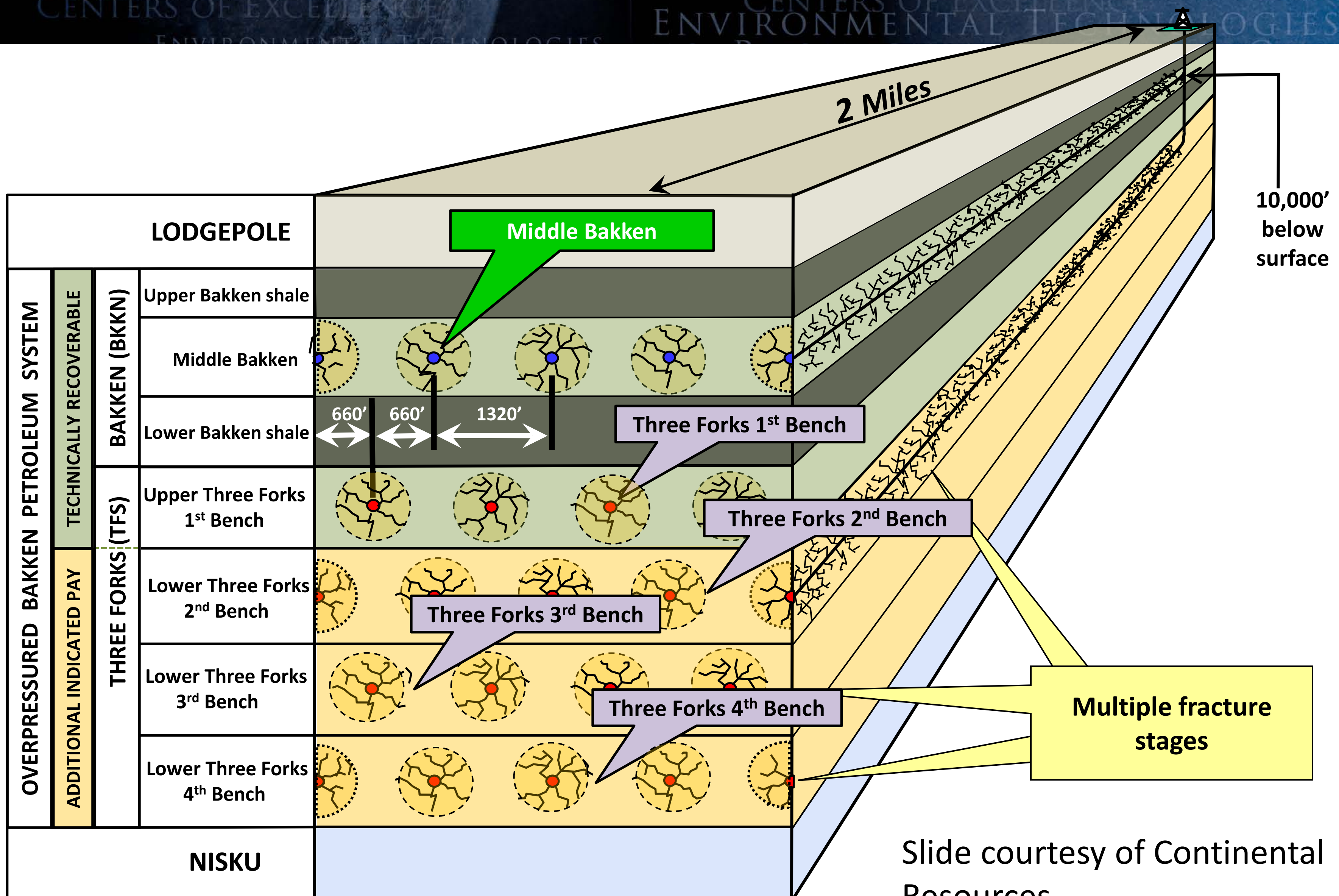
Past Reservoir Development Model

- **MB and TF wells on 320 acre spacing**



Slide courtesy of Continental Resources

Current Development: Bakken & Three Forks



Slide courtesy of Continental Resources

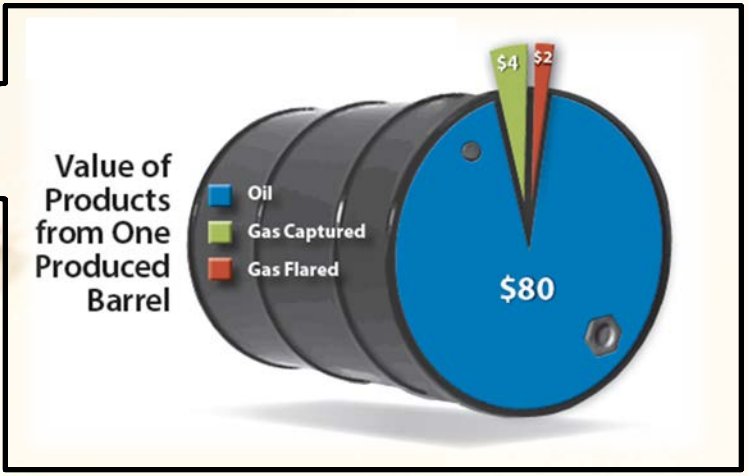
EERC Focus Areas

- Flare gas collection and utilization.
- Improved waste handling and options for beneficial reuse.
- Options for water recycling, treatment, and reuse.
- Other surface and downhole operational issues (corrosion, scaling, casing integrity).

Benefits of Wellsite Operations Optimization

- Reduce costs and improve efficiency.
- Reduce development and operational impacts to surrounding landowners, infrastructure, and the environment.
- Reduce demands on freshwater resources.

Public Education



Acceptability

			pCi/g
✔		Human	2
✔		Banana	4
?		Cat Litter	5
⊘		Brazil Nuts	6
⊘		Coffee Grounds	27
⊘		Granite Countertop	27
⊘		Phosphate Fertilizer	123

Completed EERC Projects Leading to the Optimization Program Concept

- Evaluation of options for flare gas utilization.
- Demonstration of flare gas utilization in a bifuel drilling application.
- Evaluation of options for nontraditional water supply sources for hydraulic fracturing:
  - Feasibility of recycling and reuse of fracture flowback.
  - Demonstration of brackish groundwater treatment and subsequent use in fracturing.

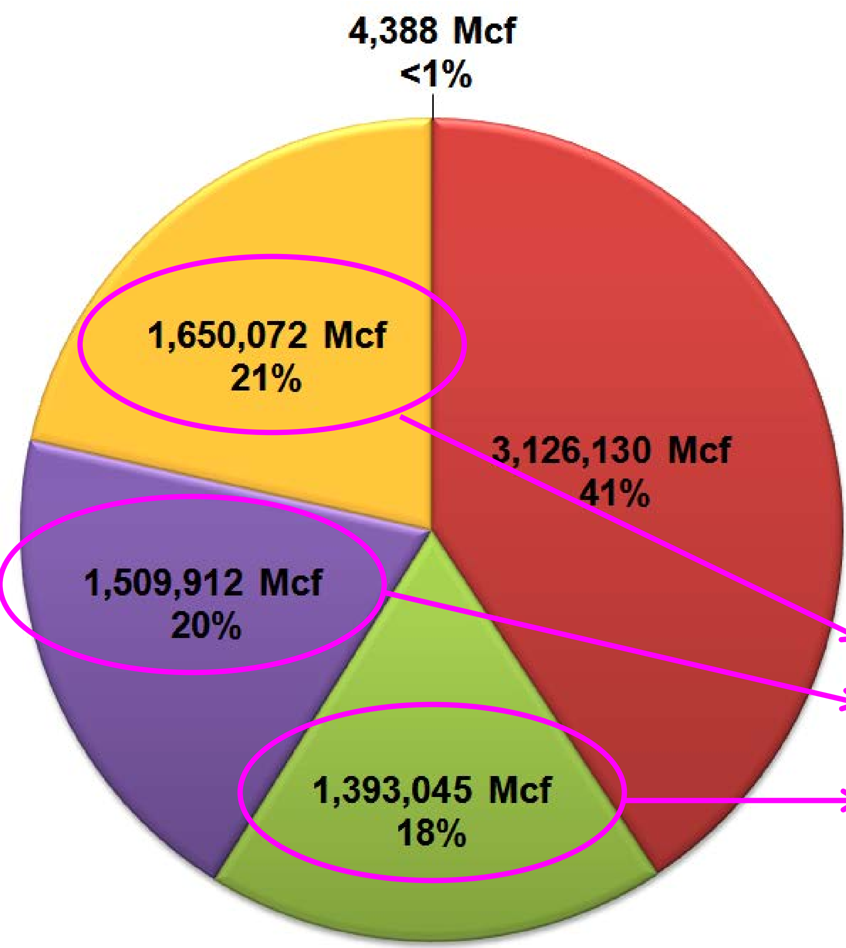
Photos: news.nationalgeographic.com; www.hcn.org

Observations Regarding Flaring

- Current flaring in the Williston Basin is a result of:
  - A rapid increase in oil production.
  - Growing but still insufficient intrabasin infrastructure to move rich gas to processing.
  - Growing but still limited infrastructure to move dry gas and NGLs to markets outside the state.
- With that said,
  - Forecasts indicate that oil and gas production should stabilize.
  - Industry is investing significant amounts of money to develop infrastructure and processing capabilities.
- The opportunity to capture revenue from flared gas is a moving target.
  - Location-specific (geographic)
  - Time-limited (temporal)

Flare Gas Data – November 2013

Flaring Allocation by Total Gas Flared in November

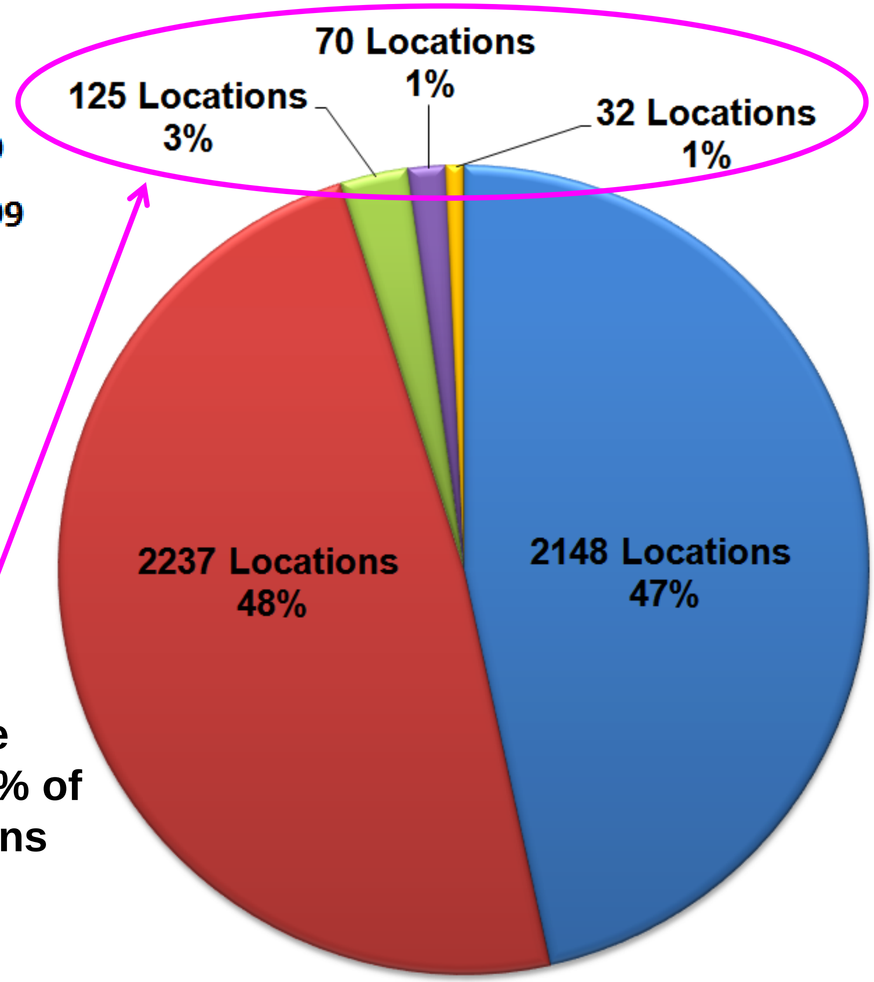


Flaring Rate (Mcf/day)

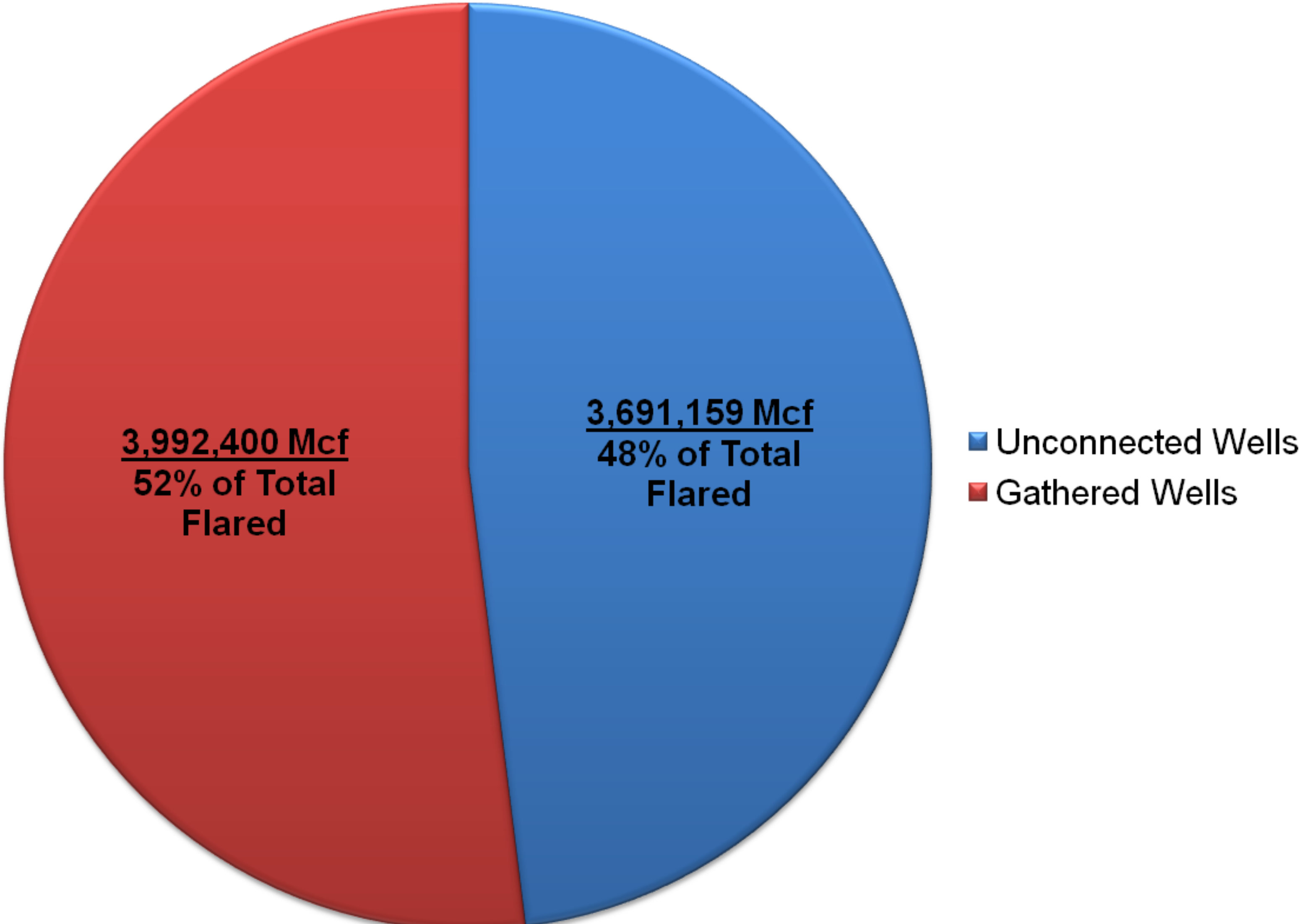
- <1
- 1-299
- 300-599
- 600-1199
- 1200+

~ 60% volume from 4% of locations

Flaring Allocation by Number of Wells/Locations

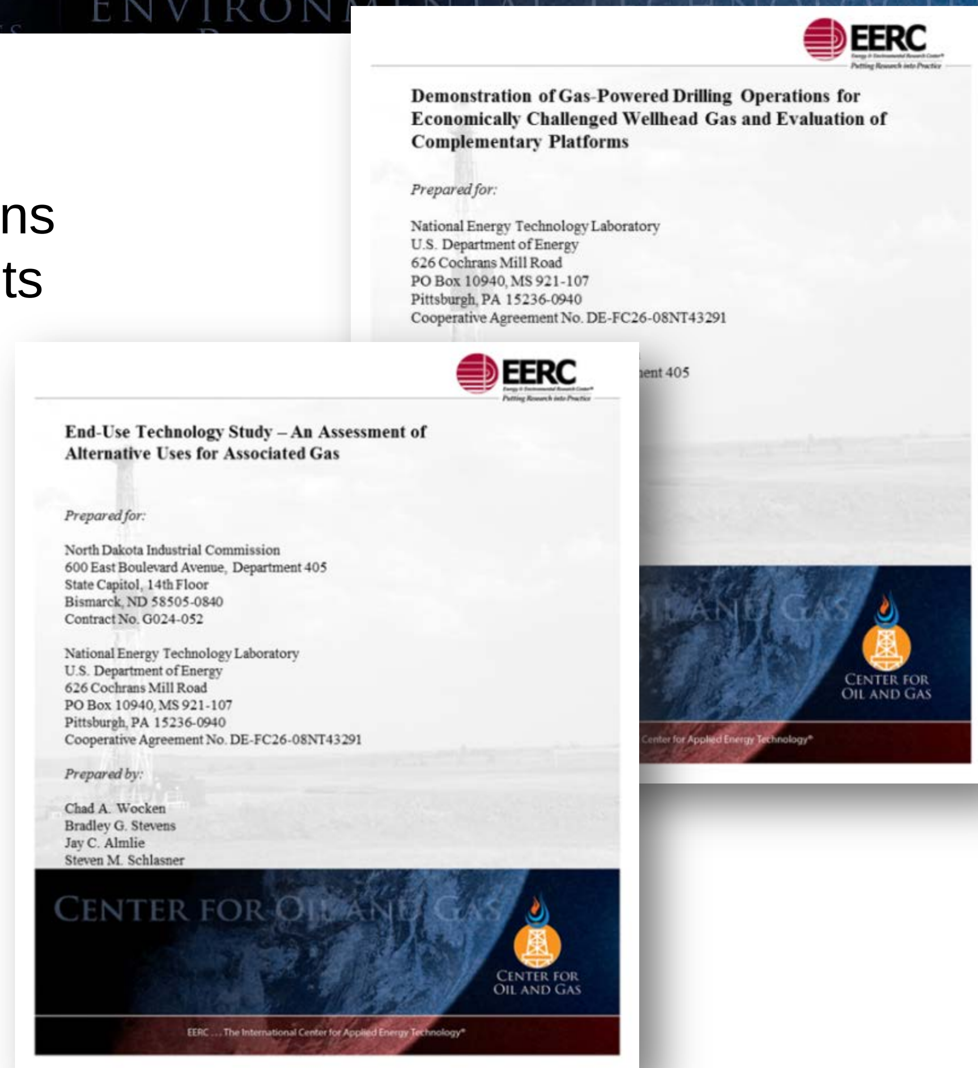


Flare Data Analysis – November 2013



Evaluation of Associated Gas Use

- Associated gas alternative use study – analysis of gas use options upstream of gas-processing plants
  - Small-scale gas processing
  - Compressed natural gas (CNG)/liquefied natural gas (LNG) for vehicles
  - Electric power production
  - Chemical production
- 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

A Use for Flared Natural Gas

- Power production for drilling rigs is a near-term opportunity.
- Diesel engines properly outfitted with bifuel systems can utilize a mixture of diesel and natural gas.
- Significant fuel savings can be achieved:
  - 30%–60% reduced fuel costs
  - Reduced fuel delivery and associated traffic, engine emissions, and fugitive dust

Image: www.drillingcontractor.org

Summary of Results

- Diesel fuel consumption reduced by 18,000 gallons for two wells over a period of 47 days.
- Fuel-related net cost savings of nearly $60,000.
- Reduced delivery truck traffic.
- Reduced NO_x 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.
- Currently ECO-AFS has Bi-Fuel on 21 rigs and 200 generators in North Dakota.

Technology	Possible Impact to Flare Volume	Pros	Cons
NGL Removal	9% reduction deployed at 227 largest flaring locations	• Ease of deployment • Ease of operation • Extracts highest value product from rich gas	• Best deployed during first 12 months of operation • Increases truck traffic, liquids storage
Power Diesel Replacement	0.5% reduction Power production at 100 1-well locations	• Fuel cost savings • Ease of deployment • Ease of operation	• Limited applicable sites
Power Local Load, diesel replacement	10% reduction Power production at 100 1-MW locations	• Reduces overall electrical load growth • Ease of deployment • Ease of operation	• Limited applicable sites
Power Grid Support	5% reduction One 45-MW grid connect plant	• Supports utility in electrical load growth management • Ease of deployment • Ease of operation	• Grid interconnect • Guaranteed fuel supply
CNG/LNG	0.1% reduction 25,000 mile/day fleet	• Fuel cost savings	• Low demand for fuel • Infrastructure and vehicle conversion takes time
Truck Transport	30% reduction 100 1-MMCFD sites	• Significant flaring impact	• 900 trucks • 9 trucks/day/1-MMCFD
GTL	8% reduction 2500 bpd production	• Conversion of gas to a higher value liquid product	• Immature at relevant scale • High capital cost • Complex operation • Requires large, consistent gas supply

Technology Summary Points

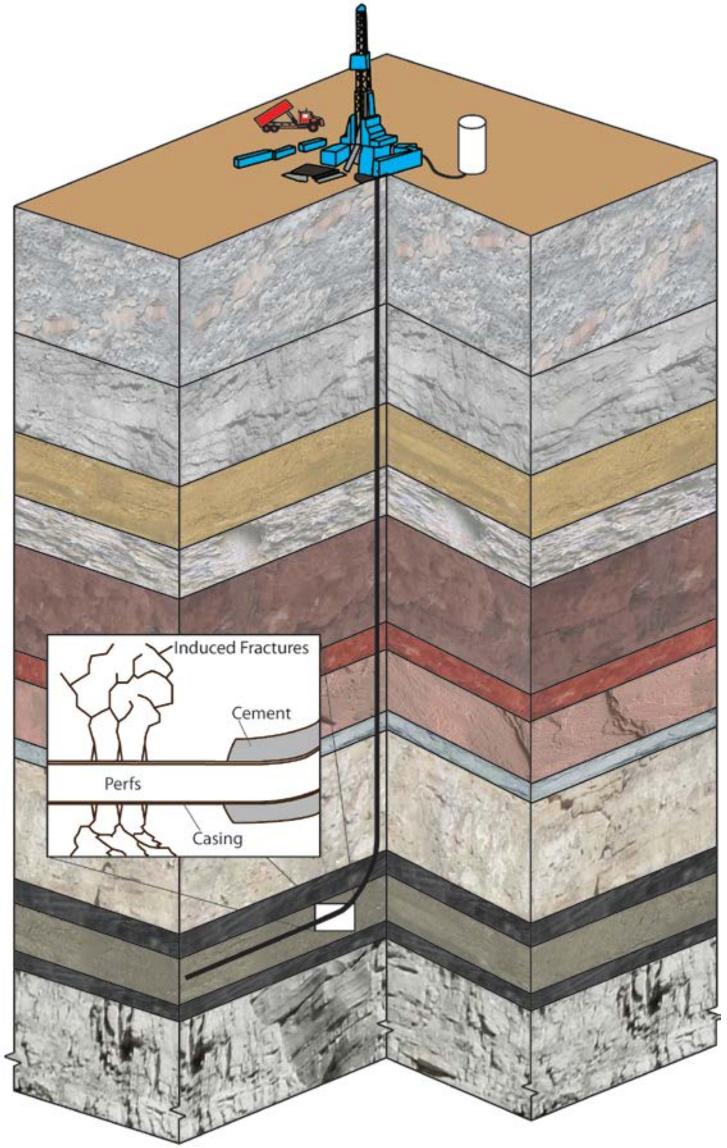
- Many technologies exist that can be deployed to utilize flared gas.
- Each technology, if deployed widely, can provide a small incremental benefit to gas utilization and flare reduction.
- Distributed-scale technology alone cannot be economically deployed widely enough to achieve the target of 90% gas conservation.
- Additional alternatives may be investigated to improve gas conservation without adversely impacting oil production or exacerbating other challenges such as truck traffic:
  - Gas reinjection for pressure maintenance and improved overall oil recovery

NDPC Flaring Task Force

- EERC's involvement is one outcome of the Bakken Production Optimization Program.
- NDPC's Flare Reduction Goals:
  - Capture 74% by 4th Qtr. 2014
  - Capture 77% by 1st Qtr. 2015
  - Capture 85% by 1st Qtr. 2016
- Key mechanisms to achieve reduction goals:
  - Gas processing expansions and new processing plants
  - New and expanded infrastructure (over $1.7B investment)
  - Requiring Gas Capture Plans to be included with ADPs

Water Needs for Fracturing

- Hydraulic fracturing requires ~ 2 to 5 million gallons of freshwater per well.
- The water is mixed with chemicals (biocides, proppants, polymers) prior to injection.
- A percentage of the frac water returns to the surface (flowback) and is recovered and disposed of (or recycled).
    - Typically contains dissolved solids (salts), suspended solids, residual hydrocarbons, and fracturing chemicals.



Putting Water Needs in Perspective

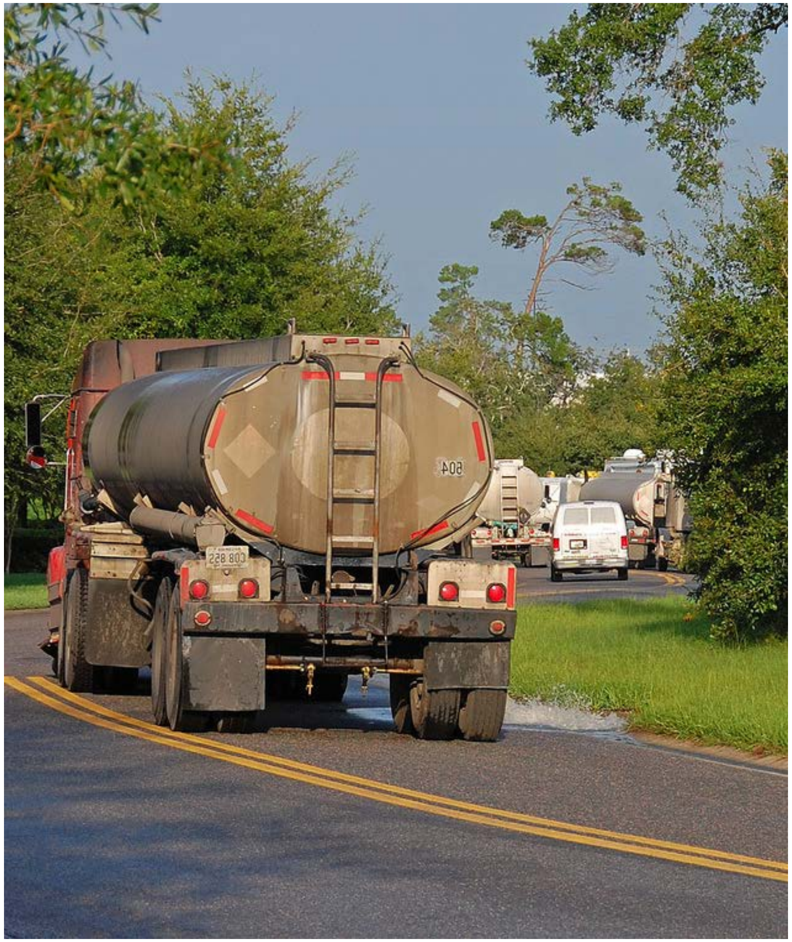
- Estimated water demand assuming 2200 wells per year at 4 million gallons per frac: ~ 24.1 MGD
  - 1.8% of total ND fresh water withdrawals
  - Equivalent to about 1.8 inches per year off the surface of Lake Sakakawea.
- Daily pumping volume for a center-pivot irrigator on a ¼ section of land in ND: ~ 1 million gallons
- Typically daily use for a 50,000-person Midwestern city: 10 million gallons.

Bakken Water Opportunities Assessment: Phase 1

- Partners
  - DOE NETL
  - North Dakota Industrial Commission (NDIC) Oil and Gas Research Council (OGRC)
  - North Dakota Petroleum Council (NDPC)
  - Five major producers
- Goal was to evaluate the feasibility of recycling hydraulic fracturing flowback waters in the Bakken play.
- **At the time of the study (2009-2010)**, we concluded that because of low initial flowback water recovery rates (15% to 40% of original volume within 10 days) and extremely high dissolved salt content, recycling of Bakken fracture flowback water would be challenging.

Water Costs for Fracturing the Bakken

- Acquisition costs
  - $0.25–$1.26/bbl of raw water
  - $0.63–$5.00/bbl for transportation
- Disposal costs
  - $0.63–$9.00/bbl for transportation
  - $0.50–$1.75/bbl for disposal via deep well injection
- Total costs
  - $2.01–$17.01/bbl



Bakken Water Opportunities Assessment: Phase 2

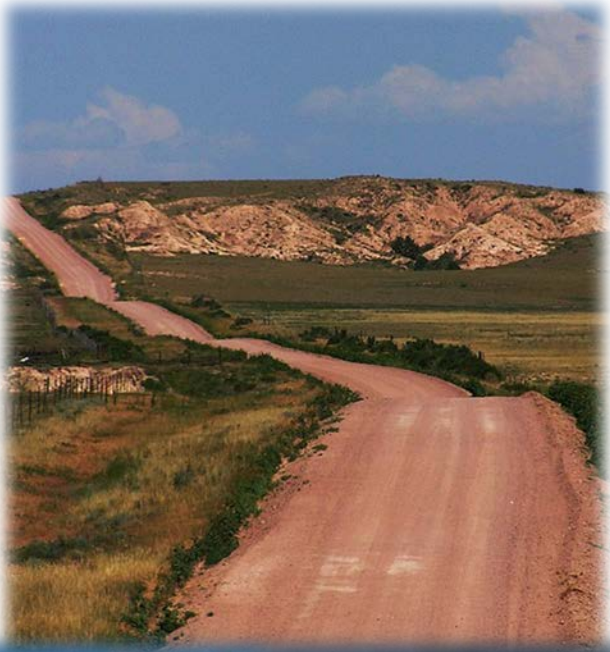
- Partners
  - DOE NETL
  - NDIC OGRC
  - NDPC
  - Hess Corporation
- Goals were to assess the technical and economic feasibility of upgrading nonpotable groundwater for use in hydraulic fracturing.
- The EERC and Hess conducted a pilot project using a portable reverse osmosis (RO) system provided by GE Water and Process Technologies to treat brackish groundwater for use in hydraulic fracturing.
- This approach was economically competitive with existing water supply sources.

A Key Advancement in Water Recycling and Reuse

- Development of customized fracturing fluid systems that can tolerate higher salinities and various impurities.
- Still requires some form of pretreatment to remove constituents of concern, such as organics and suspended solids.
- Not yet widely employed in the Bakken, but a handful of successful demonstrations have occurred.

Potential Benefits of Salt-Tolerant Frac Fluid Systems

- Less demand for freshwater
- Lower transportation costs
- Less truck traffic for freshwater acquisition and wastewater disposal
  - Reduced road maintenance
  - Less dust
  - Fewer air emissions
- Increased versatility for industry in terms of makeup water sources for hydraulic fracturing



We Need a Paradigm Shift

- Issues related to oil and gas development should not be the sole responsibility of industry.
- North Dakota and its citizens benefit from the strong economy created by oil and gas production.
- Let’s tackle optimization of this resource collectively.

For More Information…

John Harju, Associate Director for Research
(701) 777-5157; jharju@undeerc.org

Bethany Kurz, Senior Research Manager
(701) 777-5050; bkurz@undeerc.org

Energy & Environmental Research Center
Grand Forks, North Dakota
www.undeerc.org