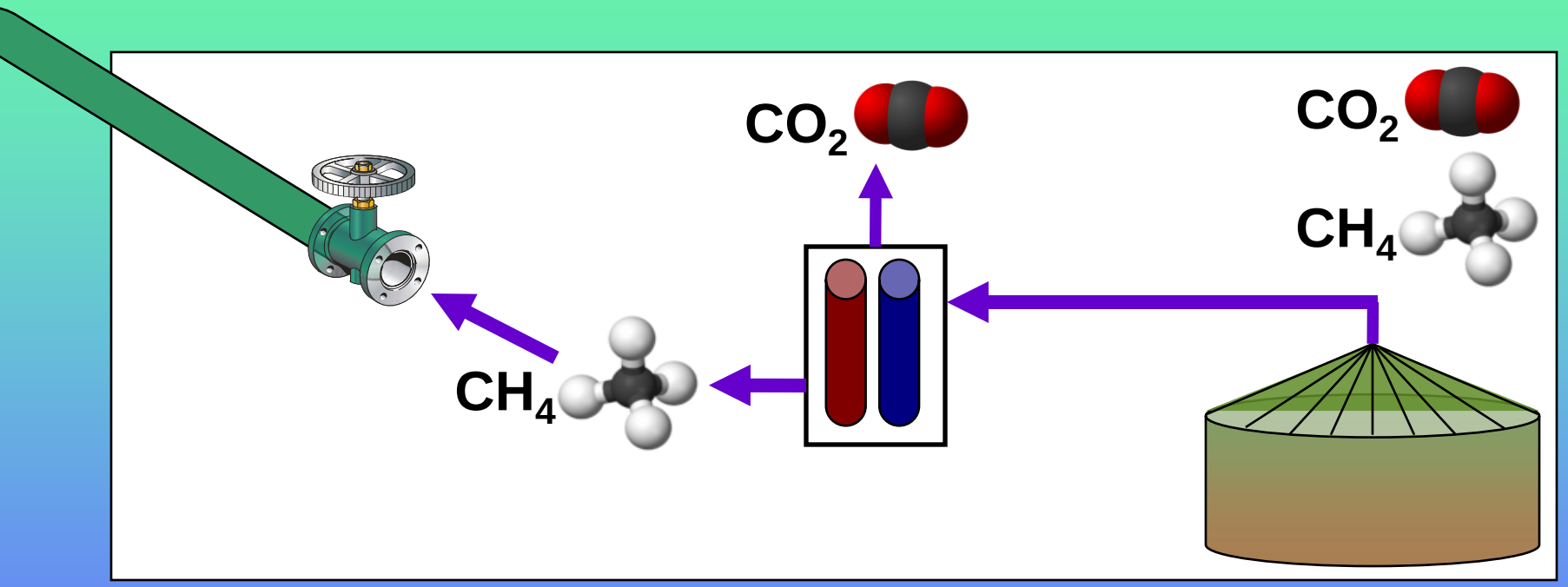
Customer-Owned Distributed Methane Interconnection Issues



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WIDRC Project: Development of a Strategy Paper on Customer-Owned Renewable Natural Gas Interconnection Issues

"The key to utilizing renewable natural gas as a pipeline fuel is the clear delineation of issues, methods and technical solutions for making its use safely interchangeable with the conventional natural gas - without unduly increasing the maintenance burden on pipeline and end-use systems." – from proposal

1) Assemble a WIDRC workgroup
2) Collect background information
3) Prepare first draft strategy paper
4) Use workgroup to zero in on important issues
5) Produce final strategy paper
6) Prepare slideshow of process and results

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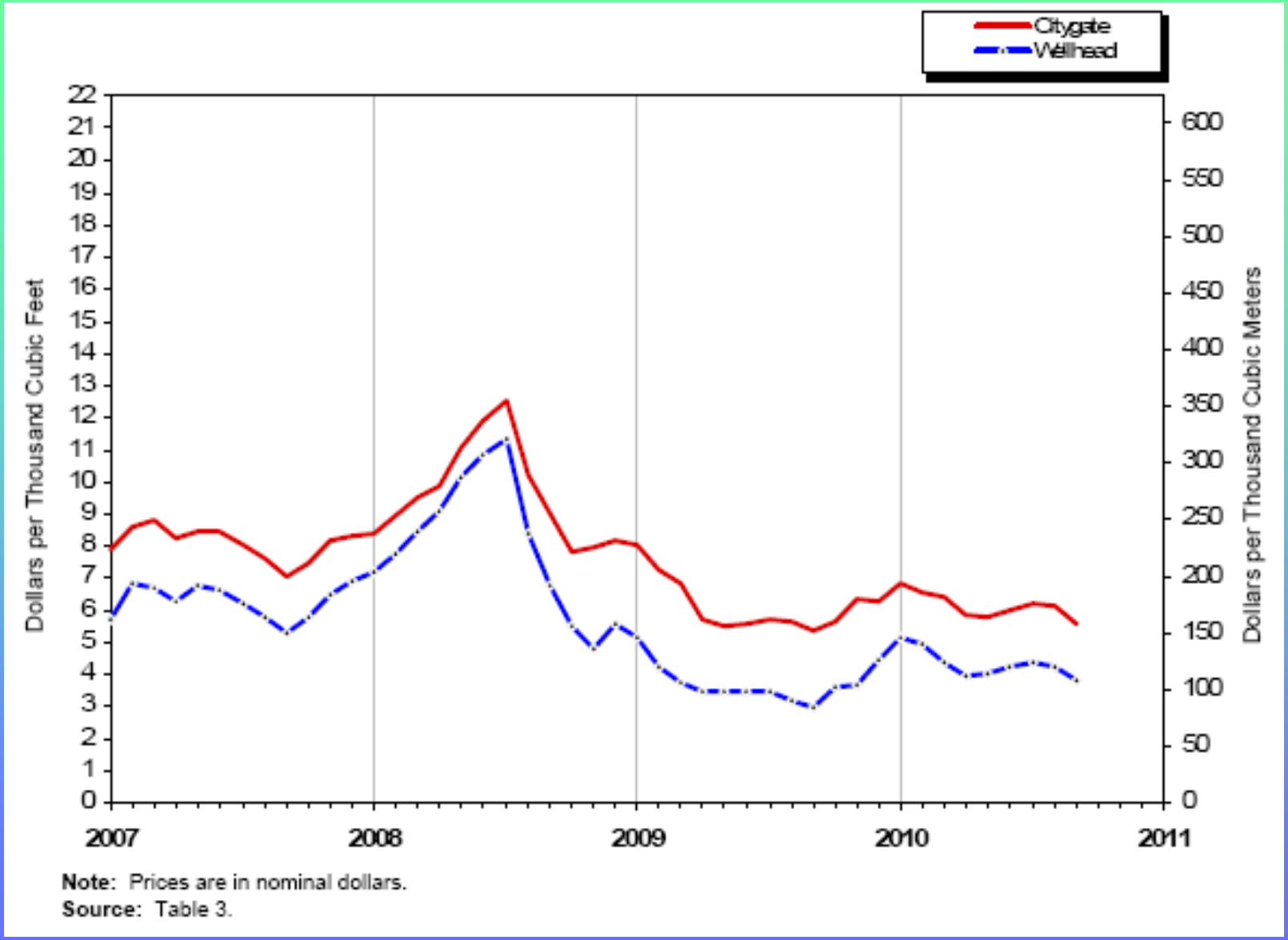
Average Price of Natural Gas in the U.S.; 2007 - 2009



Source: EIA Natural Gas Monthly, November 2010

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Biogas Production

- Farm Digesters
- Industrial Digesters
- Municipal Wastewater Digesters
- Biomass Gasification
- Landfill Gas

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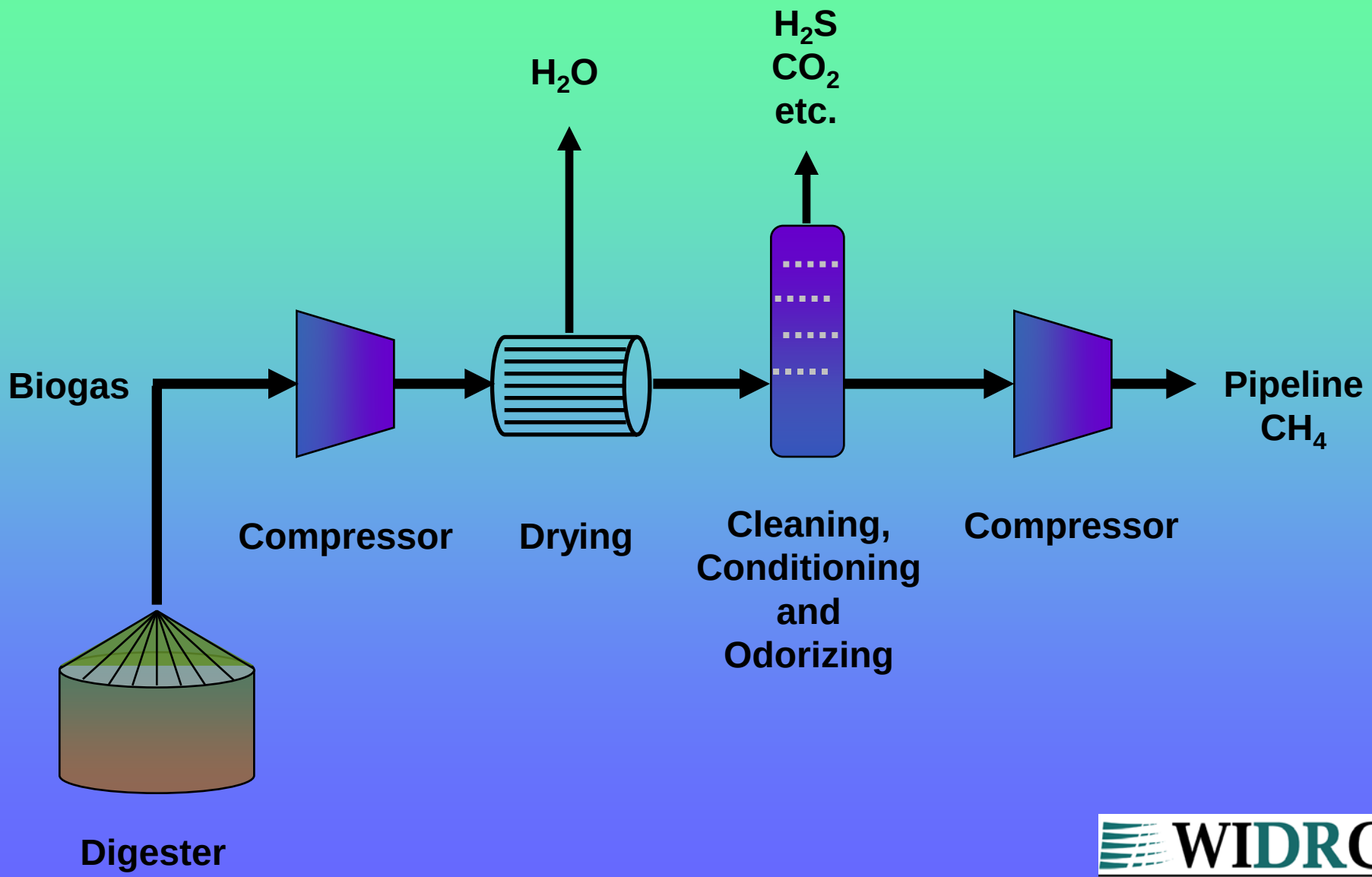
Digester Biogas to Pipeline Quality Methane



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Montchevre-Betin

Cheese Processing
Waste Digester
Belmont, WI
335 kW

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Huckabay Ridge - Stephenville, TX

--- pipeline injection of renewable natural gas ---

- 10,000 cows contributing to anaerobic digester
- 6,350,000 therms/year
- pipeline RNG injection
- gas sales to PG&E

Photo courtesy Microgy, Inc.

Developed by Microgy, Inc.
(Environmental Power Corporation)
Sold in 2010 to
EM Biogas, LLC (Element Markets, LLC)

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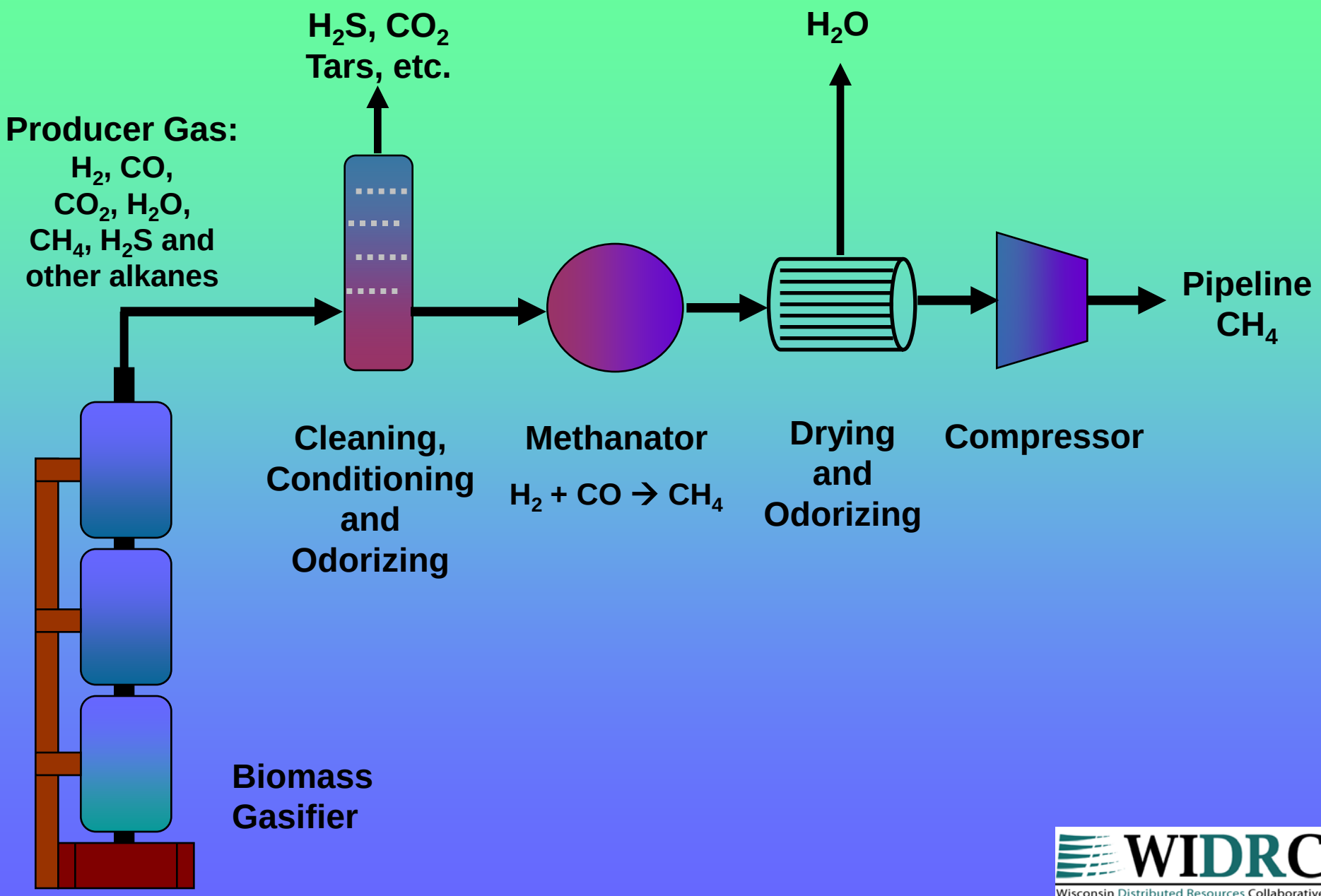
Producer Gas (via Gasification) to Pipeline Quality Methane



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Biomass Gasifier

BFC Power & Light
Cedar Rapids, Iowa
6.5 MW

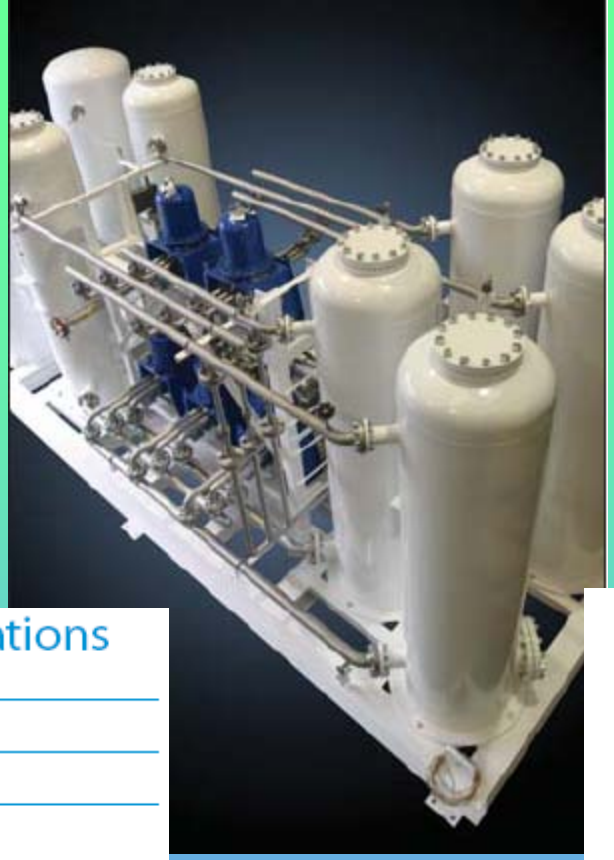
Gas Treatment Methods

Water Removal
- water trap or sump (liquid)
- dehumidification (water vapor)

Hydrogen Sulfide Removal
- iron sponge
- water scrubbing (water column absorption)
- oxygen injection
- activated carbon

Carbon Dioxide Removal
- pressure swing adsorption (PSA)
- water scrubbing (water column absorption)
- molecular sieves
- membranes

Pressure Swing Adsorption



QuestAir™ M-3200/M-3100 Specifications

PSA Feed Gas Conditions	
Methane Concentration	25% to 90%
Pressure	5.5 to 31 bar(g) (80 to 450 PSIG)
Temperature	4 to 50°C (39 to 122°F)
PSA Product Gas	
Flow Range	10 to 10,000 Nm^3/hr (0.01 – 9 mmSCFD)
Methane Concentration	Up to 99%
Pressure Drop	<1 bar (<15 psi)
Temperature	+/-10°C of feed temperature typical
PSA Exhaust Gas	
Pressure	0.2 to -0.5 bar(g), (3 to -7 PSIG) (-7 PSIG for optimal performance)

Iron Scavenger Sponge for Hydrogen Sulfide Removal

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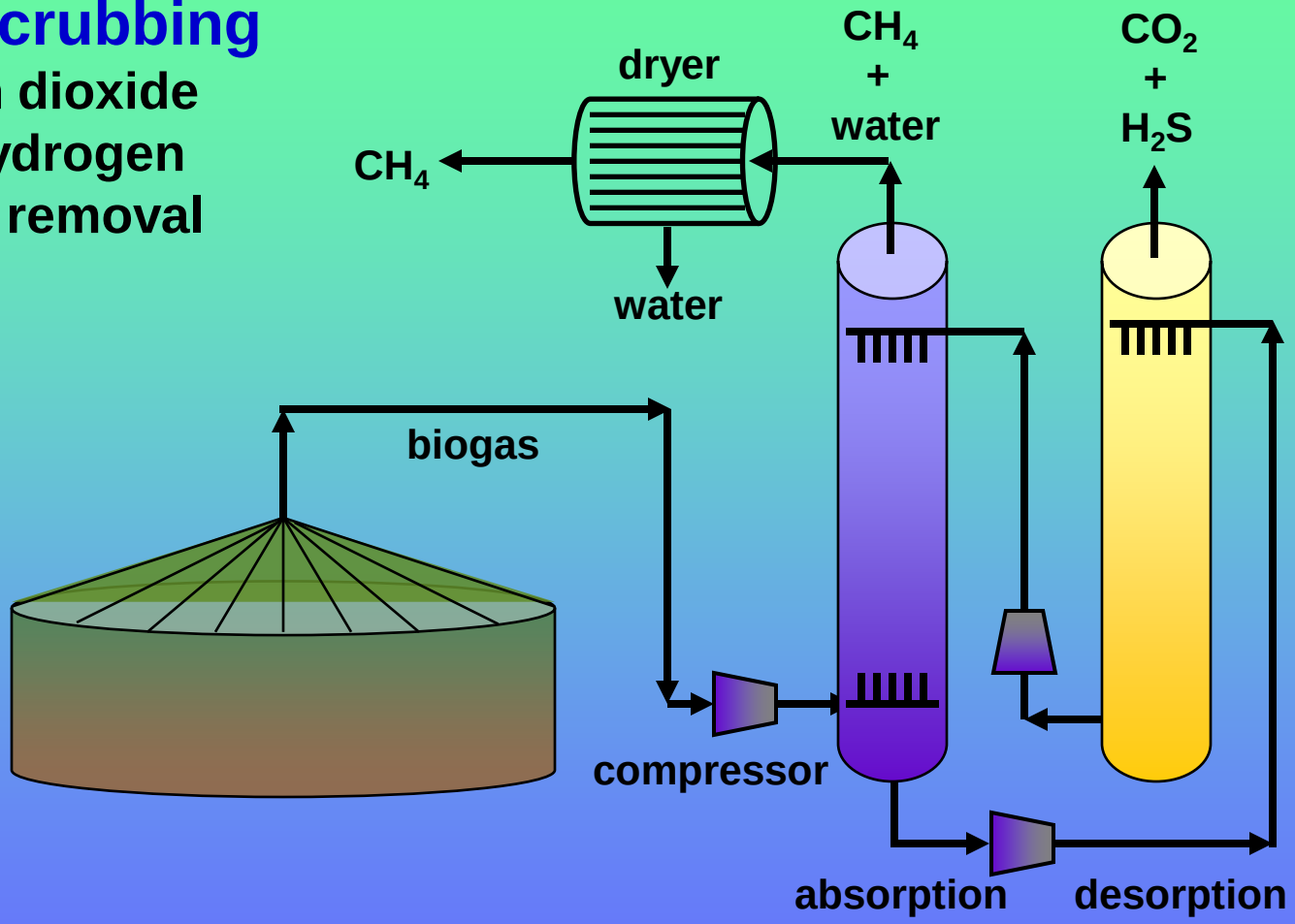
Gas Treatment Methods

Water Scrubbing

carbon dioxide and hydrogen sulfide removal



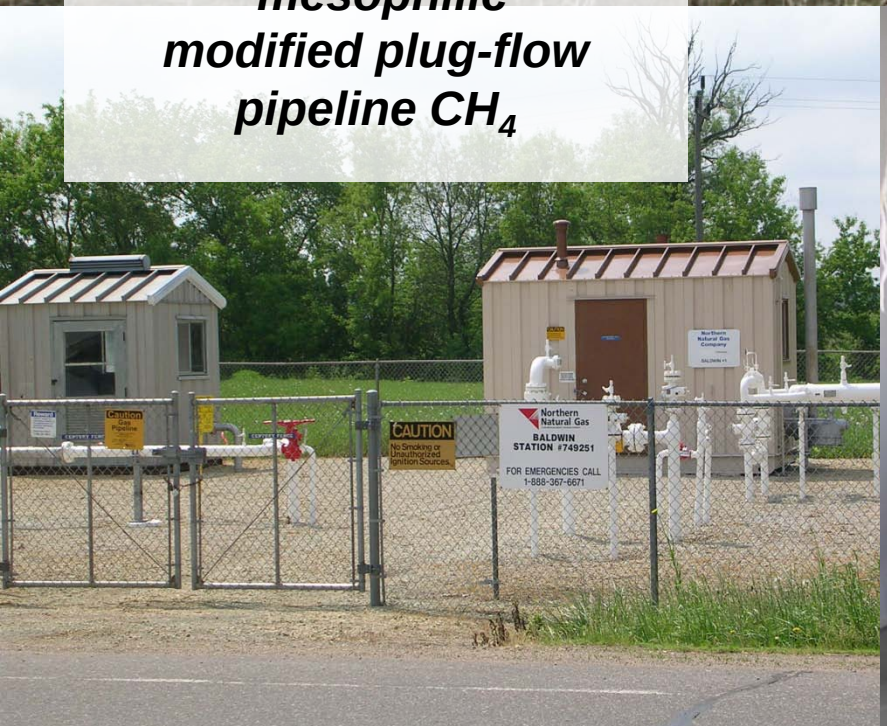
Emerald Dairy

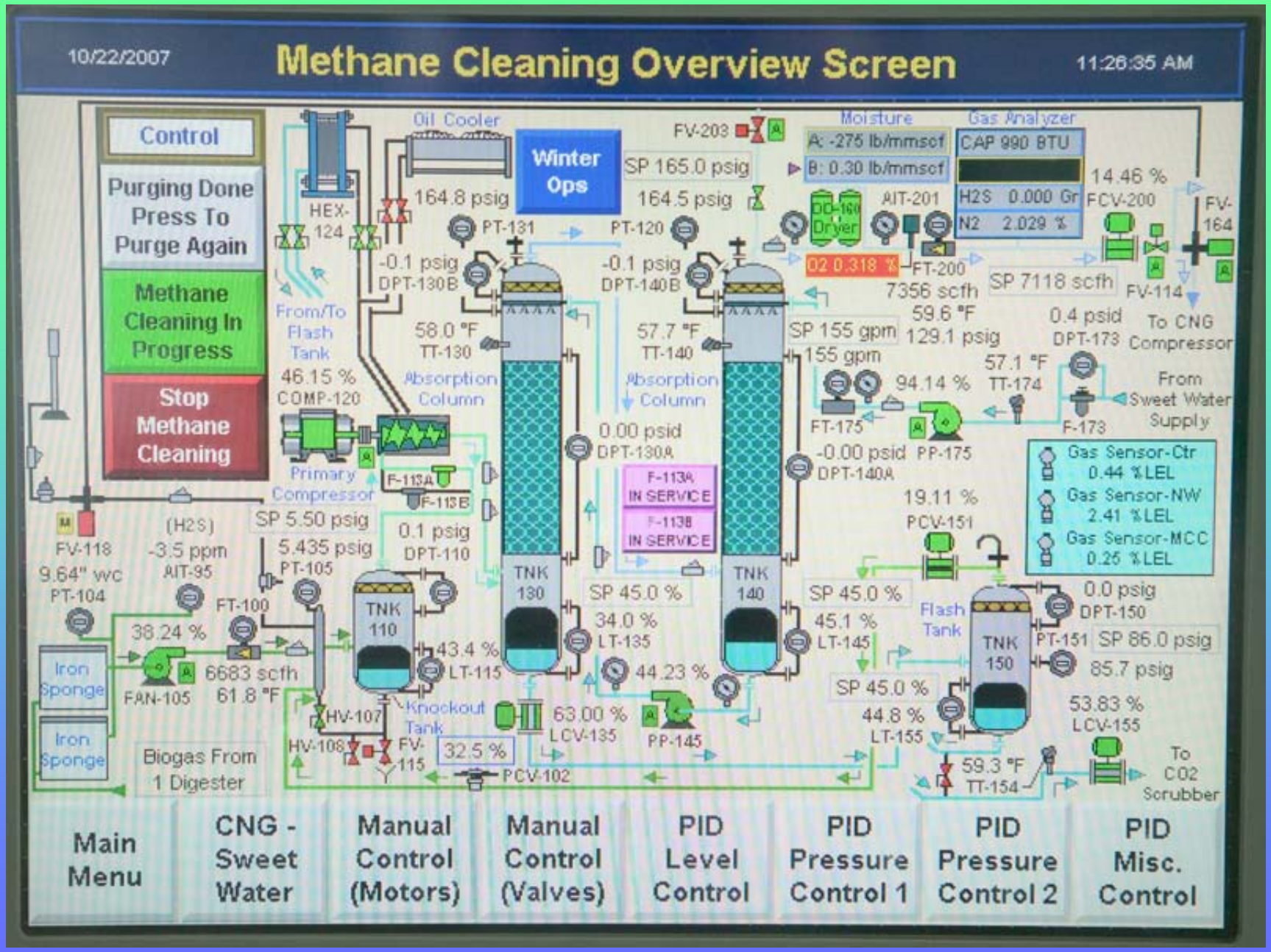
Emerald, WI

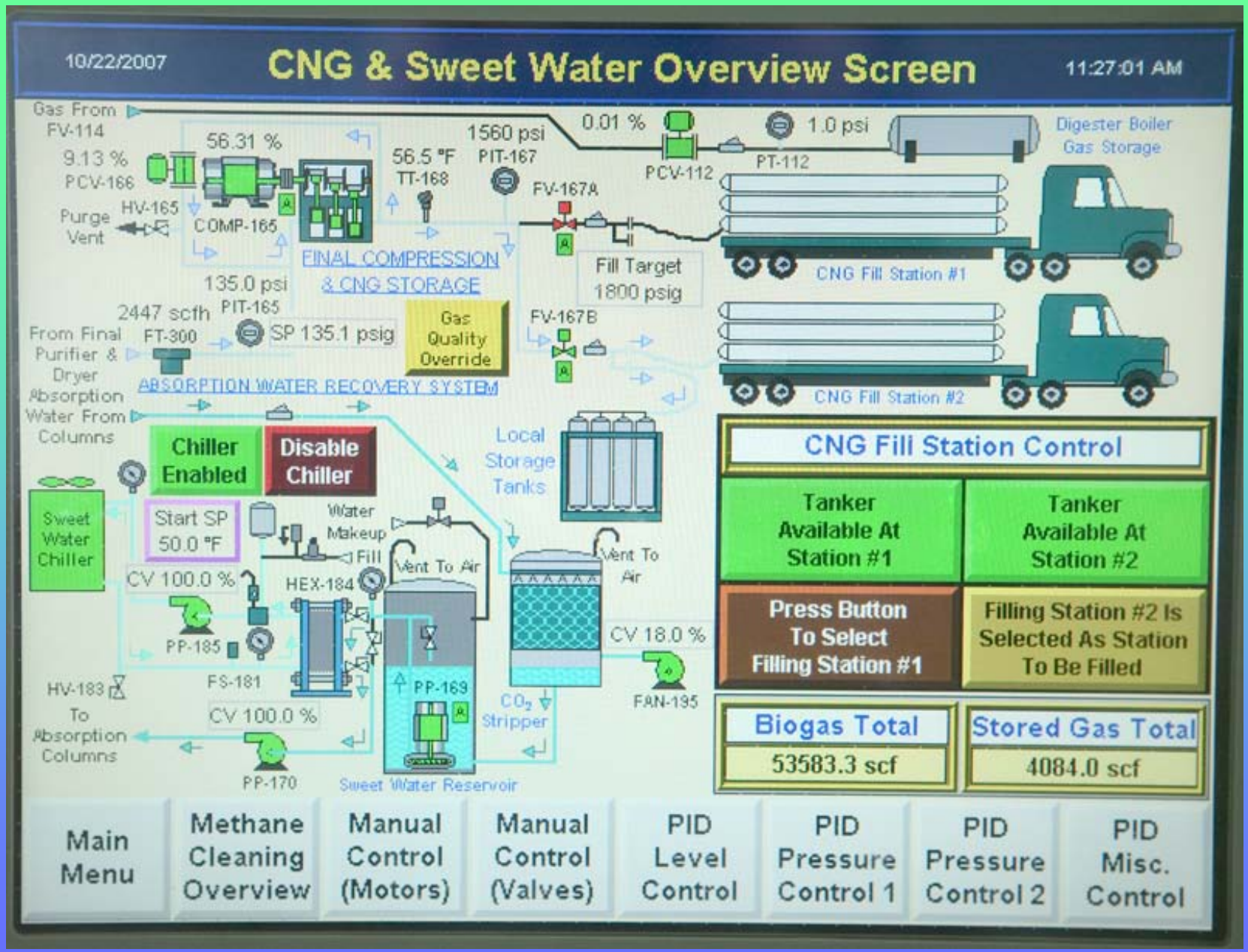
mesophilic

modified plug-flow

pipeline CH_4







Northern Natural Gas Compamy Interconnect Facility - Baldwin, WI

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Renewable Natural Gas (RNG) transported from Emerald Dairy in Compressed Natural Gas (CNG) transport trailer

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Monitoring Transfer Pressure

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Gas Quality Monitoring Equipment Building

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Oxygen Content

Water Content

Hydrogen Sulfide Content

Chromatograph

Transfer Flow Rate

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Chromatograph Report

Baldwin-Wisc stream 1 on 10/26/2007 12:37:23

	MolPct	BTUGross	RelDens	
C6+ 50/50/00		0.0000	0.00	0.0000
PROPANE		0.0000	0.00	0.0000
i-BUTANE		0.0000	0.00	0.0000
n-BUTANE		0.0000	0.00	0.0000
NEOPENTANE		0.0000	0.00	0.0000
i-PENTANE		0.0000	0.00	0.0000
n-PENTANE		0.0000	0.00	0.0000
NITROGEN		2.3909	0.00	0.0231
METHANE		96.8446	980.40	0.5365
CARBON DIOXIDE		0.7608	0.00	0.0116
ETHANE		37.2 PPM	0.07	0.0000
TOTAL		100.0000	980.46	0.5712

Compressibility Factor	1.0019
Heating Value Gross BTU Dry	982.36
Relative Density Gas Corr.	0.5721
Total Unnormalized Conc.	99.370
WOBBE Index	1298.79

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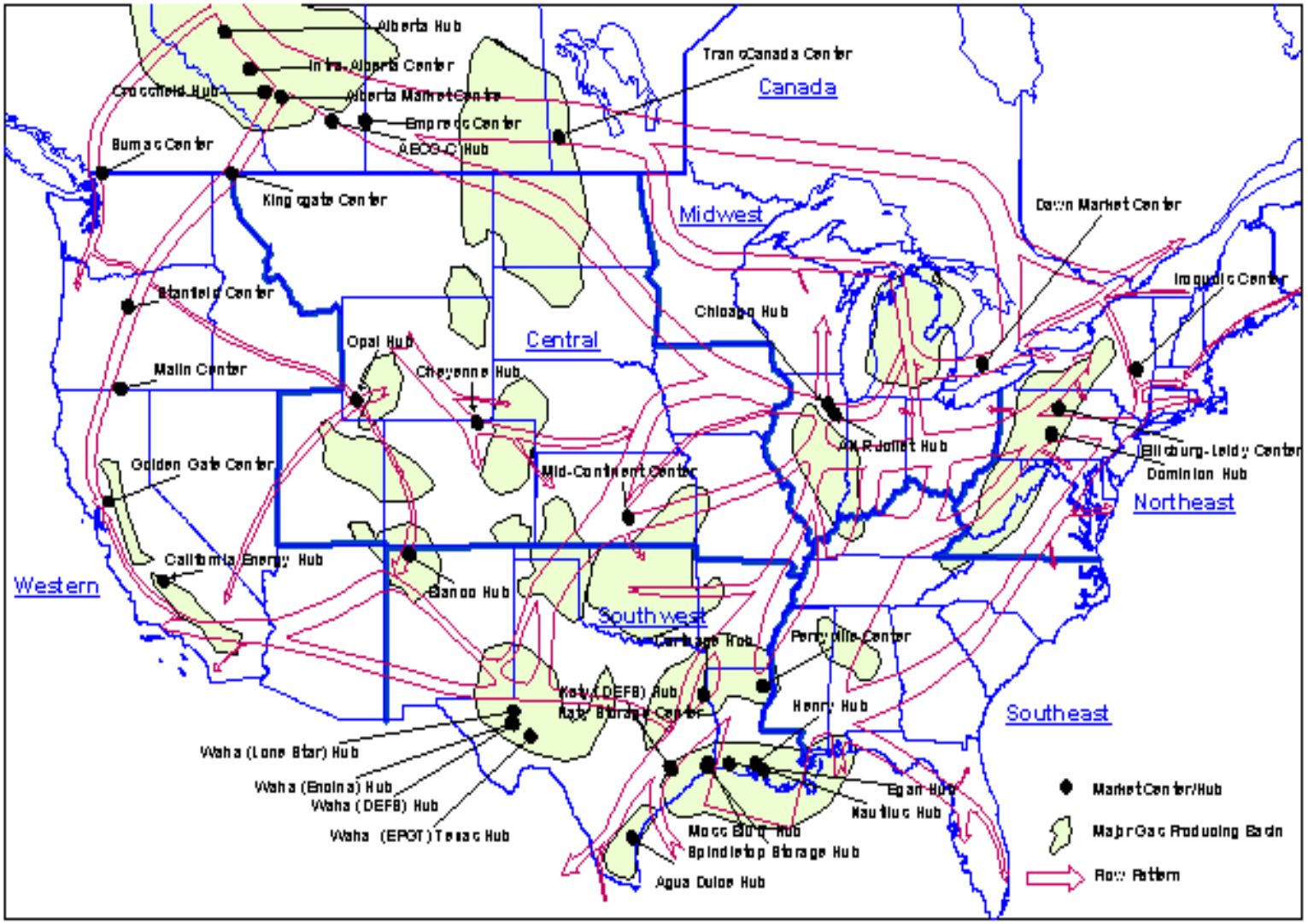
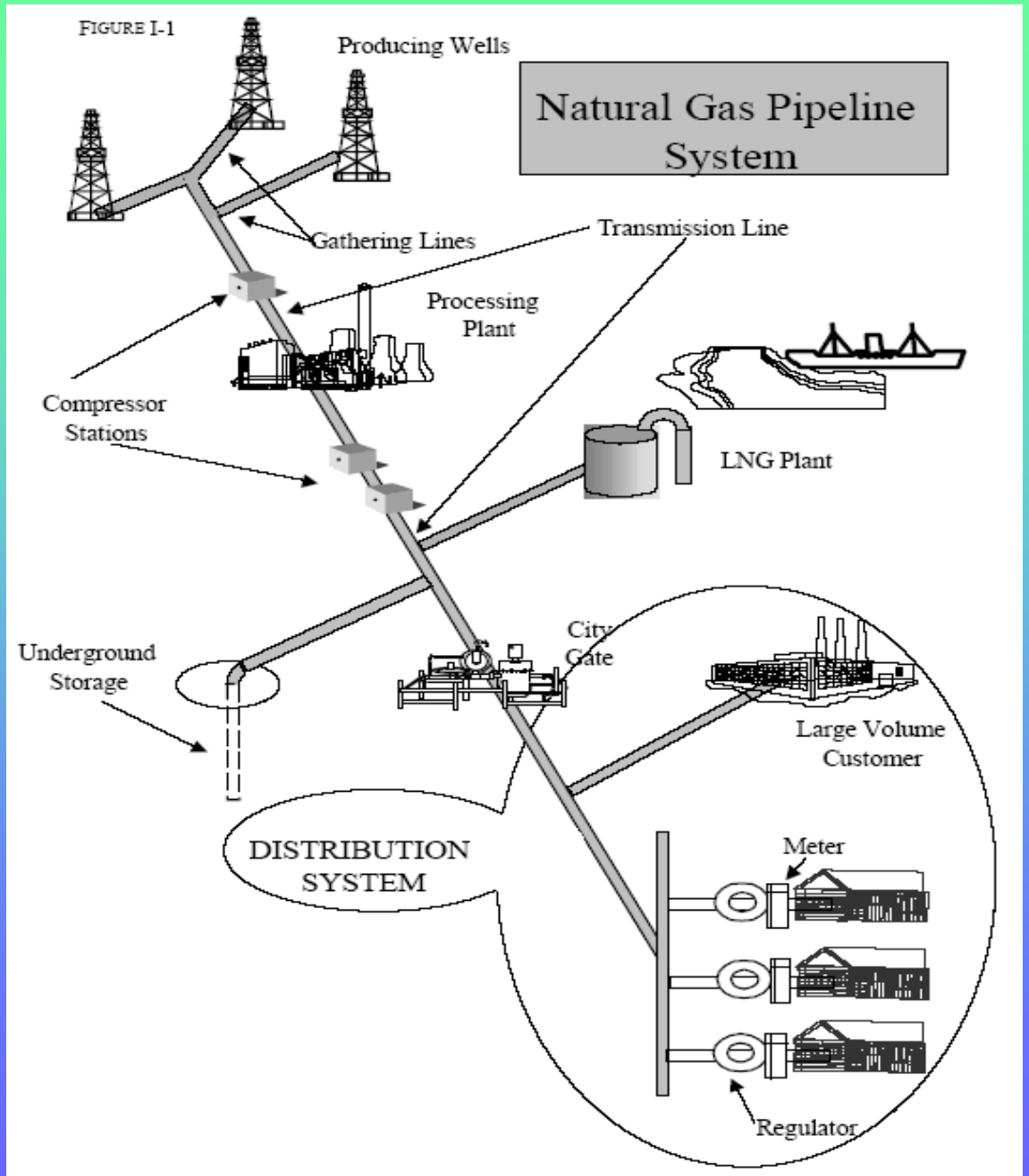
Figure 1. Natural Gas Centers/Hubs in Relation to Production Basins and Major Flow Corridors



Note: DEFS = Duke Energy Field Services Co; EPGT = EPGT Texas Pipeline Co.
Source: Energy Information Administration, GasTran Gas Transportation Information System, Natural Gas Market Hubs Database, as of August 2003.

Natural Gas Pipeline System



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Partial List of Interconnection Issues

Technical Issues Category:

- Dew Point
- Heating Value (HHV)
- Gas Composition
- Interchangeability Index
- Hazardous Substances
- Pressure
- Temperature
- Pipeline Mixing
- Operational Requirements

Business Issues Category:

- Insurance
- Warranty
- Indemnification
- Metering

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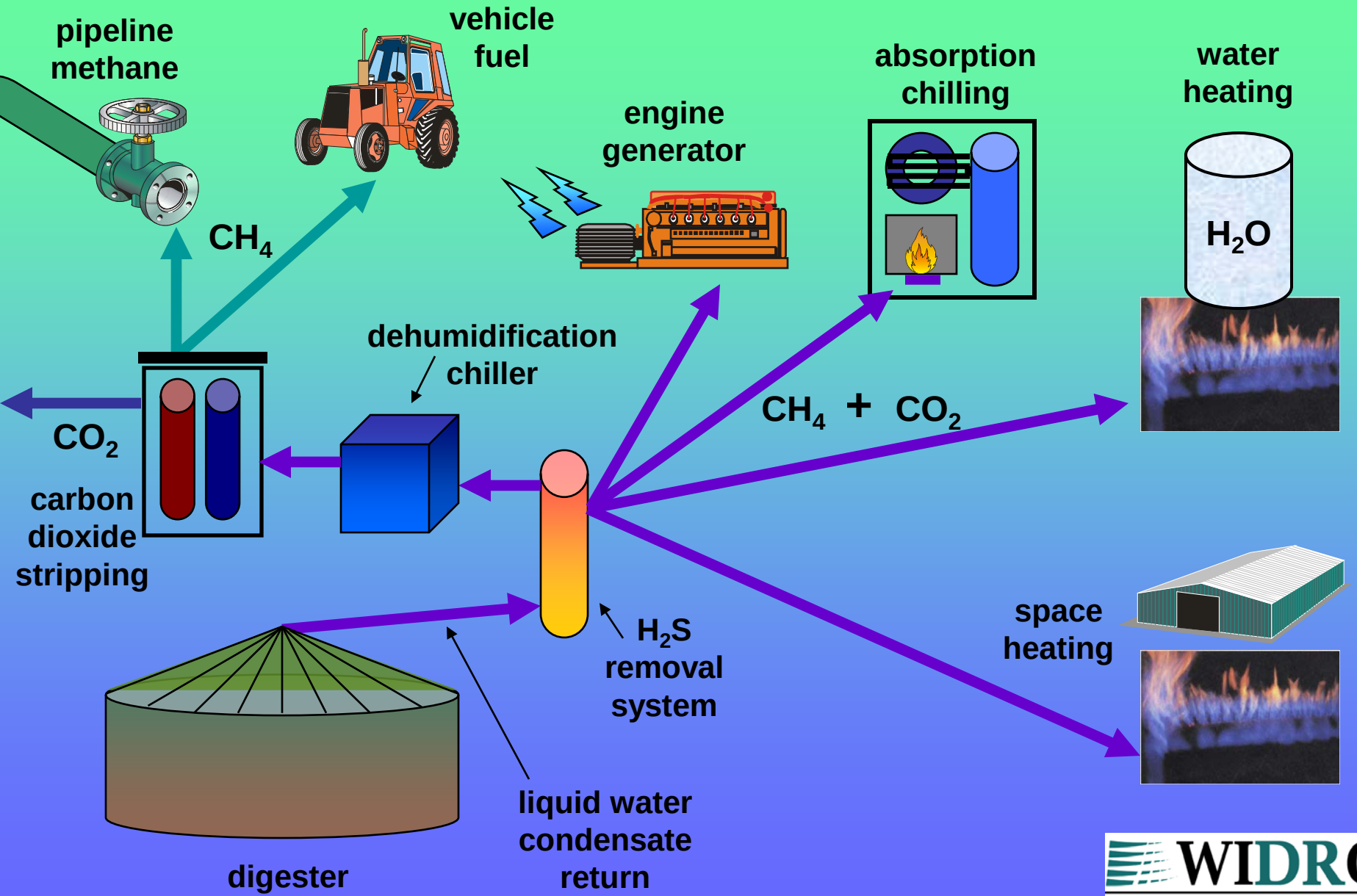
Specifications for Average Natural Gas

Component	Average Natural Gas
Methane	93.40
Ethane	3.20
Propane	0.69
n-Butane	0.25
i-Butane	0.00
n-Pentane	0.10
i-Pentane	0.00
Hexanes (+)	0.06
N_2	1.50
H2	0.00
CO_2	0.80
H_2O	0.00
Air	0.00
Total	100.00
Higher Heating Value (Btu/scf)	1032.3
LHV (Btu/scf)	931.0
LHV (Btu/lb)	20,363
Specific Gravity	0.5971
Ideal Density (lb/scf)	0.04557
Real Gas Density (lb/scf)	0.04565
Wobbe Number (HHV)	1336.0
Wobbe Number (LHV)	1204.9
H/C Ratio	3.884
Est. Octane Rating (MON) (Gas Data)	131.0
Est. Octane Rating (MON) (H/C ratio)	130.8
MN (CARB)	93.3
Stoichiometric A/F ratio	16.736
Molecular Weight	17.292

Biogas Utilization



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Indicators of Interchangeability

Wobbe Index

$W = HV / \sqrt{G}$

where HV = gross heating value/scf

G = relative density of gas

(ratio of density of gas to density of air @STP)

- The thermal burner load is directly related to the Wobbe index of a gas.
- The air supply to the combustion zone is independent of the gas composition.
- The impact of gas quality is determined by the Wobbe index
- Simple, easy to use
- Common practice in other countries

Other Indicators

AGA, Weaver Index and Methane Number

- Provide better description of incomplete combustion
- Complex, not easy to use
- Provide a relative adjustment to Wobbe index

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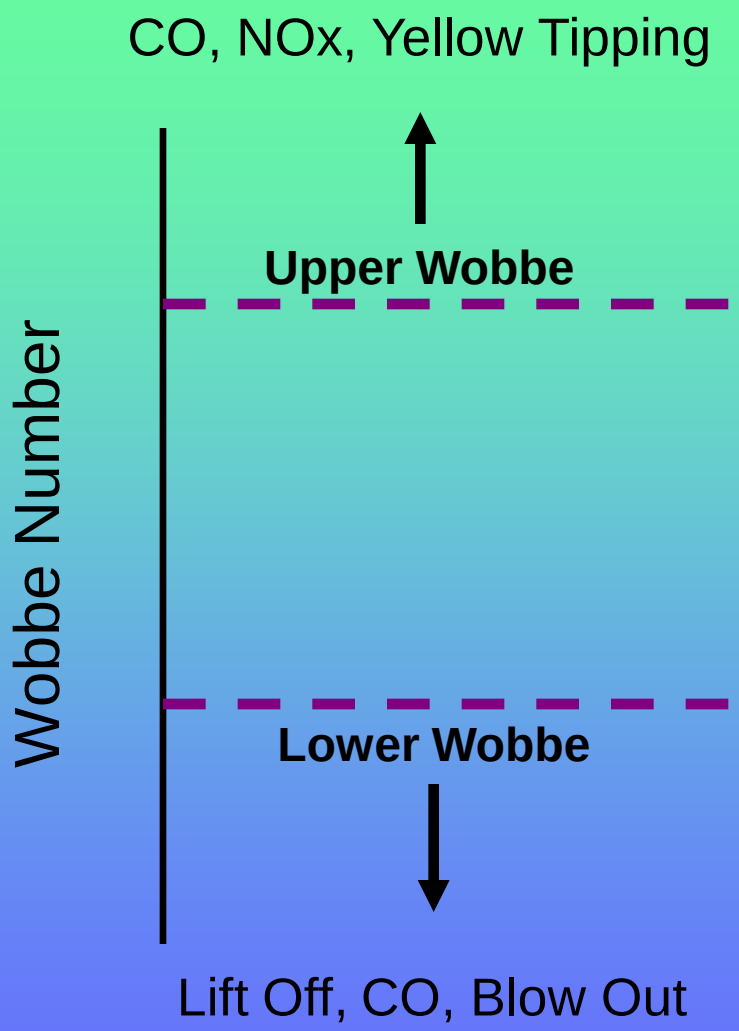

ANR Pipeline Company

– Physical and Chemical Properties or Characteristics of Interest -

Property or Characteristic	Symbol	Specified in Tariff
High Heating Value	HHV	Yes
Low Heating Value	LHV	Yes
Temperature	T	Yes
Water	H_2O	Yes
Hydrocarbon Dewpoint	D_{HC}	Under Review
Nitrogen	N_2	Yes
Carbon Dioxide	CO_2	Yes
Oxygen	O_2	Yes
Total Sulfide	S_{TOT}	Yes
Hydrogen Sulfide	H_2S	Yes
Particulates		Yes
Other Solids or Liquids		Yes

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Northern Natural Gas Specification

Component / Property	Units of Measure	Pipeline Spec[1]	CNG Spec per DOT[2]
Water vapor	Lbs per mmscf (million std cu ft)	Less than 6	**Less than 0.5**
Hydrogen sulfide	Grains per Ccf	Less than or equal to 0.25	**Less than or equal to 0.10**
Total sulfur	Grains per Ccf	Less than or equal to 20	**Less than 0.1**
Heating value	Btu per Cubic Foot	**Greater than or equal to 950**	
Temperature	Degrees Fahrenheit	**Less than or equal to 120 F.**	
Oxygen	Per cent by volume	**Less than or equal to 0.2**	Less than 1.0
Carbon dioxide	Per cent by volume	**Less than or equal to 2.0**	Less than 3.0
Non-hydrocarbon gases	Per cent by volume		**Less than 4.0**

[1] Issued May 1, 2003 Northern Natural Gas Company FERC Tariff - fourth revised sheet 281

[2] DOT regulations DOT-E-8009 13th revision

California Public Utilities Commissions - California Rule 30

Specifications	Min	Max
Btu/cu ft	970	1150
Wobbe number	1272*	1437*
MN	NA	NA
Methane (%)	NA	NA
Ethane (%)	NA	NA
Propane (%)	NA	NA
Inerts (%)	0	4

Southern California Gas Company- Rule No. 30 Transportation of Customer-Owned Gas

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Pipeline Mixing

How long will it take to mix customer-owned methane with pipeline natural gas in a pipeline?

LNG Interchangeability/Gas Quality: Results of the National Energy Technology Laboratory's Research for the FERC on Natural Gas Quality and Interchangeability

U.S. Department of Energy National Energy Technology Laboratory

DOE/NETL-2007/1290; June 2007

Computational fluid dynamics simulations and calculations using an analytical formula were used to illustrate:

- continuous (steady) cross-sectional mixing and
- transient axial mixing

of gases in pipe junctions.

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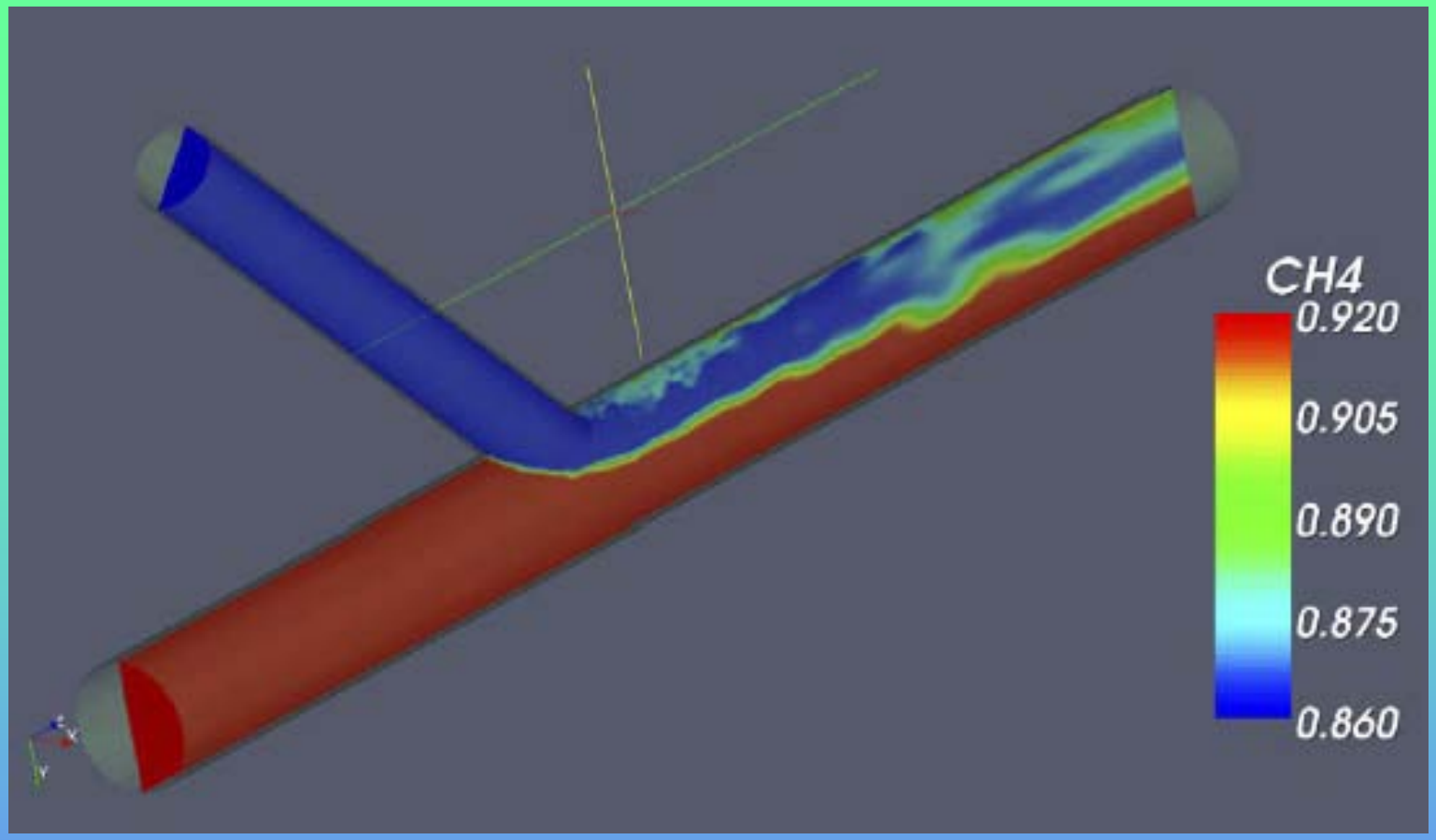

The pressure and flow volume of the utility gas pipeline will influence the degree of natural gas mixing with customer-owned methane.

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How long will it take to mix customer-owned methane with pipeline natural gas in a pipeline?

It has been shown that *steady* injection of a gas into a flowing NG pipeline would mix to an average composition in a relatively short distance; typically within 100 pipe diameters.

- **Steady state gas blending is completed in a relatively short distance.**

It has also been shown that during *transient* injection, new and original gas compositions would move through the pipeline as discrete packets of gas.

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Interconnection Issues
- Short List of Some Applicable Standards

- Title 49 of the Code of Federal Regulations (CFR), parts 190, 191, 192, and 199
- Public Service Commission of Wisconsin: PSC 133, 134 and 135
- Wisconsin Electrical Code Part 1 and 2 (NEC & NESC compliant)
- American Gas Association Report No. 4A
- American Gas Association Research Bulletin No. 36

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“Pipeline Quality Biomethane: North American Guidance Document for Introduction of Dairy Waste Derived Biomethane Into Existing Natural Gas Networks”

Final Reports – Tasks 1,2 and 3

Gas Technology Institute, Des Plaines, Illinois

Report No. GTI-09/0011; September 30, 2009

Task 1: Technology Investigation and Assessment

Task 2: Develop laboratory testing program to evaluate raw biogas

Task 3: Prepare guidance document with reference to AGA Report 4A “Natural Gas Contract Measurement and Quality Clauses”

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Questions?

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