



International Gas Union Research Conference  
Copenhagen • September 17, 2014



# BIOGAS UPGRADING USING BIOCATALYST TECHNOLOGY

Barry Blackwell, President & CEO  
Akermin, Inc.

# AKERMIN, INC.

*Developing a novel biotech driven approach to remove CO<sub>2</sub> from industrial processes*

- Proprietary technology integrating enzymes into a delivery system for long-term commercial performance
- Capital and energy-efficient, environmentally-benign solution with large market potential
- Strong, focused 16 person team
- Entering commercial phase
- St. Louis, Missouri, USA



# WHY SCRUB CARBON DIOXIDE?

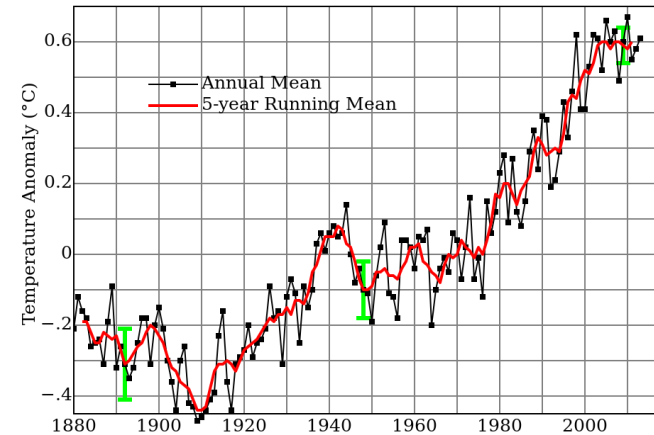
## ■ Environmental Impact:

- CO<sub>2</sub> is a main contributor to climate change

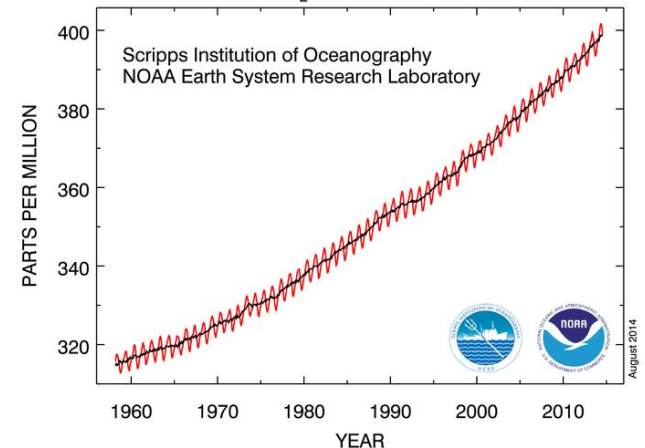
## ■ Industrial Demand:

- Natural gas treating for pipelines, NGLs, liquefaction
- Production of ammonia, urea
- Production of hydrogen
- Biogas upgrading ("bio-methane" production)
- CO<sub>2</sub> utilization; ex. EOR, chemicals, algae

Global Land-Ocean Temperature Index



Atmospheric CO<sub>2</sub> at Mauna Loa Observatory



Important for product production & waste gas clean-up and utilization

# DOMINANT APPROACH TODAY: CHEMICAL ABSORPTION WITH AMINES

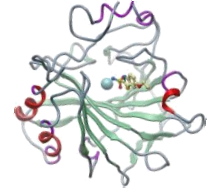
*Where does it fall short?*

- High operating costs & poor environmental profile
  - Increases energy requirements
  - Uses toxic and volatile solvents
  - Generates hazardous by-products
  - Accompanied by solvent degradation
- Inadequate for large-scale CO<sub>2</sub> capture from flue gas streams

The market is demanding lower cost, environmentally-friendly solutions

# AKERMIN'S APPROACH TO CO<sub>2</sub> CAPTURE

*Capitalizing on nature's most efficient catalyst, Carbonic Anhydrase*



## ■ Carbonic Anhydrase (CA)

- Regulates CO<sub>2</sub> in all living organisms  $H_2O + CO_2 \rightleftharpoons H^+ + HCO_3^-$
- Exceptionally fast: 1 million cycles per second
- Well-studied, can be produced on large scale

The challenge is to make a biocatalyst evolved *in vivo*, to work under harsh industrial environments with stressors such as:

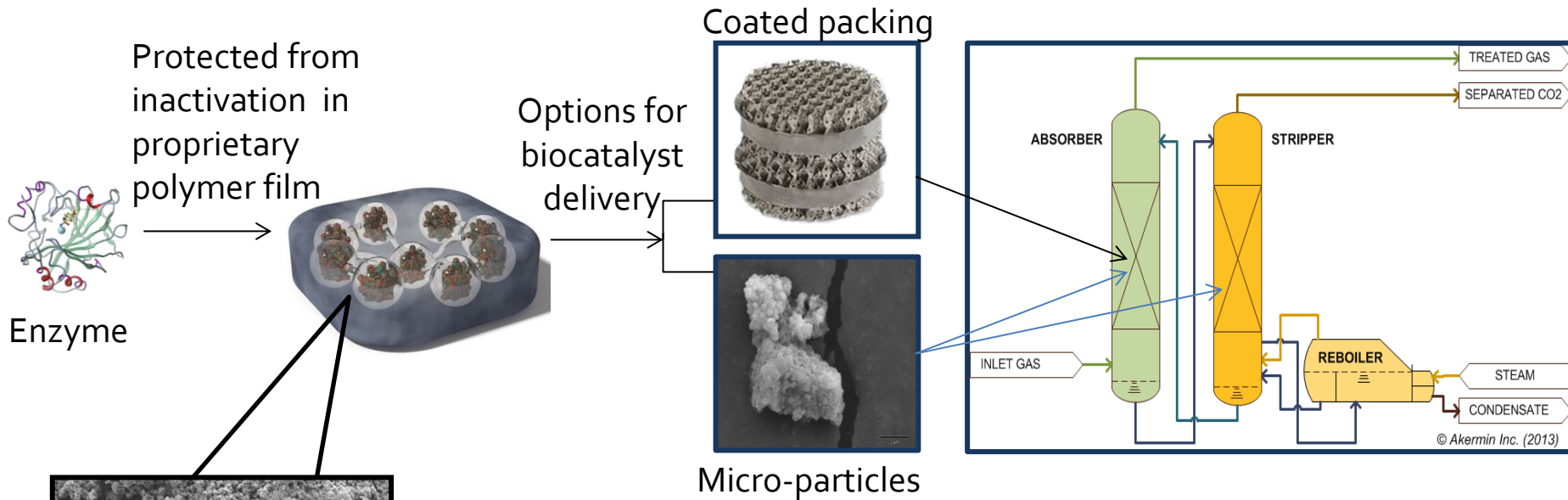


- Temperature
- pH
- Pressure
- Impurities
- Shear Forces

**Akermin has solved the problem by designing proprietary enzyme delivery systems**

# AKERMIN'S BIOCATALYST DELIVERY SYSTEM

*How we do it*



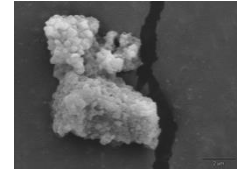
Successful biocatalyst approach enables:

- Non-toxic, non-volatile solvents
- Novel process schemes

Leverages current technology: readily scalable for retro-fit and greenfield opportunities



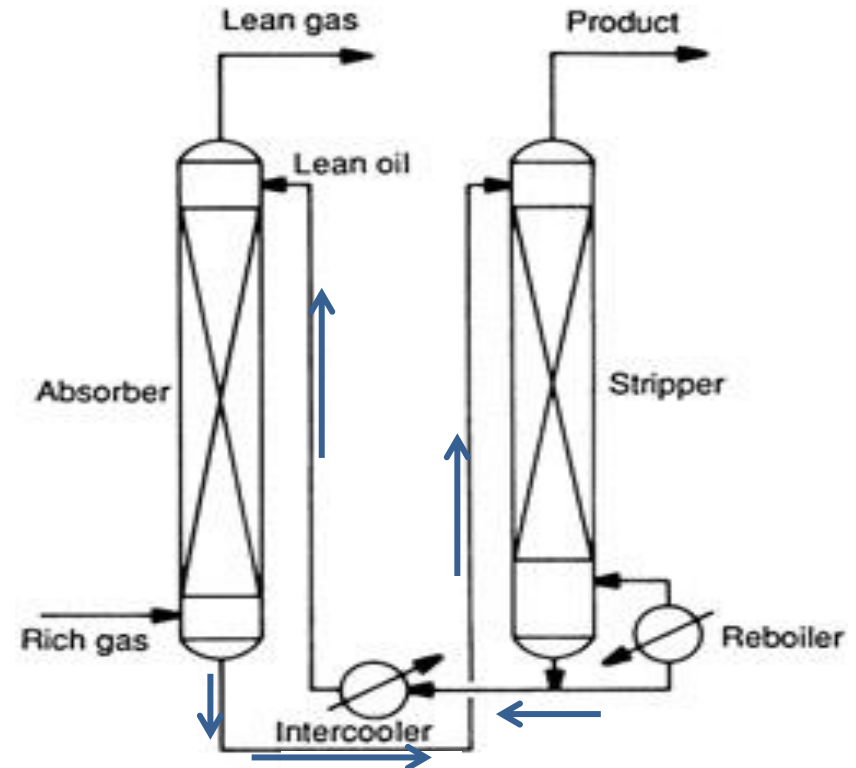
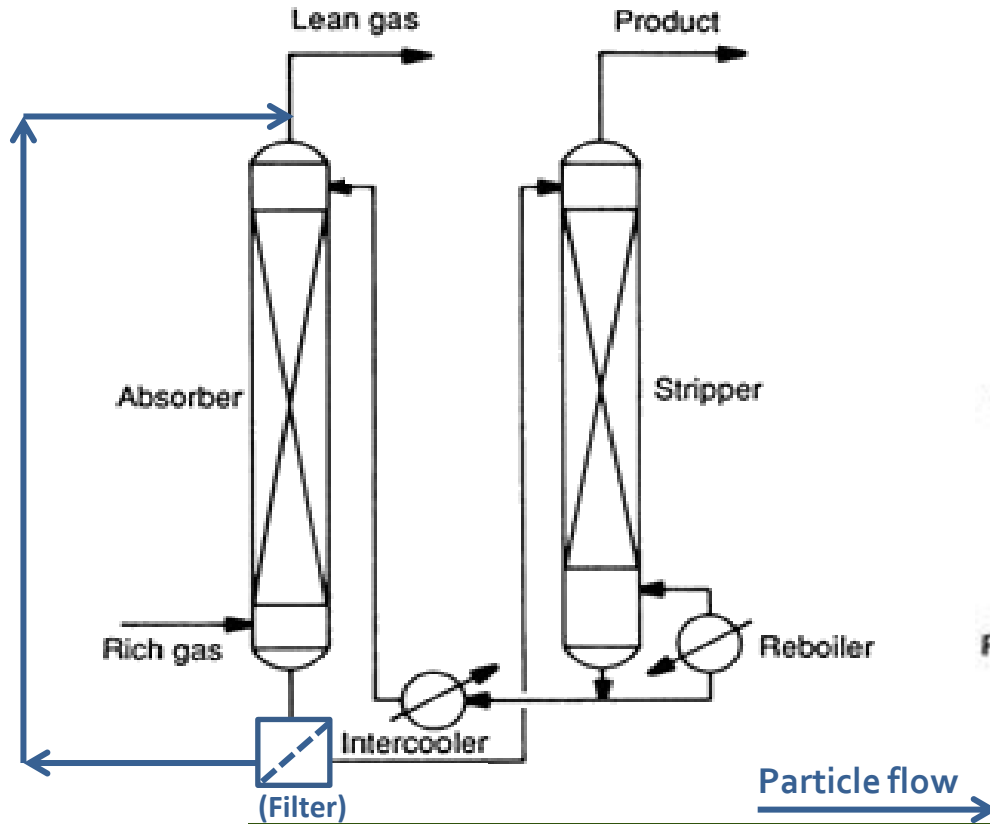
# CHALLENGE: HOW TO REPLENISH BIOCATALYST AT COMMERCIAL SCALE?



*Two concepts employing enzyme delivery as micro-particle:*

Recirculation within absorber only  
(requires particle separation)

Continuous recirculation in absorber and stripper  
(req. lower temp. stripping)



# PUTTING IT ALL TOGETHER:

*Key Benefits of AKM24 + biocatalyst delivery system + improved flow sheet*

- Replace formulated solvents with biocatalyst-enabled, generic solvents that are:
  - Non-volatile
  - Non-toxic
  - Resistant to oxygen and other impurities
  - Higher loading capacity
  - Lower regeneration energy
- Process – Simpler flow scheme with smaller columns and components
- On-line biocatalyst replacement

Enables lower cost, environmentally-friendly solution





# PILOT-SCALE EXPERIENCE

**NATIONAL CARBON CAPTURE CENTER  
WILSONVILLE, ALABAMA  
Dec 2012 – Oct 2013**



# FIELD PILOT PROJECTS

*In collaboration with the U.S. Department of Energy*

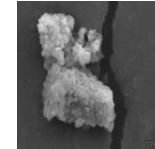


**Successful project results:  
validation of technology  
with coated packing**

- \$3.8 million award
- Largest and longest-running enzymatic trial for CO<sub>2</sub> capture
- Over 6 months of stable, robust performance
- No biocatalyst replenishment
- Completed September 2013



Akermin pilot unit at the  
National Carbon Capture Center, Wilsonville, AL



**New project: focused on  
using micro-particles**

- \$3 million award
- Demonstrate:
  - in situ biocatalyst replacement
  - expand solvent options
  - new process schemes
- Further reduce energy and capital costs
- Started October 2013

Field validation of commercial readiness



# KEY NEAR-TERM GLOBAL MARKETS

*Address demand for lower cost, environmentally-friendly CO<sub>2</sub> separation solutions*



## Biogas Upgrading

- Removal of CO<sub>2</sub> to create renewable, sustainable natural gas
- **Market:** \$100 MM (Akermin revenue)
- **Key Drivers:** Rapidly growing demand to create sustainable and renewable fuels using biomass feedstock (organic waste)



## LNG Liquefaction

- Deep CO<sub>2</sub> removal requirement (50 ppm) prior to natural gas liquefaction
- **Market:** \$100-150 MM
- **Key Drivers:** Spread between oil/gas; demand for LNG as clean transportation fuel, Power supplement



## Ammonia Production

- All CO<sub>2</sub> must be removed from raw syngas before conversion to ammonia
- **Market:** \$500 MM
- **Key Driver:** Increasing demand for fertilizers to increase crop yield

Markets Ready for Commercial Launch

# DEVELOPING CO<sub>2</sub> CAPTURE MARKETS

*Today: CO<sub>2</sub> Utilization, Tomorrow: Regulatory Driven flue gas challenges*



## Power Plants

- Flue gas from coal and natural gas fired plants
- **Market:** \$10 billion
- China, EU, and N. America drivers



## Oil Sands

- Flue gas from SAGD and oil upgrading processes
- **Market:** \$50-100 million
- Canadian pilot demonstrations support



## Refineries

- Refinery processes such as FCCUs and hydrogen
- **Market:** \$1.0-2.0 billion

Lower cost CO<sub>2</sub> capture is enabling new CO<sub>2</sub> Utilization markets: EOR, algae biofuel, and chemicals/fuels production.



# BIOGAS UPGRADING

Market  
Project ENZUP



# BIOGAS UPGRADING: BIOMETHANE PRODUCTION



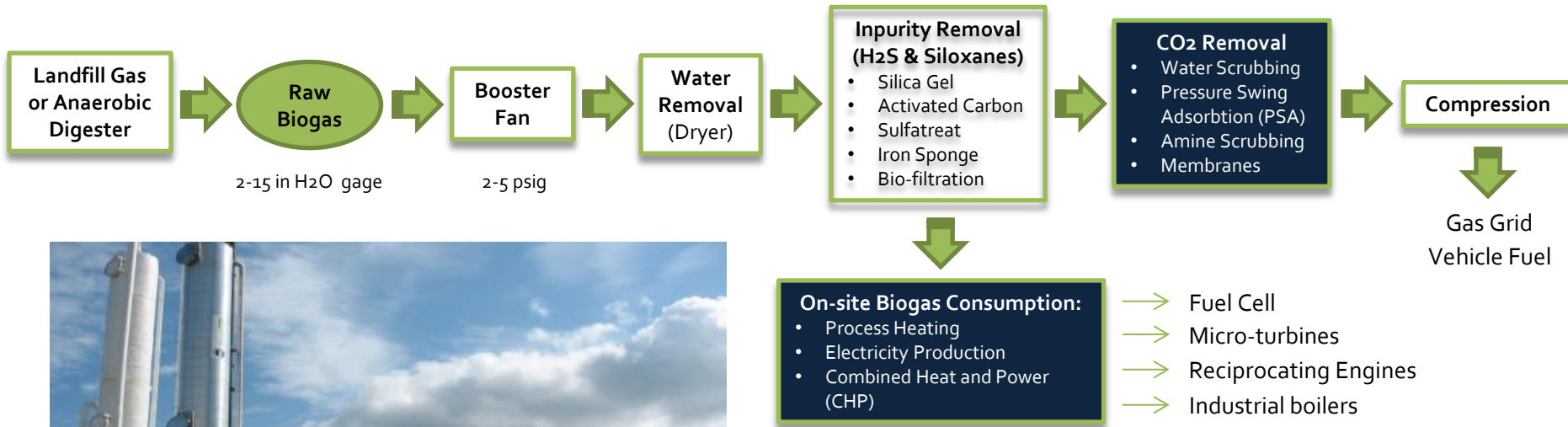
- Growing global market; >20% annual growth rate
- Sources: Ag(manure & crops), wastewater, MSW, Landfill
- Market Drivers: waste & environmental Mgt, sustainability, gov't mandates/subsidies, NG prices, gas & infrastructure shortages
- Addressable global market: ~\$200 million
- No dominant technology, fragmented delivery infrastructure
- \$2.5-5 million Upgrade unit investment
- **Akermin Value Proposition: Energy savings & Capital reduction; total cost reduction goal: >30%**

Value: Commercial validation, global positioning, green solution

# PROCESS FOR BIOGAS CLEANING & UPGRADING

**Biogas cleaning:** Removal of undesired trace substances from the biogas like minerals, sulphide, ammonia, etc.

**Biogas upgrading:** Removal of CO<sub>2</sub> to reach natural gas like quality



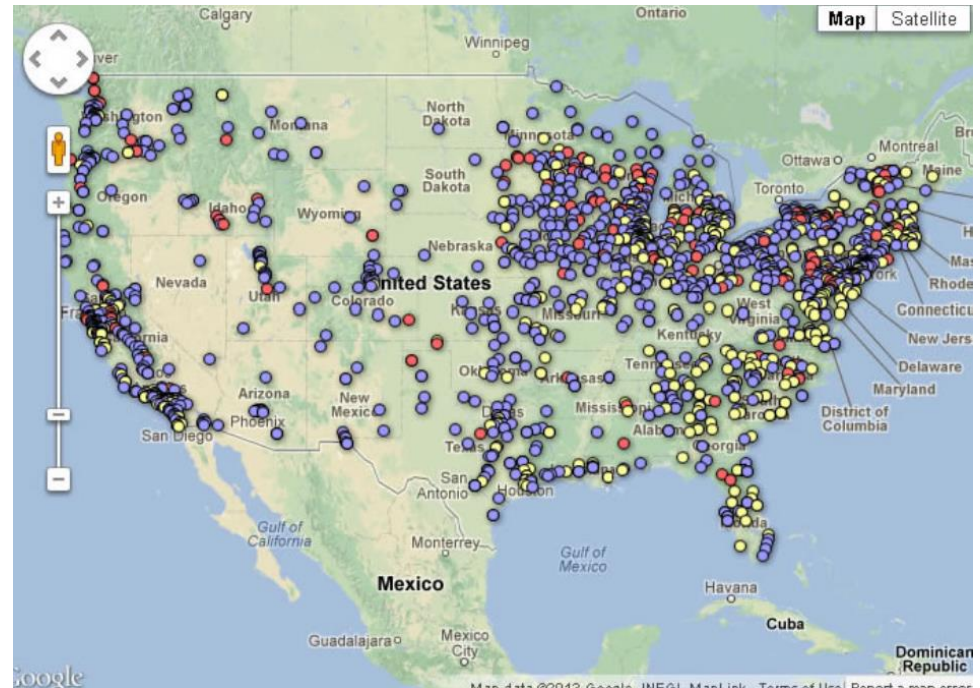
## Average Size Upgrading Plant:

- Processes 1,000 m<sup>3</sup>/hr of biogas
- Produces 600 m<sup>3</sup>/hr of bio-methane
- Emits 15-20 metric tons of CO<sub>2</sub> daily

CO<sub>2</sub> Removal Drives the Cleaning and Upgrading cost

# US BIOMETHANE OPPORTUNITY

- Over 12,000 sites
  - > 8,200 dairy
  - > 5,000 WWTP
  - Industrial/Other
- Would produce enough gas for over 6.5 million homes
- Currently around 1,500 biogas units (80% at WWTP)



## Operating US anaerobic digesters:

Red- Agricultural; Blue – WWTP (Waste Water Treatment Plant); Yellow - Landfill

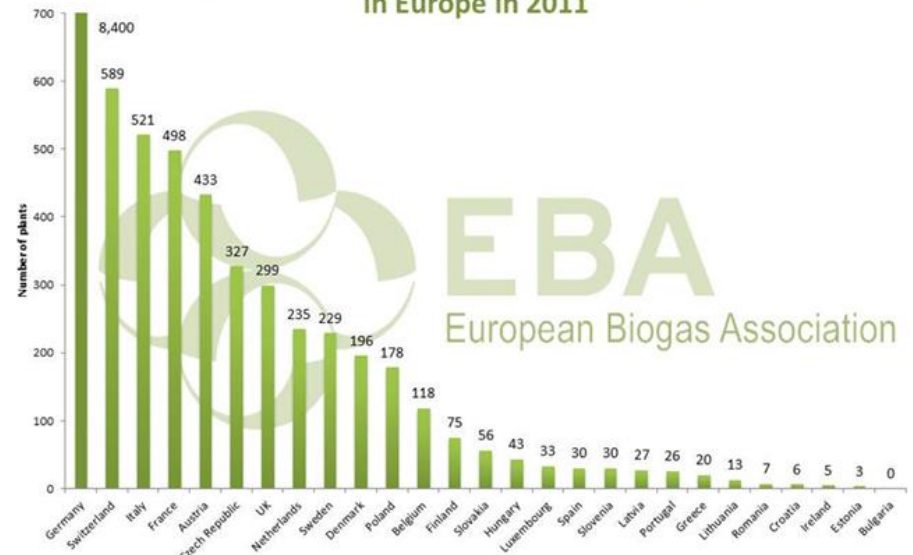
Roughly 50 sites nationwide produce bio-methane for grid injection or CNG

# EUROPEAN BIOMETHANE MARKET

*Biogas Upgrading (Bio-methane) market has been growing at over 20% per annum*

- Over 12,000 biogas plants in operation
- 250 plants upgrade bio-methane for vehicle fuels or grid injection
- Bio-methane produced in 14 countries (AT, CH, DE, DK, ES, FI, FR, HU, IS, LU, NL, NR, SE, UK)
- 10 countries inject into grid (AT, CH, DE, ES, FI, FR, LU, NL, NR, UK)

Almost 12,400 biogas plants and more than 5,300 MW<sub>el</sub> of installed capacity in Europe in 2011



EBA 2012

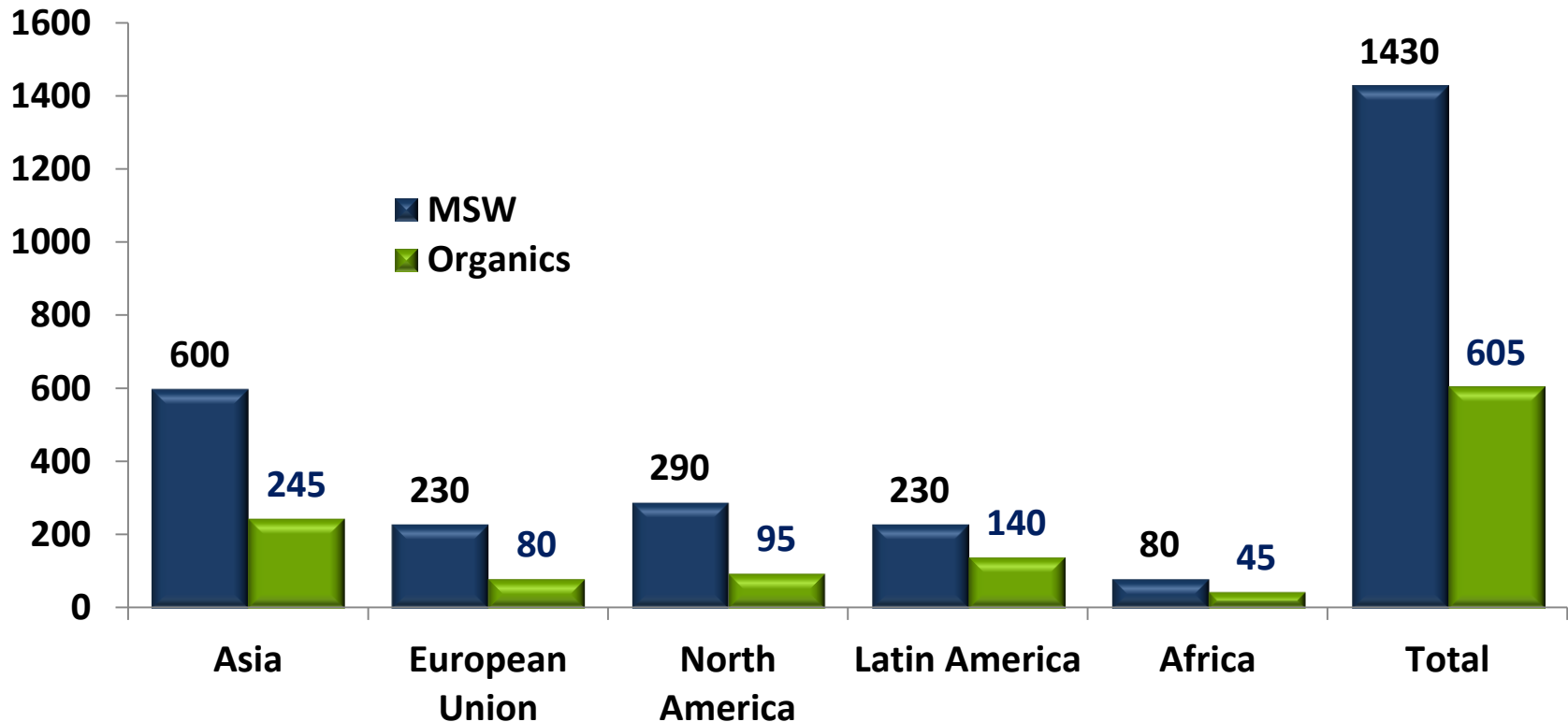
Immature bio-methane market positioned for growth

# THE BIGGEST OPPORTUNITY: ASIA

*Asia Generates Most Municipal Solid Waste (MSW); Global MSW Will Be Approx. 1430M Tons; Organic Waste Will Be 605M Tons in 2015*

## 2015 PROJECTED SOLID WASTE BREAKDOWN BY CONTINENT

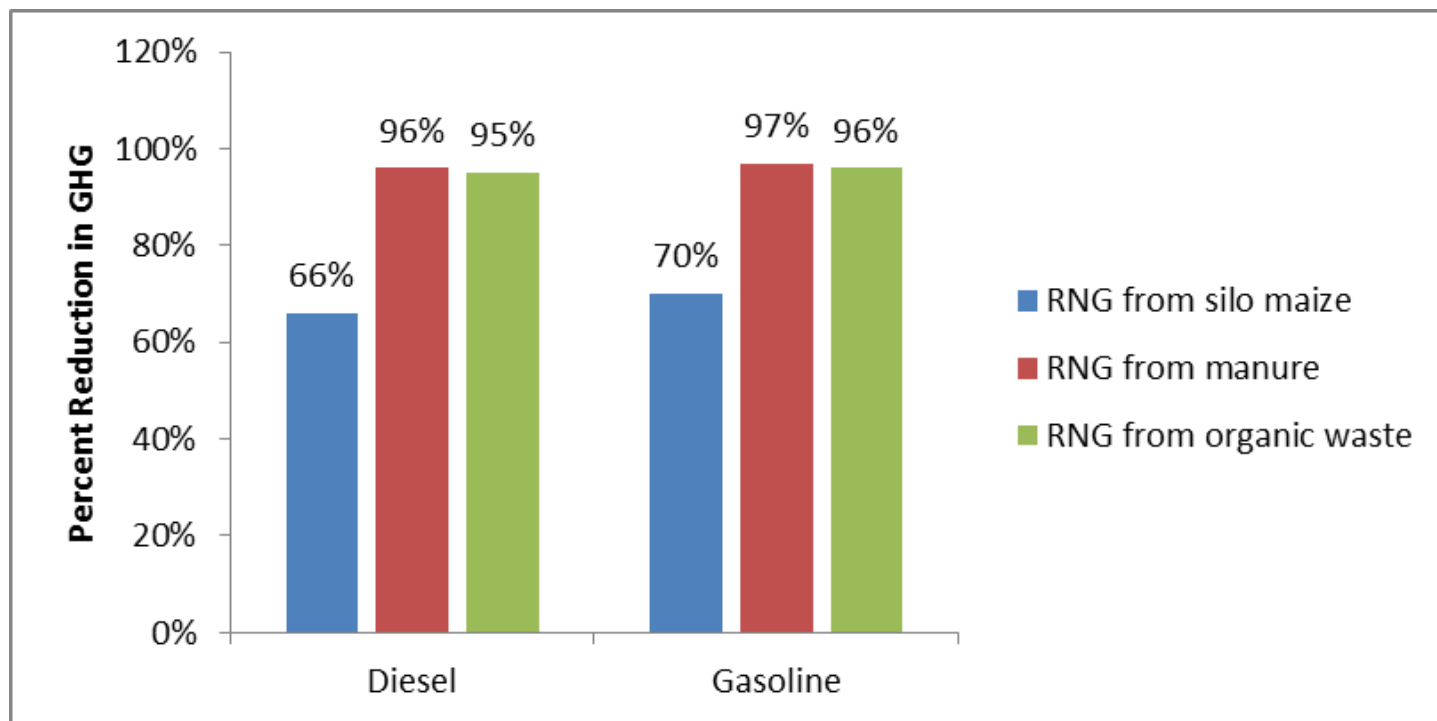
(Million Tons)



Source: ZWE

China: MMs biodigesters, limited upgrading to date

# GHG REDUCTION BY USING BIOMETHANE



**Estimated GHG Reduction for Renewable Natural Gas versus Conventional Fossil-Fuels (Source: Environment Agency Austria)**



# PROJECT ENZUP: COMMERCIAL-SCALE DEMONSTRATION FOR BIOGAS UPGRADING

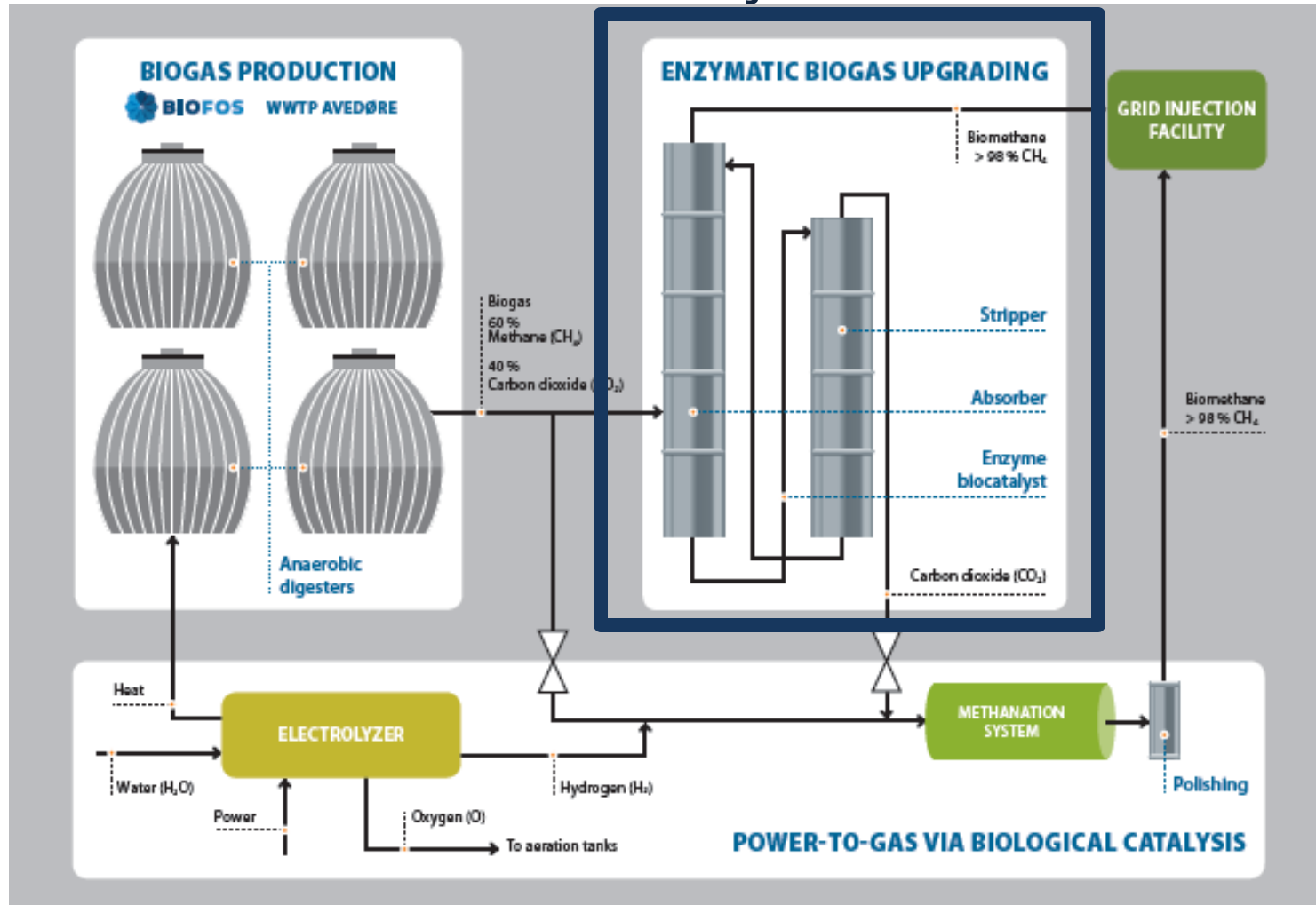
- Size: 500 Nm<sup>3</sup>/hr. biogas
- \$7 MM, three year project
- 50% funding through EUDP (Danish Energy Agency)
- Schedule:
  - Project Kickoff – Jan 2014
  - Commissioning – May 2015
  - Operations – July 2015
- 24 months operation and testing



Upgrading biogas to pipeline specification at industrial scale using Akermín's innovative biocatalyst solution

# PROCESS FLOW SCHEME

## Project ENZUP



Source:  
Biofos WWTP Avedøre  
The Avedøre Project

Process flow scheme for Project ENZUP and adjacent Power to Gas Project

# PROJECT GOALS & BENEFITS

*Economically produce grid quality bio-methane*

- CO<sub>2</sub> absorption at ambient pressure reduces capital cost and electrical power consumption for biogas compression
- Combines an environmentally-friendly biocatalyst with a non-volatile, non-toxic solvent that is resistant to oxygen and impurities
- Over 40% reduction in steam consumption for CO<sub>2</sub> regeneration at lower temperatures versus systems using amine solvents. The use of low grade reject heat at less than 105°C may reduce steam consumption and operating cost even further
- High methane recovery (99.9%)
- High process flexibility, able to quickly respond to changes in biogas flow.
- Simple process with reduced requirements for solvent reclamation

The project is fully in-line with the goal of using domestic resources from farming and industry in biogas production and makes use of the natural gas grid for distribution and storage of renewable energy

Lower cost for upgrading biogas will accelerate the use of renewable biogas in the gas grid

# WHY AKERMIN?

*Building value combining biochemistry with solvents and process schemes in gas treating*

- Transformational proprietary technology
- Leverage standard plant designs
- Strong cross-functional team
- Successful field pilot results
- Positioned for commercial entry
- Economically & environmentally attractive CO<sub>2</sub> capture solution

Strong partnership value creation opportunities



Barry Blackwell, President & CEO  
blackwellb@akermin.com • 1 314 669 2611