# DOE/NREL BIOGAS WORKSHOP
# BIOGAS TECHNOLOGIES AND INTEGRATION WITH FUEL CELLS

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# SUMMARY

- Introduction and Background
- Anaerobic Digestion
- Biogas Utilization
- Biogas Upgrading Technology
- Biogas Specification
- Biogas to Fuel Cell
- Conclusions

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*Promoting the Advancement of Anaerobic Digestion Technologies*

# Promoting the use of Biogas and Anaerobic Digestion

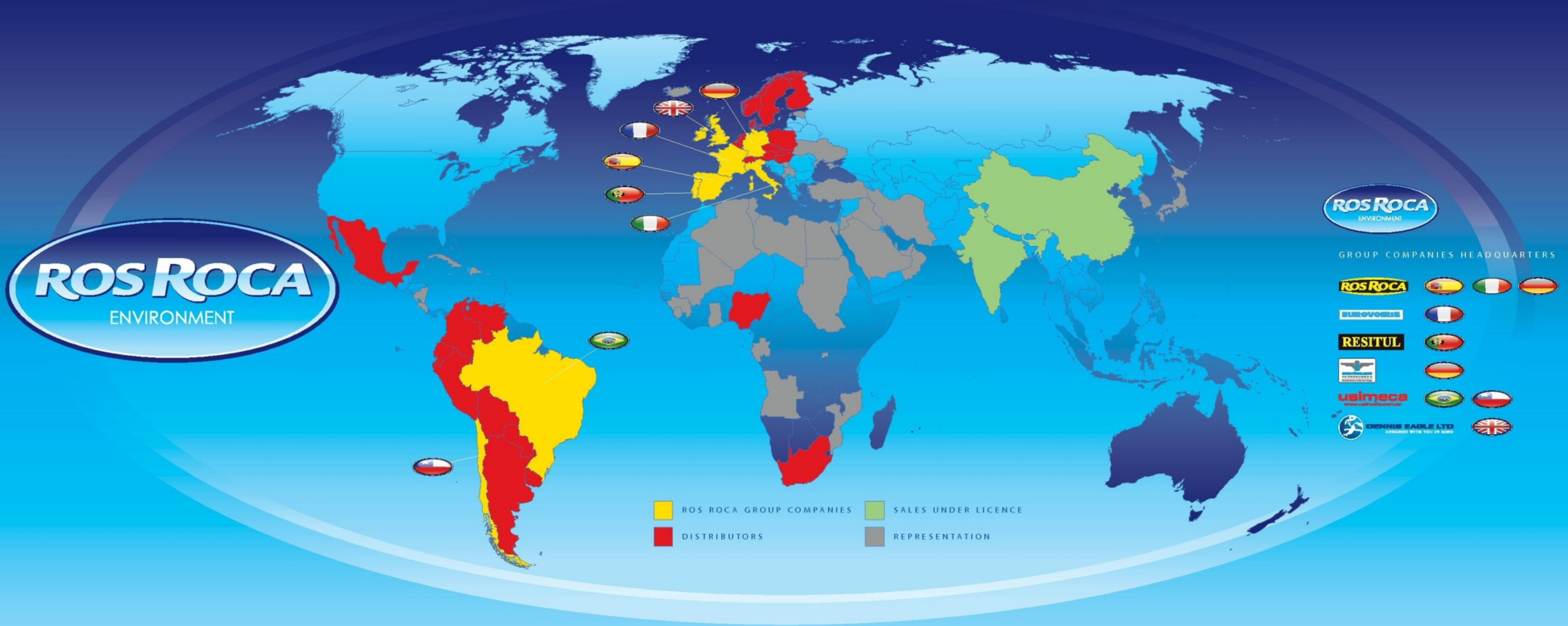
- 149 Members from the U.S., Germany, Italy, Canada and the UK
- All Industry Sectors Represented

**Key Industry Goals:**

- Promote biogas markets, technologies and infrastructure
- Achieve policy parity
- Promote as a best practice for environmental stewardship and greenhouse gas reduction


www.americanbiogascouncil.org

# Products and technologies for environmental protection




## Collection and cleaning equipment

## Pneumatic waste collection

## Biological waste technologies

## Cryogenic products and technologies


# ANAEROBIC DIGESTION

Long Established Proven Technology.

- 6 to 8m family sized digesters in Far East

- 1000 High rate Anaerobic digesters worldwide treating organic polluted industrial waste water

- More than 150 Industrial AD plants in operation treating organic fraction of SSO Municipal Waste - combined capacity > 5m tonnes.

- Germany is leading Country in Europe
  - Around 7100 biogas facilities
  - Approx 18TWh of electricity generated from biogas
  - Energy needs for approx 5.1 m households

# Potential in North America


Sources: ABC, AgStar, EPA

| Facilities | Quantity in US | Suitable* | Currently With Anaerobic Digestion |
|---|---|---|---|
| Wastewater Treatment Plant | 17,000 WWTPs | 3,500 | 1,500 |
| Dairy & Other Farm | 65,000 Farms | <65,000 | 160 (see map) |
| Municipalities | 40 million tons per year MSW | <80 million tons | <10 |

# AD Technology

## Front-end processing
Adjust water content
Separation of contaminants

Contaminants (Plastic, glass, stones, metals etc.)

## Pasteurization (ABPR 1774/2002)
> 70 ° C, > 1 h, particle size < 12 mm

## Anaerobic digestion
Mesophilic or thermophilic operation

**Biogas**

CHP

**Electricity**
**Heat**

Biogas Upgrading

**Bio methane**

## Dewatering
Separation in high quality solid and liquid fertilizer

Solid and liquid fertilzer

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# Input material for AD technology

## Municipal

- Source separated organic waste (SSO)
- Organic fraction MSW
- Sewage sludge

## Industry

- Packaged food
- Residues from food and beverage production
- Food leftovers
- Grease
- Slaughterhouse waste
- Residues from ethanol fermentation
- …………………………

## Agriculture

- Manure
- Dung
- Energy crops

**AD process is flexible and treats organic waste independent of humidity**

# Feedstocks for Anaerobic Digestion

Food waste

MSW

Packaged food waste

Dry biowaste

Wet biowaste

Energy crops

Manure

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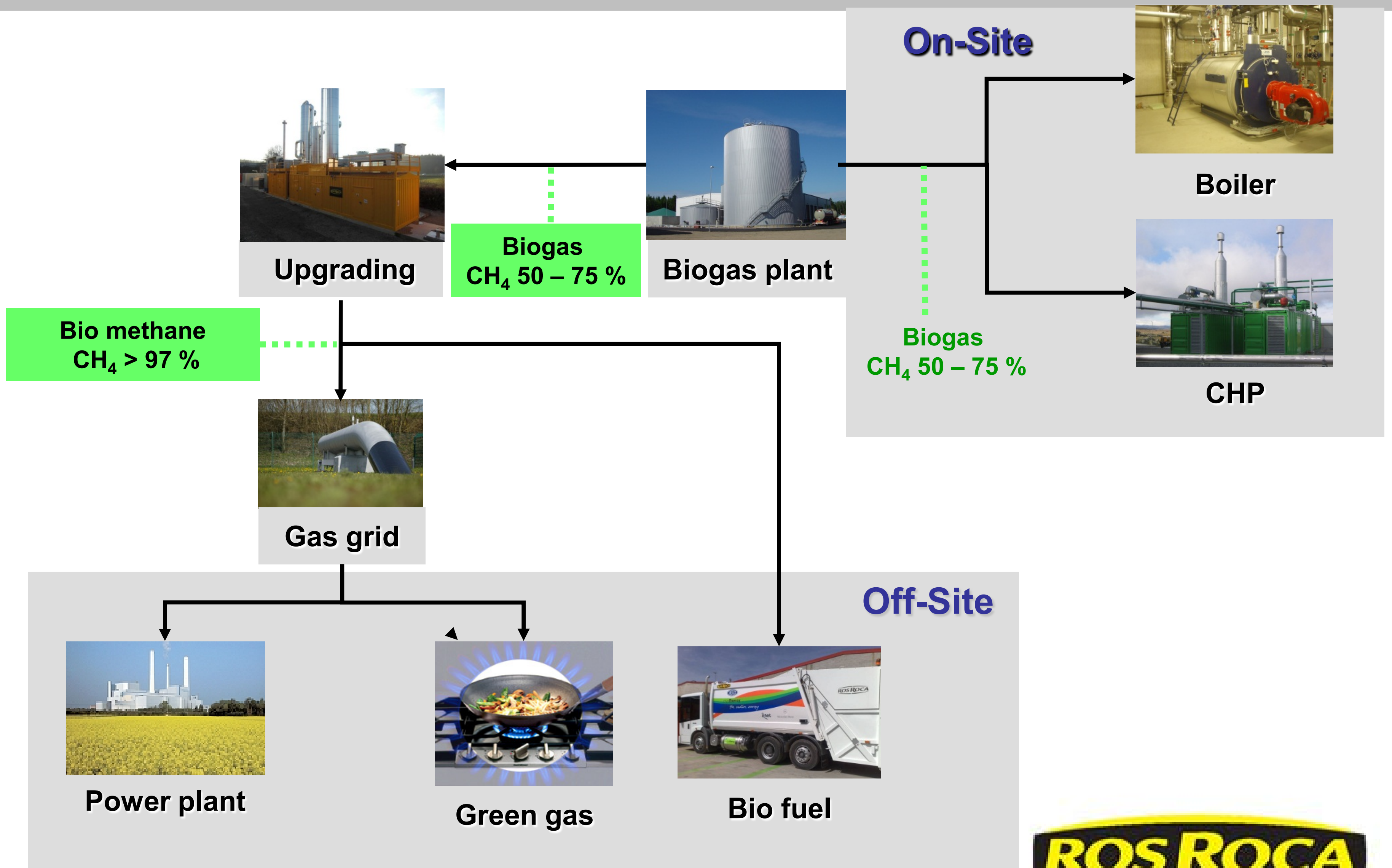
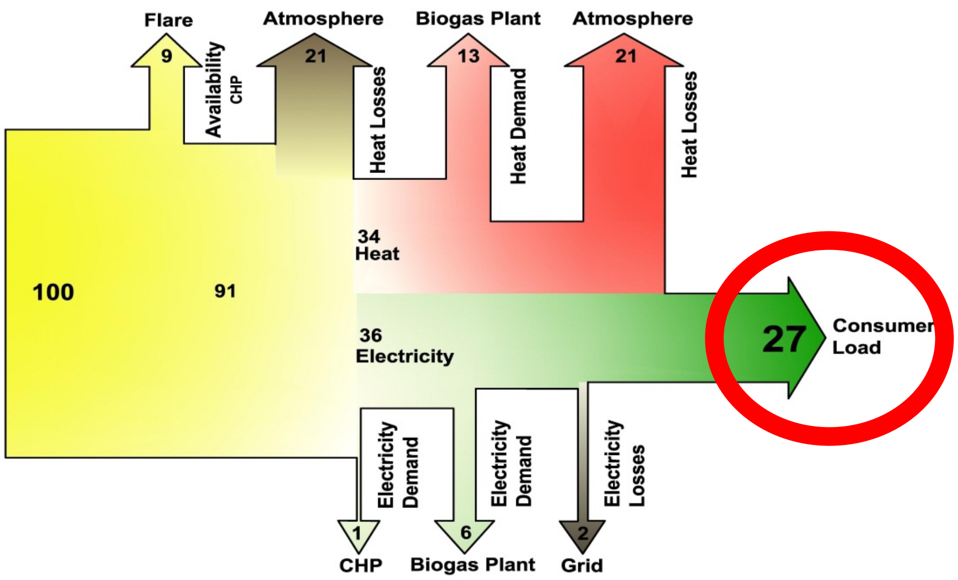
# Biogas Utilization
# Biomethane Production

# Biogas Utilization

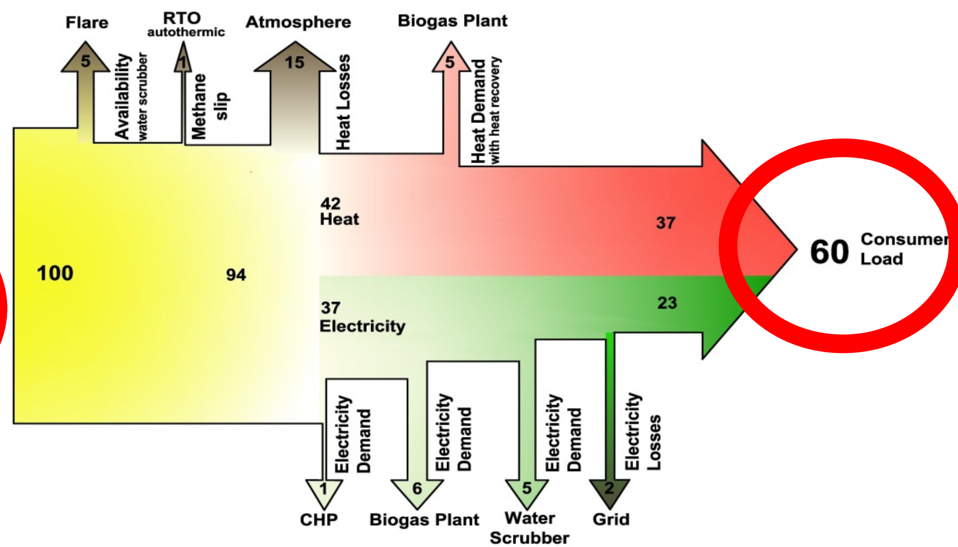


# Why biogas upgrading ?

**Energy balance of CHP on-site utilization**




**Energy balance of biogas upgrading & CHP off-site utilization**

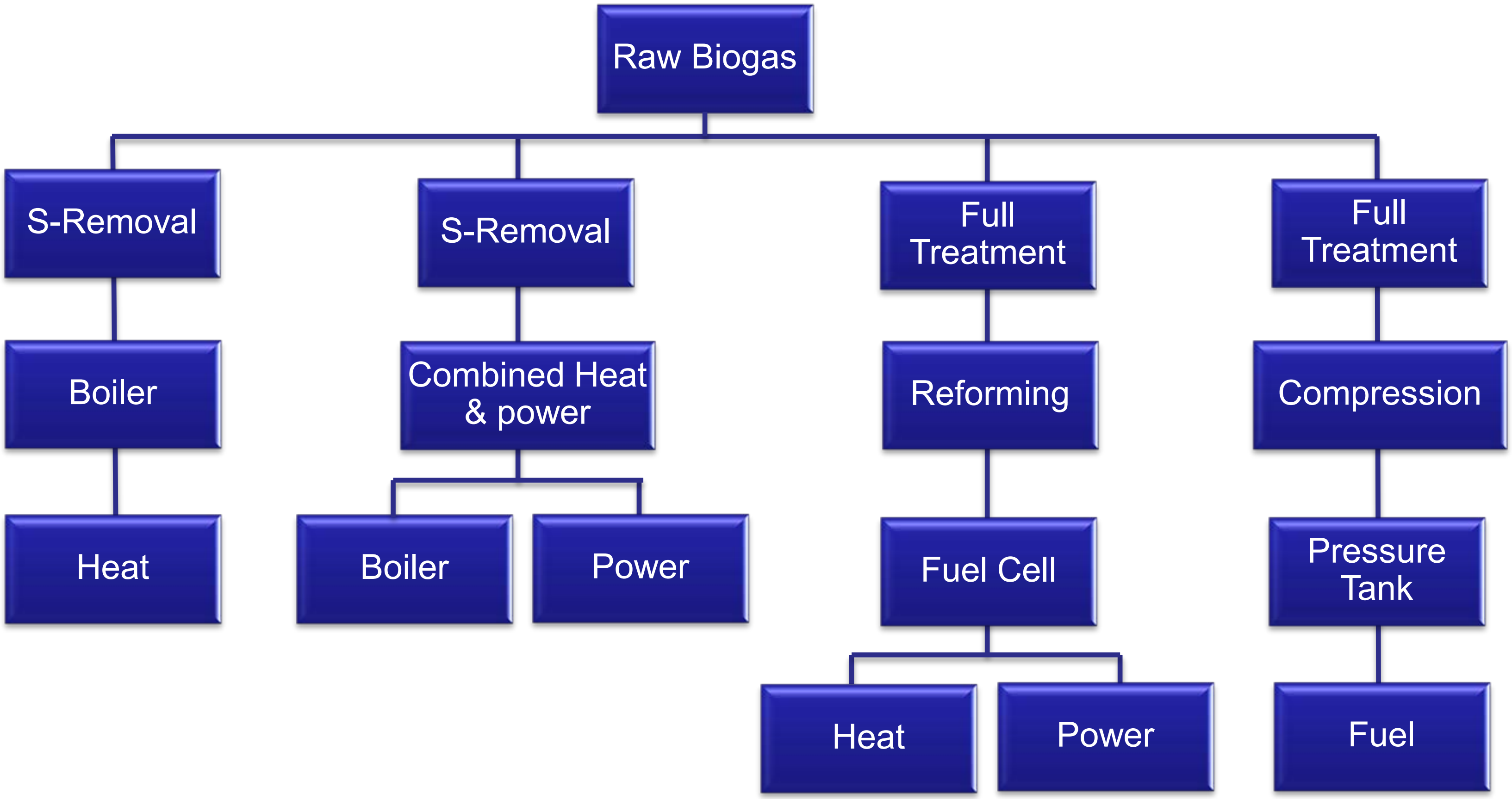



**Energetic efficiency in biogas utilization is normally higher if biogas is upgraded to bio methane and utilized in off-site CHP-installations**

# Biogas Utilization

- Boilers (0.5 to 10 PSIG)
  - Biogas boiler (low)
  - Dual-Fired (medium)
  - Blended with Natural Gas (higher)
- Electrical Generation Equipment (CHP)
  - Micro turbines (12-65 PSIG)
  - Fuel Cells (50-70 PSIG)
  - Reciprocating Engine (0.25-35 PSIG)
  - Gas Turbines (150-170 PSIG)
- High Pressure Compression
  - CNG Fueling station (3000 psig)
- Absorption Chillers (5-10” w.c.)

# Alternative Biogas Utilization and Required Clean Up



# Primary Conditioning

- Primary Conditioning
  - Boosters,
  - Water Removal,
  - H2S and,
  - Siloxane Removal.

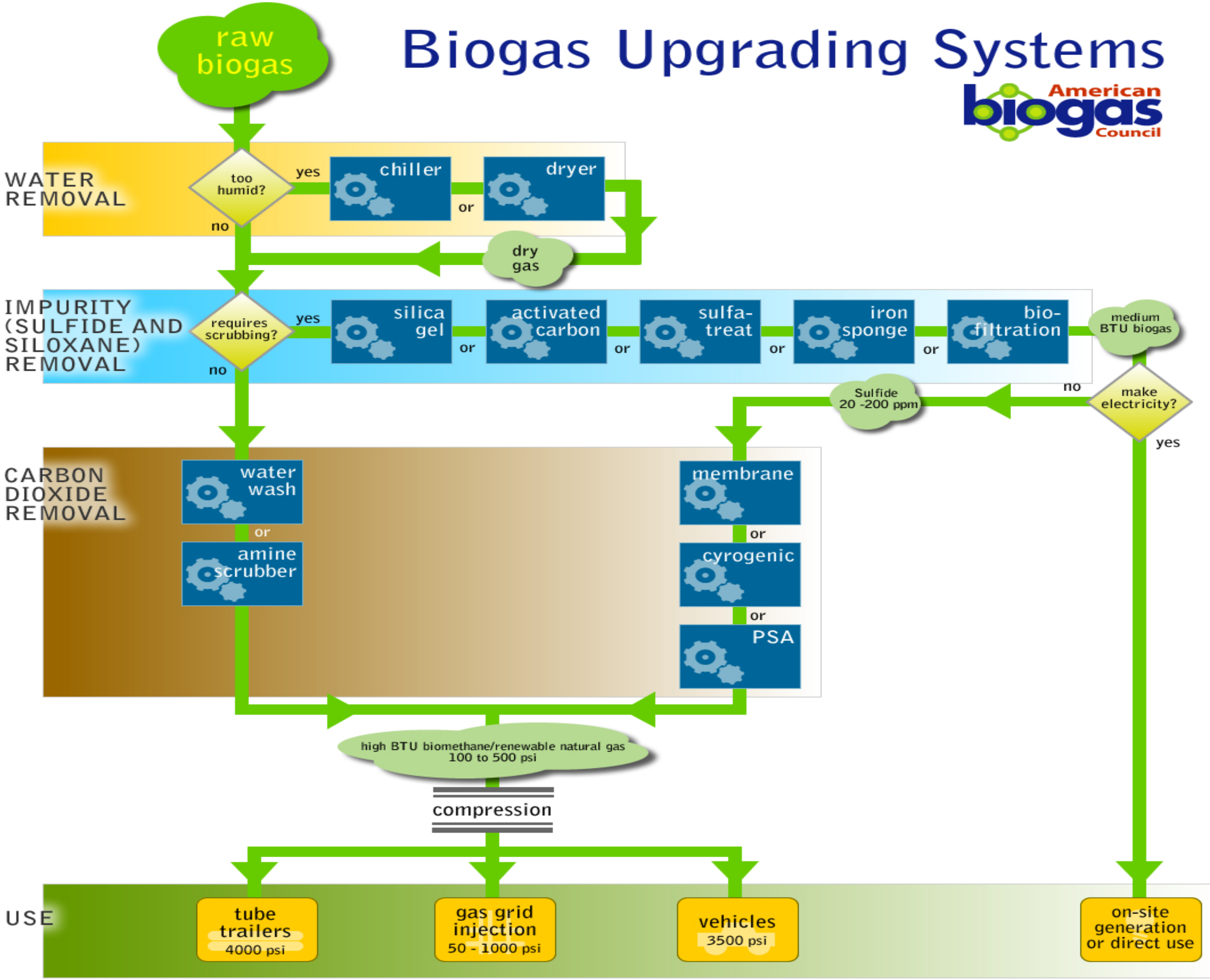
# Technology for Upgrading to meet Pipeline and Fueling Demands

- Water Scrubbing
- Amine Systems
- Pressure Swing Absorption
- Cryogenic Separation
- Membrane Separation

Other:

- Iron Sponge
- Activated Carbon

# Biogas Upgrading Systems



# Typical Biogas Upgrading plant


**Input: Biogas from existing AD plant treating commercial organic waste**

**Capacity: 1.250 $Nm^3/h$**

**Biomethane utilization: Injection in natural gas grid**

# Typical Biogas Upgrading plant

**Input: Biogas from biogas plant treating agricultural biomass and municipal organic waste**

**Capacity: 600 Nm³/h**

**Biomethane utilization: Injection into gas grid**

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# Relative Costs of Different Upgrading Technology

| Upgrade Method | Contaminant Removal | Cost to Upgrade ($/1000 cu ft) |
|---|---|---|
| Biological | $H_2S$ | 1.86 |
| Iron Oxide (sulfa treat) | $H_2S$ | 0.79 |
| Iron Oxide (Sulphur Rite) | $H_2S$ | 1.49 |
| Membrane | $CO_2$,$H_2O$ | 2.13 |
| Water Scrubber | $H_2S$,$CO_2$ | 0.38 |
| PSA | $CO_2$ | 2.53 |
| Activated Carbon | $H_2S$ | 0.45 |
| Amine | $H_2S$, $CO_2$ | 4.58 |

Source: Chen et al

# An Overview of Typical Gas Specification

- **Heating value (HHV)– Typically 950 – 1100 BTU/sft$^3$** - Since CH4 is the only source of heating value in Biomethane, meeting this specification is a matter of removing the other biogas species such as CO2.
- **Wobbe** – The heating value of the Biomethane divided by the square root of the Biomethane's specific gravity. Typically if the HHV is within specification for Biomethane, the Wobbe is as well.
- **Carbon Dioxide** – Typically 1-4% – This is the main species to remove from biogas to meet specifications. Removal is straightforward for all major technologies.
- **Nitrogen** – Usually included in a total inert specification of <4% with CO2 and O2 –N2 can be controlled by preventing air ingress into the digester. N2 removal from biogas can be costly, if required.
- **Oxygen** – Typically 0.2-1% - Like N2, O2 enters the biogas with air. O2 removal from the biogas, if required, can be costly as well.

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# Overview of Typical Gas Specification - contd

- **Water** – Typically 4-7 lbs of water per million $ft^3$ - H2O is an easy parameter for upgrading technologies to meet.
- **Sulphur – 0.25 to 20 grains of H2S or total sulphur per 100 $sft^3$ - This is technically simple to meet, but some technologies require much more costly sulphur removal technologies than others.**
- **Temperature** – Typically $40^o$ – $120^oF$ – This is a straightforward parameter to meet for all upgrading technologies to meet.
- **Pressure** – Varies between 20 to 1000+ psig, depending on the gas pipeline - The pressure required or a specific system varies and is addressed by simply by ensuring the Biomethane compressed to an adequate level for the injection point.
- **Commercially free of dust, gums, etc**. – A somewhat imprecise specification that is usually not a problem for Biomethane. A dust filter may be required if the gas specification is less than < 2 µm, for example. Biomethane does not contain gums or significant levels of non-methane organic compounds.

# Overview of Typical Gas Specification - contd

- **Biological** – This is usually covered within the previous ‘commercially free’ specification.  There are trace levels of spores and bacteria in conventional natural gas and these are typically <1 x $10^7$ counts of total bacteria per 100 $sft^3$.  Testing has shown bacteria levels in Biomethane are either the same as natural gas, but usually less.
- **Hydrogen, other trace gases** – Usually not included in a natural gas specification, but some utilities have started to include these to make it difficult or impossible for Biomethane to be accepted.
- **Heavier hydrocarbons** – Typically <1.5% for natural gas, but like the point above, some gas utilities have started to use trace gas specifications specifically for Biomethane that conventional natural gas cannot meet.

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# Biogas to Fuel Cell – Opportunities

- Fuel Cells boost net output of electricity by a minimum of 60%
- Biogas powered efficiencies
  - Reciprocating engines 30%
  - Turbine engines 40%
  - Fuel Cell 60%
- Lower Carbon Emissions per unit of electricity generated
- Some current examples –
  - Washington State, Columbia Boulevard Wastewater (3rd in USA – phosphoric acid fuel cell, activated carbon filter cleaning of $H_2S$)
  - Major Companies looking to develop pilots – BMW, Microsoft, Apple (Data Centres)
  - Fuel Cell Energy and Bloom Energy announced projects
  - Clear Edge Power/Gussing Renewable Energy Austria (50MW over next 5 yrs)

# Biogas to Fuel Cell – Challenges

- Removal of $H_2S$ ($H_2S$ content of biogas typically varies from 50 to 3000ppm). Fuel Cell require 1 ppm - trace
  - Biogas Desulphurization – 90 -95% efficiency
  - Activated Carbon and Iron Sponge will achieve Fuel Cell requirements
  - Amine, PSA and Membrane all have activated carbon filter in process to protect the amines
  - Water Scrubbing needs an activated carbon filter added to process as < 5mg/Nm3 of $H_2S$ typically post treatment
- Cost – economies of scale
- Reference Plants

# Biogas to Fuel Cell – Challenges

**BUT BIGGEST CHALLENGES ARE:**

- **US Policy Framework**
  - No coherant Federal Policy
    - REC and RPS – varies State by State
    - ITC and PTC expiring year end 2013
    - RIN – promising incentive
    - Carbon Markets – nothing at Federal level
- Tipping Fees lower – municipal organics
- Shale gas lowering energy costs – Nymex $2.42

- **Lack of Renewable Energy Incentives**
  - Policy and incentives have driven Germany/Europe Biogas deployment
    - Landfill Ban
    - Source Separation
    - Feed in Tariffs and/or equivalent

# CONCLUSIONS

- Anaerobic Digestion excellent energy source for Fuel Cells
- Necessary Biogas Upgrade technology well proven with alternatives but at a cost
- Using Fuel Cell technology will greatly enhance efficiency and reduce carbon emissions compared to alternative biogas utilization alternatives
- Technical challenges are to reduce upgrading costs and increase sensitivity of fuel cells to impurities mainly $H_2S$.
- But **MUST** address Policy Framework and Incentives

# Thank you very much for your attention

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