



## Upgrading Biogas to CNG-quality Methane: Opportunities, Challenges and Economics

沼气净化提纯至CNG级生物天然气：  
机遇，挑战和经济效益



## Agenda 日程

1. Natural Gas as a Vehicle Fuel in China  
中国CNG车用燃气
2. Opportunity– Biomethane as a source of CNG  
机遇—生物天然气作为CNG的原料
3. Biogas Upgrading Project Economics – Case Study  
沼气净化提纯项目的经济效益—案例研究
4. Xebec Technology & Project Experience  
Xebec技术&项目经验

## Xebec Adsorption Inc.- 关于Xebec公司

- n Manufacturer of gas purification & dehydration equipment  
气体净化和气体净化&脱水设备制造商
- n Renewable Energy & Industrial Markets:  
再生能源&工业市场
  - Biogas upgrading--沼气净化提纯
  - Natural gas dehydration for CNG--天然气脱水
  - Hydrogen purification--净化提纯氢气
- n Asia operations: Shanghai; Singapore  
亚太区运营处：上海，新加坡
- n 19 Biogas Upgrading reference sites; 3 in Asia  
19座沼气净化提纯项目；其中3个在亚洲



Introduction

# Biogas-to-Energy Market—沼气运用到能源市场

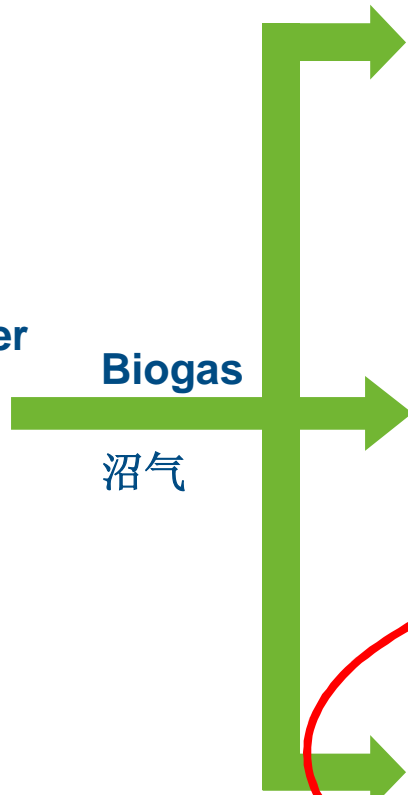
China 中国



Anaerobic Digester  
厌氧发酵



Landfill  
垃圾填埋场



Direct  
Combustion  
直接燃烧

Yes  
Home heating  
家用取暖



Renewable  
Power & Heat  
热电联产

Yes  
是

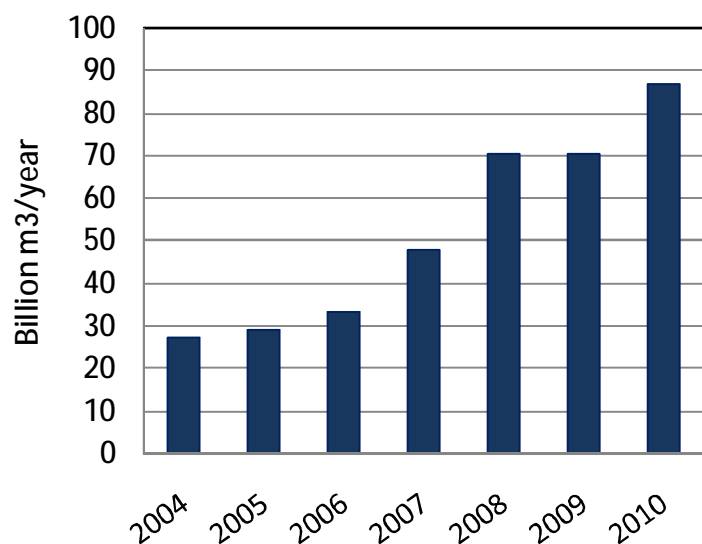


CNG fuel  
OR Pipeline  
Gas  
CNG燃料或管  
道气

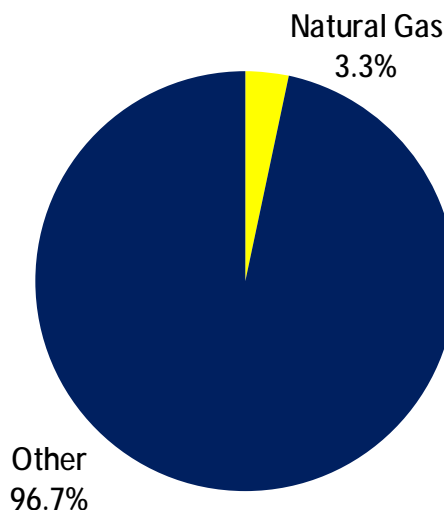
Yes  
CNG  
是

# Natural Gas Consumption in China—中国天然气消费

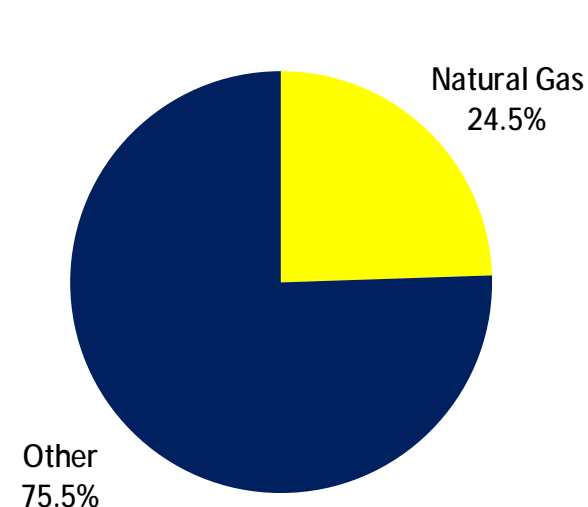
## China Natural Gas Consumption



## China



## Europe



n 21% CAGR in natural gas consumption 2004-2010

2004-2010天然气消费量为21%年复合增长率

n Relatively small portion of energy mix → Large growth potential

能源结构中相对较小的一部分，巨大的市场增长潜力

Source: IEA



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Natural Gas as a Fuel

## Natural Gas Supply & Pricing—天然气供应&价格



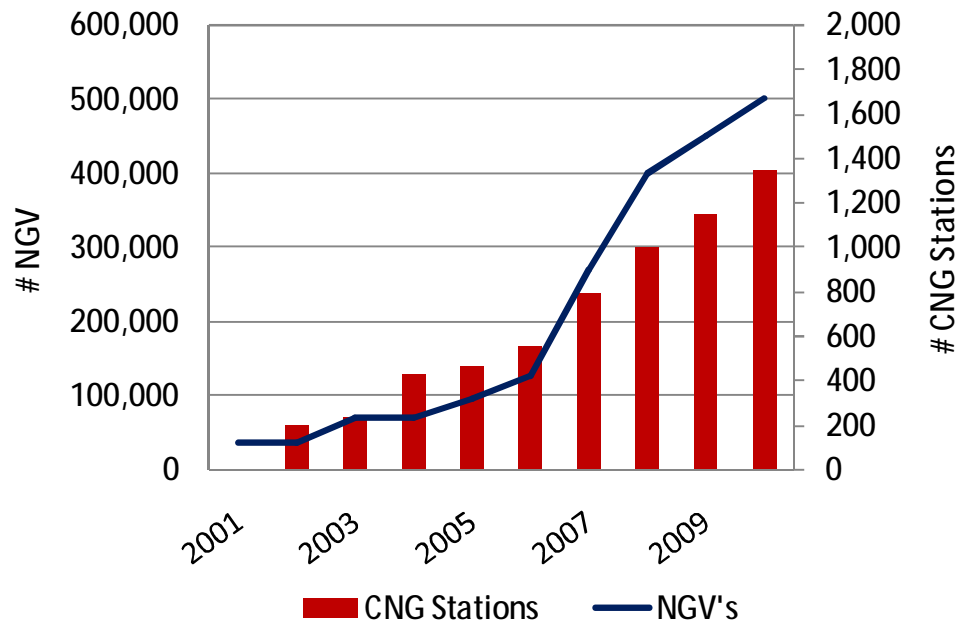
- Existing Gas Pipeline  
现有的天然气管道
- Planned new pipeline  
计划新建的管道
- LNG Import Terminals  
(existing & planned)  
LNG终端接受站

- Supply largely controlled by CNPC & SINOPEC  
大部分由中石油&中石化控制供应
- Fragmented pipeline infrastructure; large areas without gas supply  
零散的管道基础设施；很大区域无气体供应

# Natural Gas as a Vehicle Fuel in China

## 中国天然气车用燃气

Natural Gas Vehicle & Stations



| Country<br>国家    | NGV's<br>天然气汽车 | World Rank<br>世界排名 |
|------------------|----------------|--------------------|
| Pakistan<br>巴基斯坦 | 2,740,000      | 1                  |
| Italy<br>意大利     | 730,000        | 6                  |
| China<br>中国      | 500,000        | 7                  |
| Germany<br>德国    | 91,500         | 18                 |
| Sweden<br>瑞典     | 32,000         | 24                 |

Source: [www.iangv.org](http://www.iangv.org)



Natural Gas as a Fuel

# Value Proposition of CNG as a fuel in China

## 中国CNG燃料的价值建议



- n Cost of CNG retrofit: ~RMB5,200  
压缩天然气改装费用: ~5200
- n Relative Price & fuel costs:  
相对价格&燃油成本

|              | Fuel Cost<br>燃油成本     | Daily Fuel Cost<br>每日燃油成本 | Savings<br>节省的开支   |
|--------------|-----------------------|---------------------------|--------------------|
| Petrol<br>汽油 | RMB7.5/L              | RMB240/day                | RMB112/day<br>~47% |
| CNG          | RMB4.0/m <sup>3</sup> | RMB128/day                |                    |

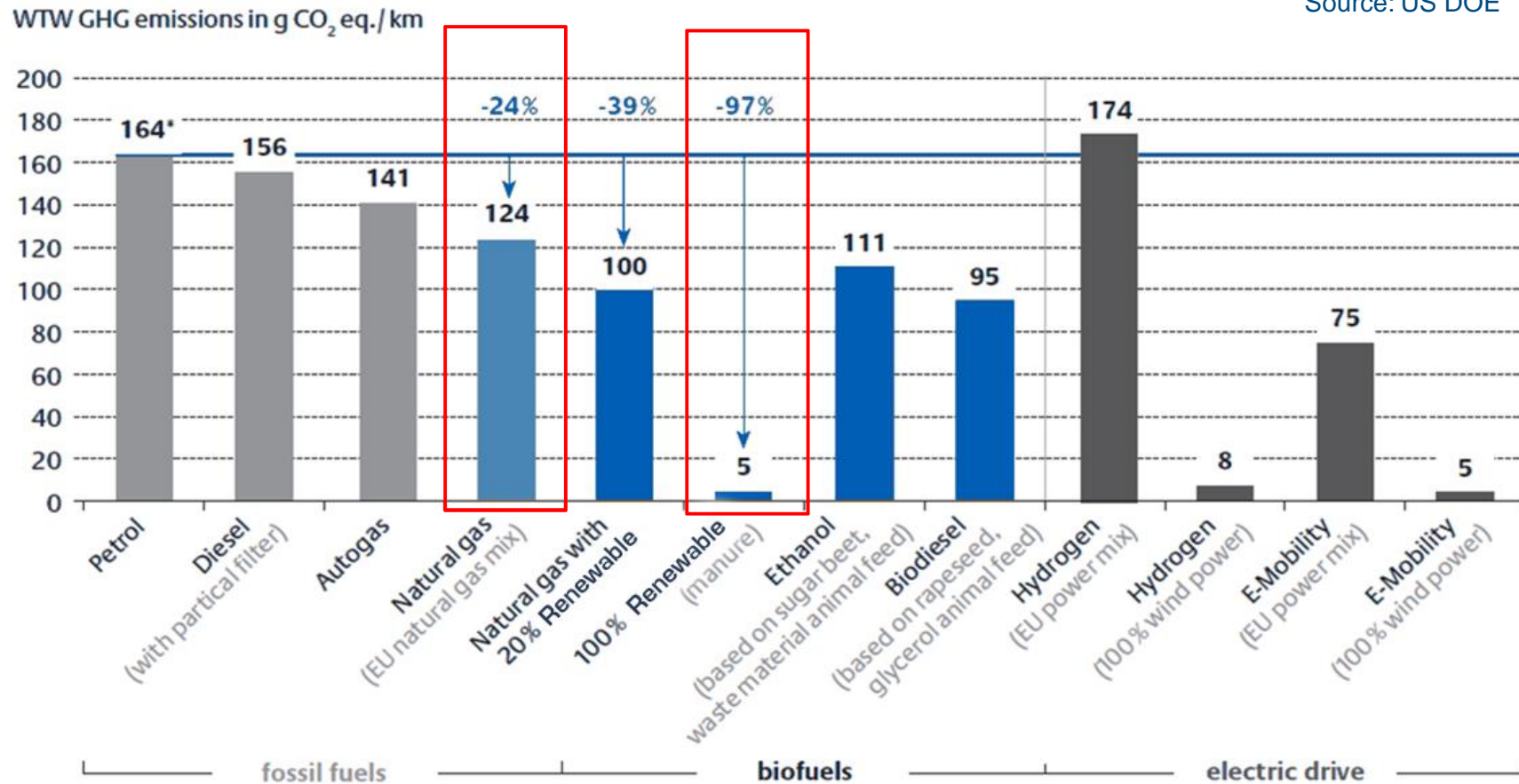
- n Payback: 2-3 months  
投资回收期: 2-3个月



# CNG from Biogas as a Renewable Fuel

## 沼气作为一种可再生CNG燃料

Source: US DOE



\* reference vehicle: gasoline engine (induction engine), consumption 71 per 100 km



Biogas as a source of Vehicle Fuel

## Opportunity for biomethane as a source of CNG 生物天然气为CNG原料的市场机遇

| Market Feature—市场特征  | Opportunity for Biomethane—生物天然气机遇   |
|--|--|
| 1. Fragmented geographic supply;<br>incomplete pipeline coverage<br>分散的地理供应；不完整的管道覆盖面    | Distributed, local source of CNG fuel<br>分布式，当地CNG原料                         |
| 2. Supply controlled by large SOE's<br>(CNPC, SINOPEC)<br>由大型国有企业控制（中石油，中石化）             | Offers CNG station developers with independent<br>supply<br>CNG站开发商可独立供应     |
| 3. Price increases<br>价格上涨   | Offers long term price stability for project<br>operators<br>为项目运营商提供长期的稳定价格 |
| 4. Increasing GHG emissions from<br>booming automotive sector<br>汽车行业的蓬勃发展增加了温室气体的<br>排放 | Biomethane is a truly renewable transportation<br>fuel<br>生物天然气是一种真正的可再生运输燃料 |

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## Biogas Project Economics— Case Study

### 沼气的经济效益—案例研究

- n Hypothetical biogas case study in Anhui Province:  
以安徽省沼气案例分析
  - Greenfield digester project  
全新的厌氧产沼气项目
  - Biogas Production 30,000 Nm<sup>3</sup>/day (707 Nm<sup>3</sup>/h)  
日产沼气每天30,000方（707方/小时）
  - Evaluate relative economics & sensitivity to key variables  
相对的经济效益评估&关键的敏感变量
- n Economic variables specific to project, but results illustrate general trends  
项目具体变量的具体效益，但能体现总体趋势

|  | Units<br>(单位) | Scenario 1<br>(方案1) | Scenario 2<br>(方案2) |
|--|---------------|---------------------|---------------------|
| <b>Operating Performance: 经营绩效</b>                               |               |                     |                     |
| Biogas Output 沼气产量   | m3/day        | 30,000              | 30,000              |
| Net Saleable CNG Per year 每年天然气净销售量                              | Nm3/year      | 5,991,840           | 5,991,840           |
| <b>Installed Capital Cost: 安装成本</b>                              |               |                     |                     |
| Anaerobic Digester 厌氧发酵罐   | CNY           | 63,000,000          | 63,000,000          |
| Biogas Upgrading & CNG Compression/Dispensing<br>沼气净化提纯&CNG压缩/加注 | CNY           | 15,180,000          | 15,180,000          |
| <b>Operating &amp; Maintenance Costs: 操作&amp;维护成本</b>            | CNY/Year      | 2,912,921           | 2,912,921           |
| <b>Sales Prices: 销售价格</b>  |               |                     |                     |
| CNG Sales Price (Per Unit CNG) CNG销售价格                           | CYN/m3 CNG    | 2.5                 | 3                   |
| Solid/liquid Fertilizer 固体/液体肥料                                  | CNY/ton       | -                   | -                   |
| <b>Revenue &amp; Profitability: 收入&amp;盈利能力</b>                  |               |                     |                     |
| Sales Revenue/Year 销售年收入   | CNY/Year      | 14,979,600          | 17,975,520          |
| Tipping Fee 处理费  | CNY/Year      | -                   | -                   |
| Net Cashflow (average 15 year)<br>净现金流 (平均15年)                   | CNY/Year      | 10,671,660          | 13,143,294          |
| Project IRR 项目内部收益率  | %             | 11%                 | 16%                 |
| Simple Payback Period 投资回收期                                      | Years         | 7                   | 6                   |

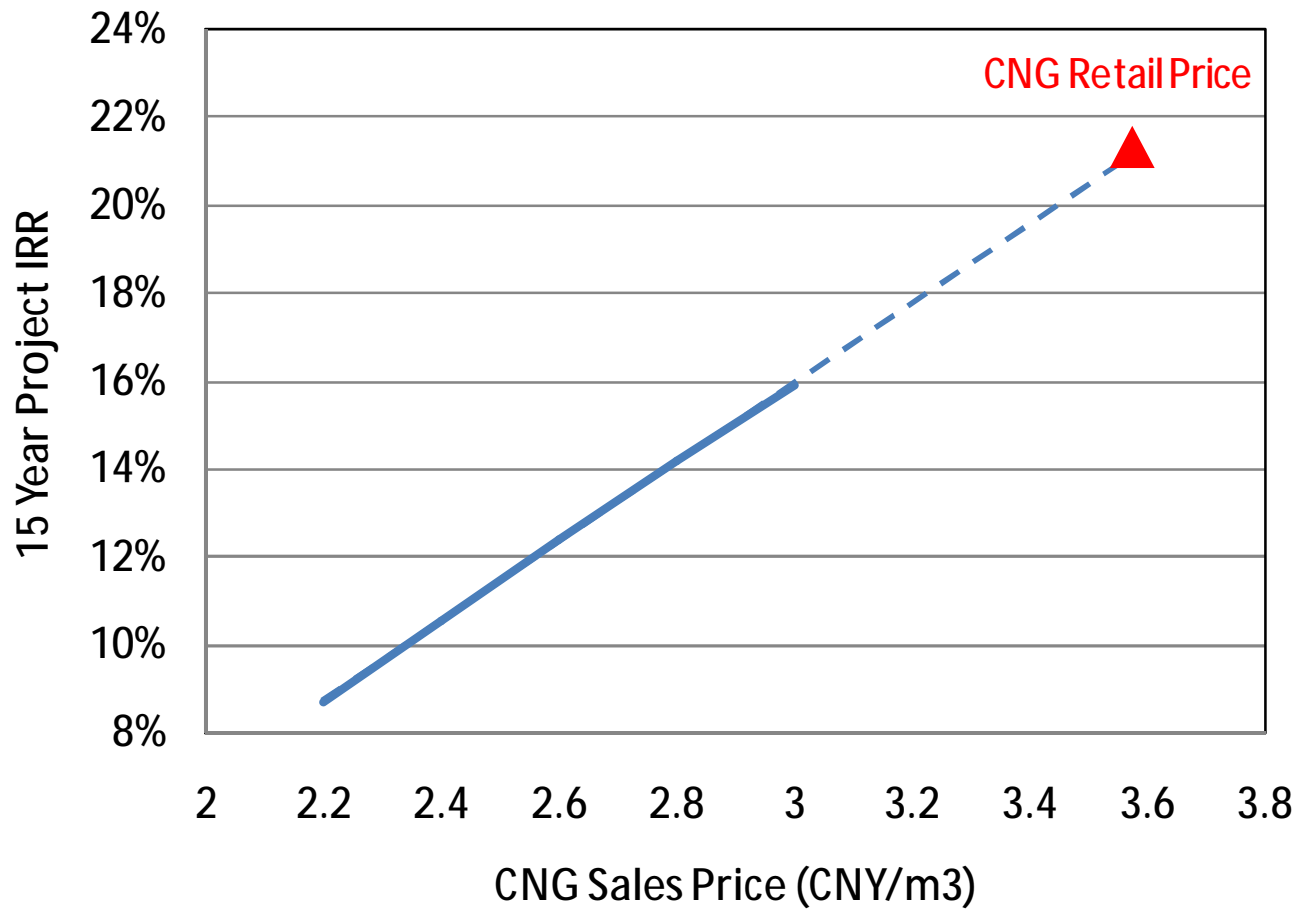


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Economic Case Study

# Biogas Project Economics— Case Study

## 沼气项目经济效益性—案例研究



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Economic Case Study

## Economic Case Study– Conclusions

### 经济效益案例研究总结

- n Project IRR's are modest (10-16%):项目内部投资收益率一般
  - Unattractive for private developers to finance with 100% equity  
对私人发展商100%的股权投资缺乏吸引力
  - Debt required to boost equity returns  
债务要求促进股权回报率
  - Government funding required to boost project IRR & encourage private investment (e.g. free land; CAPEX support)  
为提高项目投资回报鼓励民间投资需要政府的资金资助（如，免费用地，项目投资出资）
- n Financial Upside:财务上的潜在收益
  - Tipping fees 处理费
  - Revenue from by-products (biodiesel, organic fertilizers)  
副产品的收入（生物柴油，有机肥料）

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# Biogas-to-CNG Project Scope

## 沼气生产CNG项目范围



**Animal Waste /  
Agricultural Waste**  
畜禽废弃物/农业废弃物



**Anaerobic Digester**  
厌氧发酵



**Biogas**  
沼气



**Upgrading Plant**  
净化提纯工厂



**'Bio  
CNG'**  
生物  
CNG



**CNG  
Compression &  
Dispensing**  
天然气压缩&加注



**Food Waste**  
餐厨垃圾

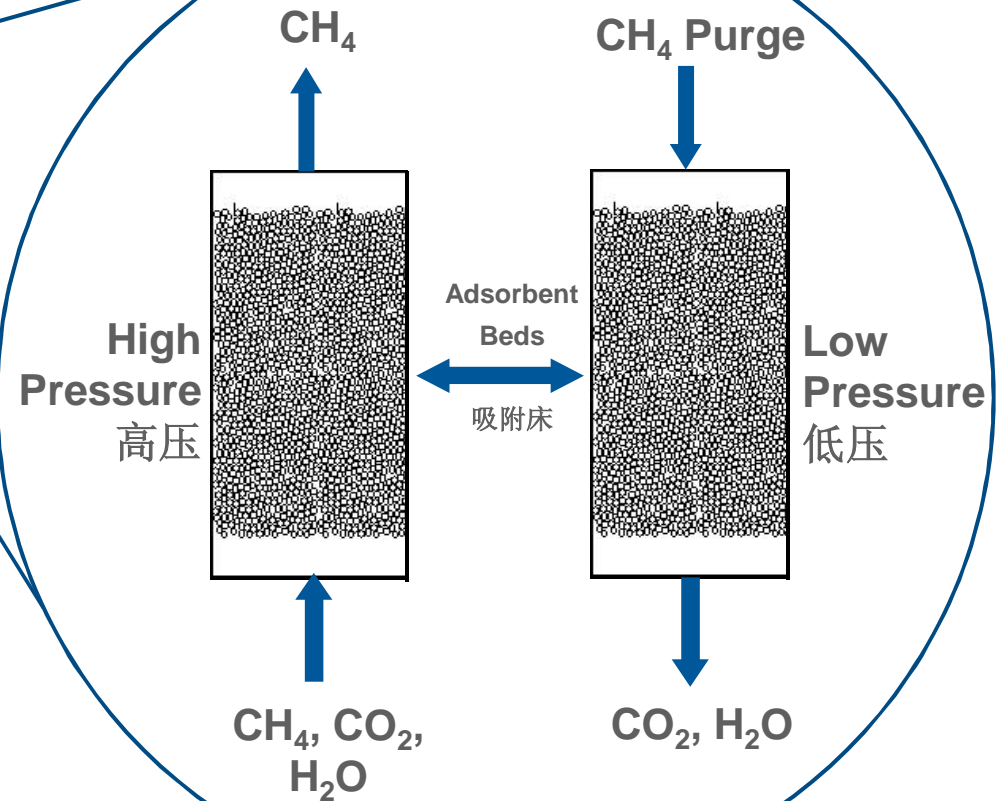


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Xebec Technology & Experience

# Xebec Biogas Purification Technology

## Xebec沼气净化技术

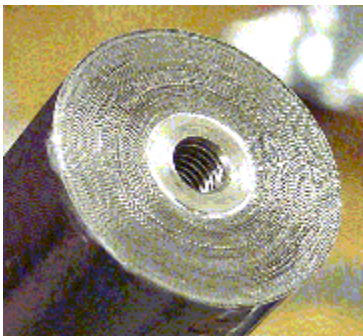


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Xebec Technology & Experience

# High performance Rapid Cycle PSA

## 高性能快速循环变压吸附



- Rapid Cycle PSA technology: 快速循环PSA技术
  - Structured adsorbent  
结构性吸附剂
  - Fast switching rotary valves  
快速变换旋转阀
- Superior performance vs beaded bed PSA:  
优越性能与传统颗粒状吸附剂PSA的比较
  - Faster PSA cycles (10-30X faster)  
更快的变压吸附周期（快10-30倍）
  - Intensified process: compact  
强化处理：紧凑
  - Fast response to changes operating conditions  
对于操作条件的改变有快速反应

# Xebec Technology for Biogas Upgrading

## Xebec沼气净化提纯技术



Xebec Upgrading Plant at Halla Food Waste Digestion Facility (Seoul, Korea)  
Xebec净化提纯装置应用于Halla餐厨垃圾厂  
(韩国首尔)

- n High product gas quality – meet GB CNG specification  
高品质气体—满足CNG GB要求
- n Lowest energy consumption: 0.25 kWh/Nm<sup>3</sup>  
低能耗：0.25千瓦时/方
- n Higher CH<sub>4</sub> recovery than domestic PSA suppliers (96% vs. 89-90% for domestic PSA)  
甲烷回收率高于国内PSA供应商
- n Compact, skid-mounted design for quick installation  
紧凑，撬装设计便于快速安装

## Xebec Biogas Project Experience—Xebec沼气项目经验

| Project<br>项目              | Location<br>地理位置     | Waste Source<br>垃圾源                 | Feed Flow (Nm <sup>3</sup> /h) | Biomethane 甲烷<br>End Use |
|----------------------------|----------------------|-------------------------------------|--------------------------------|--------------------------|
| Scenic View Dairy          | Michigan, US         | Agricultural Waste 农业垃圾             | 225                            | Pipeline                 |
| Rumpke Landfill            | Ohio, US             | Landfill 垃圾填埋场                      | ~7,000                         | Pipeline                 |
| Widnau                     | Switzerland          | Agricultural Waste 农业垃圾             | 200                            | Pipeline                 |
| Lavigny Farm               | Switzerland          | Agricultural Waste 农业垃圾             | 120                            | Pipeline                 |
| UNH                        | New Hampshire, US    | Landfill 垃圾填埋场                      | ~10,000                        | Turbine                  |
| SKS                        | Austria              | Agricultural Waste 农业垃圾             | 40                             | CNG                      |
| Swiss Farmer               | Switzerland          | Agricultural Waste 农业垃圾             | 225                            | Pipeline                 |
| STEP                       | Switzerland          | Industrial Effluent 工业废水            | 250                            | Pipeline                 |
| Hilarides Dairy            | California, US       | Agricultural Waste 农业垃圾             | 270                            | CNG                      |
| <b>Daesung</b>             | <b>Seoul, Korea</b>  | <b>Landfill 垃圾填埋场</b>               | <b>250</b>                     | <b>CNG</b>               |
| SKS                        | Austria              | Agricultural Waste 农业垃圾             | 150                            | CNG                      |
| Sempra Energy              | California           | Municipal Wastewater 市政垃圾           | 400                            | Pipeline                 |
| <b>Halla Environmental</b> | <b>Seoul, Korea</b>  | <b>Food Waste 餐厨垃圾</b>              | <b>700</b>                     | <b>CNG</b>               |
| SKS                        | Austria              | Municipal Solid Waste 市政固体垃圾        | 200                            | CNG                      |
| SKS                        | Austria              | Municipal Solid Waste 市政固体垃圾        | 200                            | CNG                      |
| SKS                        | Austria              | Municipal Wastewater 市政垃圾           | 200                            | CNG                      |
| Verdemobil                 | France               | Municipal Solid Waste 市政固体垃圾        | 50                             | CNG                      |
| <b>Loongas</b>             | <b>Harbin, China</b> | <b>Municipal Solid Waste 市政固体垃圾</b> | <b>350</b>                     | <b>CNG</b>               |
| Terasen                    | BC, Canada           | Landfill 垃圾填埋场                      | 300                            | Pipeline                 |



Xebec Technology & Experience

## Conclusions 总结

- n Rapid growth of Natural Gas as a transportation fuel in China  
在中国快速增长的天然气作为一种交通燃料
- n Biomethane represents a distributed, renewable source of CNG  
生物天然气代表着一种分布式的可再生的CNG原料
- n Large growth opportunities in food waste digestion in 2<sup>nd</sup> & 3<sup>rd</sup> tier cities  
在二、三线城市餐厨垃圾具有巨大的发展机遇
- n Biogas-to-CNG project IRR's are modest & Government funding required to encourage private investment  
Biogas-to-CNG项目目前内部收益率一般，政府的支持将提升民间资本的投资

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