OPPORTUNITIES FOR MITIGATION OF METHANE EMISSIONS IN CHINA

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OUTLINE

- Overview of Methane Emissions in China
- Success of mitigation efforts for coal mine methane
- Organic Waste Sectors
  - Municipal Solid Waste
  - Agriculture
  - Wastewater
- Fossil Fuels Sector
  - Oil and Gas
MOTIVATION – WHY METHANE?

Methane mitigation offers opportunities to:

(1) slow the effects of global warming;

(II) improve air quality;

(III) Realize co-benefits for human health, agriculture, and ecosystems.
WHY CHINA?

China’s Share of Global Methane Emissions in 2010
Total Emissions: 7193 MtCO2e

- China: 13%
- India: 9%
- United States: 9%
- Russia: 7%
- Brazil: 5%
- Indonesia: 3%
- Mexico: 2%
- Nigeria: 2%

Rest of World: 50%

Source: USEPA 2011
WHY CHINA?

- China is largest emitter of methane in the world
- Land size and population contribute to large-scale emissions
- Emissions will only increase with:
  - Population growth
  - Economic growth, as consumption per capita increases
GMI SUCCESS STORY
COAL MINE METHANE (CMM) IN CHINA

- Overview
- Successes
- Future
- Further Recommendations
CMM: A GMI SUCCESS STORY

- Prior to 1990’s, CMM was vented and released to enhance coalmine safety.

- Outreach by EPA, GMI, UNDP to encourage capture and use of CMM
  - Technical resources, financial support, information exchange, workshops, technology demonstrations, capacity-building
  - EPA feasibility studies

- Chinese government policies to encourage CMM capture:
  - Opinions on Speeding Up CBM/CMM Extraction and Utilization, 2006
  - Emission Standard of CBM/CMM, 2008
  - Tax credits and discounts, discounted loan rates to CMM projects
  - CMM-generated electricity given priority by grid operators who purchase at subsidized price
RESULTS FROM CMM IN CHINA

- China leads the world in implementation of CMM capture, hosts 40 of the world’s total 96 projects at active coalmines (IEA 2009)
- CMM capture of 88 MtCO2e, with utilization of 25 Mt CO2e, in 2009 (CATF 2012)
- Generation of electricity: capacity over 1,000 MW nationally (GMI 2011)
- Chinese innovation in use of CMM for power generation:
  - Adaptation to varying methane concentrations
  - Utilization of low concentration methane
As coal demand and production continue to increase, China will continue to be the biggest emitter of CMM in the world.

Source: Adapted from Global Methane Initiative

Underground coal mines are the single largest source of coal mine methane (CMM) emissions. In these mines, methane is removed to maintain safety for the miners. Methane concentrations between 5 and 15% in the air of a coal mine represents an explosion hazard. Mines can be made safe through the use of large-scale ventilation systems that move massive quantities of air through the mines. These systems also release large amounts of very low-concentration ventilation air methane (VAM) into the atmosphere. Capturing these low concentrations of methane from VAM and utilizing it rather than venting has in the past proven difficult, but new technologies have recently been developed and deployed to oxidize the methane in ventilation air. In addition, substantial reductions in total methane release can be achieved by pre-draining the methane from the coal seam, known as degasification, prior to the coal being mined and also draining methane from post-mining operations, known as “gob”. This reduces the amount of methane that will be released into the mine that would need to be vented through a VAM process, and produces a very high quality gas that can be sold.

Source: CATF 2012
RECOMMENDATIONS

- Give China the opportunity to replicate its success with CMM capture at large coal mines by transferring technology to other GMI partners within CMM subcommittee
- Continue GMI work in China to increase capacity for CMM capture in smaller coalmines
  - Otherwise, continue consolidating and closing these mines
- Facilitate the sale of CMM-generated electricity to the grid
  - Implementation of grid priority access has been slow
  - Conversion to LNG is more profitable
- Increase capacity for use of CMM gas
TRANSFER OF LESSONS LEARNED

- China has taken advantage of co-benefits of decreased emissions of coalmine methane
  - Increased safety in mines due to reduced risk of explosion
  - CMM is a valuable resource that is now harvested as an unconventional gas
- Focus on co-benefits of policies
  - Profitable solutions – capture and use of biogas and LFG can reduce emissions and increase access to natural gas
  - Lower incidences of water-borne and sanitation-related diseases
  - Improved air quality
  - Increased energy access via biogas digesters in rural areas
  - Energy security for China through diversification of energy sources
SECTORS

- Organic Waste
  - Municipal Solid Waste
  - Agriculture
  - Wastewater

- Fossil Fuels
  - Oil and Gas
WHY THESE SECTORS?

China's Methane Emissions in 2010
Total Emissions = 924.5 MtCO2e

Coal 32%
Enteric Fermentation 23%
Wastewater Treatment 14%
Rice 14%
Natural Gas & Oil Production 1%
Manure Management 2%
Stationary & Mobile Combustion 4%
Biomass Combustion 5%
Landfills 5%

Source: USEPA 2011
DEFINITIONS AND METHODOLOGY

- Emissions can be approximated by (EPA, 2012):

\[ E = A \times EF \times (1 - ER) \]

- E = total emissions
- A = activity rate
- EF = emission factor
- ER = emission reduction factor
ORGANIC WASTE SECTORS

- Municipal Solid Waste (MSW)
- Agriculture
- Wastewater
MUNICIPAL SOLID WASTE (MSW)
MSW IN CHINA: CURRENT STATUS

- Total Chinese population (2010): 1.34 billion
- Rate of growth slowing, est. peak (2025): 1.4 billion

<table>
<thead>
<tr>
<th>2010 Statistics</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Share (%)</td>
<td>49%</td>
<td>51%</td>
</tr>
<tr>
<td>MSW per Capita (kg)</td>
<td>517 kg</td>
<td>390 kg</td>
</tr>
<tr>
<td>Collection Rate (%)</td>
<td>67%</td>
<td>25%</td>
</tr>
<tr>
<td>Incineration Rate (%)</td>
<td>17%</td>
<td>6%</td>
</tr>
<tr>
<td>Recycling Rate (%)</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Composting Rate* (%)</td>
<td>2.5%</td>
<td>5%</td>
</tr>
<tr>
<td>Total MSW Produced (Mt)</td>
<td>326 Mt</td>
<td>277 Mt</td>
</tr>
<tr>
<td>Total Diverted (Mt)</td>
<td>46 Mt</td>
<td>12 Mt</td>
</tr>
<tr>
<td>Total Landfilled (Mt)</td>
<td>172 Mt</td>
<td>62 Mt</td>
</tr>
<tr>
<td>Total Dumped (Mt)</td>
<td>108 Mt</td>
<td>203 Mt</td>
</tr>
</tbody>
</table>

*We assume 5% of all organic MSW composted, not just that collected.
MSW IN CHINA: MITIGATION OPTIONS

1. **Change** patterns of consumption in order to reduce the quantity of MSW produced

2. **Increase** how much MSW is collected and how much is diverted into composting, recycling, and incineration

3. **Improve** the technology and management of landfills in order to increase the amount of landfill gas (LFG) collected
Question: How much methane is China expected to produce annually from MSW between 2010 and 2030?

Used EPA’s China Landfill Gas Model to develop projections

Divided China into two categories: Urban & Rural

For each of the 2 categories we created 3 scenarios:

- **LOW EMISSIONS**
  - INCREASED investment in all aspects of MSW management

- **MEDIUM EMISSIONS**
  - Largely STATUS QUO, recycling & composting rates stabilize while incineration grows

- **HIGH EMISSIONS**
  - REDUCED investment in all aspects of MSW management
  - Declines in recycling & composting continue, growth in collection & incineration halt
POTENTIAL FUTURE CH$_4$ FROM MSW:
ANNUAL CH$_4$ EMISSIONS (2011-2030)

Projections developed with
LMOP China Landfill Gas Model
Total Projected CH$_4$ Emissions (2011-2030)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>119 bcm or 51.7 MtCO$_2$e</td>
<td>128 bcm or 55.7 MtCO$_2$e</td>
</tr>
<tr>
<td>Medium</td>
<td>193 bcm or 83.9 MtCO$_2$e</td>
<td>152 bcm or 66.3 MtCO$_2$e</td>
</tr>
<tr>
<td>High</td>
<td>270 bcm or 117 MtCO$_2$e</td>
<td>184 bcm or 79.9 MtCO$_2$e</td>
</tr>
</tbody>
</table>

**FINDINGS**
- Future methane emissions from urban areas pose a greater threat than those from rural areas.
- There’s greater range in our urban scenarios than our rural, so how urban MSW is handled will have a substantial impact.

**POLICY RECOMMENDATIONS**
- Focus resources on improved urban MSW management
- Explore alternate means of MSW management in rural areas
AGRICULTURAL MANURE MANAGEMENT
METHANE EMISSIONS FROM AGRICULTURE IN CHINA, 2006

Our Work Focuses on Methane Emissions from Manure Management

Objective:

- Analyze possible reductions in methane emissions from use of household biogas digesters
- Report total uncaptured emissions from biodigesters based on different policy scenarios (assuming that what is captured by the biogas digester is utilized and not emitted).

Source: Yusuf et al, 2012
CURRENT STATUS OF HOUSEHOLD BIOGAS DEVELOPMENT IN CHINA

- The government has invested heavily in household biogas digester installation to promote rural energy security.

- Poor maintenance has diminished biodigester functionality, leading to CH$_4$ leakage.

- New policies have tried to address maintenance failures, but capacity is limited.

- Current technology doesn’t adequately address future trends in CH$_4$ emissions from agriculture.
  - Shift in CH$_4$ emissions from agriculture from southern to northern provinces
  - Increasing number of large and medium scale livestock facilities
PROJECTED INCREASE IN LIVESTOCK (2010 TO 2030)

Data Source: Chinese Agriculture Statistical Yearbook, 2011

Projection Assumptions:
- Linear growth based on 2000-2010 data
- Poultry trend (FAOSTAT, 2012)
- Other livestock (China Statistical Yearbook, 2011)
PROJECTED INCREASE IN CH₄ EMISSIONS FROM LIVESTOCK MANURE (2010 TO 2030)

Data for Calculations:
- Based on linear growth in livestock
- IPCC CH₄ emission factors from manure for 10 domestic species
- Swine contribute the most to total emissions, with an emissions factor of 4
METHODOLOGY: PROJECTED UNCAPPED \( \text{CH}_4 \) EMISSIONS FROM BIODIGESTER MANAGEMENT OF LIVESTOCK MANURE

**Background**

- Goal: Calculate total uncaptured \( \text{CH}_4 \) emissions from biogas digester management of livestock manure based on growth in emissions from manure management.

- Run three scenarios, each with two levels of functionality

<table>
<thead>
<tr>
<th>Scenarios (constant 2010 – 2030)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1: 2010 number of biodigesters (38 million)</td>
</tr>
<tr>
<td>Scenario 2: 75% of the 2020 gov’t target (60 million)</td>
</tr>
<tr>
<td>Scenario 3: 2020 gov’t target (80 million)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status Quo: 40% Biodigesters function</td>
</tr>
<tr>
<td>Optimal Functionality: 100% function</td>
</tr>
</tbody>
</table>
PROJECTED UNCAPTURED CH$_4$ EMISSIONS FROM BIODIGESTER MANAGEMENT OF LIVESTOCK MANURE 2012-2030

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane Emissions (MT CO2e)</td>
<td>40 Million</td>
<td>60 Million</td>
<td>80 Million</td>
<td>40 Million</td>
<td>60 Million</td>
<td>80 Million</td>
<td>40 Million</td>
</tr>
</tbody>
</table>

**Fully Functioning**
- 40 Million
- 60 Million
- 80 Million

**60 % Functioning**
- 40 Million
- 60 Million
- 80 Million
RECOMMENDATIONS

- Reallocate funding from the installation of new biodigesters to maintenance to ensure that existing biogas digesters do not fall into disrepair.
  - Added co-benefits include enhanced rural energy security and respiratory health improvements

- Fund research and investment in technology improvements to make biogas production more cost effective in cold climates.

- Enhance financial support for the development of biogas infrastructure in large and medium-scale livestock operations.
WASTEWATER TREATMENT
WASTEWATER TREATMENT

China's Methane Emissions in 2010
Total Emissions = 924.5 MtCO2e

- Coal: 32%
- Enteric Fermentation: 23%
- Wastewater Treatment: 14%
- Rice: 14%
- Landfills: 5%
- Biomass Combustion: 5%
- Stationary & Mobile Combustion: 4%
- Manure Management: 2%
- Natural Gas & Oil: 1%

Source: USEPA 2011
GLOBAL METHANE EMISSIONS FROM WASTEWATER TREATMENT (2010)

Total Emissions = 450 MtCO2e

- China: 29%
- Nigeria: 13%
- Mexico: 7%
- US: 6%
- Indonesia: 5%
- Rest of World: 40%

Source: USEPA 2011
ACCESS TO WASTEWATER TREATMENT

- About half of Chinese live in rural areas
- About 52% of Chinese households have sewage connections
- ~2000-6000 WWTP, up from 500 in 2002
- Dramatic improvements in rural sanitation and reductions in open discharge of waste

Source: He 2007
SOURCES OF METHANE EMISSIONS IN WASTEWATER STREAMS

IPCC, 2006

Domestic Wastewater

Collected
- Untreated
  - Rivers, lakes, seas
- Treated
  - Stagnant sewer

Uncollected
- Untreated
  - Rivers, lakes, seas
  - To ground
- Treated on site:
  - Pit latrines

Sewer to plant

Aerobic treatment
- Anaerobic treatment

Wetlands

Sludge

Reactor

Lagoon

Anaerobic digestion

Incineration

Landfill

Land disposal

Yellow = Major Methane Sources
## OPTIMAL TECHNOLOGIES FOR WASTEWATER TREATMENT

<table>
<thead>
<tr>
<th>Scale</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large scale municipal</td>
<td>Anaerobic with methane recovery</td>
</tr>
<tr>
<td>Small scale municipal, some suburban and periurban areas</td>
<td>Constructed wetland</td>
</tr>
<tr>
<td>Small scale rural</td>
<td>Pit latrine with household biogas digester</td>
</tr>
</tbody>
</table>

- Anaerobic treatment with methane recovery, Bailonggong WWTP, Shanghai
- Constructed wetland, Shenyang
- Household biogas digester
HOUSEHOLD DOMESTIC BIOGAS

- Used to treat human and animal waste.
- Produces co-benefits for rural energy and indoor air quality.
- China is on track to have 80 million household biogas digesters by 2030.
- Increasing the quantity and operational functionality of biogas digesters provides significant opportunities to mitigate methane emissions from rural wastewater and generate energy.
## Emissions Projection Methodology

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Urban</th>
<th>Rural</th>
<th>Biodigesters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing WWT Technology</td>
<td>Sewage mainly treated in central WWTPs</td>
<td>Open discharge and pit latrines</td>
<td>38 million</td>
</tr>
<tr>
<td>Moderate Expansion</td>
<td>Improved management of WWTPs yields lower emissions</td>
<td>Some open discharge replaced by pit latrines</td>
<td>60 million</td>
</tr>
<tr>
<td>Maximum Feasible Technology</td>
<td>95% of sewage treated in well-managed WWTPs with negligible emissions and low methane sludge management</td>
<td>92% of rural households have pit latrines</td>
<td>80 million</td>
</tr>
</tbody>
</table>

- Population and urbanization trends from the UN.
- Assumes 60% functionality of biodigesters.
Operational efficiency of household biogas digesters is assumed to be 60%.
## FUTURE EMISSIONS PROJECTIONS

<table>
<thead>
<tr>
<th>CH$_4$ Emissions (2030)</th>
<th>Existing Technology</th>
<th>Moderate Technology Expansion</th>
<th>Maximum Feasible Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>87 MtCO$_2$e</td>
<td>62 MtCO$_2$e</td>
<td>26 MtCO$_2$e</td>
</tr>
<tr>
<td></td>
<td>7% increase from 2010</td>
<td>~25% decrease</td>
<td>~65% decrease</td>
</tr>
</tbody>
</table>

### Outlooks

- **Existing Technology**
  - Household biogas digesters reduce CH$_4$ emissions by 9 Mt CO$_2$e (~10% total domestic wastewater CH$_4$ emissions)
  - Urbanization curbs even greater emissions increases

- **Moderate Technology Expansion**
  - Tradeoff between improved wastewater treatment and methane emissions in rural areas (pit latrines instead of open discharge)
  - More reductions possible with low methane sludge management

- **Maximum Feasible Technology**
  - Negligible emissions resulting from near universal urban WWTP coverage, but higher energy requirements
  - Widespread adoption of biogas digesters to limit emissions from rural areas
FUTURE EMISSIONS PROJECTIONS: KEY INSIGHTS

- Improving wastewater effluent quality in centralized systems requires greater energy inputs. These estimates do not account for indirect GHG emissions due to energy demands of aerobic wastewater treatment.

- Improved rural sanitation has major co-benefits for public health and water quality of lakes and rivers, but may lead to greater methane emissions because pit latrines are a primary emissions source.

- Rural methane emissions may be curbed by:
  1. Expansion of household biogas, and
  2. Urbanization.

- Adoption of maximum feasible wastewater treatment technology could reduce wastewater methane emissions by ~66%.
RECOMMENDATIONS

1. Improve quality and detail of available data on country-specific emissions factors and utilization of wastewater treatment technologies in rural and urban areas in China.

2. Implement appropriate wastewater treatment technologies:
   - Sludge management and biogas recovery from large-scale anaerobic digestion;
   - Biogas capture and utilization from latrines; and
   - Constructed wetlands in rural areas.
METHANE EMISSIONS REDUCTION OPPORTUNITIES FROM THE FOSSIL FUEL SECTOR
CHINA’S OIL & GAS SECTOR
OUTLINE - OIL & GAS SECTOR

- Overview
- Market Activity
- Emissions and Projections
- Mitigation Technologies
- Recommendations
OIL & GAS SECTOR: INTRODUCTION

- Three of the eight low cost mitigation measures identified by UNEP are in the oil and gas sector.

- According to the U.S. GHG Inventory for 2006,
  - 91% of GHG emissions from the oil and gas sector are associated with the natural gas industry, and
  - 90% of the GHG emissions from the natural gas industry is methane.

- Focus on natural gas industry assuming these trends are applicable to China.
MARKET ACTIVITY
MARKET OVERVIEW

Why market structure matters
• Players and incentives

Why pricing matters
• Profitability of green technologies

Why the future of shale gas matters
• A new leakage source
MARKET OVERVIEW FOR NATURAL GAS

- Limited share in China’s total energy consumption (4% in 2010)
- Rapidly growing demand
  - Current: World’s 4th largest natural gas consumer (130 billion cubic meters, bcm, 2011)
  - Future: May approach 500 bcm by 2030, nearing current US consumption
- Increasing import dependence

Sources: IEA 2012, EIA 2012
CURRENT MARKET STRUCTURE

- An oligopolistic structure, dominated by three vertically integrated state-owned enterprises

Sources: IEA 2012, EIA 2012
NATURAL GAS PRICES

- Pricing mechanism
  - Most provinces: Regulated (Cost-of-Service)
  - Pilot program in two provinces since 2011: Relatively market-based
    (Netback Approach \(\rightarrow\) Prices are linked to petroleum end-products)

- Price level
  - High gas price comparing with US and most non-OECD countries
    e.g. End-user price (USD/MMBtu, 2011): 7-25 in China, 4-5 in US
  - Mainly due to increasing price of imported gas

Sources: IEA 2012, EIA 2012
UNCONVENTIONAL GAS TYPES

Unconventional gas
Gas resources that have traditionally been considered difficult or costly to produce

Shale gas
Natural gas trapped within shale formations

Coalbed methane
Natural gas contained in coalbed

Tight gas
Natural gas found in low permeability formations

Coalmine Methane (CMM): Methane released from the coal and surrounding rock strata due to mining activities.

Source: IEA 2012, EPA website
UNCONVENTIONAL GAS IN CHINA

Before 2015
- Coalbed Methane (CBM) is and will continue to be the primary source of unconventional gas production
  - CBM: 10 bcm in 2010, targeted at more than 30 bcm in 2015
  - Shale gas: No commercial production till now, targeted at 6.5 bcm in 2015

In the long run
- Shale gas has the potential to be the major source in the future.
  - Larger remaining recoverable resource potential
    Shale gas 36 trillion cubic meters (tcm), CBM 9 tcm
  - Optimistic projection: As much as 300 bcm in 2030

Sources: IEA 2012, EIA 2012, China MLR Release
CURRENT SHALE GAS DEVELOPMENT

- Preliminary stage of assessment and exploration
  - Two rounds of public auctions have taken place for exploration licenses
## SHALE GAS MARKET: DIFFERENT FROM CONVENTIONAL GAS MARKET

| Pricing | Pricing Mechanism: Market-based approach  
| Price level: Uncertain, but production subsidy is higher than conventional gas |
|---|---|
| Market Structure | Might no longer be dominated by the Big Three  
| Non-Big-Three companies hold the exploration licenses for 20 of the 21 shale gas blocks that have been public auctioned.  
| A variety of new players including power utility giant, real estate group, energy trading company, and coal mining company, etc. |
EMISSIONS FROM NATURAL GAS: PROJECTIONS
Many entities have made projections for natural gas development.

We chose to use IEA projections because:

- IEA’s projections for 2030 fall within projected ranges from other sources.
- IEA’s projections are provided in terms of low, moderate, and high scenarios.
- IEA’s projections are applicable for 2020 and 2030.
THREE IEA SCENARIOS FOR NATURAL GAS PRODUCTION IN CHINA

- Production volumes used as activity rate, A, to calculate emissions,
  \[ E = A \times EF \times (1-ER) \]

---

**2020**

- Low
- Moderate
- High

**2030**

- Low
- Moderate
- High

“Golden Rules Case”

Unconventional

Incl. coal bed methane and shale/tight gas

Conventional
CHINA’S NATURAL GAS PRODUCTION AND CONSUMPTION, 2000-2011

Source: EIA International Energy Statistics
THREE IEA SCENARIOS FOR NATURAL GAS CONSUMPTION IN CHINA

- Production and import volumes used as activity rate, A, to calculate emissions,

$$E = A \times EF \times (1-ER)$$

Consumption in China is the summation of imports and production.
EMISSION FACTORS FOR METHANE FROM OIL AND NATURAL GAS SYSTEMS

- Emission factors for OECD countries are much lower than in the rest of the world.
- Emission factors are highly uncertain.

Select $10^5$ kg/PJ as the bulk emissions factor.

Based on 1996 IPCC GHG Inventory Data.
Note that the same emission factor is applied to conventional / unconventional production and imports (i.e. consumption) since emission factors are highly uncertain.

Units are in Mt CO$_2$e
MITIGATION STRATEGIES
U.S. EPA NATURAL GAS STAR

- Documents more than 120 cost-effective methods for reducing methane emissions from oil and gas sectors.

- Technologies apply to production, transportation and distribution of Oil and Natural Gas.

Source: U.S. EPA Website, 2012
REDUCED EMISSIONS COMPLETIONS

- Captures CH$_4$ during well-cleanup after hydraulic fracturing.

- 8,700 – 33,000 $USD per well, 7,000 – 23,000 Mcf per well captured

- 28,000 – 90,000 $US per well at US Gas Prices
METHANE CAPTURE VS. RETURN ON INVESTMENT

(I) Reduced Emissions Completions

(II) No-Bleed Pneumatic Controllers

(III) Plunger Lift Systems

U.S. EPA Website, 2012
Leaking Profits, NRDC, 2012
# Calculating Return on Investment at Chinese Gas Prices

<table>
<thead>
<tr>
<th>Tech</th>
<th>Savings Volume (mcf)</th>
<th>US Prices ($3/MMBTU)</th>
<th>Chinese Prices ($6.5/MMBTU)</th>
<th>Purchase Cost ($)</th>
<th>Operating Costs ($/yr)</th>
<th>Payback Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>REC</td>
<td>270,000</td>
<td>810,000</td>
<td>1,755,000</td>
<td>500,000</td>
<td>121,250</td>
<td>5</td>
</tr>
<tr>
<td>APS</td>
<td>20,000</td>
<td>60,000</td>
<td>130,000</td>
<td>60,000</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>PLS</td>
<td>18,250</td>
<td>54,750</td>
<td>118,625</td>
<td>10,363</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

## Analysis

- **REC** shows a shorter payback period in both US and China, making it the most cost-effective option.
- **APS** has a longer payback period in the US, indicating a more significant initial investment with lower ongoing costs.
- **PLS** has the shortest payback period in China, suggesting it is more viable in that market.

These calculations help in understanding the financial viability of different technologies at Chinese gas prices, aiding in informed decision-making.
KEY FINDINGS

- Payback period in China is much shorter than in US given Chinese market prices

- 7 technologies can achieve more than 70% of portfolio emissions reductions

- Cost-effective technologies can generate up to 90% emissions reductions

<table>
<thead>
<tr>
<th>Tech Deployment Scenario</th>
<th>2030 Emissions [Mt CO2-eq]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business as Usual Emissions</td>
<td>50</td>
</tr>
<tr>
<td>Possible Emissions Reduction</td>
<td>5</td>
</tr>
</tbody>
</table>
RECOMMENDATIONS
TECHNOLOGICAL RECOMMENDATIONS

- All feasible emissions capture technology should be employed in a growing gas Chinese gas industry.
- Joint study of emissions factors would add to significance of emissions reduction calculations.
- Prepare materials emphasizing how cost-effective low-emissions technologies are at Chinese gas prices.
- EPA/GMI might leverage the US-China Shale Gas Initiative to advocate for low-emissions technology.
OVERALL SECTOR RECOMMENDATIONS

- Natural gas industry is developing rapidly – it is in their best interest to “do it right”
- Prepare materials emphasizing how cost-effective low-emissions technologies are at Chinese gas prices.
- EPA/GMI might leverage the US-China Shale Gas Initiative to advocate for low-emissions technology.
- US-China Shale Gas Initiative can facilitate methane mitigation technology transfer
- Work with the “Big Three” Chinese energy companies, but also other companies exploring shale gas in China
- Promote the adoption of the Golden Rules for Natural Gas
RECOMMENDATION SUMMARY
# RECOMMENDATIONS

<table>
<thead>
<tr>
<th>Sector</th>
<th>Emission Reductions Range for 2030 (% of Total Sector Emissions)</th>
<th>Co-Benefits</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organic Waste Sectors</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Municipal Solid Waste</td>
<td>47-90 MtCO$_2$e (24-45%)</td>
<td>• Public health and sanitation</td>
<td>• Capital costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Improve recycling and composting</td>
<td>• Labor requirements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Alternative fuel source</td>
<td>• Dispersed rural population</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Aesthetic value</td>
<td>• Urban land-use</td>
</tr>
<tr>
<td>Agriculture: Manure</td>
<td>17-36 MtCO$_2$e (17-36%)</td>
<td>• Rural energy security</td>
<td>• Cold-weather technology development</td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td>• Air quality and respiratory health</td>
<td>• Dispersed Populations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Water quality</td>
<td>• Human capital constraints to maintenance</td>
</tr>
<tr>
<td>Wastewater</td>
<td>20-58 MtCO$_2$e (23-66%)</td>
<td>• Public health and sanitation</td>
<td>• Capital costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Water quality and scarcity</td>
<td>• Rapid urbanization limits city planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Nitrous oxide mitigation</td>
<td>• Dispersed rural populations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Rural energy security</td>
<td></td>
</tr>
<tr>
<td><strong>Fossil Fuel Sectors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td>31- 44 MtCO$_2$e (&lt;90%)</td>
<td>• Energy security</td>
<td>• Technology transfer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Economic growth</td>
<td>• Technology advancement</td>
</tr>
</tbody>
</table>
SUMMARY OF RECOMMENDATIONS TO GMI FOR ALL SECTORS

- **Organic Waste**
  - Improve quality and detail of available data about treatment processes in all waste sectors
  - Explore options for effectively capturing and utilizing biogas from waste treatment processes

- **Fossil Fuels**
  - US-China Shale Gas Initiative can facilitate methane mitigation technology transfer
  - Work with the “Big Three” Chinese energy companies, but also other companies exploring shale gas in China
  - Promote the adoption of the Golden Rules for Natural Gas
RATIONALE

- Co-benefits offer positive societal impact
  - Profitable opportunities for emissions reduction
  - Improved air quality
  - Improved sanitation and health
  - Increased access to energy in rural areas
  - Energy security

- China has an opportunity to demonstrate leadership in climate change policy
  - Methane mitigation policies offer a means
  - Model successful capture and utilization technologies to other developing countries
  - Foster and strengthen international collaboration through increased partnerships with organizations like GMI, US-China Shale Gas Initiative, Climate and Clean Air Coalition, etc.

- Action on methane as interim measure to defer action on CO₂.

- With the expiration of the CDM, China needs a new mechanism to support projects
THANK YOU

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