OPPORTUNITIES FOR MITIGATION OF METHANE EMISSIONS IN CHINA

Presenters: Shannon Brink, Harrison Godfrey, Mary Kang, Shelly Lyser, Joseph Majkut, Samantha Mignotte Wei Peng, Matt Reid, Madhurita Sengupta, Laura Singer

Faculty Advisor: Professor Denise Mauzerall

PRINCETON UNIVERSITY
WOODROW WILSON SCHOOL
of Public & International Affairs

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AUTHORS

Shannon Brink, Master in Public Affairs Candidate, Development Economics

Harry Godfrey, Master in Public Affairs Candidate, Domestic Policy

Mary Kang, Ph.D. Candidate, Civil and Environmental Engineering

Shelly Lyser, Master in Public Affairs Candidate, Domestic Policy

Joseph Majkut, Ph.D. Candidate, Atmospheric and Oceanic Sciences

Samantha Mignotte, Master in Public Affairs Candidate, Rural and Agricultural Development

Wei Peng, Ph.D. Candidate, Science, Technology, and Environmental Policy

Matthew Reid, Ph.D. Candidate, Civil and Environmental Engineering

Madhurita Sengupta, Master in Public Affairs Candidate, International Affairs

Laura Singer, Master in Public Affairs Candidate, Energy Security

Project Advisor

Denise Mauzerall, Professor of Environmental Engineering and International Affairs, Woodrow Wilson School and Department of Civil and Environmental Engineering

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:

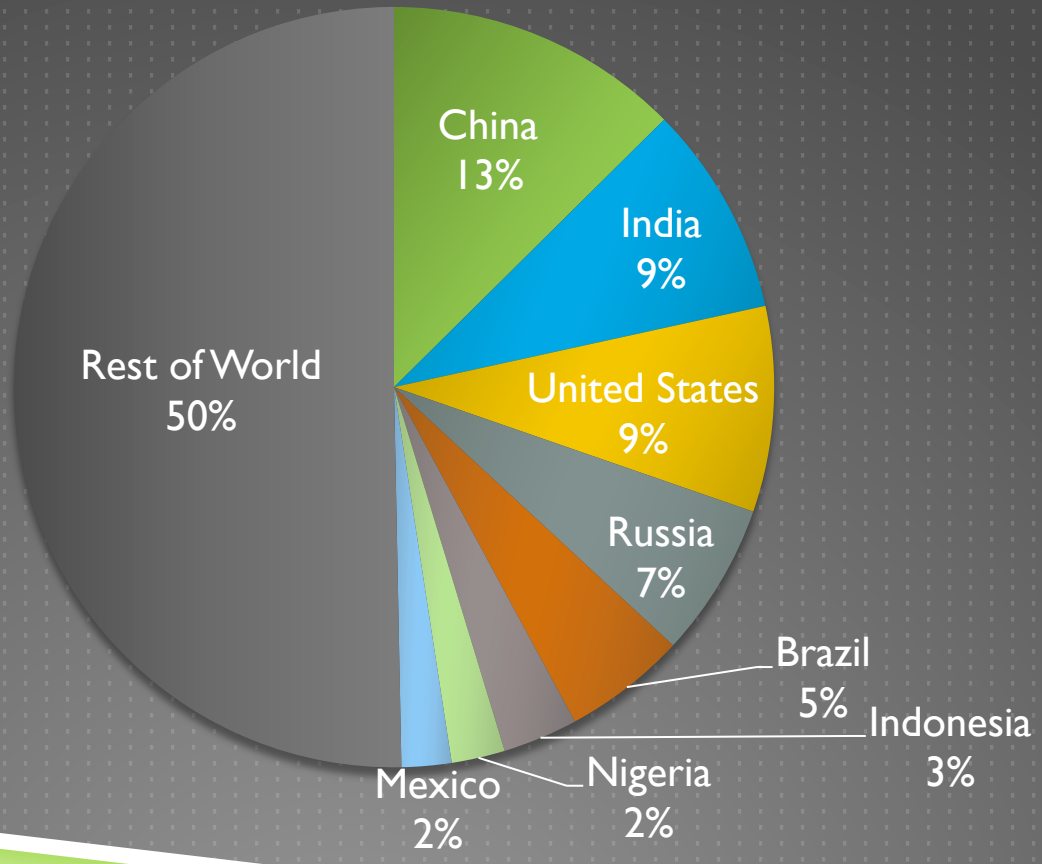
(I) slow the effects of global warming;

(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



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

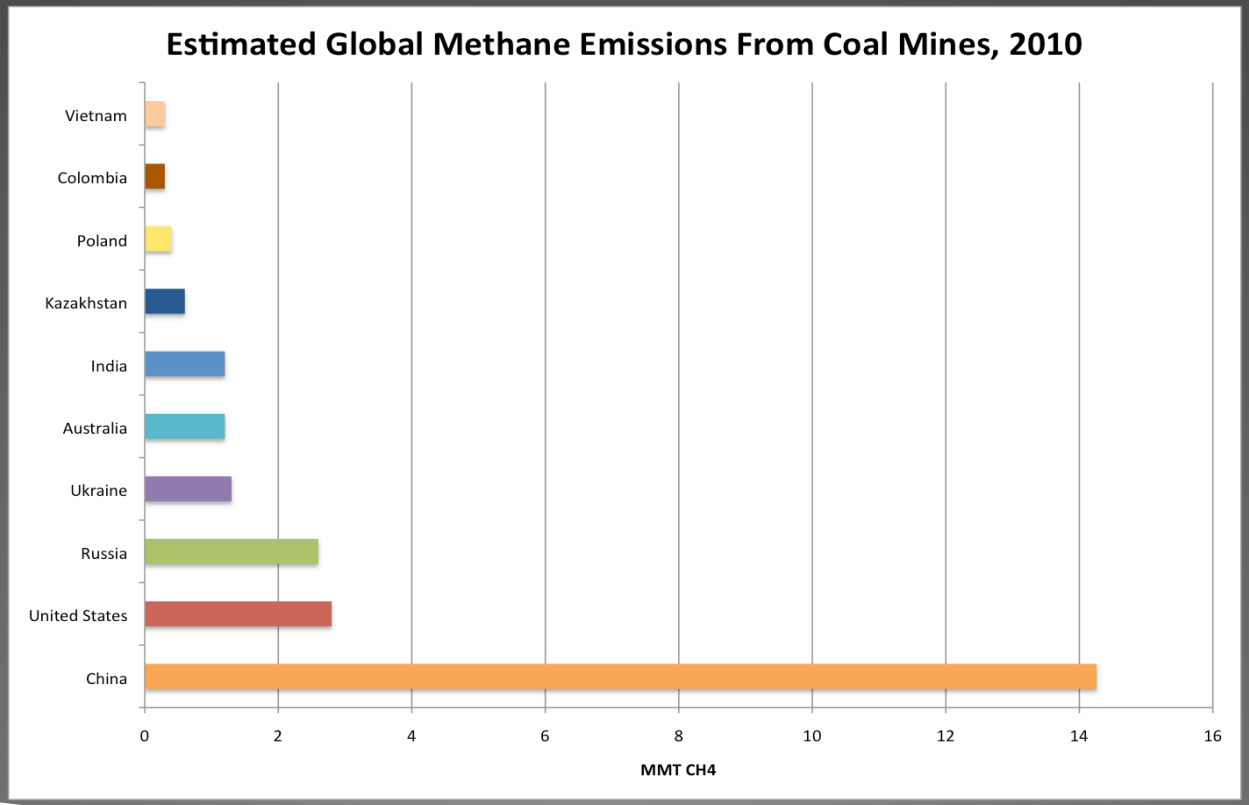
- Prior to 1990's, CMM was vented and released to enhance coalmine safety.
- Outreach by EPA, GMI, UNDP to encourage capture and use of CMM
  - Technical resources, financial support, information exchange, workshops, technology demonstrations, capacity-building
  - EPA feasibility studies
- Chinese government 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

FUTURE OF CMM IN CHINA

As coal demand and production continue to increase, China will continue to be the biggest emitter of CMM in the world.



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

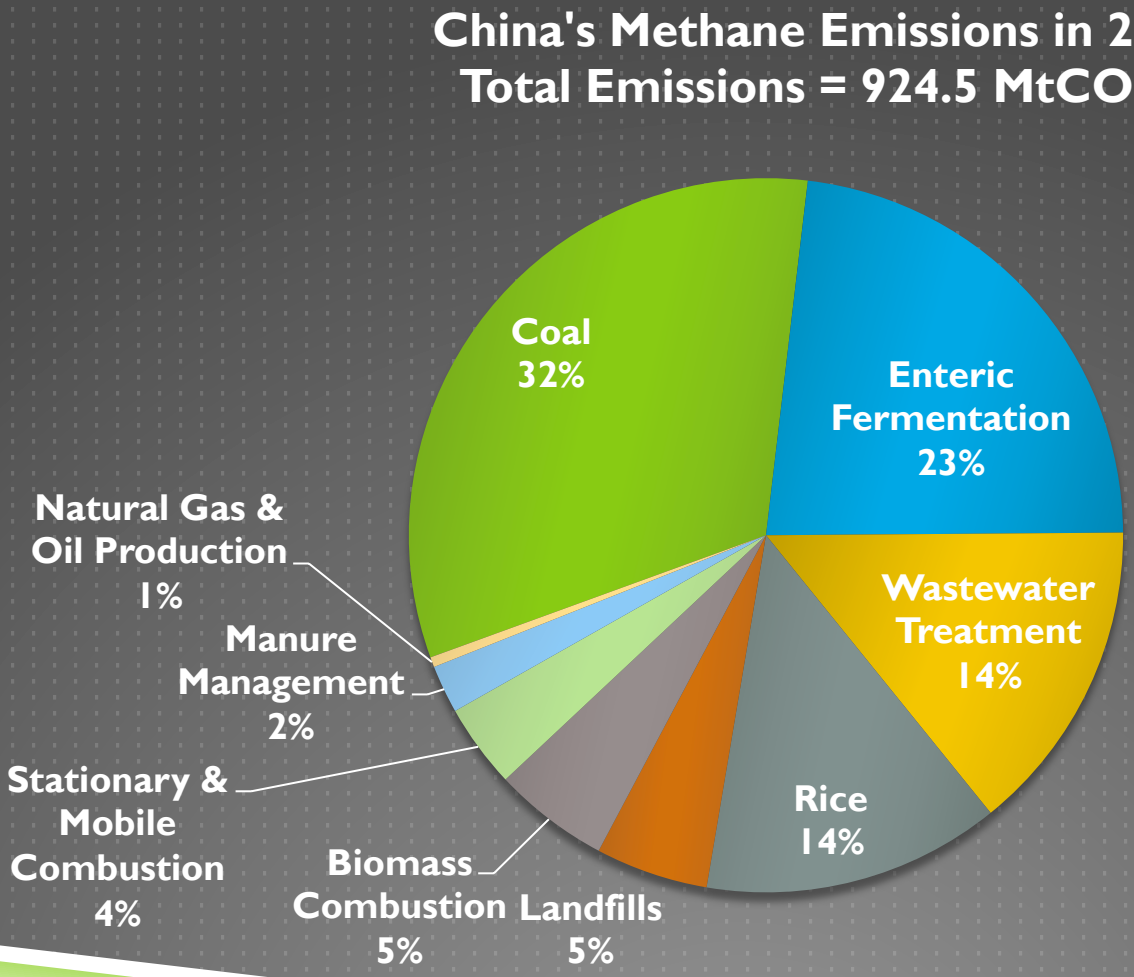
TRANSFER OF LESSONS LEARNED

- 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?



Source: USEPA 2011

DEFINITIONS AND METHODOLOGY

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

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

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 billon
  - Rate of growth slowing, est. peak (2025): 1.4 billion

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

*We assume 5% of all organic MSW composted, not just that collected.

Multiple Sources

MSW IN CHINA: MITIGATION OPTIONS

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

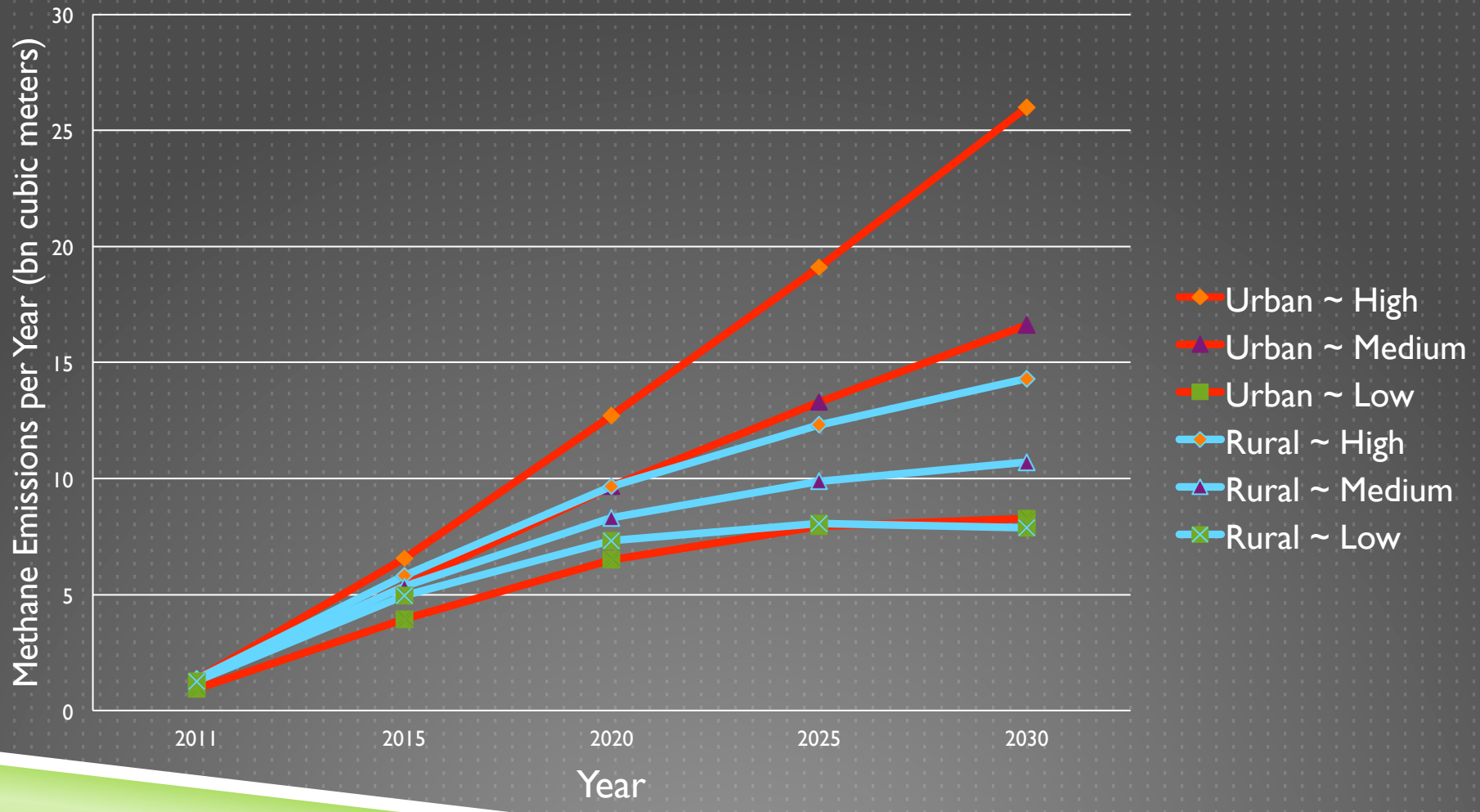
2. **Increase** how much MSW is collected and how much is diverted into composting, recycling, and incineration

3. **Improve** the technology and management of landfills in order to increase the amount of landfill gas (LFG) collected

POTENTIAL FUTURE CH_4 FROM MSW: METHODOLOGY OF ANALYSIS

- 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

POTENTIAL FUTURE CH_4 FROM MSW: TOTAL EMISSIONS, FINDINGS & RECOMMENDATIONS

Total Projected CH_4 Emissions (2011-2030)

Scenario	Urban	Rural
Low	**119 bcm** *or* **51.7 MtCO2e**	**128 bcm** *or* **55.7 MtCO2e**
Medium	**193 bcm** *or* **83.9 MtCO2e**	**152 bcm** *or* **66.3 MtCO2e**
High	**270 bcm** *or* **117 MtCO2e**	**184 bcm** *or* **79.9 MtCO2e**

FINDINGS

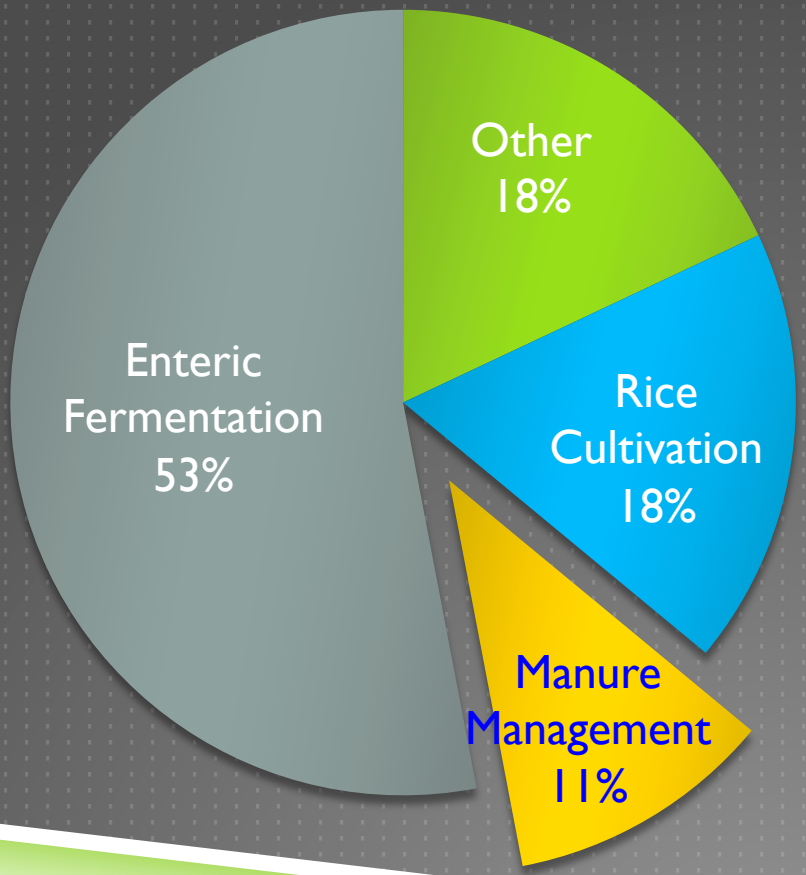
- Future methane emissions from urban areas pose a greater threat than those from rural areas.
- There's greater range in our urban scenarios than our rural, so how urban MSW is handled will have a substantial impact.

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



Source: Yusuf et al, 2012

Our Work Focuses on Methane Emissions from Manure Management

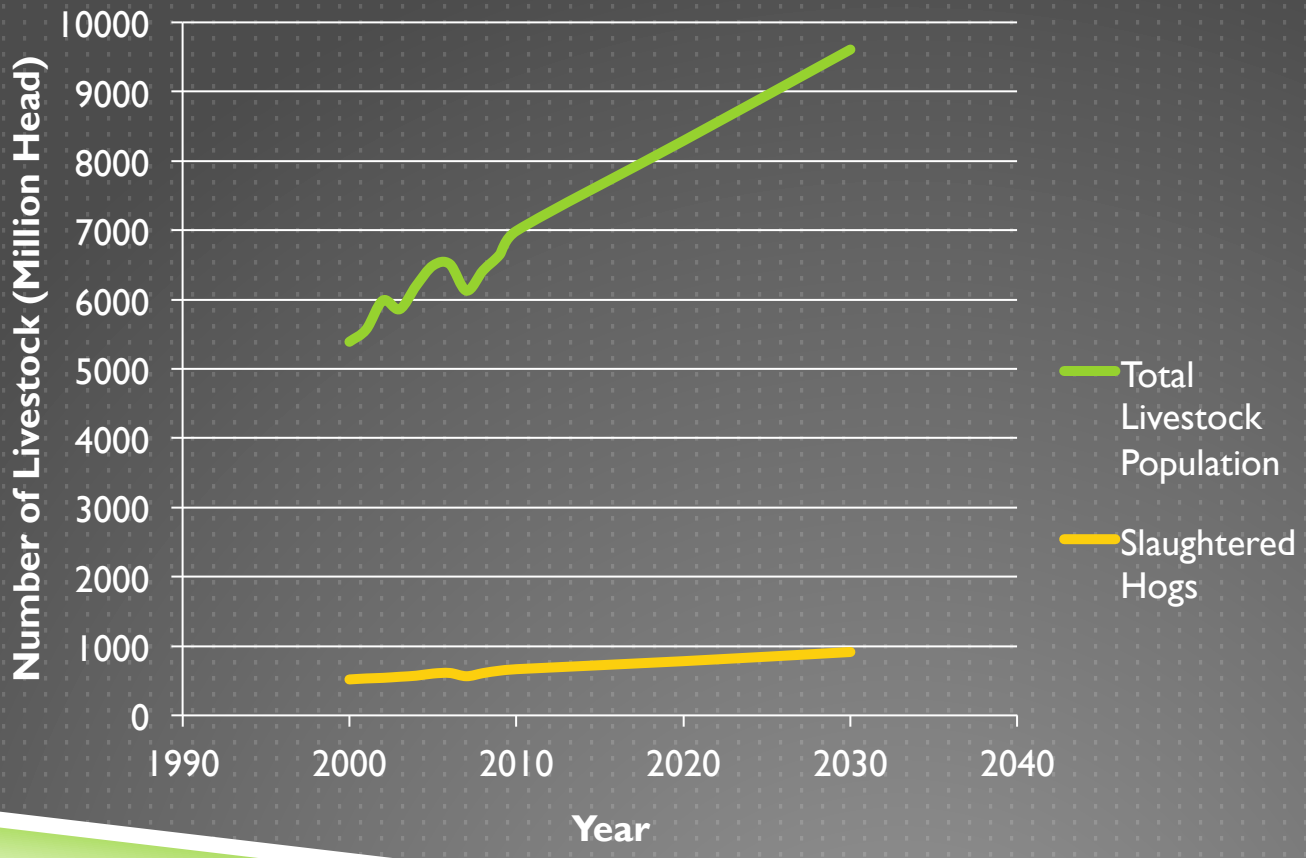
Objective:

- 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).

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)

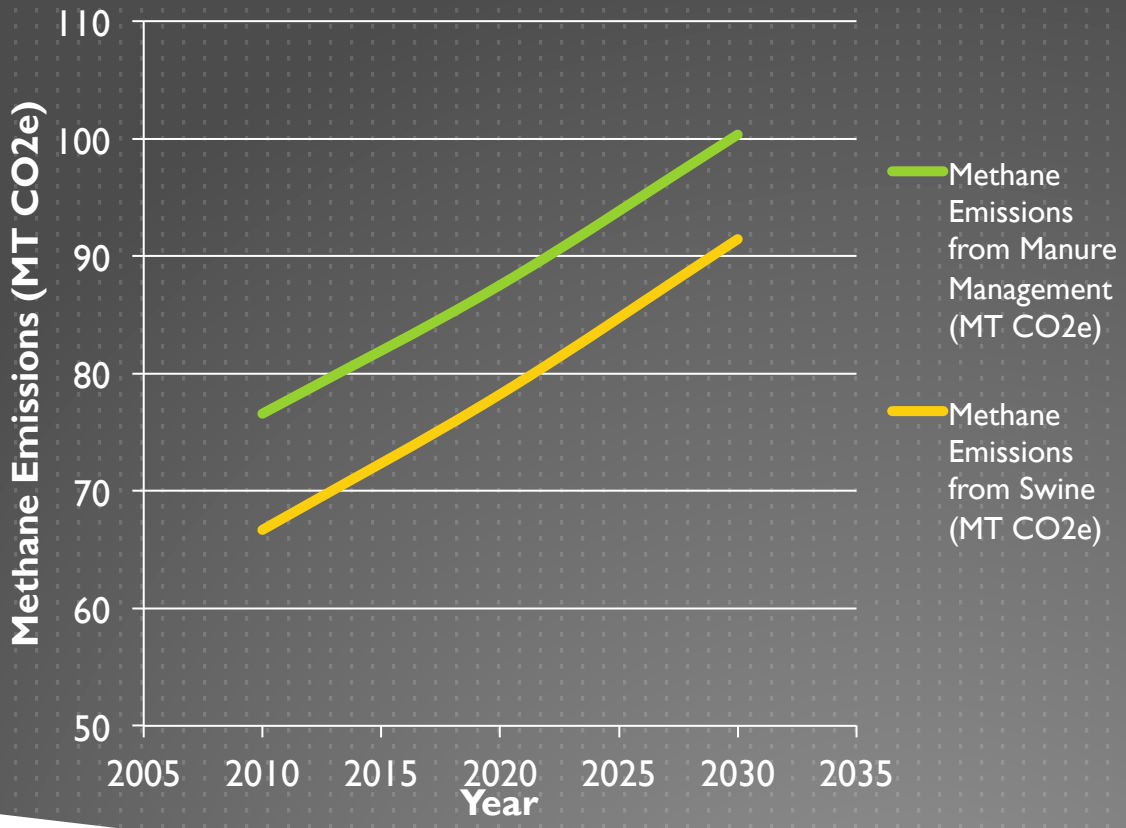


Projection Assumptions:

- Linear growth based on 2000-2010 data
- Poultry trend (FAOSTAT, 2012)
- Other livestock (China Statistical Yearbook, 2011)

Data Source:
Chinese Agriculture Statistical Yearbook, 2011

PROJECTED INCREASE IN CH_4 EMISSIONS FROM LIVESTOCK MANURE (2010 TO 2030)



Data for Calculations:

- Based on linear growth in livestock
- IPCC CH_4 emission factors from manure for 10 domestic species
- Swine contribute the most to total emissions, with an emissions factor of 4

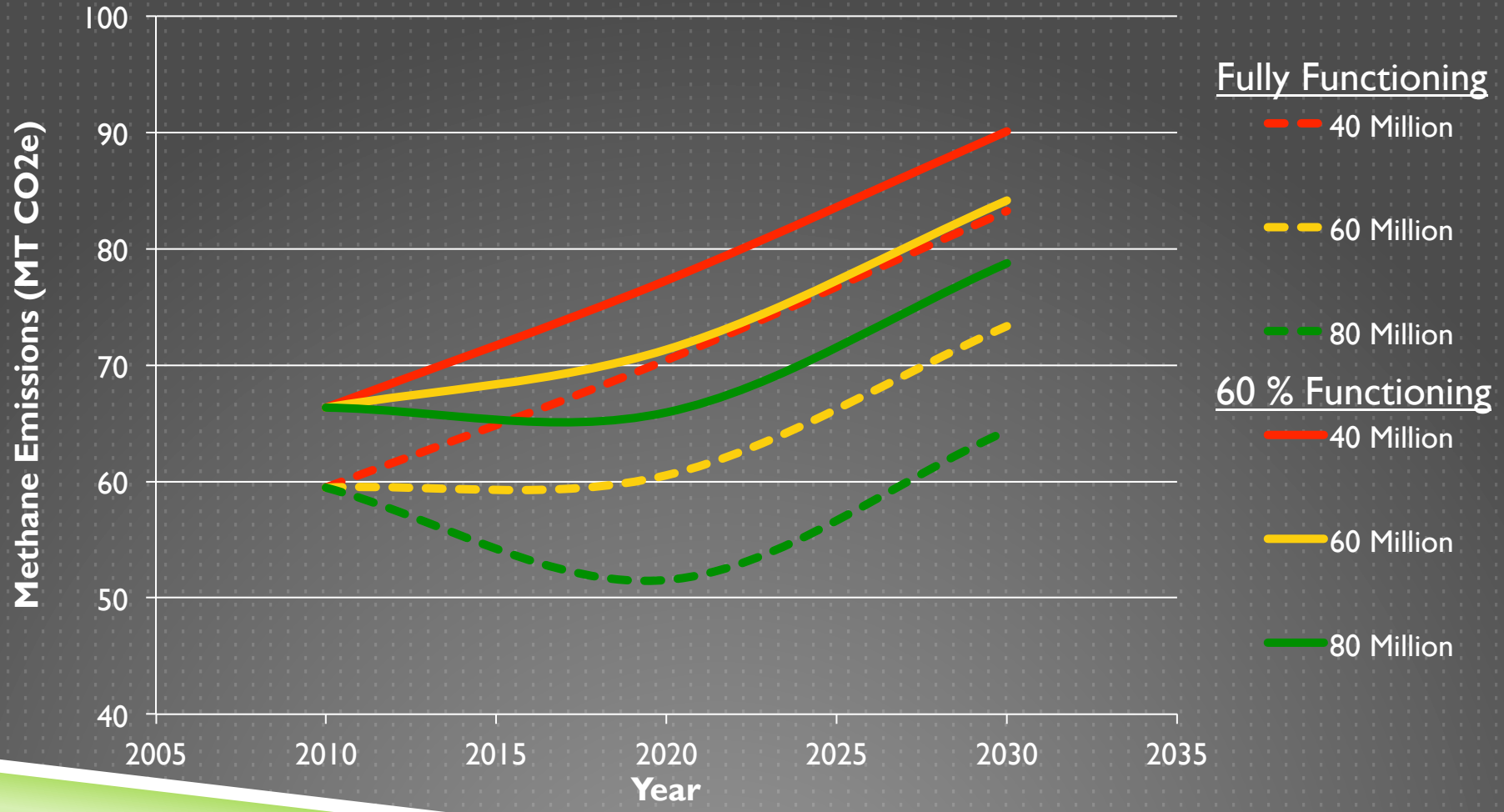
METHODOLOGY: PROJECTED UNCAPTURED CH_4 EMISSIONS FROM BIODIGESTER MANAGEMENT OF LIVESTOCK MANURE

Background

- Goal: Calculate total uncaptured 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

Scenarios (constant 2010 – 2030)
Scenario 1: 2010 number of biodigesters (38 million)
Scenario 2: 75% of the 2020 gov't target (60 million)
Scenario 3: 2020 gov't target (80 million)
Functionality
Status Quo: 40% Biodigesters function
Optimal Functionality: 100% function

PROJECTED UNCAPTURED CH_4 EMISSIONS FROM BIODIGESTER MANAGEMENT OF LIVESTOCK MANURE 2012-2030

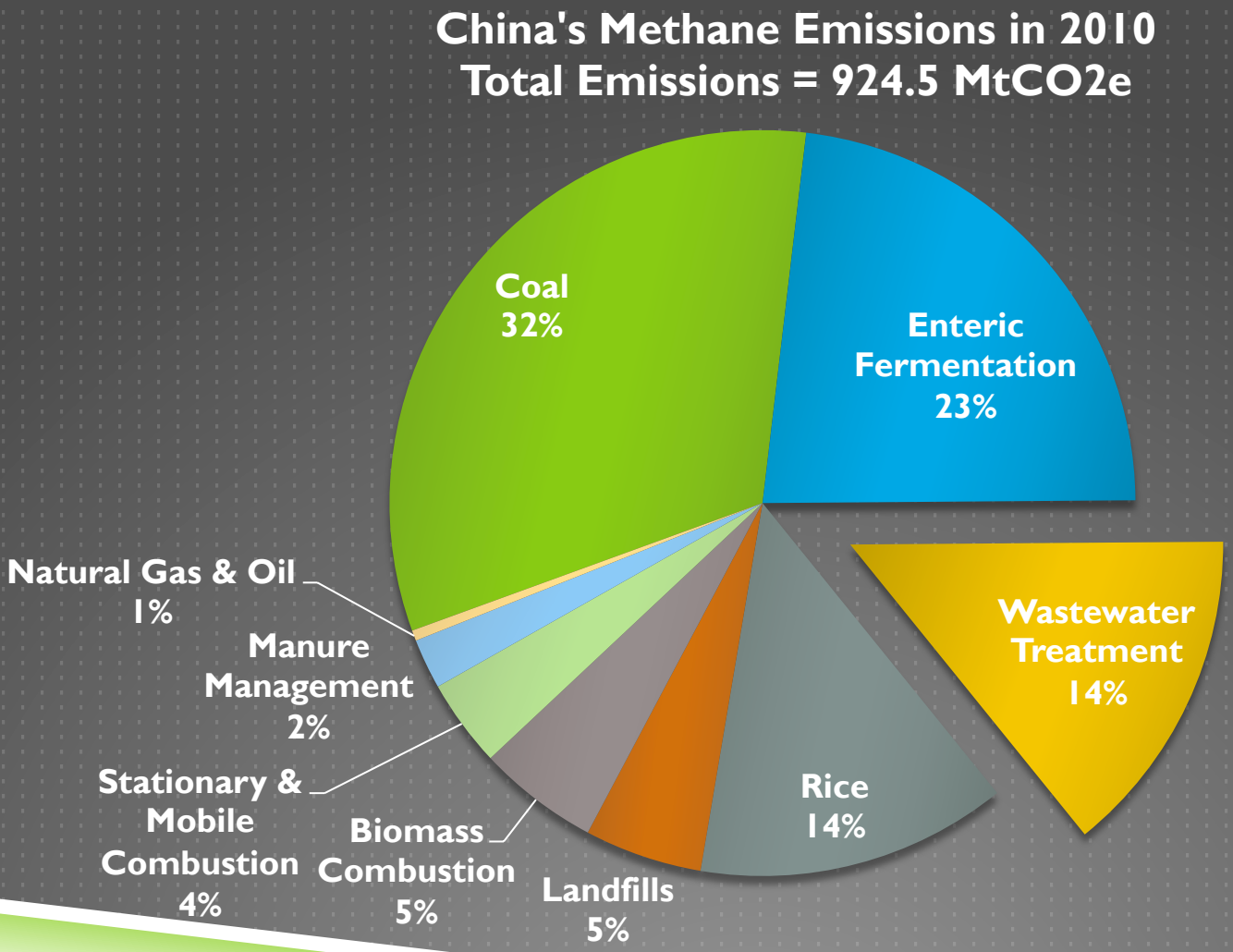


RECOMMENDATIONS

- **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

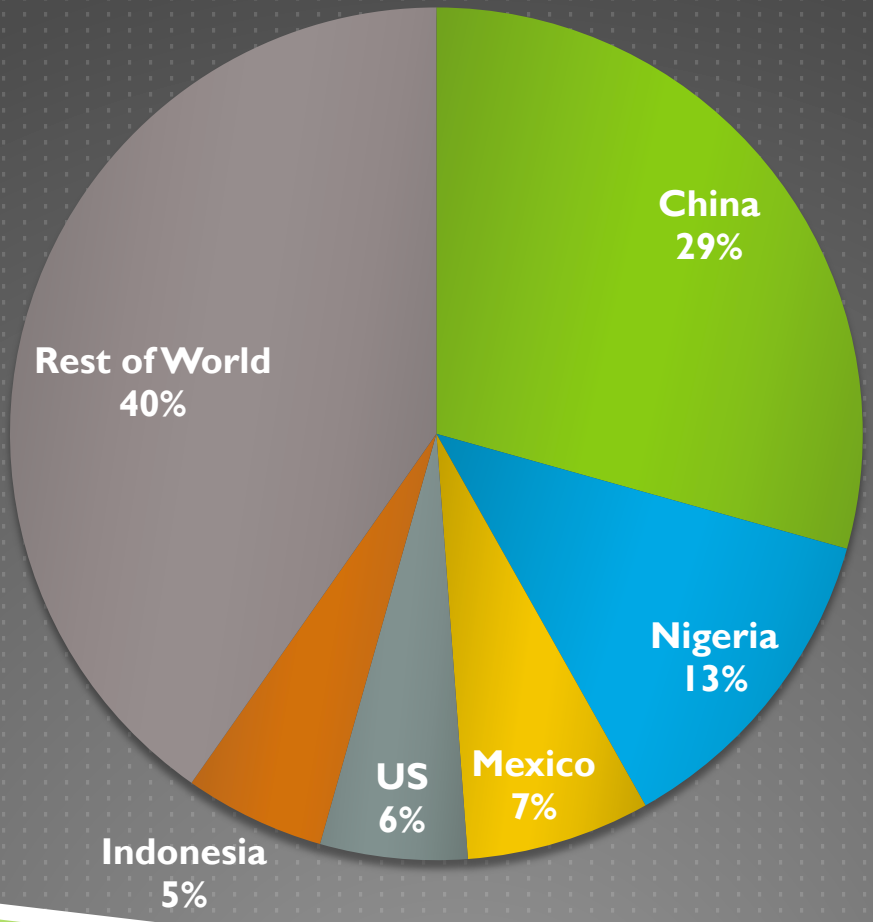
WASTEWATER TREATMENT



Source: USEPA 2011

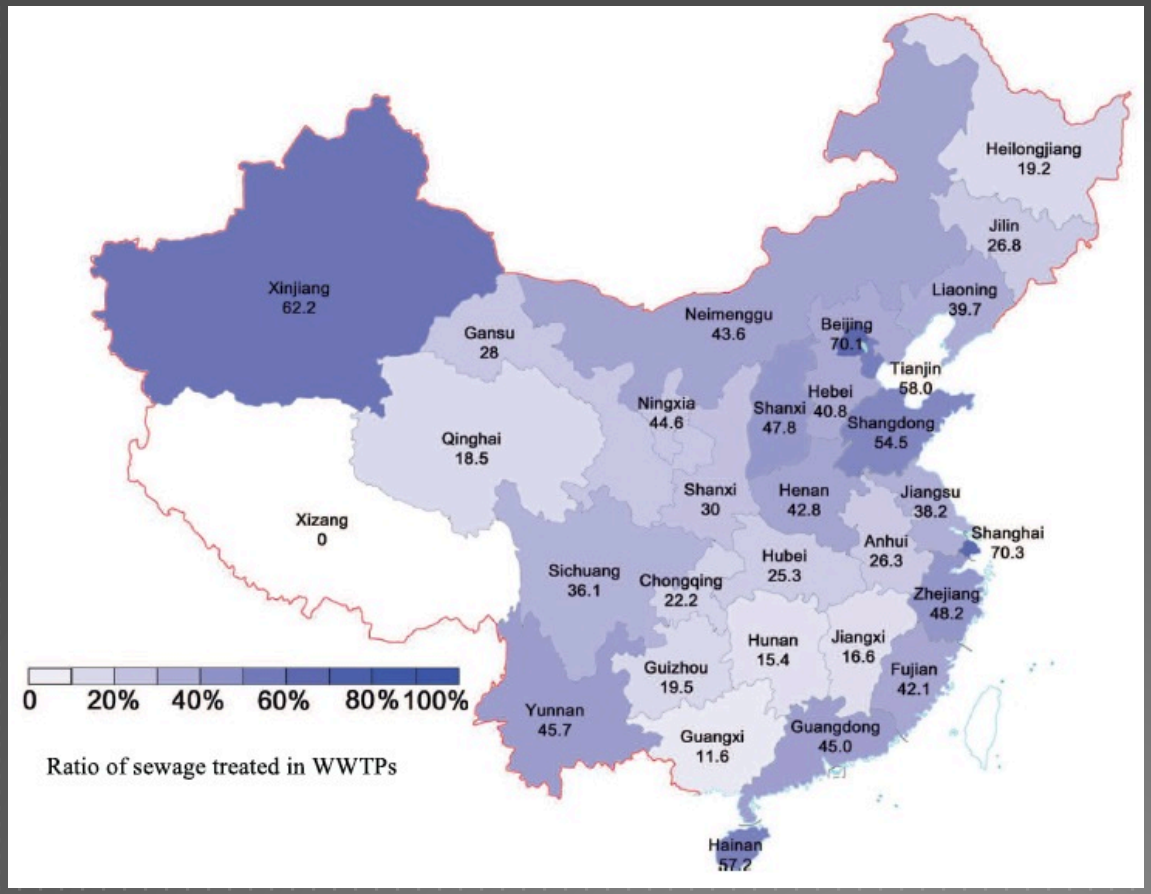
GLOBAL METHANE EMISSIONS FROM WASTEWATER TREATMENT (2010)

Total Emissions = 450 MtCO2e



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

Yellow = Major Methane Sources

Domestic Wastewater

Collected

Uncollected

Untreated

Treated

Rivers, lakes, seas

Stagnant sewer

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

IPCC, 2006

OPTIMAL TECHNOLOGIES FOR WASTEWATER TREATMENT

Scale	Technology
Large scale municipal	Anaerobic with methane recovery
Small scale municipal, some suburban and periurban areas	Constructed wetland
Small scale rural	Pit latrine with household biogas digester

Anaerobic treatment with methane recovery, Bailonggong WWTP, Shanghai

Constructed wetland, Shenyang

Household biogas digester

HOUSEHOLD DOMESTIC BIOGAS

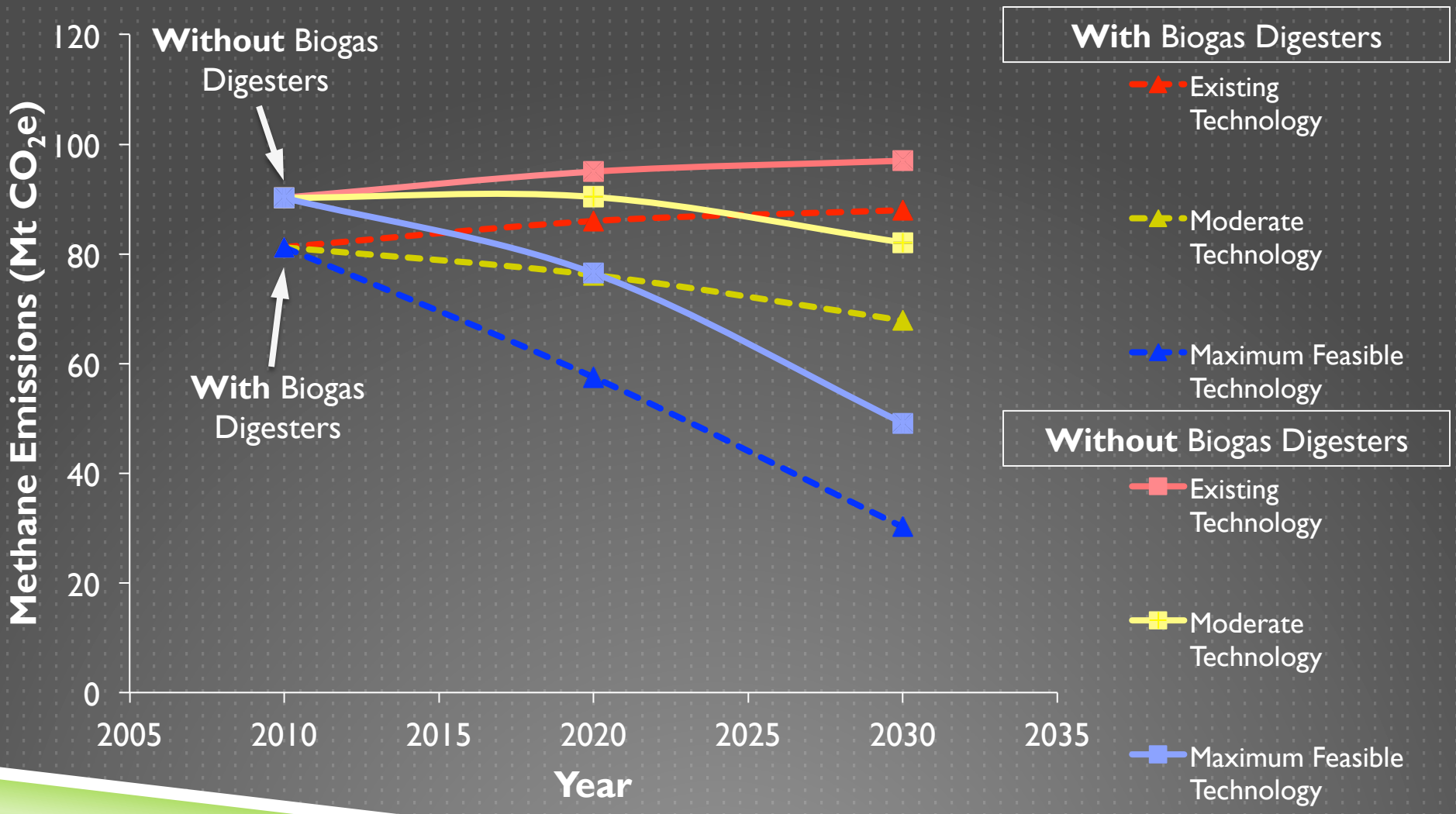
- Used to treat human and animal waste.
- Produces co-benefits for rural energy and indoor air quality.
- China is on track to have 80 million household biogas digesters by 2030.
- Increasing the quantity and operational functionality of biogas digesters provides significant opportunities to mitigate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

EMISSIONS PROJECTION METHODOLOGY

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

- Population and urbanization trends from the UN.
- Assumes 60% functionality of biodigesters.

FUTURE EMISSIONS PROJECTIONS



Operational efficiency of household biogas digesters is assumed to be 60%.

FUTURE EMISSIONS PROJECTIONS

	Existing Technology	Moderate Technology Expansion	Maximum Feasible Technology
CH_4 Emissions (2030)	87 $MtCO_2e$ 7% increase from 2010	62 $MtCO_2e$ ~25% decrease	26 $MtCO_2e$ ~65% decrease
Outlooks	• Household biogas digesters reduce CH_4 emissions by 9 Mt CO_2e (~10% total domestic wastewater CH_4 emissions) • Urbanization curbs even greater emissions increases	• 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	• 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

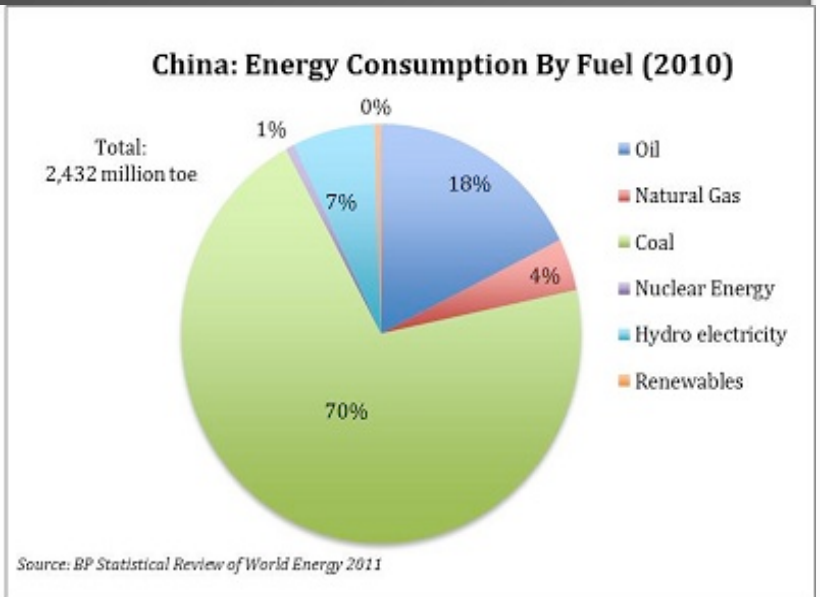
Why the future of shale gas matters

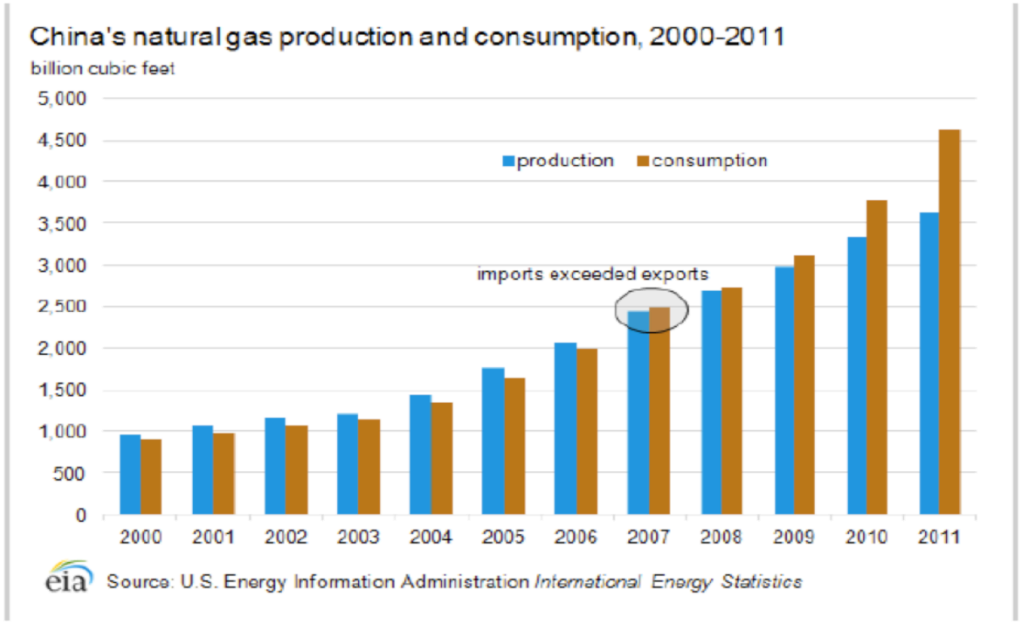
- A new leakage source

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 500bcm by 2030, nearing current US consumption
- Increasing import dependence

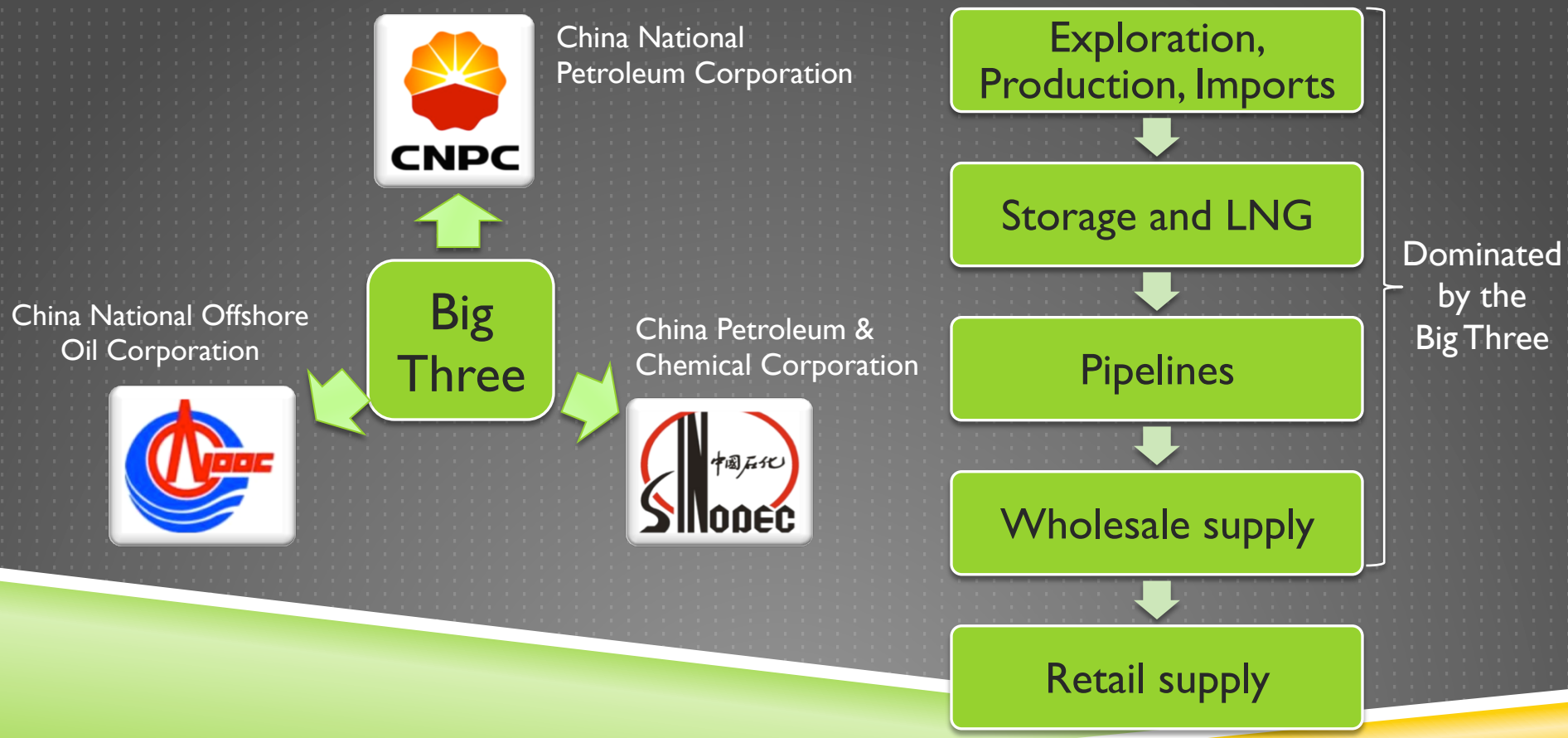
Sources: IEA2012, EIA 2012





CURRENT MARKET STRUCTURE

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



Sources: IEA 2012, EIA 2012

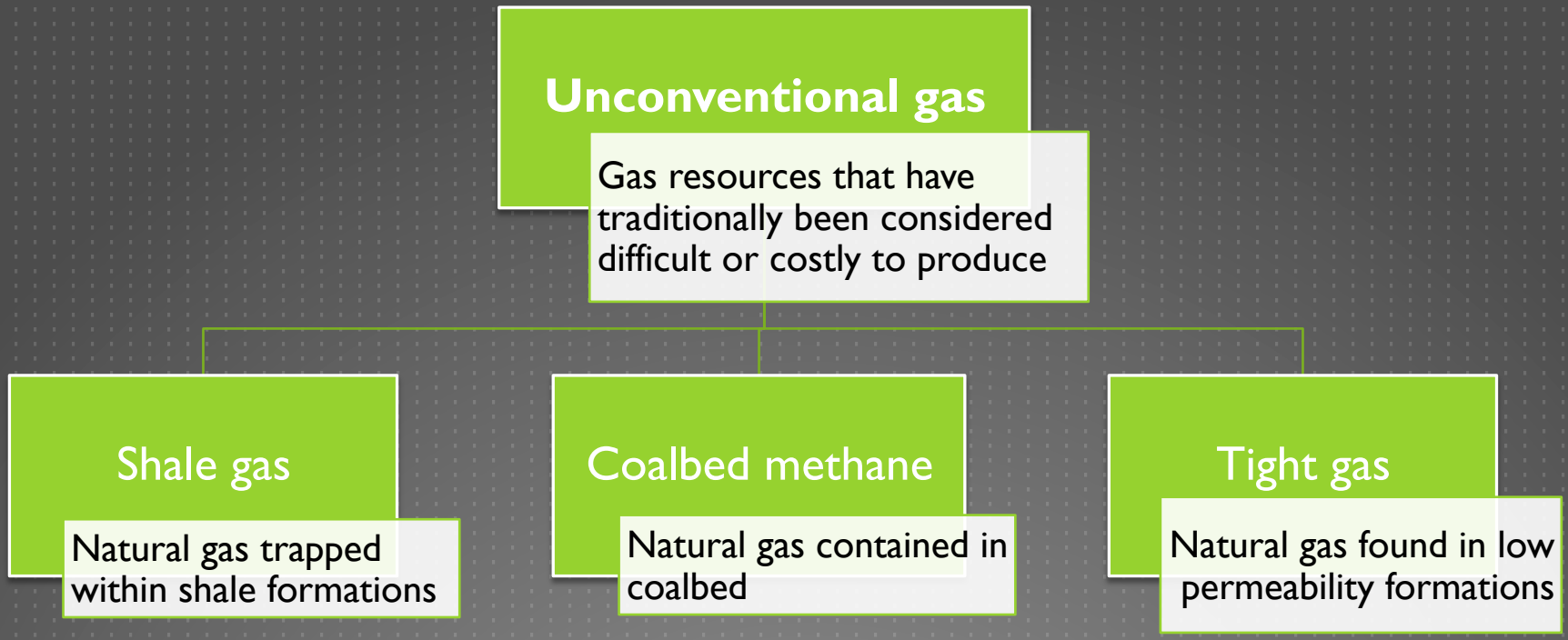
NATURAL GAS PRICES

- Pricing mechanism
  - Most provinces: Regulated *(Cost-of-Service)*
  - Pilot program in two provinces since 2011: Relatively market-based
    (Netback Approach → 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



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

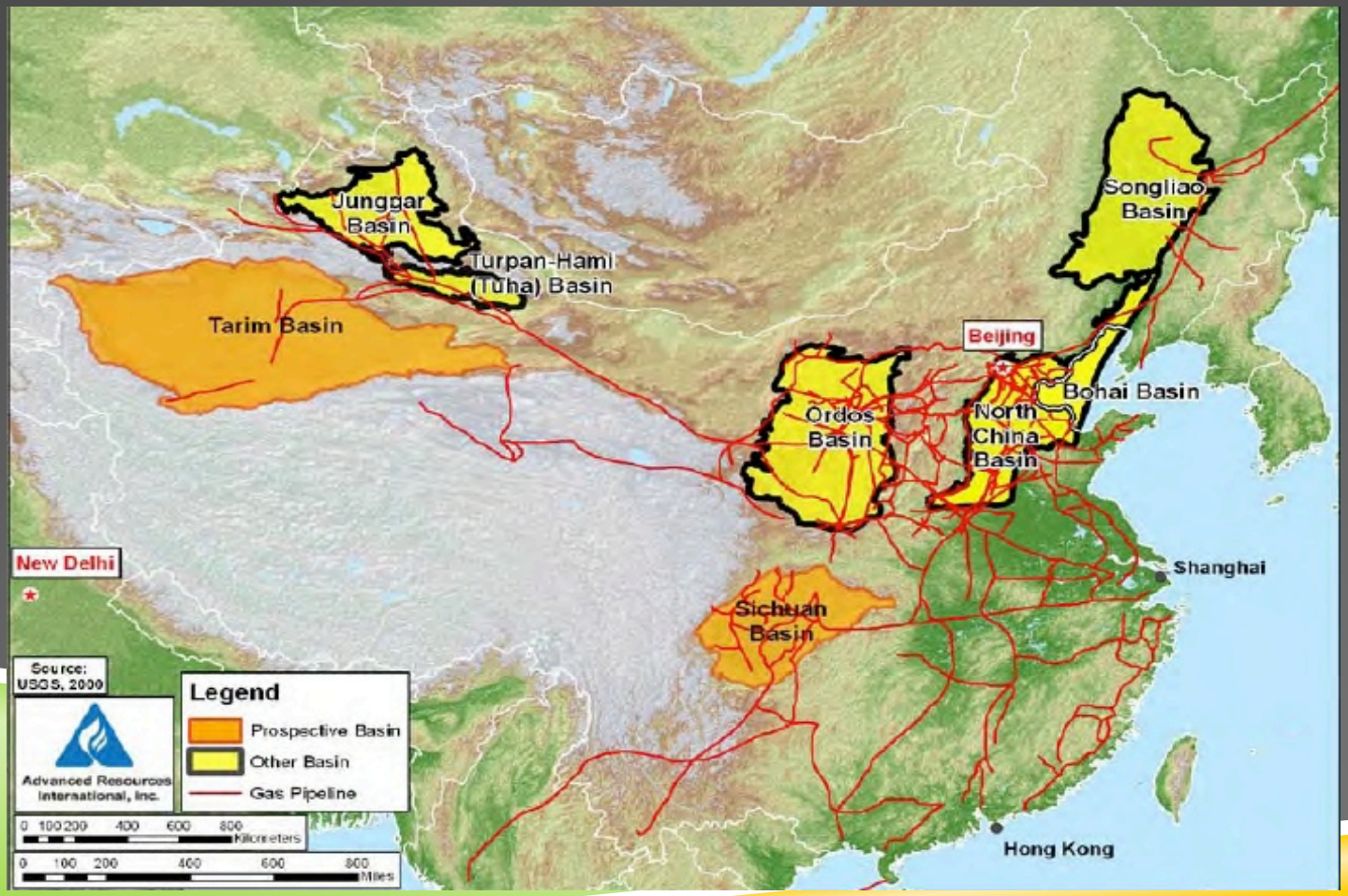
- Before 2015
  - Coalbed Methane (CBM) is and will continue to be the primary source of unconventional gas production
    - CBM: 10 bcm in 2010, targeted at more than 30 bcm in 2015
    - Shale gas: No commercial production till now, targeted at 6.5 bcm in 2015
- In the long run
  - Shale gas has the potential to be the major source in the future.
    - Larger remaining recoverable resource potential

      Shale gas 36 trillion cubic meters (tcm), CBM 9 tcm
    - Shale gas production target: 60-100 bcm in 2020.
    - 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



Source: EIA 2011

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.

China MLR Release, and interviews in China

EMISSIONS FROM NATURAL GAS: PROJECTIONS

NATURAL GAS PROJECTIONS

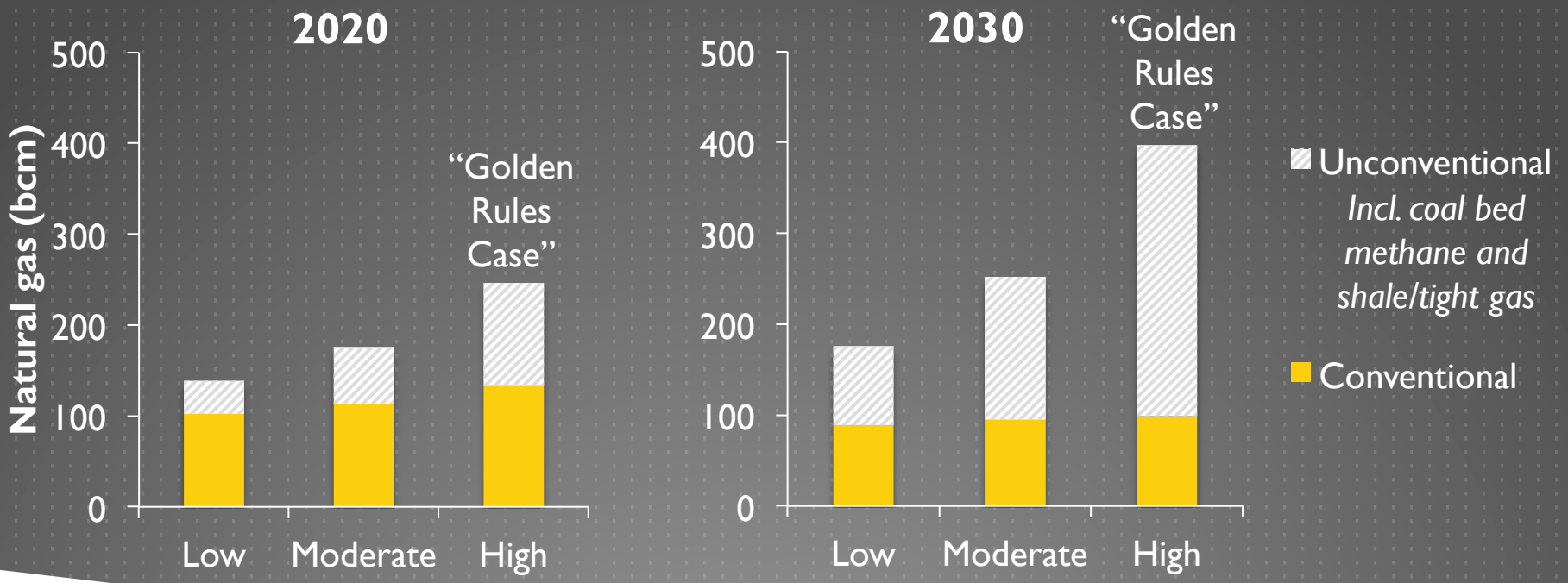
- Many entities have made projections for natural gas development.

- 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

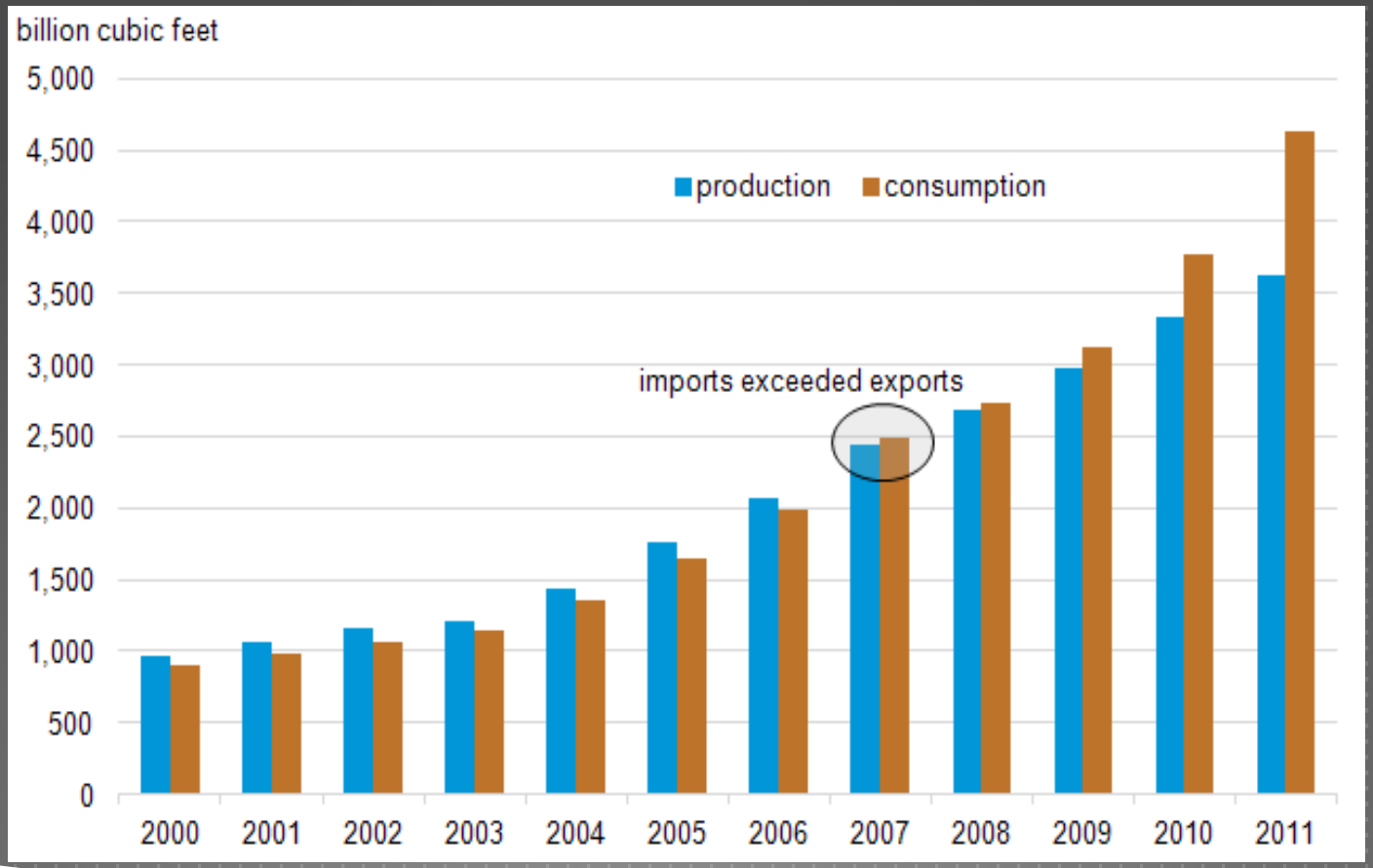
- Production volumes used as activity rate, A, to calculate emissions,

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



International Energy Agency

CHINA'S NATURAL GAS PRODUCTION AND CONSUMPTION, 2000-2011

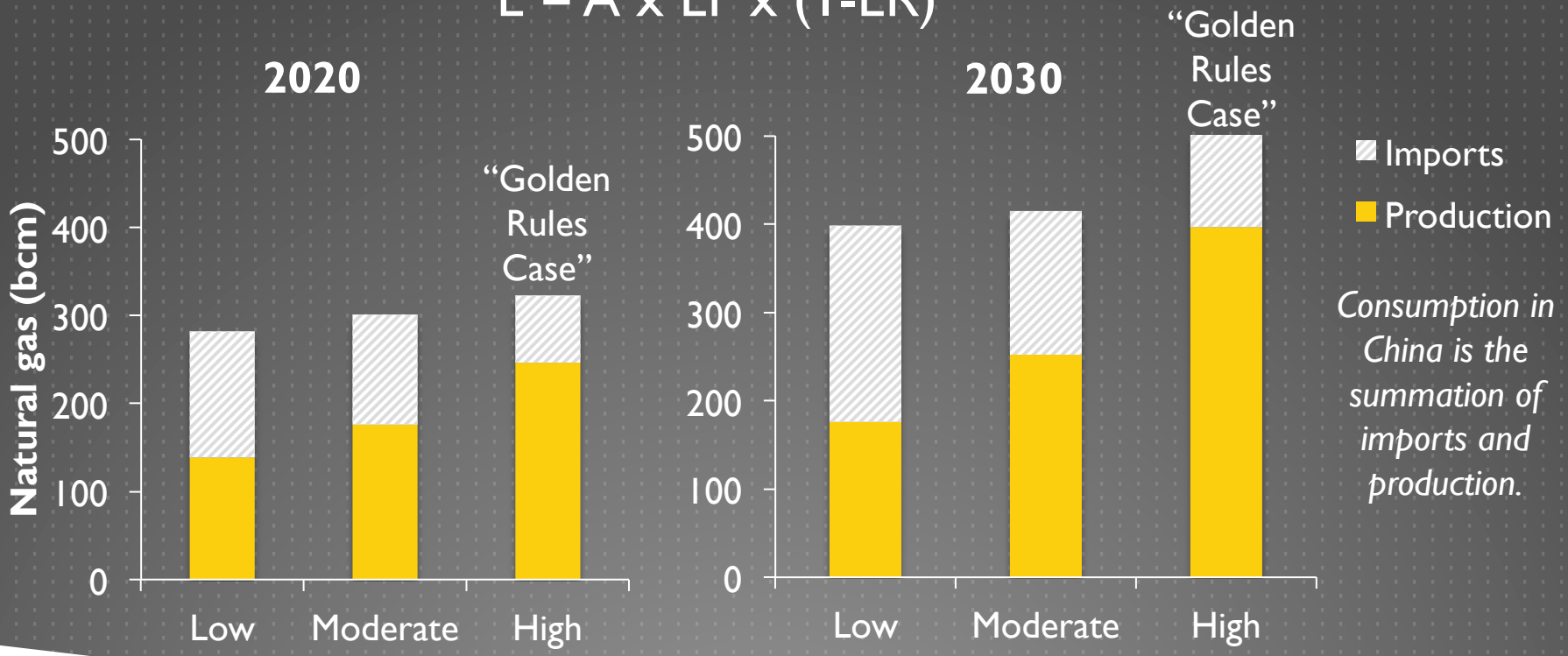


Source: EIA International Energy Statistics

THREE IEA SCENARIOS FOR NATURAL GAS CONSUMPTION IN CHINA

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

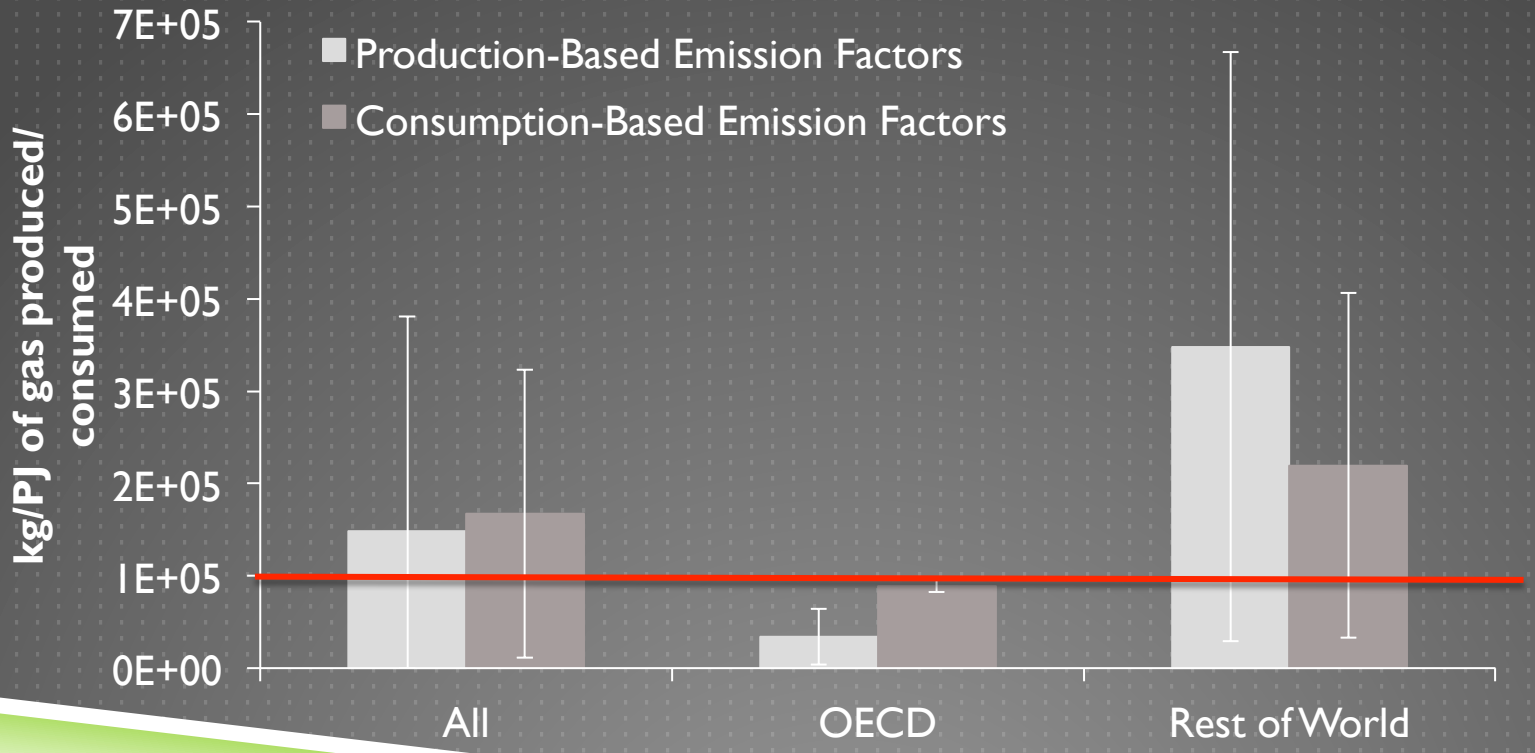
$$E = A \times EF \times (1\text{-}ER)$$



International Energy Agency

EMISSION FACTORS FOR METHANE FROM OIL AND NATURAL GAS SYSTEMS

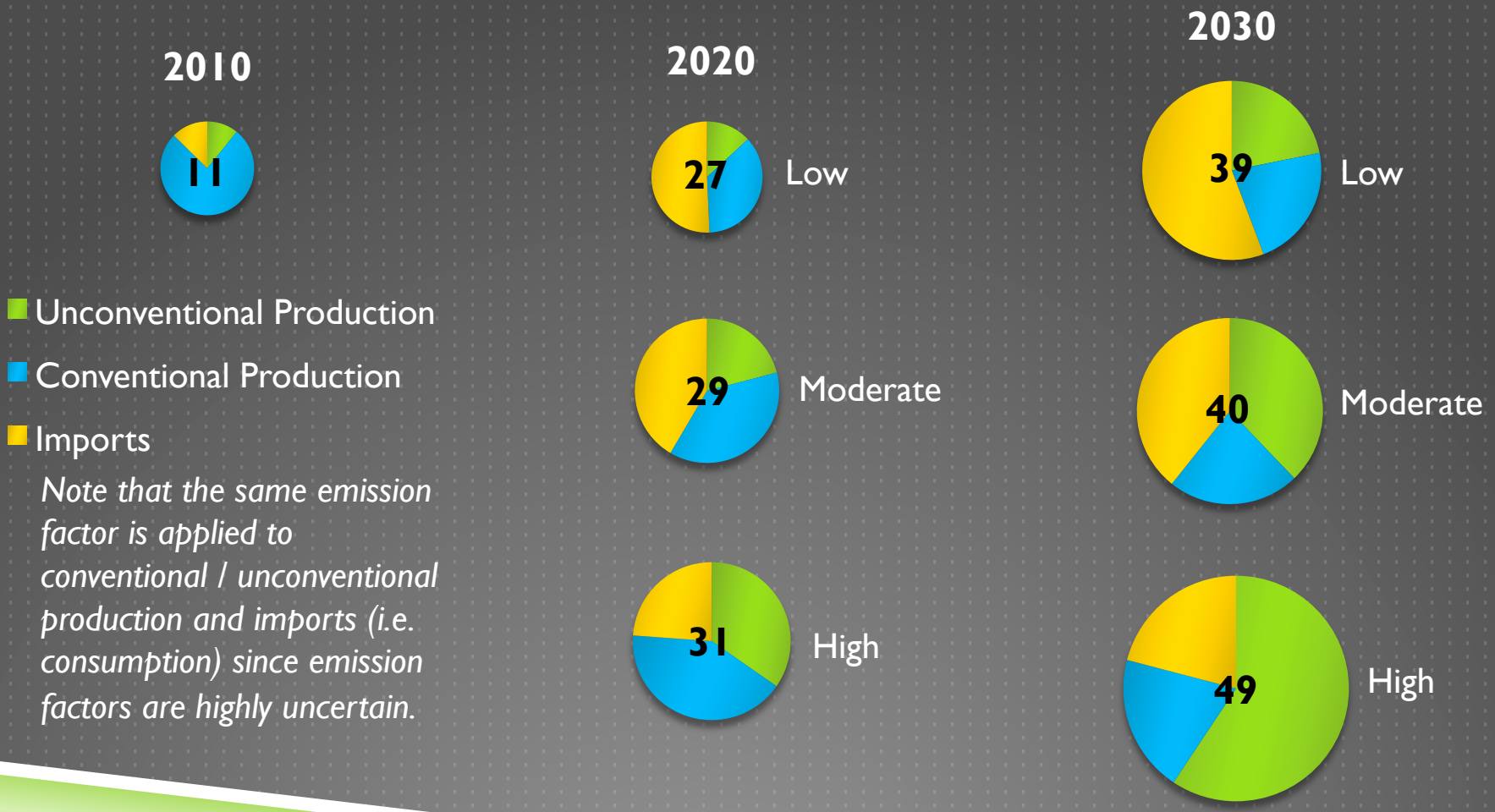
- Emission factors for OECD countries are much lower than in the rest of the world.
- Emission factors are highly uncertain.



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

Based on 1996 IPCC GHG Inventory Data

CHINA'S METHANE EMISSIONS FROM NATURAL GAS INDUSTRY



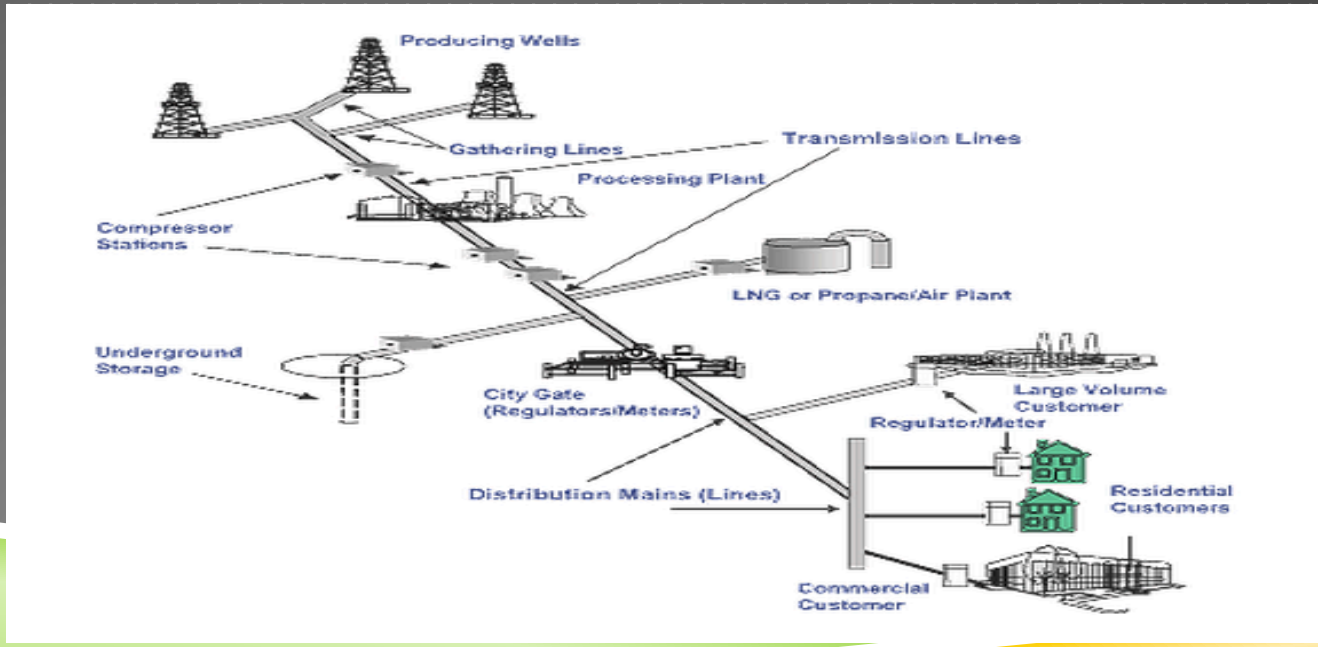
Units are in Mt CO_2e

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

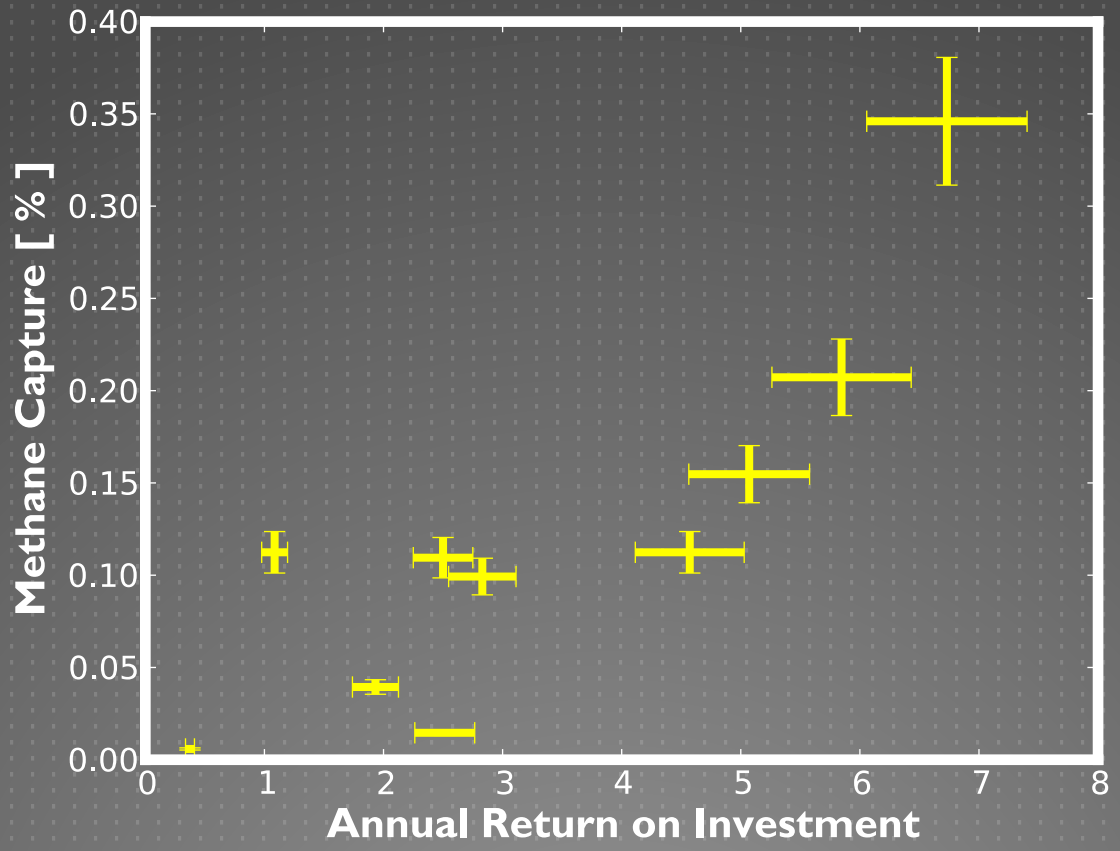
REDUCED EMISSIONS COMPLETIONS

- Captures CH_4 during well-cleanup after hydraulic fracturing.
- 8,700 – 33,000 $USD per well, 7,000 – 23,000 Mcf per well captured

Photo: US EPA

- 28,000 – 90,000 $US per well at US Gas Prices

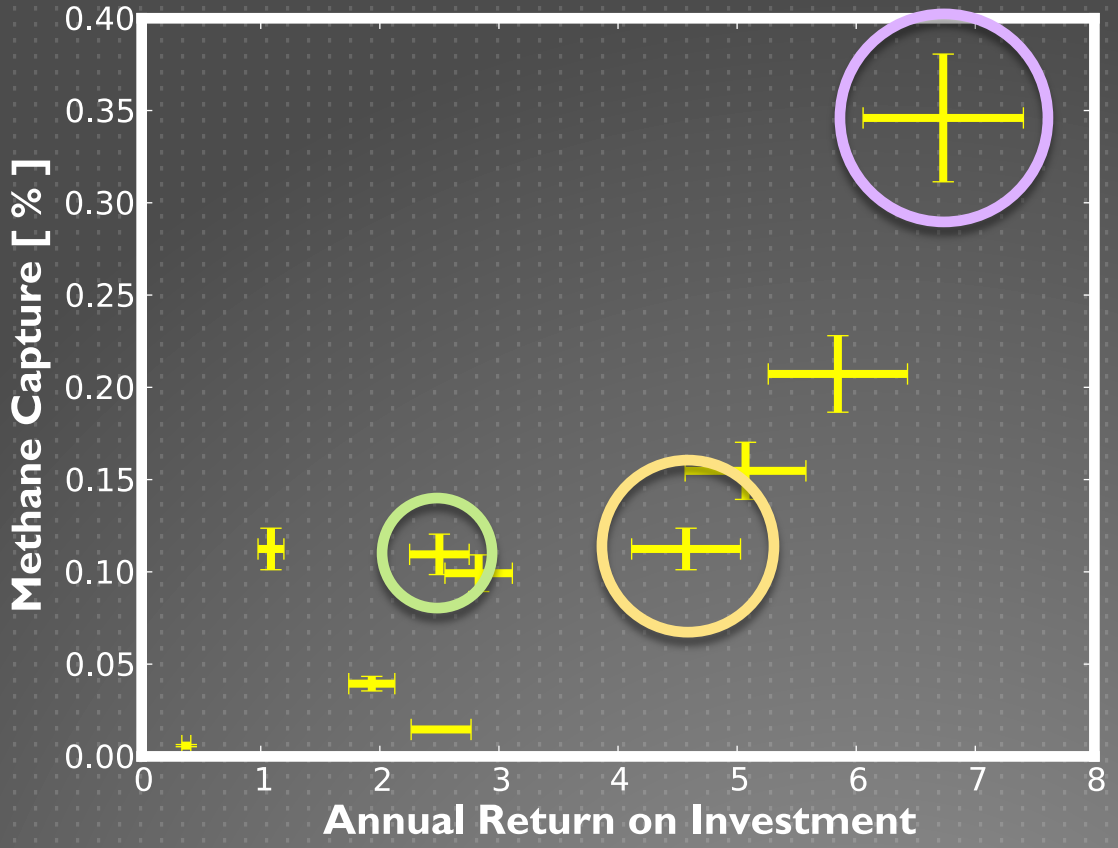
METHANE CAPTURE VS. RETURN ON INVESTMENT



U.S. EPA Website, 2012

Leaking Profits, NRDC, 2012

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

		Value of Gas Reclaimed		Technology Cost		Payback Period	
Tech	**Savings Volume** (mcf)	**US Prices** ($3/MMBTU)	**Chinese Prices** ($6.5/MMBTU)	**Purchase Cost** ($)	**Operating Costs** ($/yr)	**US** (months)	**China** (months)
REC	270,000	810,000	1,755,000	500,000	121,250	5	2
APS	20,000	60,000	130,000	60,000		12	5
PLS	18,250	54,750	118,625	10,363		2	1

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

Tech Deployment Scenario	2030 Emissions [Mt CO2-eq]
Business as Usual Emissions	**50**
Possible Emissions Reduction	**5**

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

Sector	Emission Reductions Range for 2030 (% of Total Sector Emissions)	Co-Benefits	Challenges
Organic Waste Sectors			
Municipal Solid Waste	47-90 $MtCO_2e$ (24-45%)	• Public health and sanitation • Improve recycling and composting • Alternative fuel source • Aesthetic value	• Capital costs • Labor requirements • Dispersed rural population • Urban land-use
Agriculture: Manure Management	17-36 $MtCO_2e$ (17-36%)	• Rural energy security • Air quality and respiratory health • Water quality	• Cold-weather technology development • Dispersed Population • Human capital constraints to maintenance
Wastewater	20-58 $MtCO_2e$ (23-66%)	• Public health and sanitation • Water quality and scarcity • Nitrous oxide mitigation • Rural energy security	• Capital costs • Rapid urbanization limits city planning • Dispersed rural populations
Fossil Fuel Sectors			
Natural Gas	31- 44 $MtCO_2e$ (<90%)	• Energy security • Economic growth	• Technology transfer • Technology advancement

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 CO_2.
- With the expiration of the CDM, China needs a new mechanism to support projects

THANK YOU

Presenters: Shannon Brink, Harrison Godfrey, Mary Kang, Shelly Lyser, Joseph Majkut, Samantha Mignotte, Wei Peng, Matt Reid, Madhurita Sengupta, Laura Singer

Faculty Advisor: Professor Denise Mauzerall

PRINCETON UNIVERSITY
WOODROW WILSON SCHOOL
of Public & International Affairs