6TH IEF IGU MINISTERIAL GAS FORUM

Session 1:
The role of gas technologies in low carbon energy systems

IEF-IGU Gas Ministerial

22nd November 2018

INTERNATIONAL ENERGY FORUM

BCG ENERGY

Key messages: The role of new gas technologies in resilient low carbon energy systems

Key messages

In the near term, gas offers significant climate benefits from coal fuel switching

- Some OECD markets have demonstrate significant climate benefits for coal to gas switching
- To prompt fuel switching in Asia, localized pollution controls and/or carbon price signals are critical

In the medium term, gas is complementary with increasing renewables deployment to manage intermittency

- Gas is fast to ramp up and is not time-limited like battery storage

In the long run, multiple levers are available to decarbonize gas though the value chain

- Biomethane and hydrogen technologies can decarbonize gas supply
- Methane leak prevention is critical in gas midstream
- CCUS and efficiency measures are available to reduce emissions from end use of gas

Session objectives

Identify how governments and industry can accelerate fuel switching to gas

Discuss the role that gas can play in supporting renewables deployment

Discuss what will be required to accelerate the development and deployment of new, low carbon gas technologies such as biomethane, hydrogen, and CCUS

Identify what measures should be taken to reduce methane leaks and to improve efficiency of gas consumption

Agenda

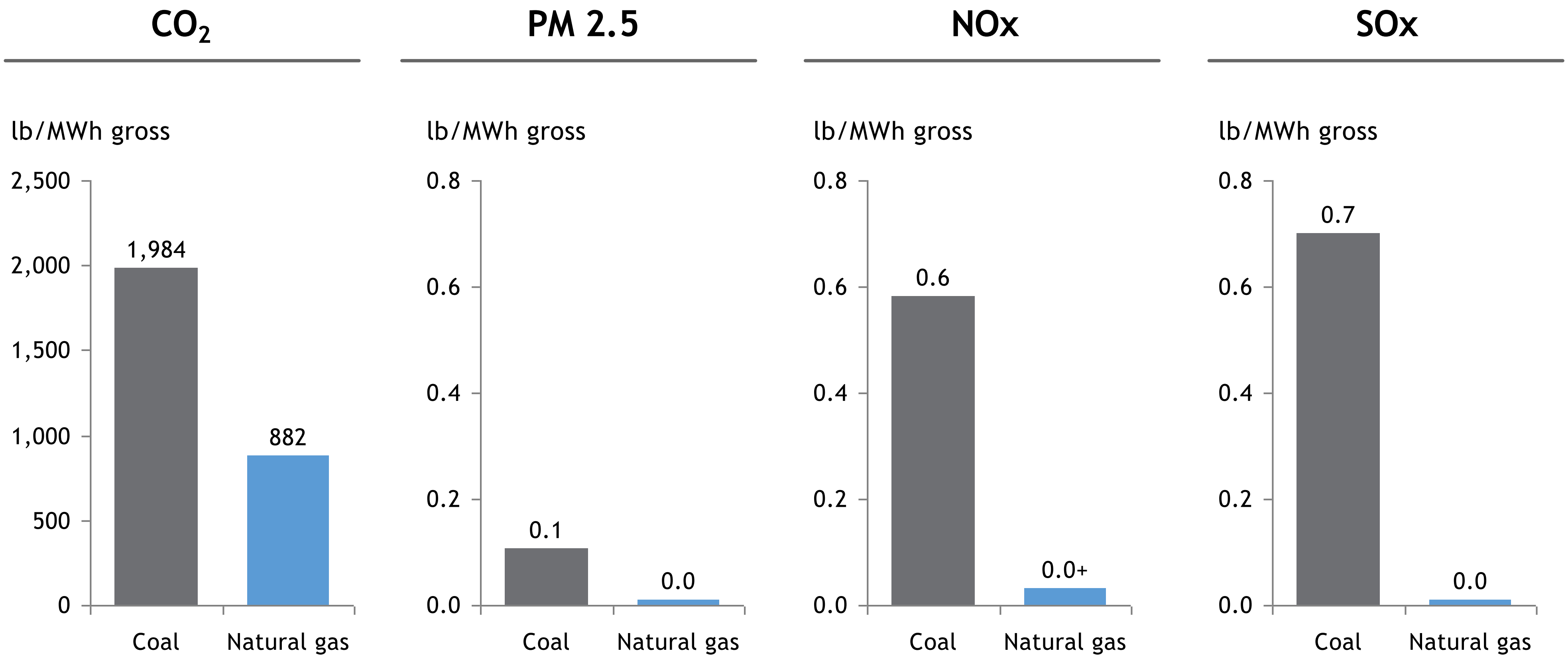
Near term: Coal to gas switching

Medium term: Complementary with renewables

Long term: Decarbonization of gas

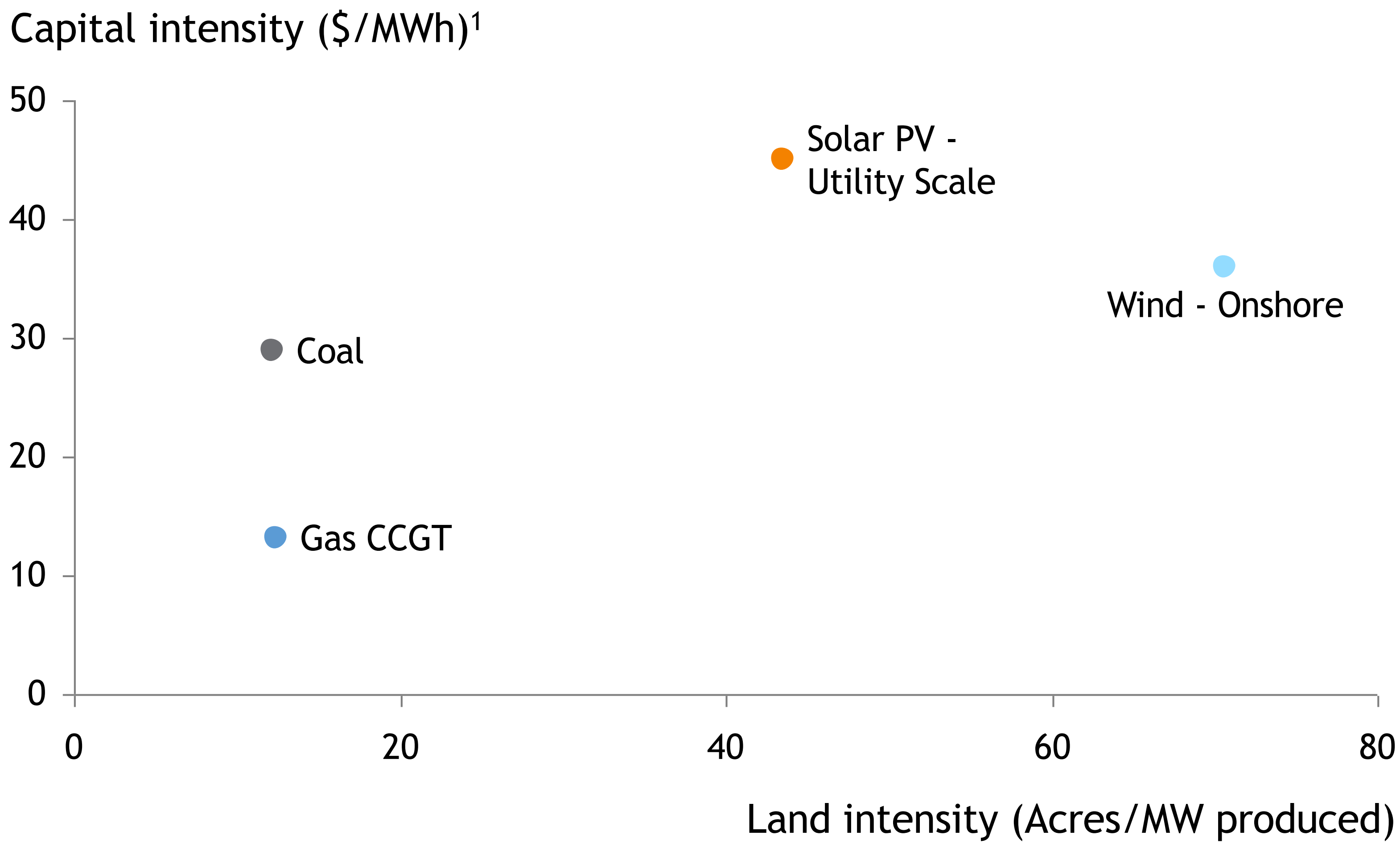
Questions for discussion

Natural gas emits half the CO_2 and a fraction of other pollutants vs. coal



Note: Coal emissions based on supercritical boiler technology; Gas based on CCGT
Data: NETL, BCG analysis

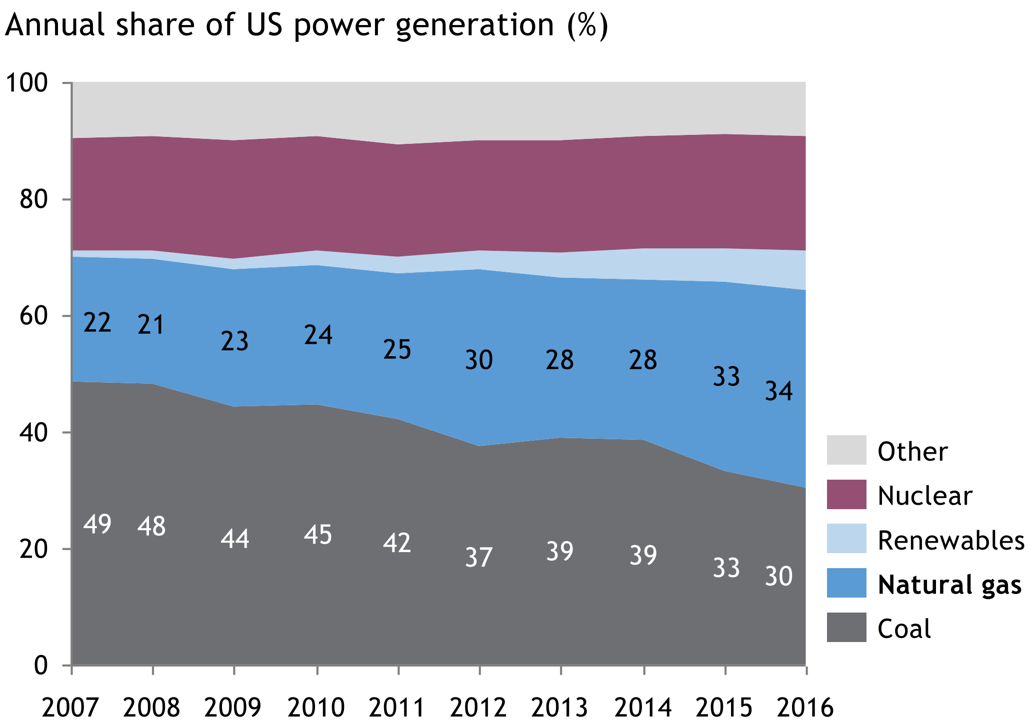
In power generation, gas is advantaged on land and capital intensity



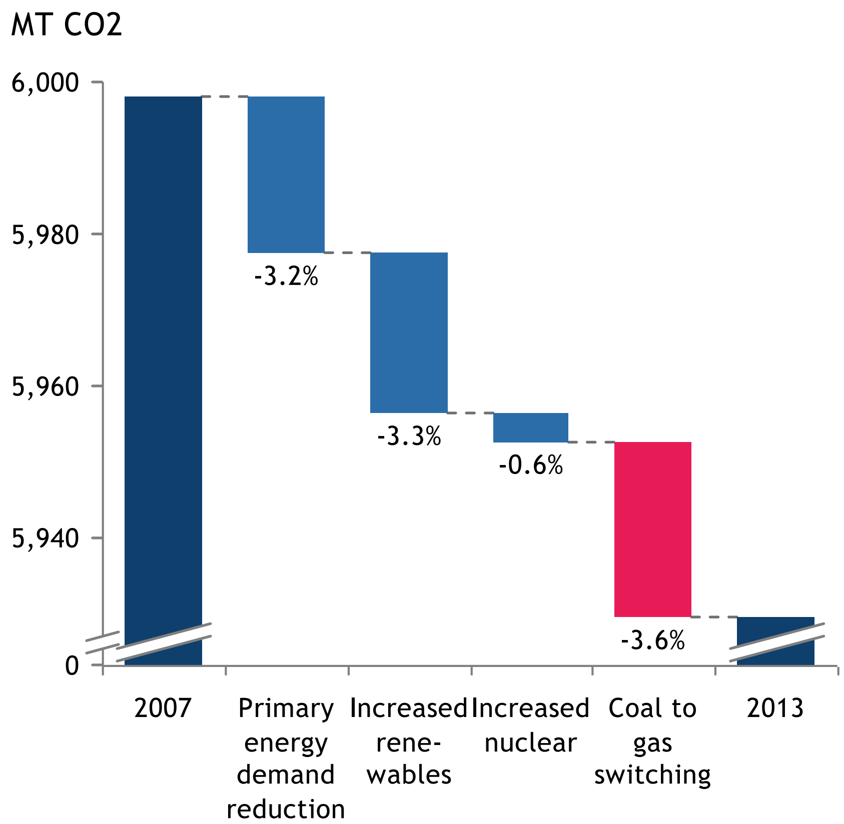
1. Based on 2017 Lazard LCOE estimates
Source: Lazard, Strata, American Gas Association, BCG analysis

Coal to gas switching responsible for greatest share of CO_2 reduction in US

US share of gas in power generation mix

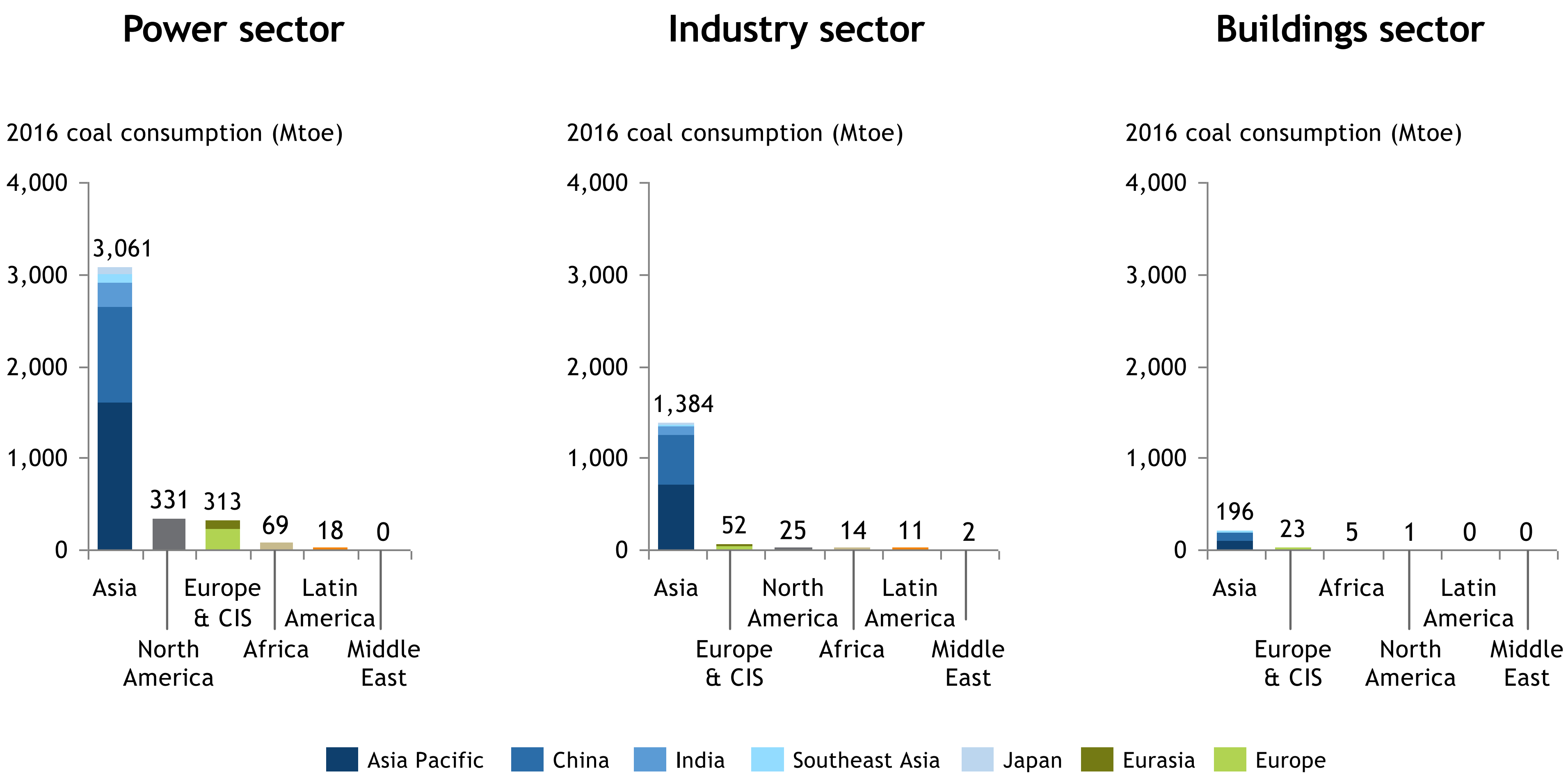


US Energy sector emissions 2007-13



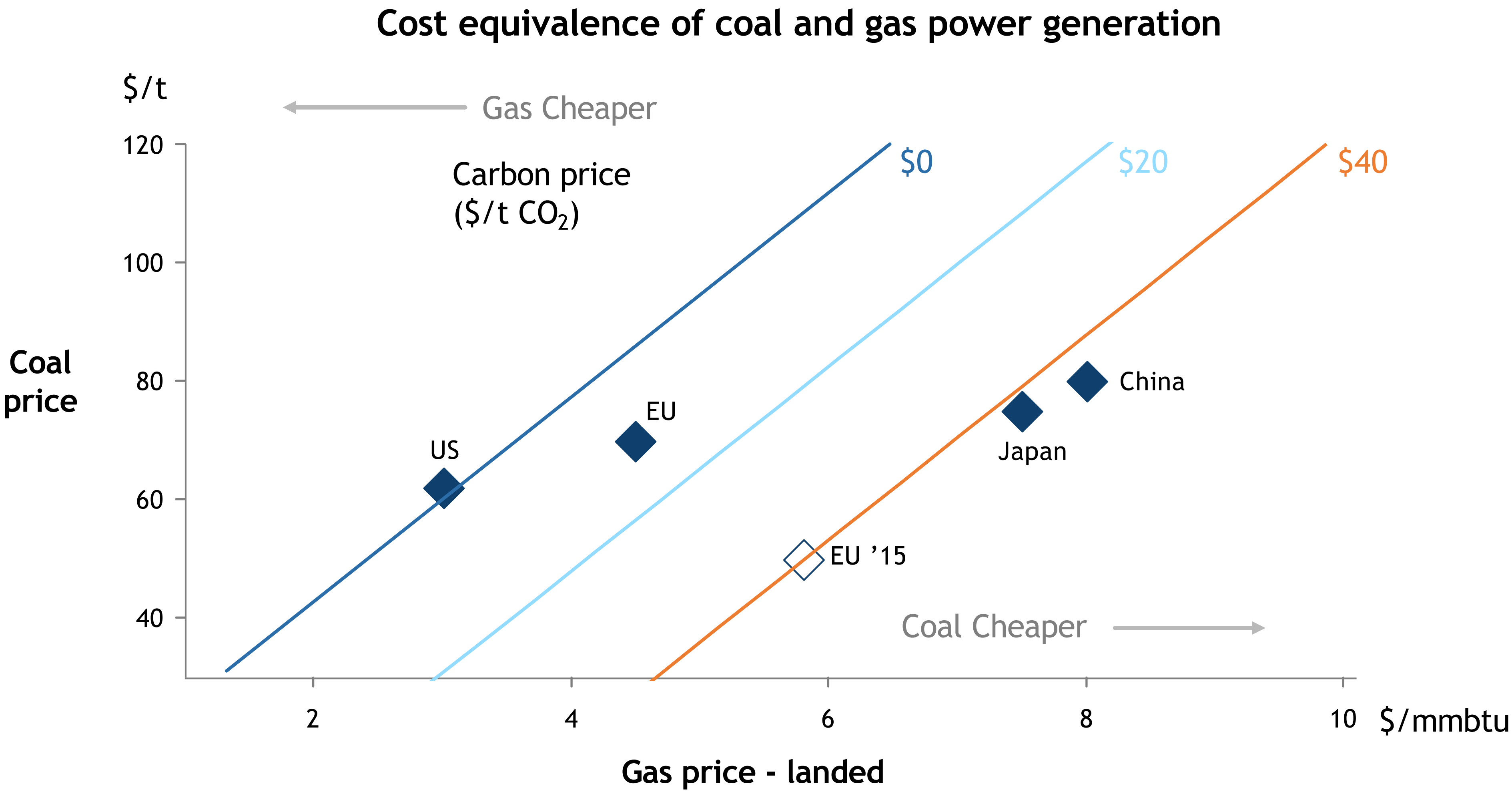
Data: EIA, Mohlin et al 2018, BCG analysis

Substantial coal to gas switching opportunity in the Asian power sector...



Source: IEA, BCG analysis

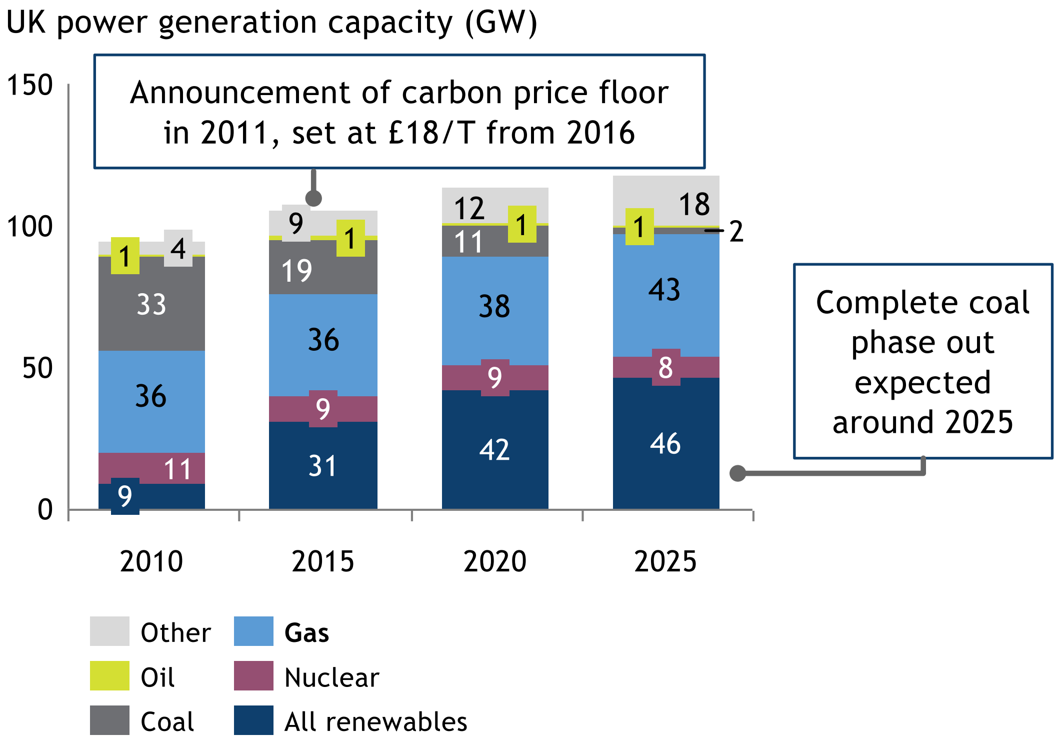
... But requires >$40 carbon pricing given current gas prices



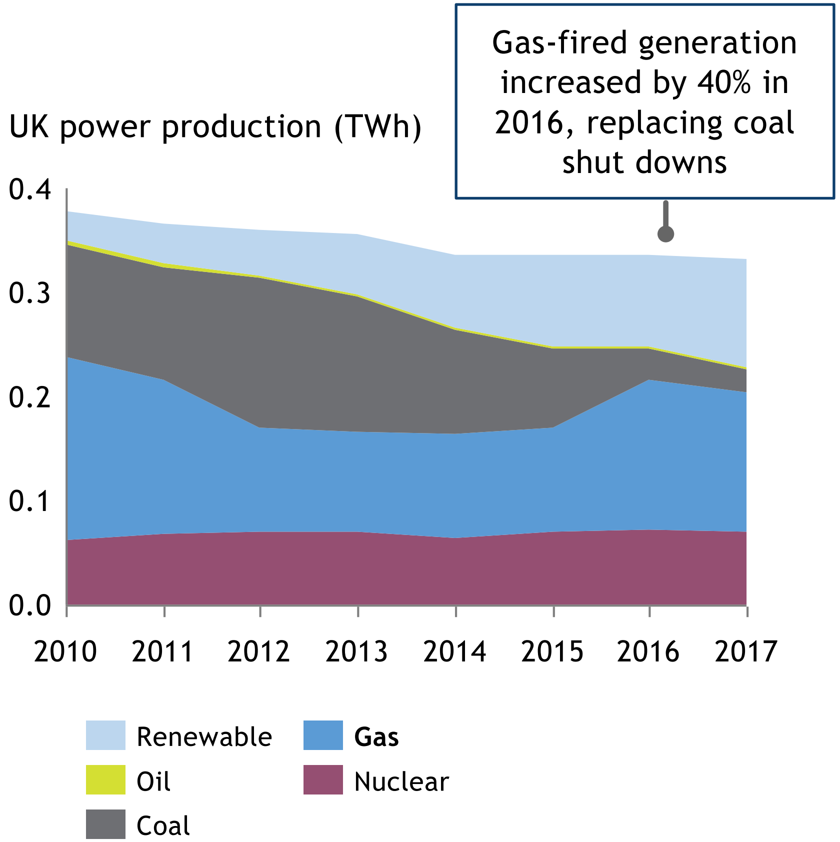
Note: Short run marginal cost for CCGT (54% efficiency) and coal plant (39% efficiency); transport cost 1 $/mmbtu, 9$/tonne
Source: BCG Analysis

In the UK, a carbon price >$20/t drove significant coal to gas switching

UK power generation capacity



UK power production by source

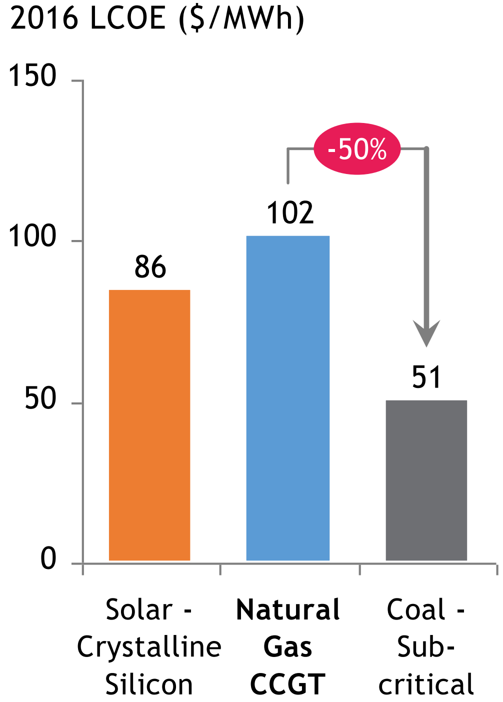


Source: IEA, Ofgem, BCG analysis

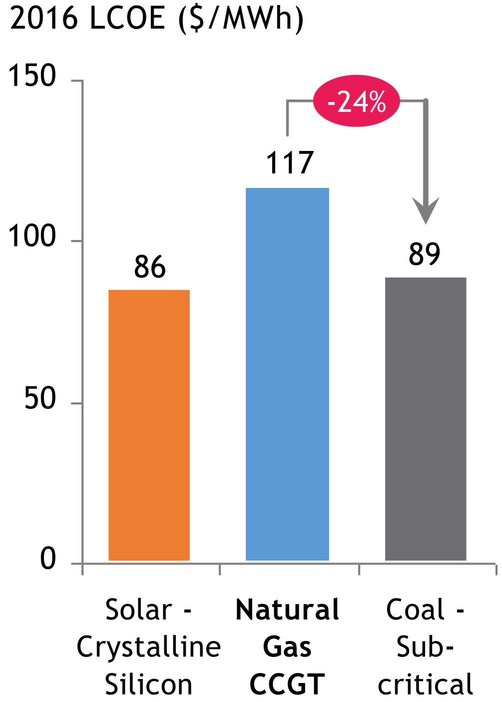
Regulation of localized pollution the most effective lever for improving gas competitiveness in Asia

Example of China

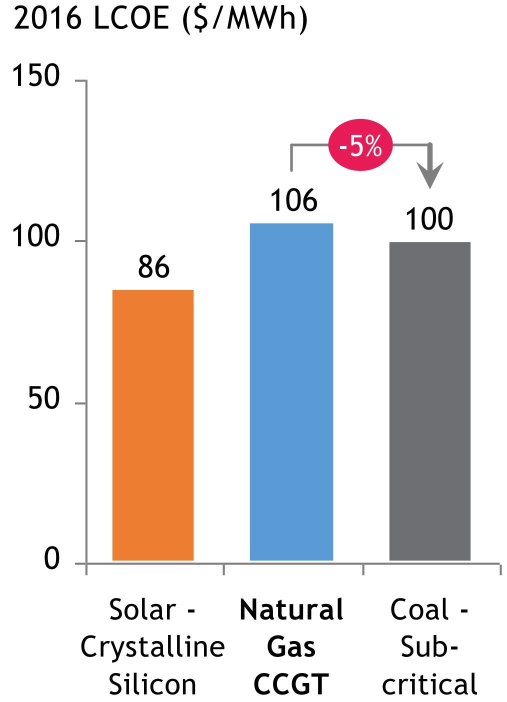
LCOE with no externality costs



LCOE with $40/t CO2 price



LCOE with local pollution externality costs



Note: Based on average base case LCOE for China in 2016 per Bloomberg; Local pollution externality costs per University of Texas LCOE study
Source: Bloomberg, University of Texas, BCG analysis

Agenda

Near term: Coal to gas switching

Medium term: Complementary with renewables

Long term: Decarbonization of gas

Questions for discussion

Renewables require additional backup beyond 40-45% of generation mix

Developed grids can absorb 40-45% of renewables without additional backup

Intermittent renewables can be absorbed through several levers
- Available reserve capacity
- Flexing non-RE sources (e.g., gas, coal)
- Demand management
- Trade with other grids

Examples

Hawaii: 40-45% renewables, ~0MW of storage

California: 41% renewables, repurposed ~4GW of hydro for pumped storage (~5% of total capacity)

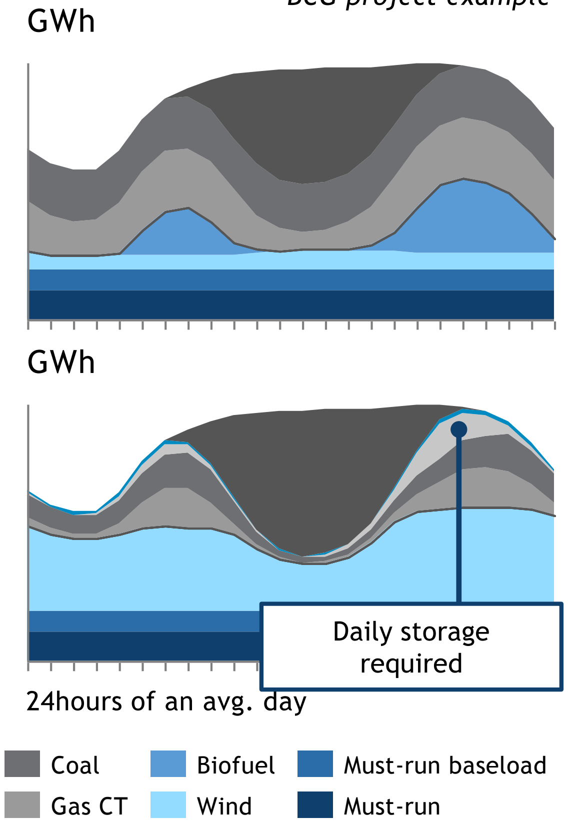
Denmark: 50-55% renewables (~45% wind), no storage capacity of note, strongly connected to Norway and Sweden

Beyond 40-45%, backup is required—Example of generation mix modeling

BCG project example

Renewables at 43% of generation

Renewables at 70% of generation

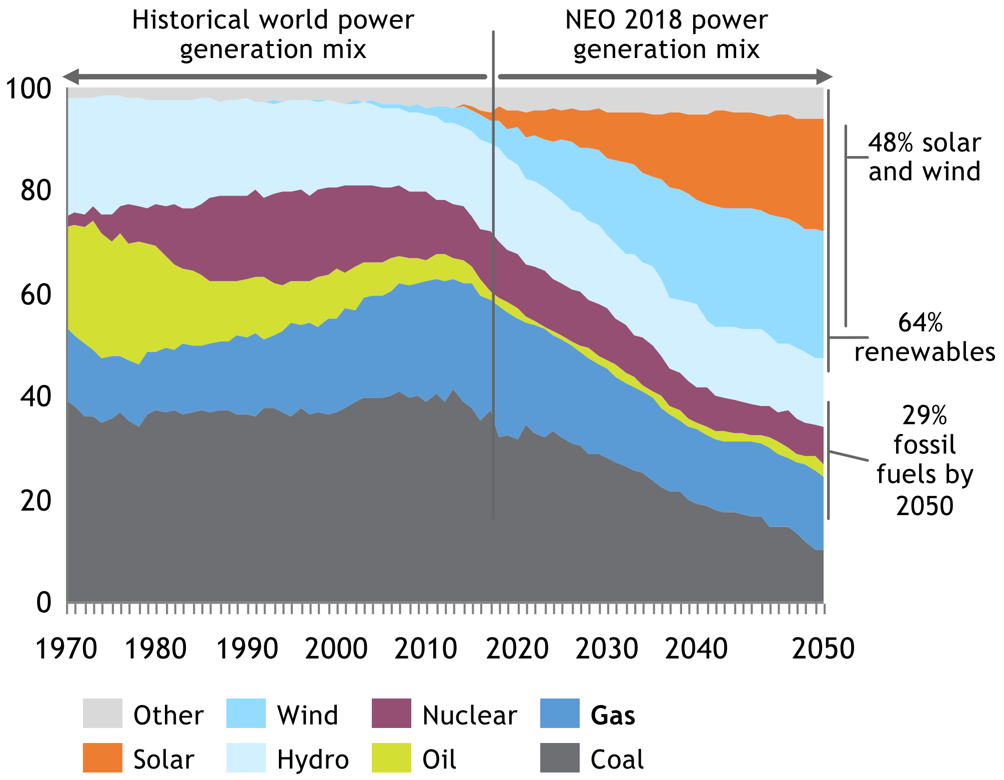


Source: IEA 2017 Country Review; BCG project experience

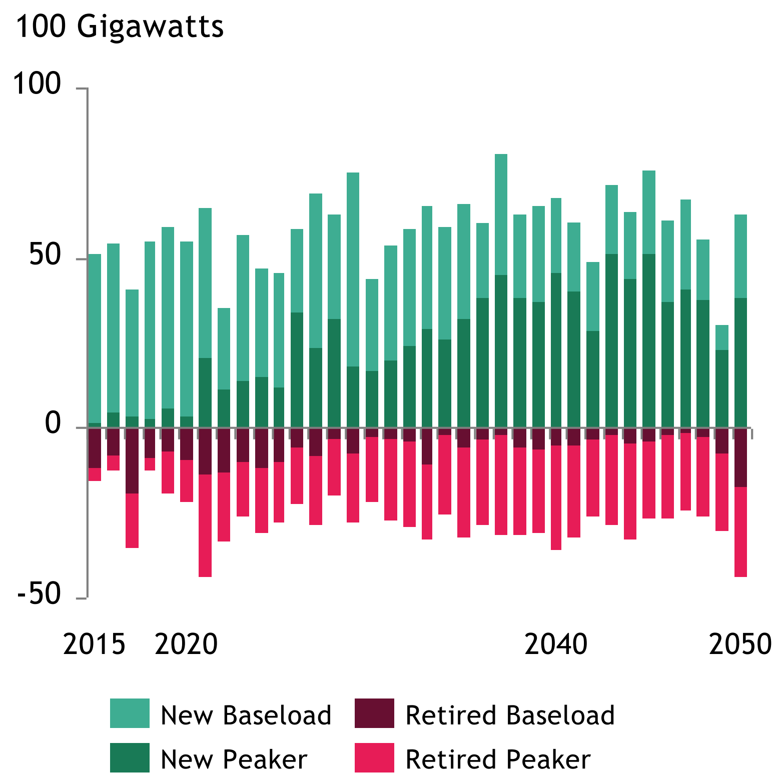
Significant role for gas peaking capacity going forward

A high renewables penetration scenario …

Power Generation Mix (%)



… Will shift gas capacity from baseload to peaking



Source: Bloomberg NEF, IEA; Bloomberg New energy finance

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Questions for discussion

Five ways to reduce emissions from the gas system

Supply

Biomethane

- Cost competitive with policy enablers in some contexts
- Limited supply & feedstock challenges

Hydrogen

- Technology still immature with multiple potential pathways & competing tech.
- Grid integration will be challenging

Transmission/ distribution

Leak reduction

- Critical driver of emissions for natural gas
- Proven technology available, but there are key barriers to adoption

End use

Efficiency

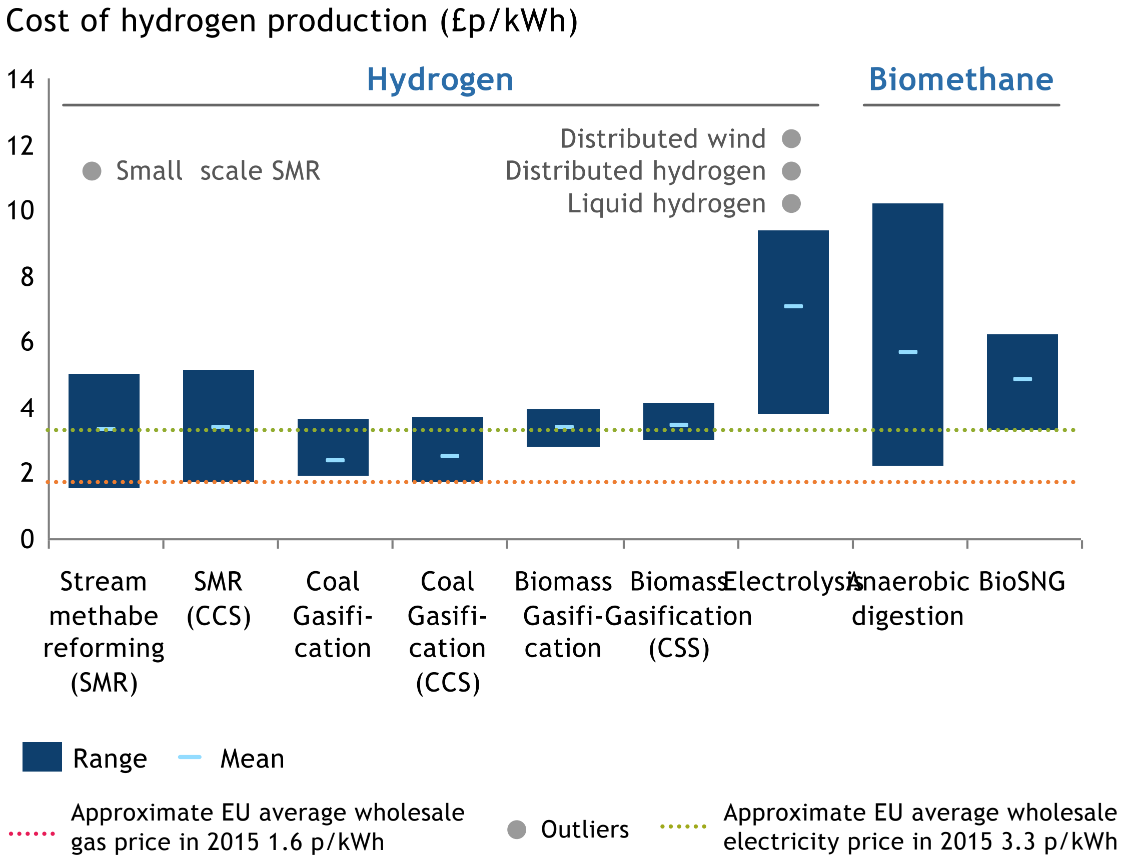
- New tech. with significant benefits (CHP, heat exchangers)
- Challenge is how to deploy and integration up tech. solutions

Carbon capture

- Demonstrated in some contexts, but not yet achieved scale
- Requires high carbon price or public support

In Europe, hydrogen and biomethane are nearing cost competitiveness due in part to policy

Renewable gas technology cost estimates - Europe



Policy drivers of renewable gas cost competitiveness

Market price & supply support:
- Carbon price – minimum future price of $40/t planned
- Renewable gas portfolio standards in place

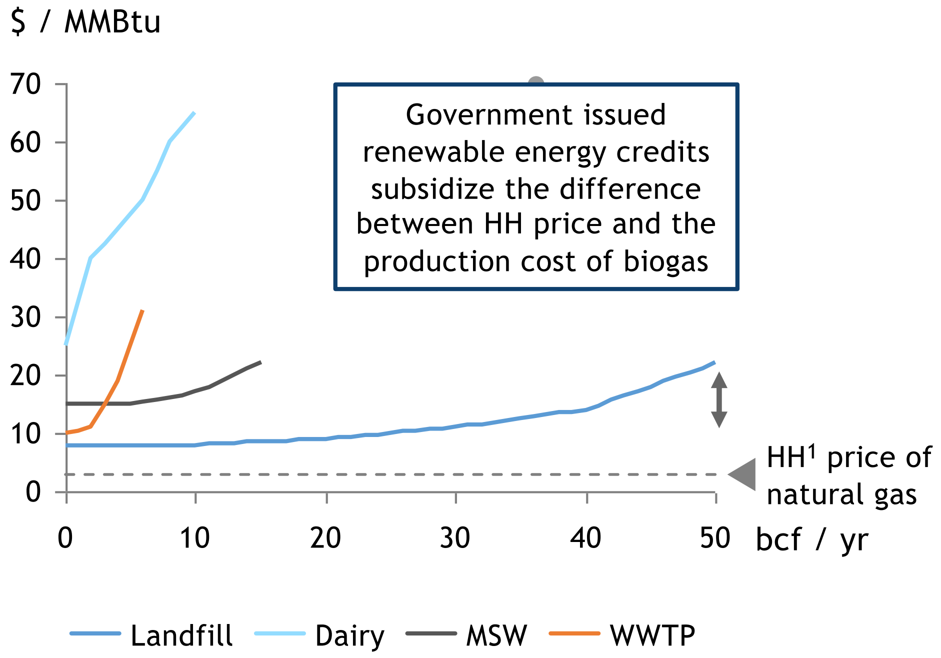
Capital investment:
- Building capital conversion support
- CCS infrastructure development – direct or subsidized

New regulations and standards:
- Feed-in / injection rules
- Safety standards established for hydrogen use
- Feedstock standards for biomethane

Source: Imperial College London, BCG analysis

In the US, biomethane supply limited and uncompetitive vs. Henry Hub – Example of California

California biomethane supply costs and availability



Known available annual supply in California (bcf)

Landfill	~50
Dairy	~10
Waste water treatment plants	~6
Municipal solid waste	~15
Total	**~80**

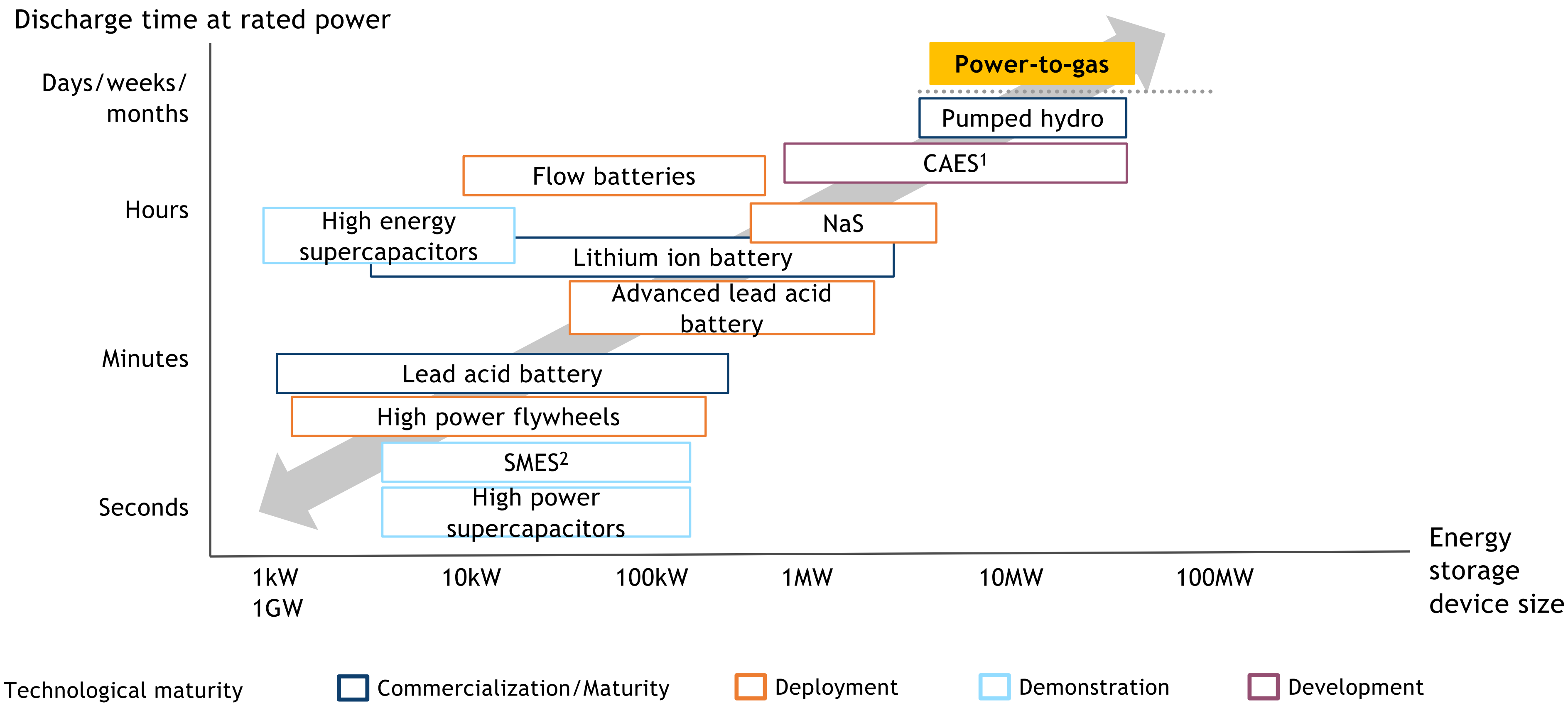
Total CA gas consumption of 2.1TCF/yr

Capturing all available biogas in California will be cost prohibitive

1.Henry Hub
Source: EIA, UC Davis

Power-to-gas provides highly flexible, seasonal long-term storage

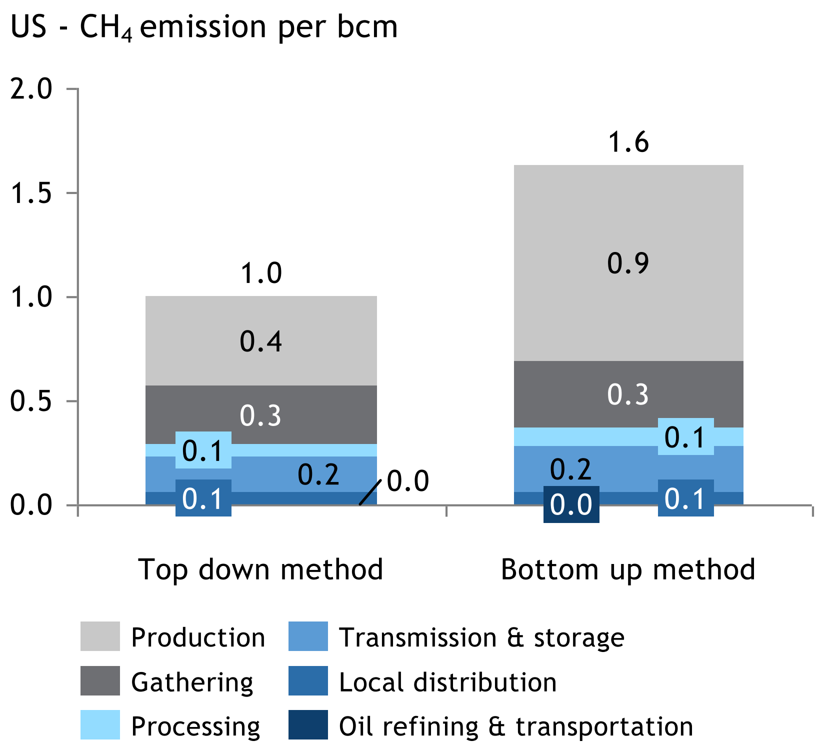
Storage technologies by discharge time and device size



1. Compressed air energy storage 2. Superconducting magnetic energy storage
Source: IEA, IRENA, EASE, AECOM, HSBC, BCG

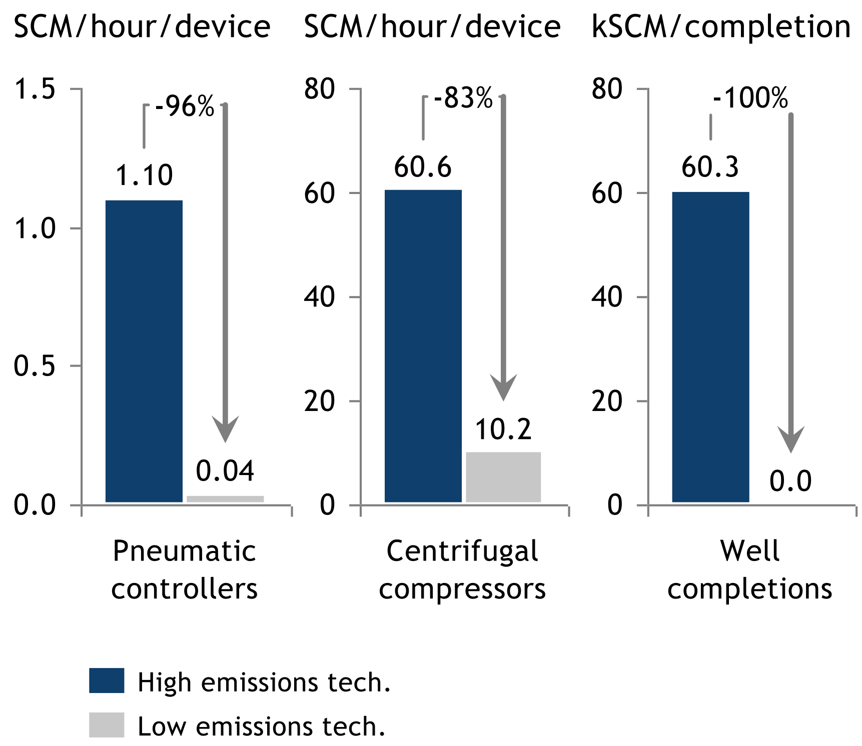
Proven solutions are available to address key sources of methane emissions

Majority of methane leakage driven by upstream production & gathering



Existing solutions can largely eliminate upstream fugitive methane

Example – range of emissions factors for technology or methods



Source: EDF study in the journal Science; CCAC O&G Methane Partnership

New technologies and approaches are emerging to reduce methane emissions

Detection and measurement

- Devices and systems with infra-red cameras or optical path laser spectroscopy technology
- Satellite technology for measurements of fugitive emissions
- Drones equipped with technology to scan areas / equipment
- Continuous detection systems for shale sites

Maintenance / repairs

- Systems for Directed Inspection & Maintenance (DI&M)
- Big-data software to optimize repair campaigns
- IoT and blockchain technology applications
- Sealing robots
- Platform with real-time view of emissions (e.g. for distribution networks)
- Innovative business models (ESCO)

New equipment

- Innovation in established technologies
  - Electro-centrifugal pumping technology
  - Compressed-air pumps
  - “low/intermittent-bleed” pneumatic controllers
  - Vapor recovery systems
  - Electric circulation pumps for dehydrators
  - Compressors/VRUs to capture casing head gas
- AI and simulation applications to test applications of new technology

Venting / flaring operations

- New small scale LNG applications
- Mobile gas to liquids
- Solutions for efficient well venting for liquids unloading (e.g. foaming agent)
- Solutions to stabilize hydrocarbon liquid storage tanks
- Software to support efficient operation with equipment

Sources: OGMP Report, OGCI Sep 18 Report, WRI (reducing-methane-us-working-paper) BCG experts

Industrial efficiency measures can reduce emissions – example of CHP and heat exchangers

Combined heat and power (CHP)

- Top cycle CHP uses waste heat from electricity generation directly for heating
- Bottom cycle CHP uses excess heat from industrial processes to produce electricity
- Can achieve up to 50% energy savings vs conventional gas boilers, with <5yr payback period in the US

Heat exchangers

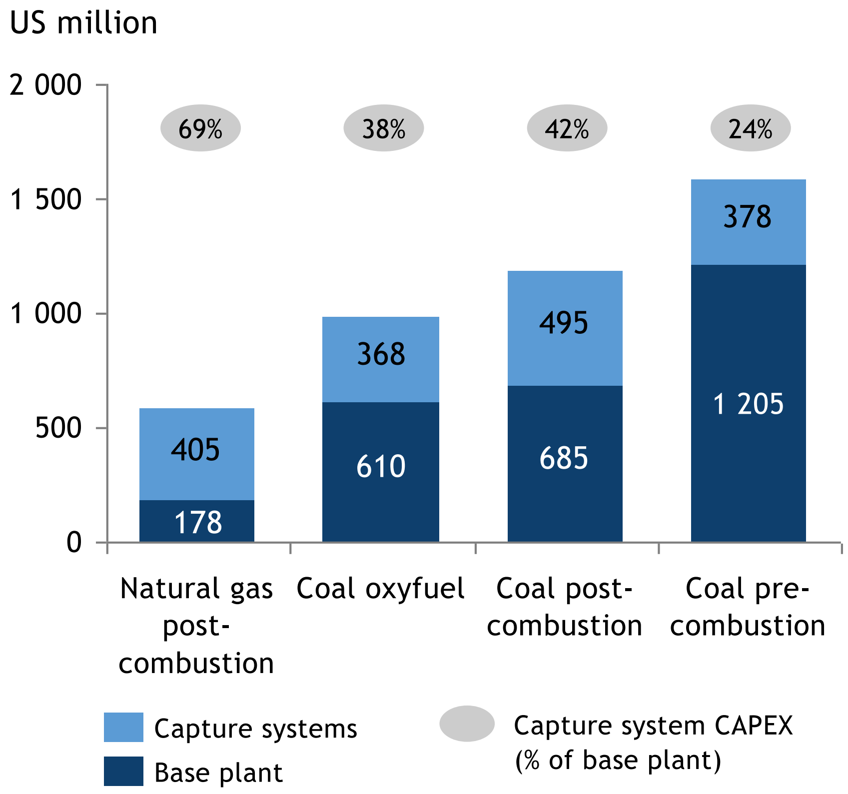
- Regenerative burner systems add heat exchangers to gas exhaust systems
- At >800°C can achieve 30% savings compared to traditional gas heat system, and up to 60% energy savings vs oil fired system

Key challenge is how to accelerate adoption

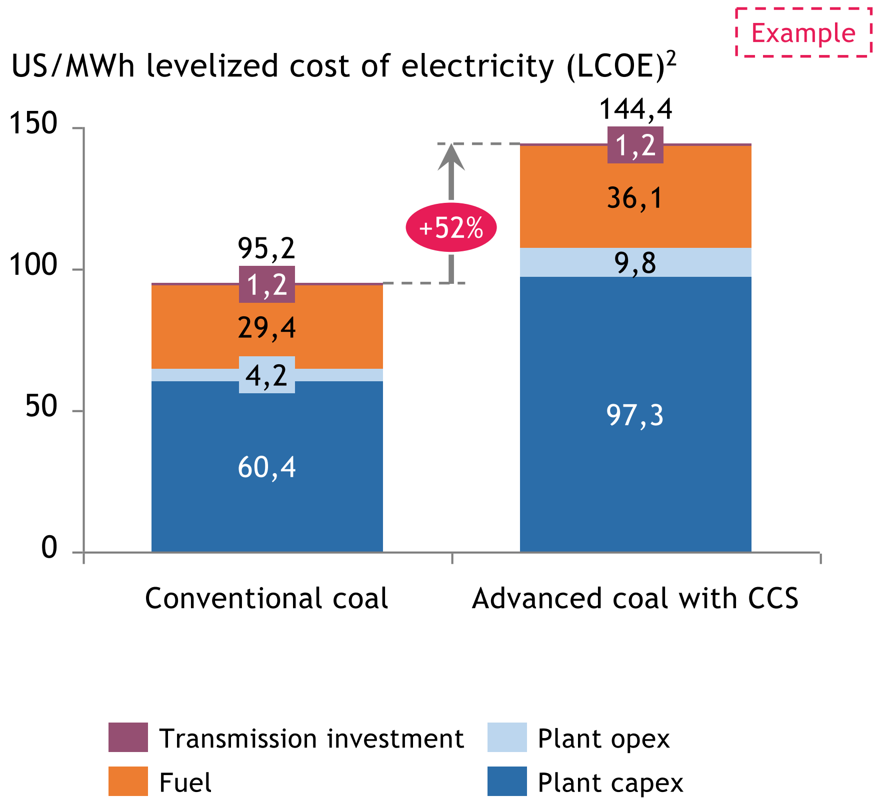
Source: BCG 2018 Global Gas Report

CCS for power gen is a relatively expensive technology

CAPEX of a 250MW power plant with various capture systems (first-of-a-kind)



Including CCS in a power plant increases LCOE by 20%



1. Natural gas plant is based on combined cycle technology. Post-combustion and oxy-fuel base plants are supercritical pulverized coal. Pre-combustion base plant is an IGCC unit. Does not include cost of pipelines, storage etc. 2. Based on expected costs in 2020; EIA 2015
Source: Schlumberger 2012, Global CCS Institute, EIA Energy Outlook 2015

CO2 capture is the main cost component for CCS in power systems

While storage is the major technical constraint

CCS value chain

	Capture	Transportation	Storage
Technology	Capture technology with significant progress • Large-scale CCS power projects moving into operation and construction	Technology for CO2 pipelines well established Existence of small scale shipment of CO2 • Limited to niche sectors (i.e. food industry)	Established storage in deep underground rock formations • Depleted O&G field (DOGF) • Deep saline aquifers (SA) • Enhanced Oil Recovery (EOR) Limited availability worldwide • Suitable sites 25-50 Mt CO2
Economics	70-90% of the overall cost of a large-scale CCS project • Capture (capex) and compression process (opex) Current cost: ~60 \$/tCO2	Costs roughly proportional to distance for pipeline transport • Onshore ~5 \$/tCO2 • Offshore ~9 \$/tCO2 Shipment more expensive • 12-18 \$/tCO2[1]	Large variation in storage costs • SA: 5-25 \$/tCO2[2] • DOGF: 5-15 \$/tCO2[2] Risk of investing in exploration of unsuitable SA

CCS not yet at mature stage: cost reduction and technology development are needed

1. 12 \$/tCO2 for ~180 km shipments of 20 Mt CO2 p.a., 18 \$/tCO2 for ~1500 km shipments and including liquefation costs 2. Onshore vs. offshore
Source: US DOE, Global CCS Institute, European Technology Platform for Zero Emission Fossil Fuel Power Plants

Agenda

Near term: Coal to gas switching

Medium term: Complementary with renewables

Long term: Decarbonization of gas

Questions for discussion

Questions for discussion

1. Accelerating coal to gas switching
   - What policies are most effective for accelerating coal to gas fuel switching?
   - How can additional investment in Asian coal power generation capacity be avoided?
   - What measures should industry be taking to accelerate fuel switching?

2. Role of gas in supporting renewables deployment
   - What is required to accelerate investment in gas peaking capacity?
   - Will gas peaking be complementary or competitive with battery storage?

3. Requirements to accelerate biomethane, hydrogen, and CCUS
   - What technologies have the greatest potential for reducing emissions from gas supply and consumption?
   - What scale of investment is required to develop these technologies?
   - How can the industry achieve "quick wins" to demonstrate the viability of these technologies?

4. Measures to reduce methane emissions and improve gas end use efficiency
   - What is the role of policy vs. industry action in reducing methane emissions and improving efficiency?
   - Are new technologies required, or is it purely a challenge of scaling up existing technology?
   - What are success stories that industry and government can highlight?