Basic Study of Applying CMM (Coal Mine Methane) Concentration Technology in Poland

2 June, 2014

Osaka Gas Co.,Ltd

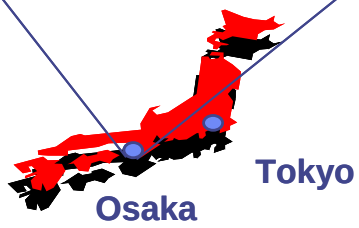
Contents

1. Outline of Osaka Gas and Development of CMM Concentration Technology

Outline of Osaka Gas Group

- Started business operations in **1905**
- Amount of sales: **1.38 trillion yen**
- Supplying **7.09 million** of natural gas to customers in Kansai Region (about 25% of Japan gas market share in sales volume)
- Imports **7.6 million tons of LNG** annually (approximately 5% of world traded volume)
- **140** affiliated companies
- **19,360** employees (Osaka Gas + consolidated subsidiaries)

Natural gas service area






Natural Gas Value Chain

LNG procurement/ transportation	LNG receiving/ gas production	Distribution/ supply	Control/ maintenance


Household


Commercial use


Industrial use


Power generation
District heating and cooling

R & D：Research and Development

Carbon Materials and Upgrading Technology of Osaka Gas Group

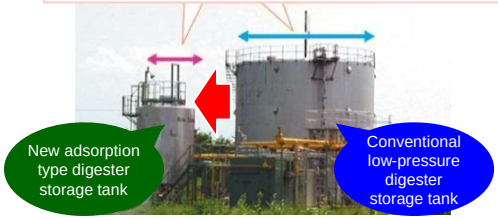
- Osaka Gas Group (OGG) offers a wide-ranging knowhow on using of carbon materials.
- OGG has extensive experience in designing, construction and operation of Pressure Swing Adsorption (PSA).

Achievement in use of carbon materials

Adsorbent (activated carbon)

Downsizing of LNG/biogas storage tank by using carbon materials.

1/20 of size for the same storage capacity



Carbon fiber / Fluorene (Osakagas Chemical)

Carbon fiber: to be used as a light heat insulating material for bullet trains and furnaces for producing silicon for solar batteries

Fluorene: dominating the world market share as a material of lens for mobile phones and digital cameras

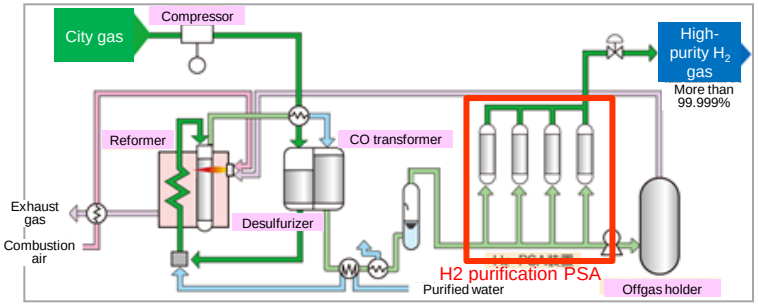
Carbon fiber (heat insulating)

Fluorene (camera lens)

Achievement in PSA technology

PSA for hydrogen purification

Self-developed high efficiency PSA for hydrogen purification is applied to H_2 production system by city gas reforming



H_2 production system for FCV H_2 station HYSERVE300

VPSA for concentrating the low-CH_4 concentration CMM

Methane concentration in Low-CH_4 concentration CMM can be concentrated up to +35% by VPSA technology using activated carbon.

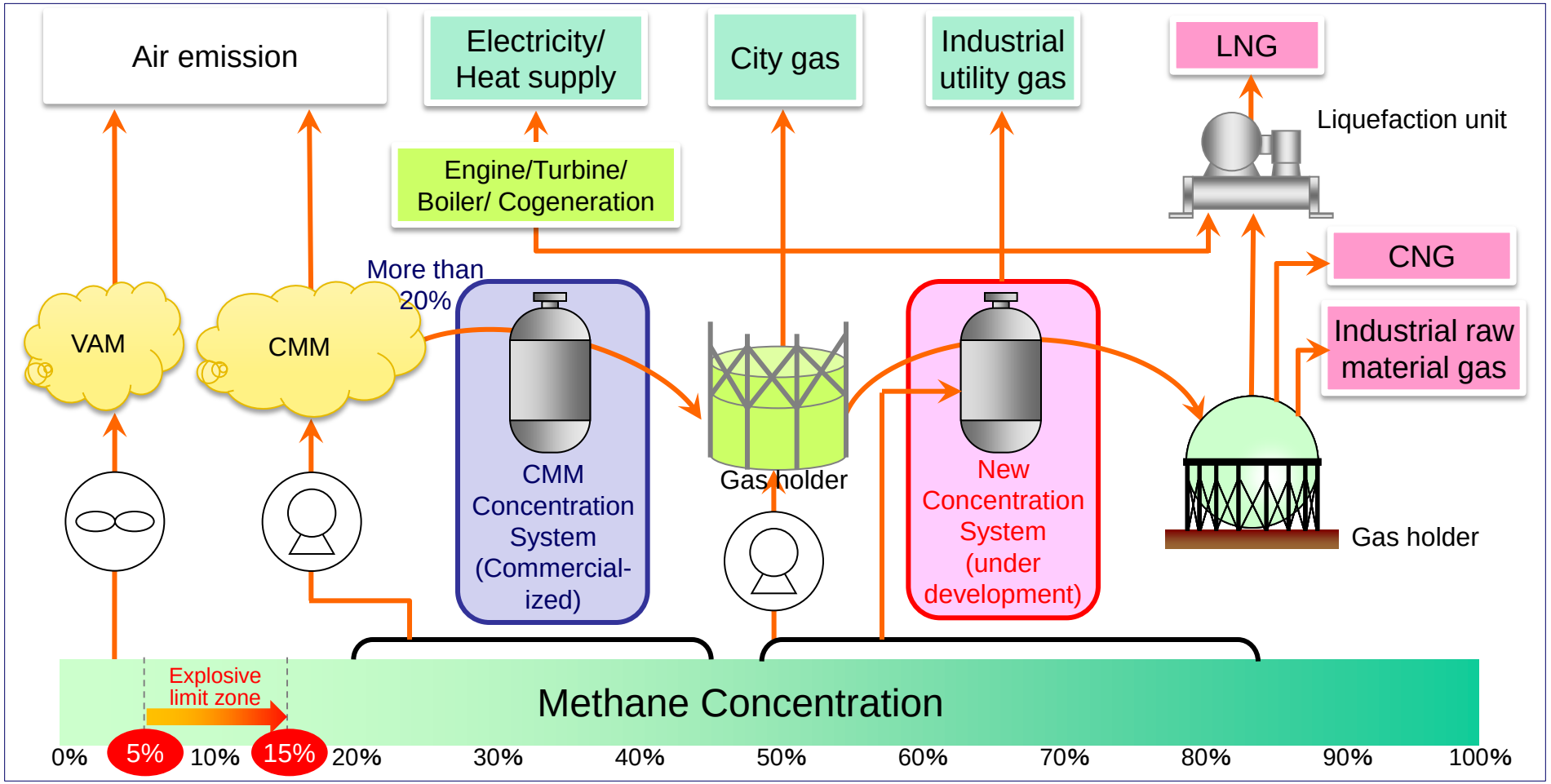
Pilot test at Fuxin coal mine in China (2007-2008)

PSA for biogas upgrading (bench test is being conducted.)

Utilization of CMM with CMM Concentration Technology

- Utilization of concentrated CMM (around 50% CH_4) as regional city gas
- Utilization of concentrated CMM (over 90% CH_4) as natural gas

Extended use of CMM by applying CMM concentration technology

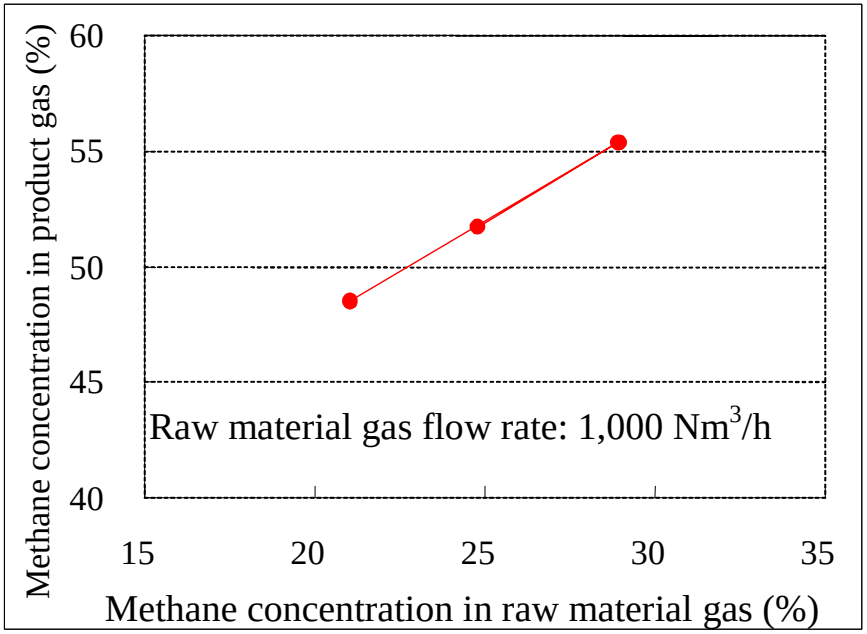


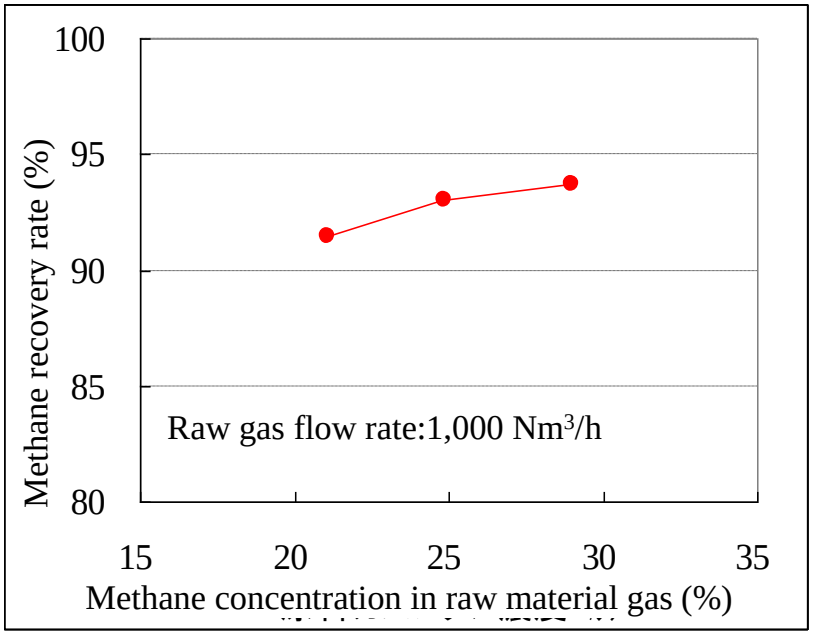
Concentration Technology of CMM (commercialized)

Demonstration test was operated on the scale of 1000 Nm^3/h (½ of commercial equipment). It achieved sufficient performance: methane concentration for +25% and more than 90% of methane recovery rate.

Location	Fuxin City (Liaoning, China) In West-northwest area for 180km from Shenyang City
Test term	2008.4 - 2009.12
Inlet Conditions	Methane Concentration of CMM：20～30% Inlet CMM Flow rate：1,000 Nm^3/h

Purification equipment (adsorption vessel)

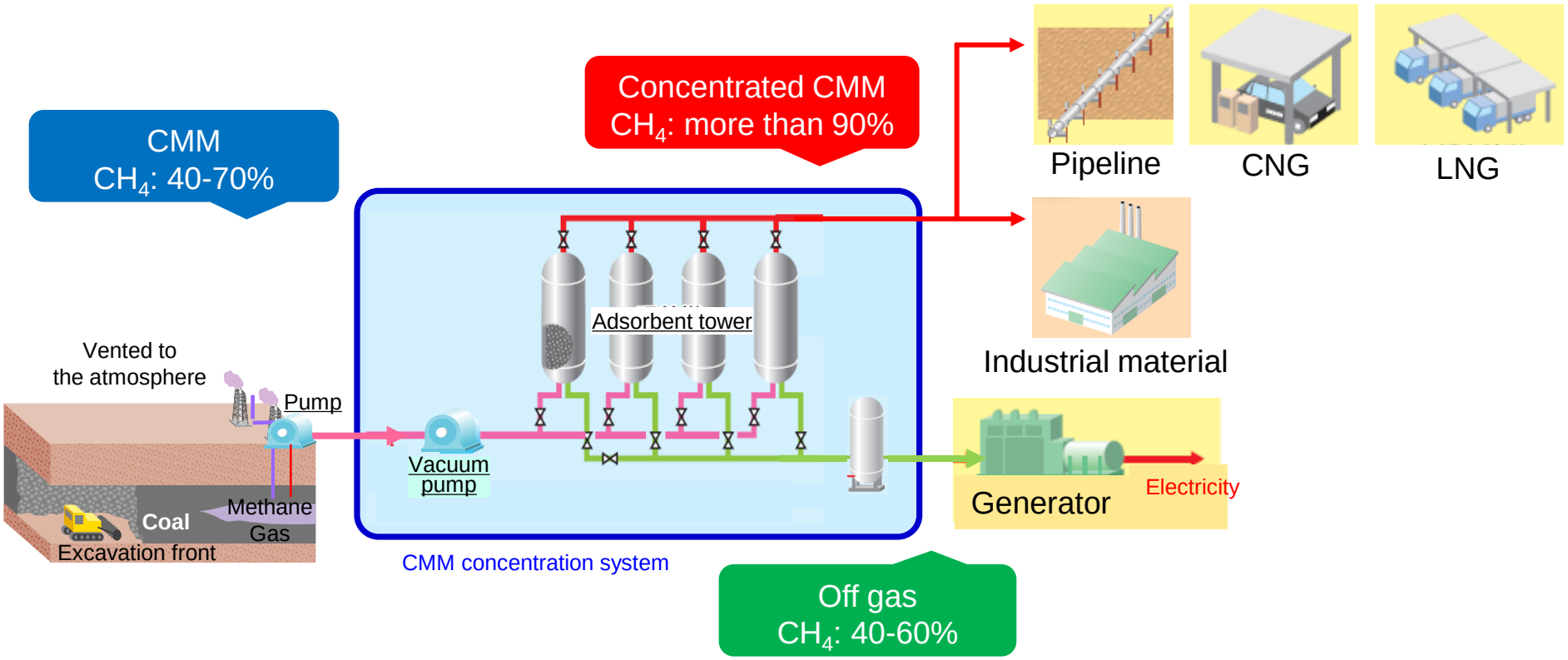




* International collaborative program of the NEDO

Concentration Technology of CMM with high methane concentration

CMM with high methane concetration can be used for the gas sales in addition to the use of gas engine generation by applying a new concentration technology



Target of raw gas			Feature
Material	Components	Methane concentration	
CMM, AMM, CBM	CH_4, N_2, O_2, CO_2	More than 50%	Adsorbent adsorbs other than CH_4. Concentrating more than 90%

Results of Bench test at Osaka Gas Laboratory

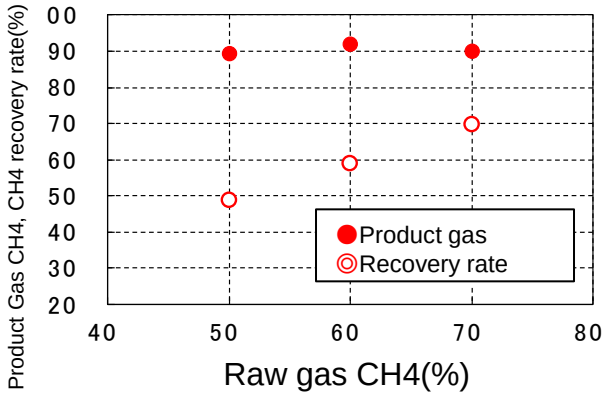
- A bench test equipment: about 1/1000 scale of demonstration equipment 1000Nm^3/h
- Influence of methane concentration in raw/product gas was investigated.

Specification of bench equipment

Main components	Adsorption vessels, switch valve, compressor, CH_4 analyzer, flow meter
Equipment Size	L2.5m × D1.8m × H3.0m
Adsorption vessel volume	5.7 L
Gas process volume	10～20 L/min

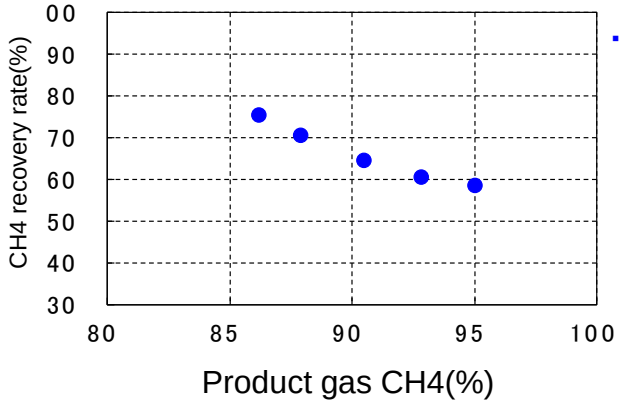
Results of bench test

・Influence of CH_4 concentration in raw gas



- Raw gas was concentrated to over 90% in each cases
- Recovery rate increased with the increase of CH_4 concentration of raw gas

・Influence of CH_4 concentration in product gas

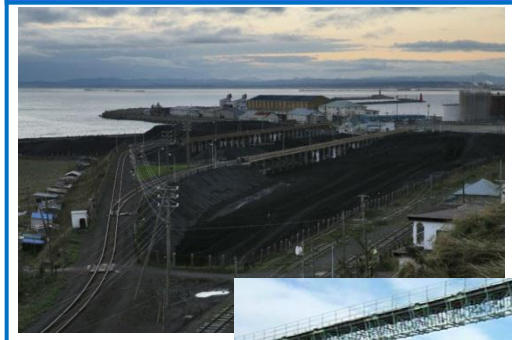


- CH4 recovery rate decreased with the increase of CH_4 concentration of product gas.

Results of Actual Gas Testing at Kushiro Coal Mine

- Using a bench test equipment, concentration testing of extracted gas at Kushiro Coal Mine.
- It is verified that the stable concentration performance is achieved while the methane concentration of raw gas fluctuates.

Outline of Kushiro Coal Mine



Company	Kushiro Coal Mine
Coal storage	120 million tons
Coal Production	0.7 Mt/y
CMM	250 - 300 Nm^3/h
Article	Accepting personnel from China and Vietnam coal company to teach mining operation

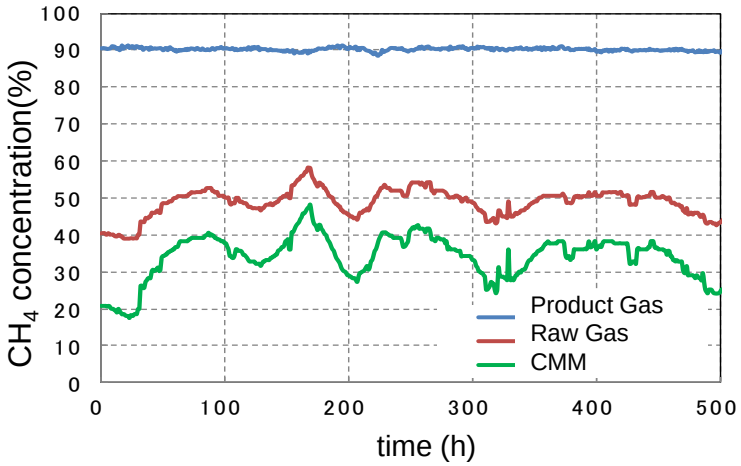
Field Test Results

・Concentration performance

methane concentration of raw gas was adjusted by adding cylinder methane gas.

			CMM	Cylinder	Raw	Product
Flow Rate		NL/min	9	4	13	5
Conc.	CH_4	%	36	100	56	91
	N_2	%	58	0	40	8
	O_2	%	3	0	2	0
	CO_2	%	3	0	2	1

・Stability



Stabilizing CH4 concentration of the product gas by operational control depending on the CH4 concentration of inlet gas of the equipment.

2. Investigation Results in Poland

Energy situation in Poland

1. Coal

- Amount of coal production was 77 million tons in 2010, and have been decreasing yearly. Being produced by underground mining mainly.
- Coal mining area is centered at GZW Coal Mine in the south of Poland and covers 80% of total resources in Poland. The other 20% is produced at LZW Coal Mile in the east.
- Three main mining companies, KW, KHW and JSW, dominate the share for about 95%.

2. Natural Gas

- 75% of natural gas has been imported, and 90% of them have been supplied by Russia. The import agreement with Russia is planned to be continued until 2020 (or 2022). Poland purchases 8.5 billion m^3 annually.
- The most largest gas company is PGNiG that dominates the market share for 97%.
- LNG receiving terminal is being constructed in the north of Poland and will be completed at the end of 2014.

  Poland will purchase LNG from Qatar for 20 years from 2015. PGNiG is purchaser and Gas Systems Company is contractor and operator of the LNG terminal.
- The sales of gas is liberalized this year and the wholesale market is opened. The sales of electricity is also liberalized.
- Gas companies are required to trade more than 40% of trading amount from 2014. It is planned to be increased to more than 55% from 2015.

Introduction of CMM Concentration Technology in Poland

1. Situation of CMM extraction

- The methane concentration of extracted CMM is about 40-60%.
- Legal regulation: Extraction of CMM should be stopped when the methane concentration of extracted CMM falls below 30%.
- Legal regulation: The methane concentration of CMM vented to the air should be lower than 0.75%.

2. Situation of CMM use

- The attention to the CMM use has been highly increasing, and the capital investment for the CMM use has been progressing actively.
- KW and JSW have used CMM for the fuel of gas engine in Joint Implementation (JI) with Japanese electric power company “Chugoku Electric Power CO.,INC”.
- All the coal mines having CMM recovery stations use the CMM for gas engine boilers.
- It is difficult to apply the OG’s CMM concentration technology because the gas engines at those sites were designed for the use of low-concentration methane.

  Ex.) The gas engine of KW can applied to CMM between 30-78% of methane concentration.
- JSW aims at increasing the rate of CMM utilization from 85% of present state to 90% in the coming year. Therefore, JSW is not active enough to install CMM concentration equipment.

Situation of CMM Use in KW

According to the last field investigation, the collected information from AGH University and KW shows that there is a possibility for installing CMM concentration equipment to the following coal mines having CMM extraction facilities.

No	Coal mine	CMM extraction facilities	Extracted amount of CMM [Mm^3/yr.]	CH4 concentration	Existing facilities using CMM
1	KWK Bielszowice	○	7		Gas engine 0.5 MW
2	KWK Bobrek-Centrum				
3	KWK Bolesław Śmiały				
4	KWK Brzeszcze	○	39		
5	KWK Chwałowice	○	6		
6	KWK Halemba-Wirek	○	3		Gas engine 0.5 MW
7	KWK Jankowice				
8	KWK Knurów-Szczygłowice	○	35		Gas engine 2 MW Gar boiler 10 MW
9	KWK Marcel	○	4		Gas engine 2 MW
10	KWK Piast				
11	KWK Piekary				
12	KWK Pokój				
13	KWK Rydułtowy-Anna	○	7		
14	KWK Sośnica- Makoszowy	○	6.4	67%	Gas engine 2 MW Gas boiler 10 MW
15	KWK Ziemowit				

Situation of CMM Use in KHW

According to the last field investigation, the collected information from AGH University and KHW shows that there is a possibility for installing CMM concentration equipment to the following coal mines having CMM extraction facilities.

No	Coal mine	CMM extraction facilities	Extracted amount of CMM [$Mm^3/yr.$]	CH4 concentration	Existing facilities using CMM
1	KWK Murcki Staszic				
	Murcki section	Planning	Planning		Gas engine 1.5 MW × 2
	Staszic section	○	8	69%	Pipeline
2	KWK Mysłowice Wesoła	○	14	38-45%	Gas engine 1.5 MW × 2 (Planning to add 1.5 MW × 2)
3	KWK Wieczorek	—	—	—	
4	KWK Wujek	○	2	—	Boiler 6 MW (Planning to add Gas engine 1.5 MW)
5	KWK Kazimierz - Juliusz	—	—	—	

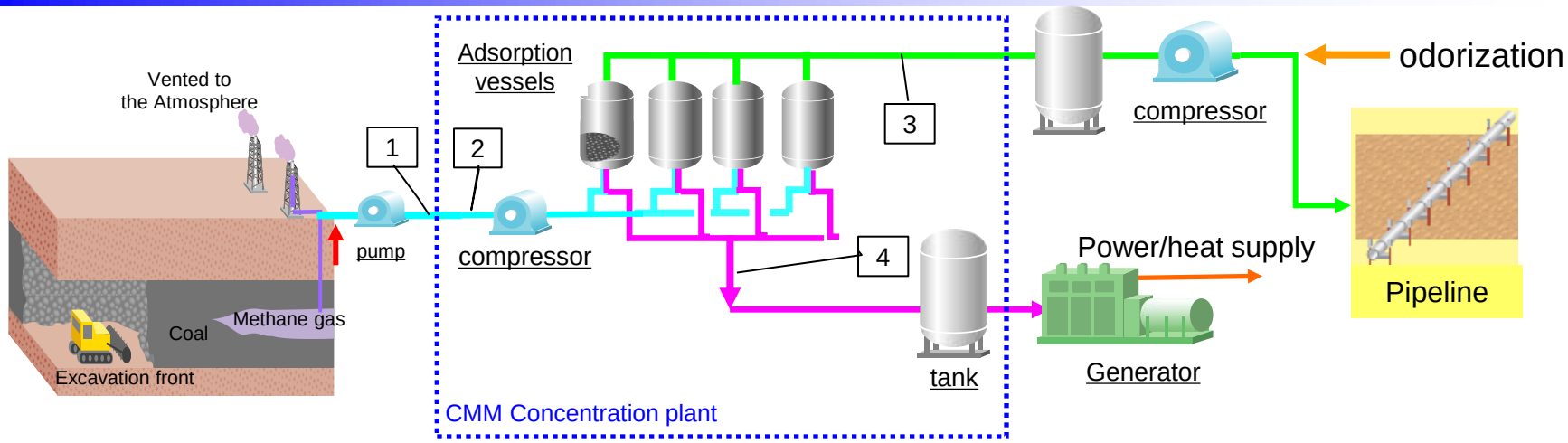
Situation of CMM Use in JSW

According to the last field investigation, the collected information from AGH University and JSW shows that it is difficult to install CMM concentration equipment because the rate of CMM utilization reaches nearly 85-90%.

No	Coal mine	CMM extraction facilities	Extracted amount of CMM [$Nm^3/yr.$]	CMM concentration	Existing facilities using CMM
1	KWK Borynia-Zofiówka-Jastrzębie				
	Borynia section	○	21	—	Gas boiler 1.8MW Boiler 1.2 MW × 2
	Zofiówka section	○		—	CMM pipe connected to Borynia
	Jas-Mos section	○	9	—	CMM pipe connected to Borynia
2	Budryk Coal Mine	○	10	—	Gas engine 10 MW
3	Krupiński Coal Mine	○	33	—	Gas engine 3 MW+3.9 MW Producing LNG
4	Pniówek Coal Mine	○	41	45-70%	Gas engine 3.9 MW Coal boiler 25 MW

3. Overviews of Preliminary Feasibility Study

Demonstration model <pilot scale>



◎ Specification of CMM concentration plant

CMM Flow rate	1,000	Nm^3/h
Methane concentration	20.0	%
Methane recovery rate	72.0	%
Power consumption	150	kW

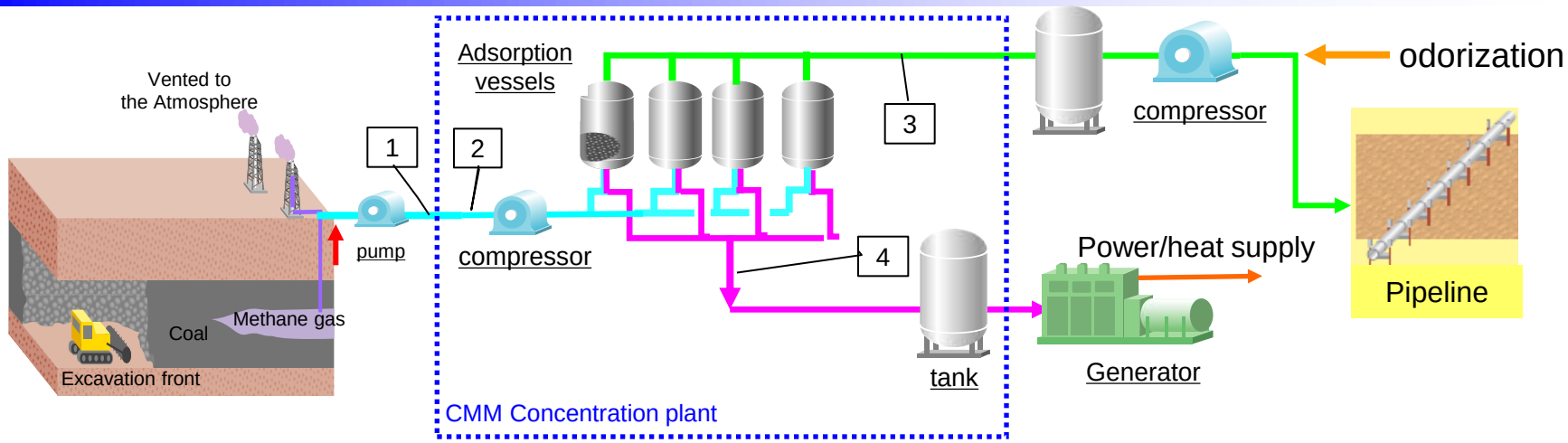
◎ Specification of Generator

Generated output	865	kW

◎ Material balance

No.			1	2	3	4
			Raw gas	PSA In	Product	GE In
Total flow		Nm3/h	1,000	1,000	560	440
CH4 flow		Nm3/h	700	700	504	196
composition	CH4	%	70.0	70.0	90.0	44.5
	N2	%	25.0	25.0	8.3	46.2
	O2	%	4.0	4.0	1.3	7.4
	CO2	%	1.0	1.0	0.3	1.8
	Total	%	100.0	100.0	100.0	100.0

Demonstration model <commercial scale>



◎ Specification of CMM concentration plant

CMM Flow rate	3,000	Nm^3/h
Methane concentration	20.0	%
Methane recovery rate	72.0	%
Power consumption	250	kW

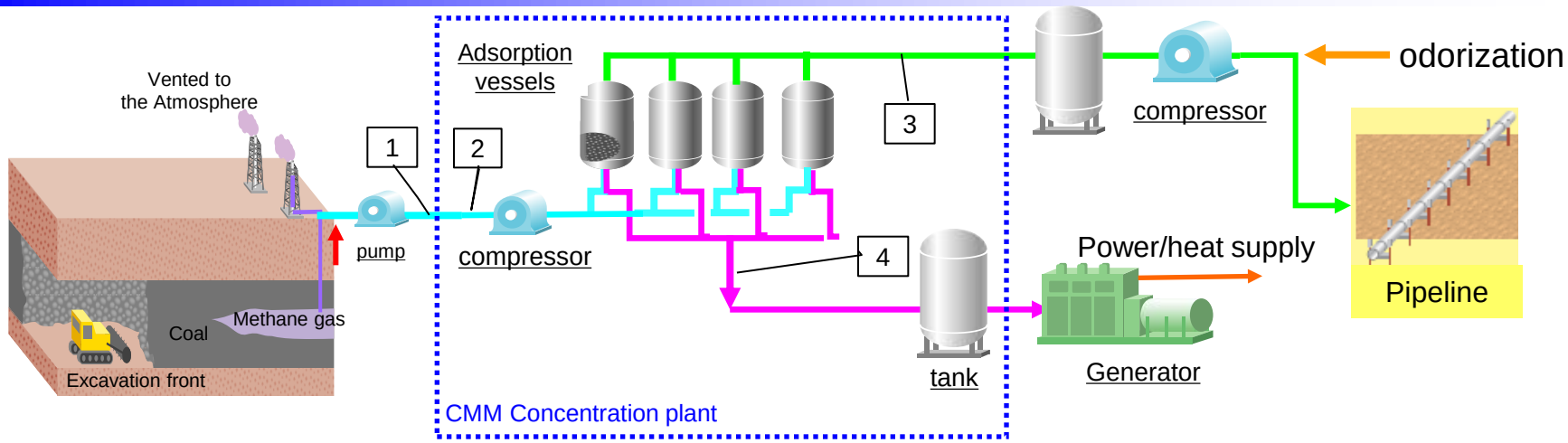
◎ Specification of Generator

Generated output	2,508	kW

◎ Material balance

No.			1	2	3	4
			Raw gas	PSA In	Product	GE In
Total flow		Nm3/h	3,000	3,000	1,680	1,320
CH4 flow		Nm3/h	2,100	2,100	1,512	588
composition	CH4	%	70.0	70.0	90.0	44.5
	N2	%	25.0	25.0	8.3	46.2
	O2	%	4.0	4.0	1.3	7.4
	CO2	%	1.0	1.0	0.3	1.8
	Total	%	100.0	100.0	100.0	100.0

Result of FS <commercial scale>



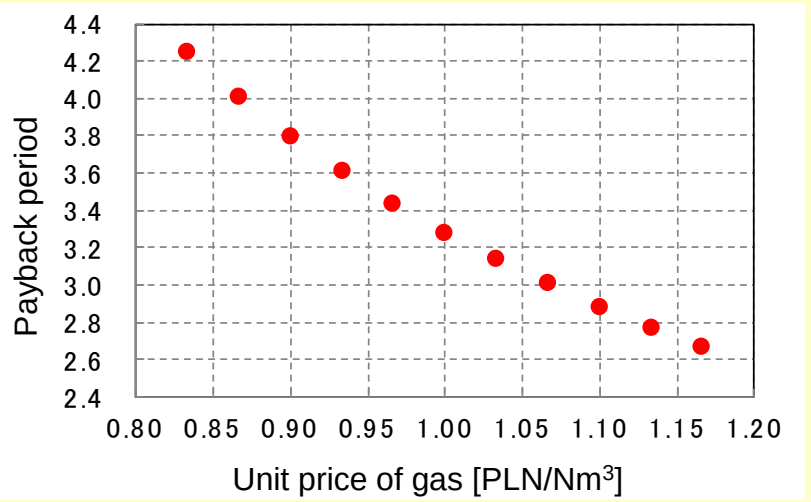
Results of preliminary estimation

The production gas is injected into the pipeline. The off gas is mixed with raw CMM and used for existing gas engines.

- Amount of product gas: 13.44 million Nm^3/year
- Power generation: 18,067 MW/year
- Annual advantage: 10 million PLN/year (only in the wholesale gas trade)
- Payback period: 3.3 years
- Capital expenditure (rough estimate): 32 million PLN for concentration equipment (the facilities included in the dotted blue square)

Influence of CMM wholesale price

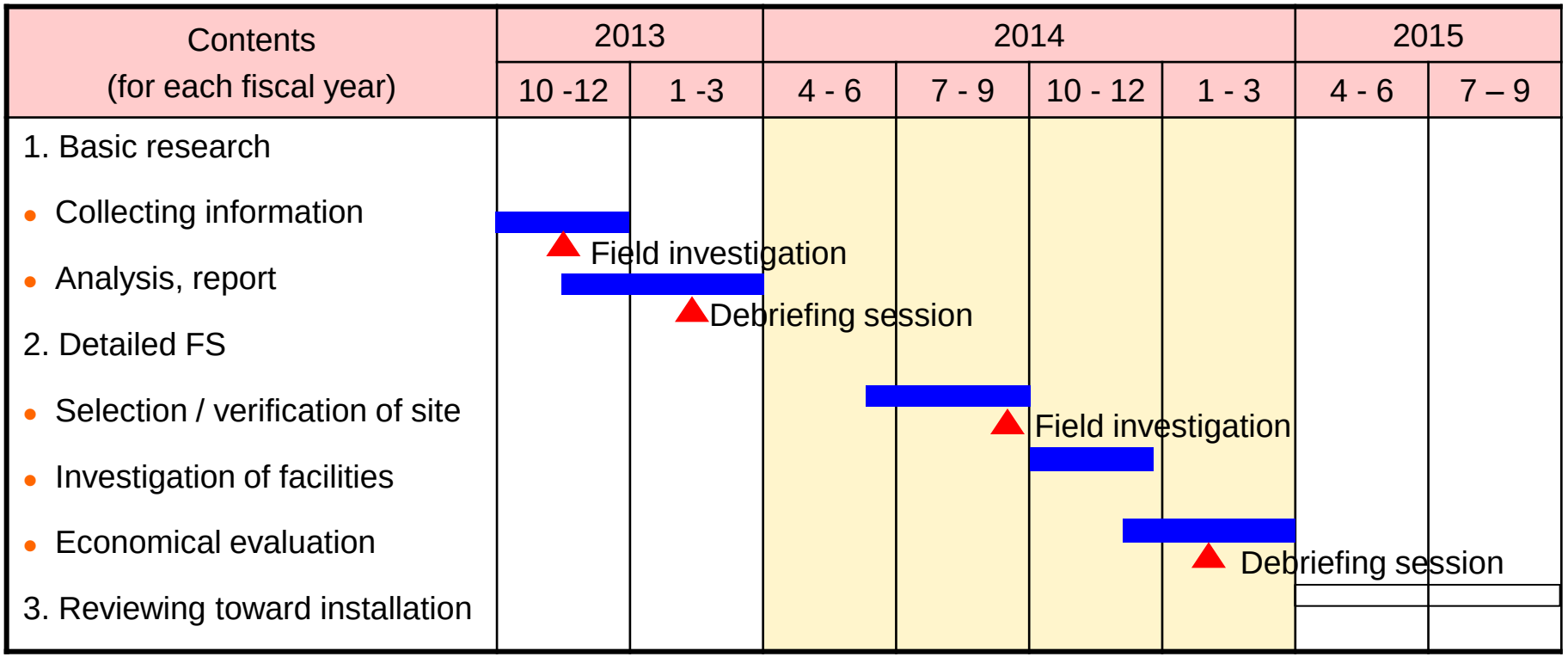
Payback period decreases with the increase of product gas price.



4. Future Plan (proposal)

Division of roles at the Detailed FS and Schedule (proposal)

Content		Japan	Poland
FS	Selection of sites Verification of site condition Estimation of costs	・Concentration equipment (including a compressor of raw gad, excluding a storage tank)	・Peripheral devices (utility) ・Unit price of each utility ・Gas supplying facility (compression, transmission)
	Economical evaluation	・Joint implementation (field investigation of necessary)	



End