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Development of Residential Gas Engine CHP System “COREMO” Optimized for Cold Regions and Its Evaluation on Environmental Performance

Main author
Kiyotaka Takeda
Hokkaido Gas Co., Ltd.
Japan
kiyotaka.takeda@kitagas.com

Co-authors
Hiroshi Kamiya*
Masahiko Iida*
Noritaka Nakaya*
Yasuhiro Hamada**
* AISIN SEIKI Co., Ltd.
**Hokkaido University

ABSTRACT

Recently, residential CHP systems using gas engines or fuel cells have been introduced into the market for the purpose of energy conservation in Japan. Meanwhile, in Hokkaido, as a cold region, energy consumption in the household sector is about 1.5 times compared with the national average.
Under such circumstances, AISIN SEIKI Co., Ltd. and Hokkaido Gas Co., Ltd. developed a residential gas engine CHP system "COREMO" optimized for cold regions and the system has been on sale since 2011.

COREMO has three good points compared with conventional residential gas engine CHP systems. Firstly, it needs small indoor space for installation. Secondly, the operation method of the system is load following, while conventional system converts surplus electricity into heat. Thirdly, a high efficiency condensing boiler is used as backup.
The exhaust heat of COREMO is used only for heating, while exhaust heat of general system is used for hot-water supply. The engine operates only when heating is required and electricity demand is over a certain value, so a hot-water tank for heat reserving which requires a large indoor space is unnecessary. The operation method of the engine is load following in order to keep high efficiency. When engine's power generation is insufficient, commercial power is used. Hot-water supply and heating that cannot be covered by engine's exhaust heat are supplied by a condensing boiler which has small-scale and high efficiency. In the case of common residence in Sapporo which is the largest city in Hokkaido, COREMO reduces 40% of purchased electricity and 1 ton of CO_2 annually, and effects by introduction of the system are better than conventional type as previously reported in IGRC 2011.

Heat generation efficiency at rated operation reaches 64.0%LHV increasing of 5.0 points from the previous system. The dimension of the system is W700 x D400 x H1,018 and it achieves 22% volume downsizing.
Two useful functions have been added to the 2013 model COREMO. One is the power supply during blackout. If a blackout occurs when COREMO is operating, it keeps generating and supplies 750W of electricity to the condensing boiler and the emergency plug. The other is that the exhaust heat is used to reheat the bath, so it operates even in summer. These improvements reduce another 70 kg-CO_2 emissions.

19 units of COREMO have been installed to residences at a town block, which is named "Eco Town North 48", in Sapporo, and we conducted measurements in order to confirm effects by introduction of the system. The exhaust heat from COREMO is used not only for panel heater and floor heating but also preheating for ventilation.
COREMO cuts 73% of purchased electricity of the town block at the peak of electricity demand. Compared with the conventional system (commercial power + non-condensing boiler), the amount of CO_2 reduction reached an average of about 1.1 tons/year, and energy costs, which includes electricity and gas, were decreased by 60,400 yen (US$628 on Dec. 6th, 2013) annually.

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2.1 Introduction

The carbon dioxide emissions which originated from energy generation in the FY2008 in Japan increased by 7.5% from 1990, the reference year of the Kyoto Protocol. The emissions from the residential sector, which accounts for 15% of the total, increased by 34.2% from the reference year. Under such background, condensing boilers for hot-water supply and space heating have become common. In addition, due to higher energy saving and environmental performance, the residential combined heat and power (CHP) system has attracted attention, and systems using gas engines and fuel cells have recently been introduced into the market in Japan.

Meanwhile, in Hokkaido as a cold region, compared with the national average, CO_2 emissions in the household sector are about 1.6 times higher, and energy consumption about 1.5 times higher. Under such circumstances, AISIN SEIKI Co., Ltd. and Hokkaido Gas Co., Ltd. developed a residential gas engine CHP system called "COREMO" optimized for cold regions and the system has been on sale since 2011.

We conducted demonstration tests on 11 COREMO systems at residences in Sapporo and evaluated the effectiveness of COREMO for conserving energy. Then, we described the improved points of the latest 2013 model COREMO.

2.2 Features of "COREMO"

The composition and specifications of "COREMO" are shown in Fig.1 and Table1, respectively. The most remarkable feature of this system is that the exhaust heat during the power generation is used only for space heating, while exhaust heat of general system is used for the hot-water supply. The engine operates only when heating is required and electric use is over a certain value, so a hot-water tank for heat-reserving, which requires a large space, is unnecessary. The operation method of the engine is load following. When the engine's power generation is insufficient, commercial power is used. Hot-water supply and space heating that cannot be covered by the engine's exhaust heat is supplied by a condensing boiler which is small-scale and high efficient. The effect of cost reduction due to the omission of the hot-water tank can be expected. In the case of common residence in Sapporo which is the largest city in Hokkaido, it is estimated that COREMO reduces 40% of purchased electricity and 1 ton of CO_2 annually[2),3)].

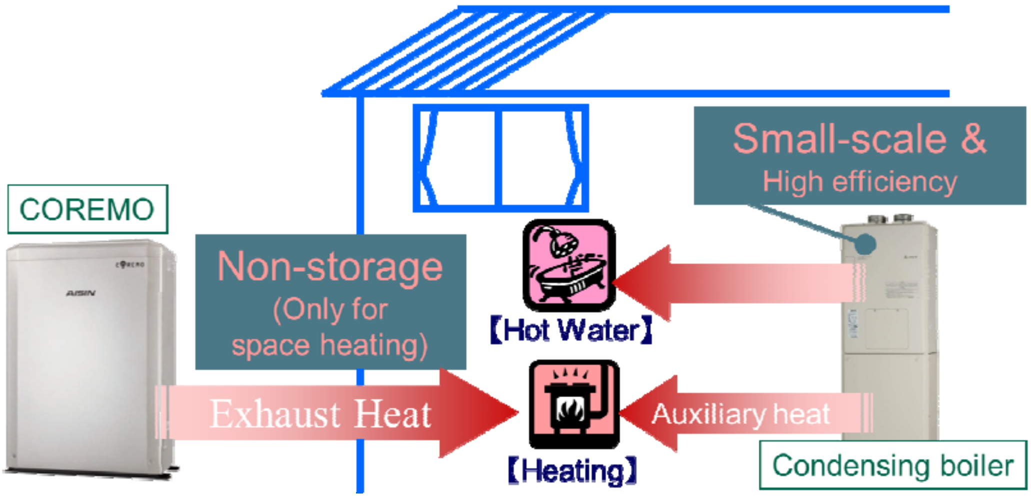

Fig.1 A schematic diagram of "COREMO"

Table 1 Specifications of the 2013 model "COREMO"

Maximum power output	1.5kW
Minimum power output	0.5kW
Power generation efficiency	26.0%LHV (at rated operation)
Heat generation efficiency	64.0%LHV (at rated operation)
Dimensions	W750 × D480 × H1,018mm
Weight	118kg

Fig.2 Photo of "COREMO"

2.3 The improved points of the latest 2013 model COREMO

The latest 2013 model COREMO has improved basic performance. The Heat generation efficiency at rated operation has reached 64.0%LHV, increasing 5.0 points from the previous system. The dimensions of the system are W700 x D400 x H1,018 and it achieves a 22% volume downsizing. Fig.2 shows the appearance of the latest COREMO.

Two useful functions have been added to the 2013 model COREMO. The first is a power supply in case of blackouts. When a blackout occurs if COREMO is operating and city gas is available, it keeps generating and supplies 750W of electricity to the condensing boiler and the emergency plug(Fig.3). So, the customers can use hot-water, heating, and some household electrical appliances.

The other feature is that the exhaust heat is used in reheating the bath, so it operates even in summer. These improvements reduce another 70 kg of CO_2 emissions.

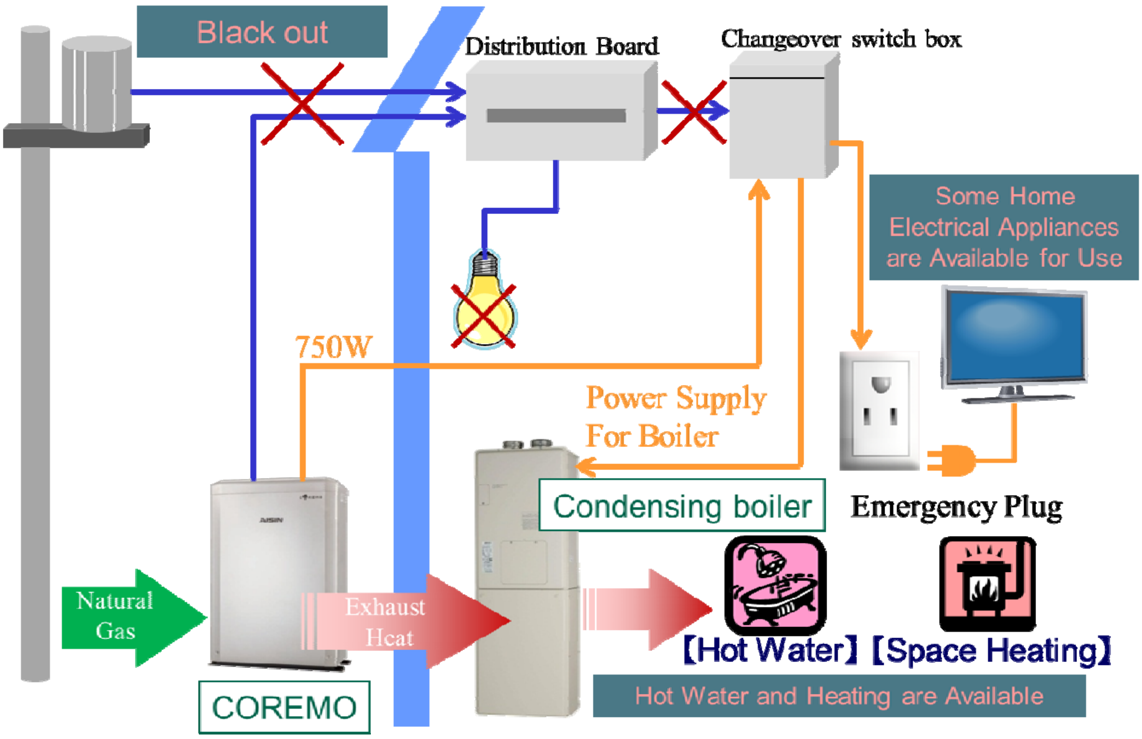

Fig.3 A schematic diagram of "COREMO" in case of blackouts

2.4 Demonstration Tests

19 COREMO units were installed to residences in a town block, which is named "Eco Town North 48", in Sapporo, and we conducted measurements in order to confirm effects by introduction of the system. Exhaust heat from those COREMO units are used for preheating for ventilation, while the exhaust heat from the system is used for hot-water heating in the usual way(Fig.4). Those COREMO units operate not only when hot-water heating is required, but also when the ventilation temperature is lower than a set value. So those COREMO units operate for a long time during winter and the exhaust heat of the system, which is 1.4 to 3.7 kW, is used for a base load of space heating.

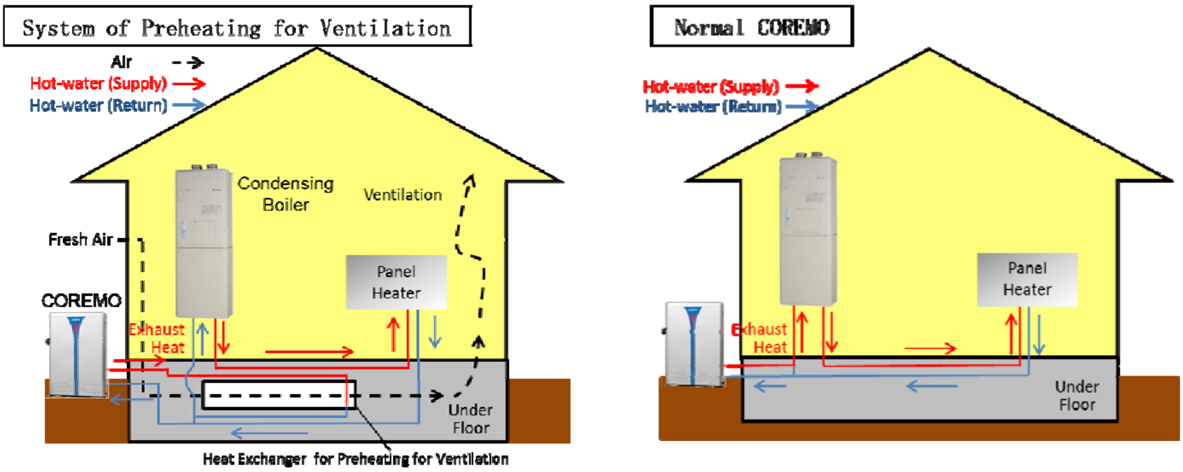

Fig.4 A schematic diagram of the system of preheating for ventilation and normal COREMO

2.5 Effects by introduction of the system through Demonstration Tests

11 units were selected from the abovementioned 19 systems for measurements, in order to confirm the effects by introduction of the system. The contribution rate of supplied power was on average 37% annually, and above 60% during winter (Fig.5). The operating time of the system was high during winter (Fig.6), and it was 2,984 hours/year on average. The contribution rate and the operation time are high during winter because the gas engine operates when space heating is required and the ventilation temperatures are low. The gas engine operates at a high load because the electrical and the heat demand tend to be high during winter, and it produces high power efficiency. COREMO cut 73% of the purchased electricity in the town block at the peak of electricity demand (Fig.7). The operating results after one year of installation are shown in Table 2. Compared with the conventional system (commercial power + non-condensing boiler), the amount

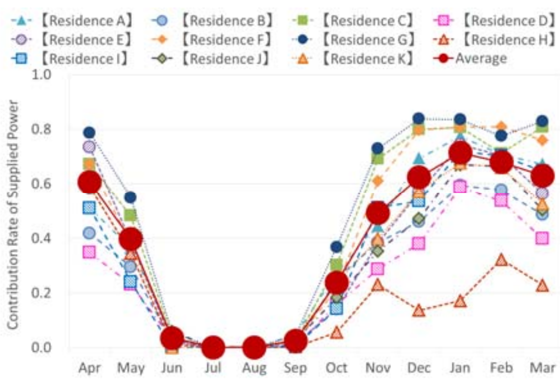

Fig.5 Contribution Rate of Supplied Power

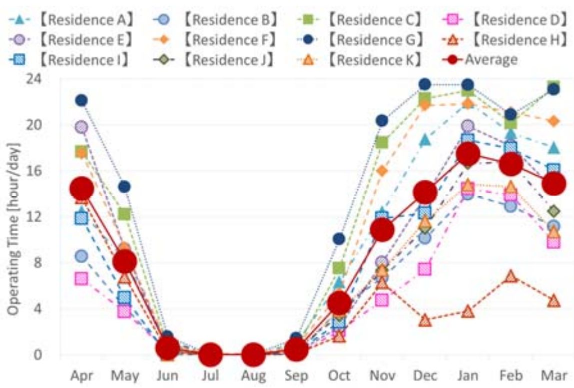

Fig.6 Operating Time

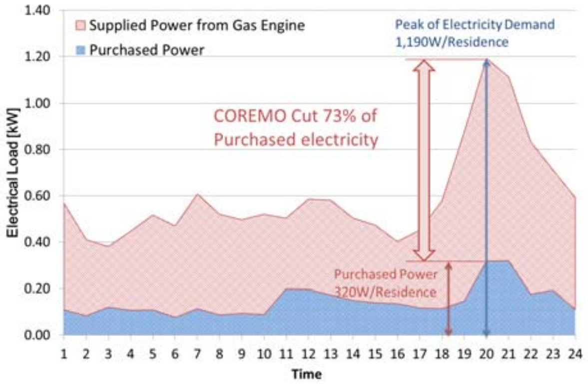

Fig.7 Effect of Electric-load Leveling of COREMO

Table 2 Operating Results (Apr.2013 - Mar.2014)

	Electrical Demand	Supplied Power from Gas Engine	Domestic Hot Water Demand	Space Heating Demand	Supplied Heat from Gas Engine	Operating Time of Gas Engine	Amount of Gas Consumption	Amount of Electricity Consumption	Amount of Primary Energy Reduction	Amount of CO_2 Reduction	Amount of Energy Cost Reduction
	kWh	kWh	kWh	kWh	kWh	h	Nm3	kWh	kWh	kg-CO2	Yen
【Residence A】	5,706	2,332	4,694	19,389	7,802	3,638	2,559	3,374	6,451	1,633	88,384
【Residence B】	3,136	1,057	5,462	13,315	4,499	2,183	1,877	2,079	4,444	1,021	53,503
【Residence C】	4,247	1,964	4,454	19,039	9,191	4,445	2,467	2,283	5,810	1,445	76,011
【Residence D】	2,323	654	2,917	12,965	3,958	1,917	1,576	1,668	3,247	723	38,355
【Residence E】	3,380	1,271	5,726	15,802	6,657	3,227	2,176	2,109	4,952	1,155	60,622
【Residence F】	4,012	1,803	4,122	20,193	8,614	4,102	2,512	2,209	5,908	1,432	75,312
【Residence G】	6,513	3,319	6,479	22,107	10,450	4,904	3,086	3,194	8,539	2,206	116,997
【Residence H】	2,330	434	4,076	10,452	3,001	1,428	1,410	1,895	2,932	623	32,642
【Residence I】	2,289	862	4,842	11,446	6,207	2,941	1,636	1,427	3,604	829	41,661
【Residence J】	2,522	796	4,390	12,878	4,283	2,108	1,709	1,726	3,820	856	45,148
【Residence K】	1,833	667	2,847	11,883	3,972	1,929	1,480	1,165	2,946	670	35,566
Average	3,481	1,378	4,546	15,406	6,239	2,984	2,045	2,103	4,787	1,145	60,382

of CO_2 reduction reached an average of about 1.1 tons/year, and energy costs, which includes electricity and gas, were decreased by 60,400 yen (US$628 on Dec. 6th, 2013) annually. According to the results of multiple linear regression analysis, the amount of reduction in primary energy correlates highly with heat (space heating and hot water) demand and electric demand(Figs.8 and 9).

2.6 Comparing the systems using preheating for ventilation and normal systems

The difference of the results between the systems using preheating for ventilation and the normal systems is shown in Table 3. The operation time, the supplied power from gas engines, and the supplied heat from gas engines increased 927 hours/year, 328kWh/year, and 1,968 kWh/year on average compared with the normal systems, respectively. It reduced another 132 kg of CO_2 emissions and 5,000 yen (US$49 on Dec. 6th, 2013) of energy costs annually.

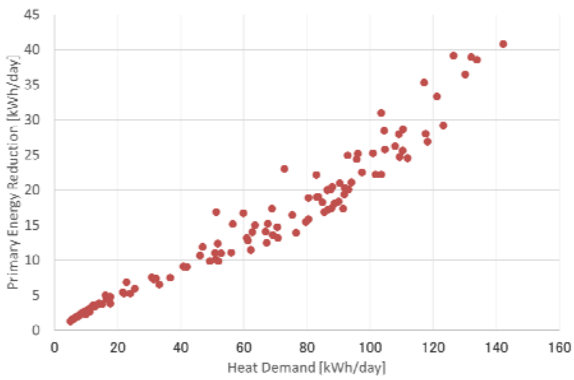

Fig.8 Relation between heat demand and primary energy reduction

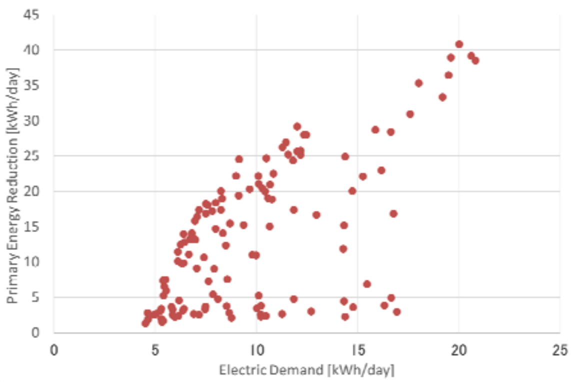

Fig.9 Relation between electric demand and primary energy reduction

Table 3 Difference between the systems using preheating for ventilation vs. normal type. (Numerical value of COREMO with preheating for ventilation – Numerical value of normal COREMO)

	Supplied Power from Gas Engine	Supplied Heat from Gas Engine	Operating Time for Gas Engine	Gas Consumption of Gas Engine	Gas Consumption of Condensing Boiler	Consumption of Primary Energy	CO_2 Emissions	Energy Costs (Electricity and Gas)
	kWh/year	kWh/year	h/year	Nm^3/year	Nm^3/year	kWh/year	kg/year	yen/year
Residence A	316	1,112	524	144	−109	−419	−137	−5,995
Residence B	99	570	289	67	−56	−133	−43	−1,807
Residence C	609	3,909	1,854	460	−382	−677	−241	−8,888
Residence D	156	1,145	546	132	−112	−173	−62	−2,405
Residence E	280	2,133	1,003	245	−208	−296	−108	−3,799
Residence F	814	4,495	2,108	540	−439	−942	−328	−12,585
Residence G	677	2,342	1,132	306	−229	−871	−289	−12,419
Residence H	53	464	215	53	−45	−52	−20	−808
Residence I	364	3,586	1,643	402	−350	−336	−131	−4,143
Residence J	195	1,404	665	163	−137	−209	−76	−2,790
Residence K	41	487	220	54	−48	−34	−14	−341
Average	328	1,968	927	233	−192	−376	−132	−5,089

2.7 Conclusions

The latest 2013 model COREMO has improved heat generation efficiency and it achieved a downsizing of 22% in volume. And useful functions, such as a power supply in case of blackouts and reheating the bath by using the exhaust heat, have been added to the latest model. These improvements have reduced another 70 kg of CO_2 emissions.

19 COREMO units were installed to residences in a town block, called “Eco Town North 48”, in Sapporo, and we conducted measurements in order to confirm the effects by introduction of the system. The exhaust heat from those COREMO is used for the ventilation warming, while exhaust heat from the system is used for hot-water heating in the usual case. The operating results after one year of installation showed that the amount of CO_2 reduction reached an average of about 1.1 tons/year, and energy cost, which includes electric power and gas were decreased by 60,400 yen (US$628 on Dec. 6th, 2013) annually, compared with the conventional type (commercial power + non-condensing boiler).

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