Appendix 1 Reference HOB and boiler efficiency

1. Methods and summary of researches

Research on boilers has been conducted to identify reference HOB and set default values of energy efficiency for reference HOB and project HOB in Mongolia.

1.1 Identification of reference HOB

"**Vertical type heat only boiler**" is determined as a reference HOB in Mongolia based on the following researches.

- Research on published information (see 2.1.1 for details)
- Interview with experts (see 2.1.2 for details)
- Field survey (see 2.1.3 for details)

1.2 Energy efficiency for reference HOB and project HOB

"**0.533**" is set **for reference HOB** and "**0.610**" is set **for project HOB** as boiler efficiency based on the following researches.

- Research on published information (see 2.2.1 for details)
- Actual measurement of boiler efficiency (see 2.2.2 for details)

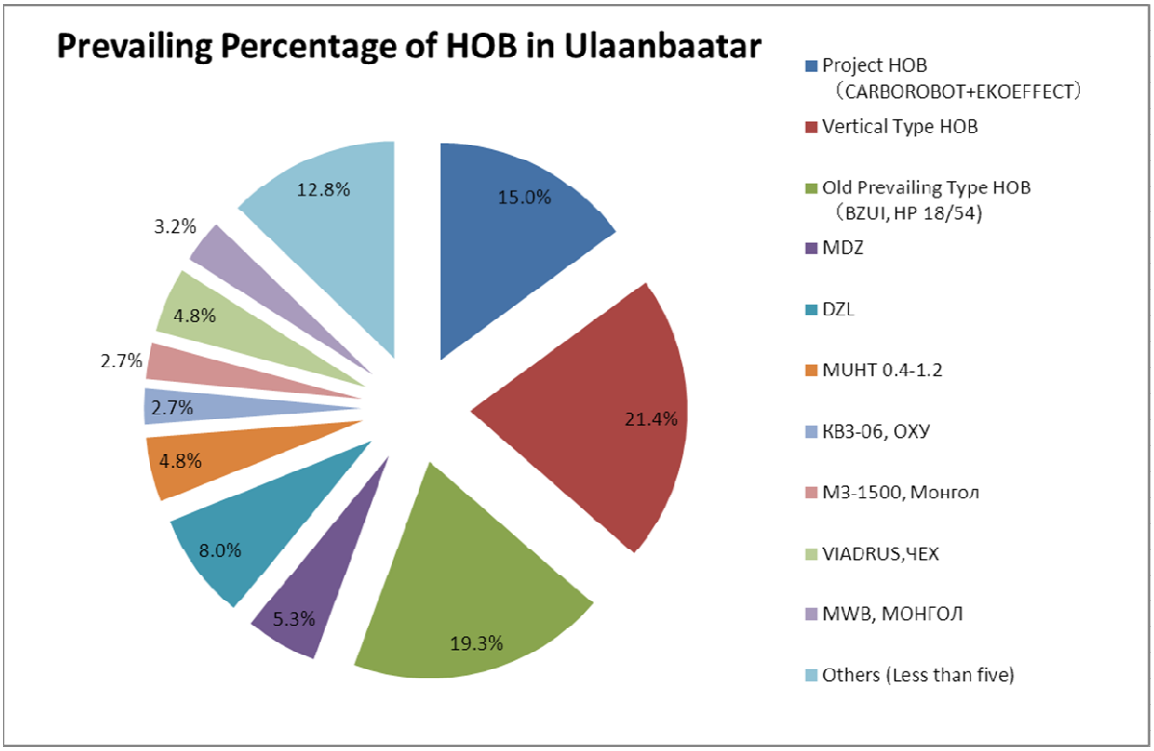
2. Detailed results of researches

2.1 Identification of reference HOB

2.1.1 Research on published information

Based on "National general registration of air pollutant emission sources in 2011" (АГААР БОХИРДУУЛАХ ЭХ YYCВЭРИЙН 2011 ОНЫ УЛСЫН НЭГДСЭН ТОО БҮРТГЭЛ) provided by "Government Implementing Agency for Meteorology & Environmental Monitoring", it is found that the vertical type HOB has the top market share of about 21%, and the old prevailing type HOB (brick boiler) also has a high share of 19% in central six districts of Ulaanbaatar city where almost half of the entire Mongolian population live. The central six districts are "Khan-Uul district", "Bayhanzurkh district", "Somginkohairkhan district", "Sukhbaatar district", "Chingeltei district" and "Bayngol district".

It is also found that boilers with energy efficiency higher than the vertical type and old prevailing type HOB have been installed in Ulaanbaatar, namely CARBOROBOT and EKOEFFECT (15%), DZL (8.0%), MDZ (5.3%) and so on. However, those high efficient boilers have been installed with financial assistance from foreign countries and international agencies.



[source] “National general registration of air pollutant emission sources in 2011”, Government Implementing Agency for Meteorology & Environmental Monitoring

2.1.2 Interview with experts

Interviews with four experts of HOBs in Mongolia have been conducted.

It is indicated by the experts that vertical type HOBs such as "CLSG" and "HP10/60Ж" are commonly used at the present day and will be continuously used in the near future.

Head of Heat Exchange and Thermodynamics Professor team, Director of Experiment and research center for boiler, Mongolian consulting engineer

The boiler which coal is manually loaded into a fixed fire grate by manual operation is suggested as a reference HOB. Since there are many types of HOBs in Mongolia, it is difficult to set the reference HOB as the type of HOB. However, it may be said that the vertical HOBs such as "CLSG" and "HP10/60Ж" are commonly used under the present circumstances of Mongolia.

Senior officer of Environmental Monitoring of Government Implementing Agency for Meteorology & Environmental Monitoring

Boilers made by bricks will decrease in the future. “CLSG” which is made in China and “HP10/60Ж” which is made in Mongolia are not expensive and are easily introduced.

Director of Millennium Challenge Account-Mongolia Energy and Environment Project

Old HOBs will be used continuously, or low price HOBs will be introduced easily without assistances of the foreign donor. Since there are many types of HOBs in Mongolia, it is difficult to identify them as reference HOB. Meanwhile, the concept, the vertical HOB is a reference HOB, is agreed.

Chairman of Consulting engineer of Mongolia Master of Technical science of Authority of partial engineering supply of Ulaanbaatar city

"BUZI100" which is made by bricks can be the candidate of reference HOB. However, a new construction of BUZI100 is prohibited in Ulaanbaatar city. It is expected that the low price HOBs such as the vertical type will be used commonly.

2.1.3 Field survey

The field survey of HOB was implemented in Lun soum, Bornuur soum, Erdene soum and Altanbulag soum in Tuv aimag.

It was found in this field survey that more than half of HOBs were the vertical type HOBs and all of the newly purchased boilers were also vertical type HOBs.

Table 1 Results of Field Survey of Operating Boilers in Local Areas of Mongolia

Type of HOB	Quantity	Remarks
Vertical Type Boiler	12	Example: HP10/60Ж, CLSG, etc. The newly purchased boiler was the vertical type boiler. <Information on new Installation > 2011 (Erdene soum): HP30Ж 2012 (Lun soum): HP30Ж 2013 (Bornuur soum): LSH
Brick Boiler	3	There is no new boiler installation.
Small Capacity Boiler	7	The quantity of this type of boiler is many in the supply to the small building. There is no new boiler installation.
Total	22	

2.2 Energy efficiency for reference HOB and project HOB

Further researches to determine the default value of reference and project boiler efficiency have been

conducted.

2.2.1 Results of the research on published information

The following is the result of the research on the published documents regarding boiler efficiency of HOBs in Mongolia.

The range of boiler efficiency varies from 20% to 63% for the existing classic designed HOBs and from 75% to 85% for the project (high efficient) HOBs in Mongolia in those documents.

Proposed CDM new methodology:NM0144-rev

Title of the NM144-rev: Energy efficiency improvements carried out by an Energy Service Company (ESCO) in Ulaanbaatar, Mongolia to replace old boilers with new ones (the Project)

Title of the project activity: Energy improvements carried out by an Energy Service Company (ESCO) in Ulaanbaatar, Mongolia to replace old boilers with new ones (the Project)

Source: http://cdm.unfccc.int/methodologies/PAmethodologies/pnm/byref/NM0144-rev

Boiler efficiency of 16 sample boilers was measured during 2003 to 2005 in Ulaanbaatar. 13 out of 16 samples fall into the capacity of HOB in Mongolian standard, which is between 0.10 to 3.15 MW.

1) Boiler Efficiency of Baseline (existing classic design HOB)

42% - 63% (range of 16 sample)

2) Boiler Efficiency of Project (new design HOB)

82.5% (predicted Project Boiler data)

Registered CDM project activity: Ref.0295

Title of the small-scale project activity: A retrofit programme for decentralized heating station in Mongolia

Source: http://cdm.unfccc.int/Projects/DB/RWTUV1150300431.15/view

Boiler efficiency of the existing decentralized heating stations in Ulaanbaatar was measured by TÜV Hanover in 2003. Further study on HOB boiler (810 kW and 1,200kW capacity) efficiency and the CDM project boiler was carried out by the Technical University of Ulaanbaatar.

1) Boiler Efficiency of Baseline (existing classic design HOB)

[From TÜV Hanover report]

40 %

[From study by the Technical University of Ulaanbaatar]
BZUI 100 (operating in eighty percent of Mongolia's heating stations) 34.04%
DTH 34.20%

2) Boiler Efficiency of Project (new design HOB)
[From study by the Technical University of Ulaanbaatar]
MZ 1500 84.80%

CARBON FINANCE in MONGOLIA 2011
Source:
http://www.cdm-mongolia.com/files/Final_Carbon%20Finance%20in%20Mongolia_2011.pdf#search=%27CARBON+FINANCE+in+MONGOLIA+2011%27

The document states that the average efficiencies of the baseline boilers are 40-50%, however, whether such values are based on the actual measurements or not is not stated.

1) Boiler Efficiency of Baseline (existing classic design HOB)
Average efficiency: 40-50 %

2) Boiler Efficiency of Project (new design HOB)
N/A

Preliminary Market Assessment for Heat-Only Boilers in Mongolia
Source: http://pdf.usaid.gov/pdf_docs/PNADC231.pdf

The document states that the baseline boiler efficiencies as follows, however, whether such values are based on the actual measurements or not is not stated.

1) Boiler Efficiency of Baseline (existing classic design HOB)
(< 100 kW) :20 – 40 %
(100 – 500 kW) :35 – 50%
(500 – 3 MW) :45 – 60 %
(3 – 30 MW) :55 – 60 %

2) Boiler Efficiency of Project (new design HOB)
New HOB (Mongolia) :55% (different type from the project HOB)

New HOB (Czech Republic)	:75%
New HOB (Austria)	:85%

2.2.2 Results of the actual measurement of boiler efficiency

Measurement of boiler efficiency was carried out to support the result of the research on the published documents to determine the default values of HOB boiler efficiencies.

1) Number of samples

Measurement was conducted on five project type HOBs and five reference type HOBs.[1] In total, sample numbers are 16 for the project type HOBs and 20 for the reference type HOBs.

The average monthly high/low temperature when HOB usually operates is shown in the table below. Since ambient temperature might be a factor to determine boiler efficiency, representative months have been chosen to measure boiler efficiency, which is October, November and December. It is anticipated that colder temperature will result in higher boiler efficiency, therefore, January is excluded from measurement samples.

Table 2 Average Monthly Temperature in Ulaanbaatar

	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Average High Temp C	8.1	-3.4	-11.9	-14.1	-8.9	-0.8	8.7
Average Low Temp C	-4.6	-14.4	-21.6	-25.0	-21.6	-13.8	-5.2

[Source: World Meteorological Organization web site]

2) Measurement methods

Theoretically, boiler efficiency can be derived from quantity of heat output divided by calorific input value. Thus, measurement was carried out on heat input and heat output of both project and reference type HOB. The value of heat input which is the total amount of heat supply is calculated by multiplying the amount of coal put into the HOBs and net calorific value of coal. The amount of coal put into the HOBs was measured using a certified spring scale, and net calorific value of coal was measured in the coal analysis. For the heat output which is the total amount of heat absorption in outlet hot water, the amount of heat supply was measured by verified heat meter or thermocouple and ultrasonic flow meter.

3) Measurement results of the project type HOB

Table 3 shows measurement results of the project HOB, in which catalog value of the boiler

[1] Feasibility/Demonstration Studies for New Mechanisms Project/Activities, Global Environment Centre Foundation http://gec.jp/main.nsf/en/Activities-Climate_Change_Mitigation-nmfsrepDB-List

efficiency is 80% or higher. Standard deviation has been analyzed for 12 measurement samples with a capacity of 0.10 MW – 1.00 MW, which is the scope of the proposed methodology, and then 11 data are found to be within the range of two times of standard deviation ($\mu \pm 2\sigma$). The average value is calculated to be 61.0% by averaging those 11 data.

Table 3 Actual measurement of boiler efficiency for the project HOB

Boiler No.	Type of Boiler	Site	Measurement Day	Measurement equipment	Boiler efficiency (%)
P1	CARBOROBOT 180kW	79th school	Oct. 30, 2012	Heatmeter	60.7
P2	CARBOROBOT 180kW		Oct. 31, 2012		63.1
P3	CARBOROBOT 180kW		Dec. 6, 2012		69.1
P4	CARBOROBOT 180kW		Dec. 7, 2012		67.5
P5	CARBOROBOT 300kW	35th school	Dec. 4, 2012	"Thermocouple-type thermometer" + "Ultrasonic Flowmeter" (TUF)	64.5
P6	CARBOROBOT 300kW		Dec. 5, 2012		61.2
P7	CARBOROBOT 180kW	79th school	Nov. 18,2013	Heatmeter	56.2
P8	CARBOROBOT 180kW	79th school	Nov. 19,2013		57.0
P9	CARBOROBOT 180kW	79th school	Nov. 27,2013		81.1*
P10	CARBOROBOT 180kW	79th school	Nov. 28,2013		56.8
P11	CARBOROBOT 180kW	79th school	Dec. 16, 2013		56.8
P12	CARBOROBOT 180kW	79th school	Dec. 20, 2013		58.2
The average value of all data					62.6
The average value of data excluding one value (P9) which is not within the range of two times of standard deviation ($\mu \pm 2\sigma$)					61.0

* 81.1% is found to be not within the range of two times of standard deviation ($\mu \pm 2\sigma$).

4) Measurement results of reference HOBs

Table 4 shows measurement results of the reference HOBs. Although the capacities of boilers measured are unknown because model numbers describing their specifications were missing for old type boilers, they are assumed to be below a capacity of 1 MW from sizes of their bodies and load of facilities which heat is supplied. It is also common in Mongolia that small capacity boilers are installed in parallel to cover large heat capacity and to continue to supply heat in case of emergency.

17 samples have been taken and those sample values fall into the range of 37.1% to 63.8%. To assess dispersion of 17 sample data, standard deviation has been analyzed, and then 16 data are found to be within the range of twice the standard deviation ($\mu \pm 2\sigma$).

Table 4 Actual measurement of boiler efficiency for the reference HOBs

Boiler No.	Type of Boiler	Site	Measurement Day	Measurement equipment	Boiler efficiency (%)
R1	CLSG	TAVAN GAN TRADE LLC	Dec. 11, 2012	Heatmeter	53.4
R2	CLSG		Dec. 19, 2012		42.8
R3	CLSG		Nov. 1, 2012	"Thermocouple-type thermometer" + "Ultrasonic flowmeter" (TUF)	40.1
R4	CLSG		Nov. 2, 2012		40.6
R5	HP	87th school	Dec. 7, 2012		49.6
R6	HP	SEN-1 residence	Dec. 4, 2012		40.7
R7	HP		Dec. 10, 2012		43.6
R8	HP	79th school	Nov. 20, 2013	Heatmeter	60.0
R9	HP	79th school	Nov. 26, 2013		63.8
R10	HP	79th school	Nov. 27, 2013		37.1
R11	HP	79th school	Nov. 28, 2013		43.2
R12	HP	79th school	Dec. 16, 2013		51.4
R13	HP	79th school	Dec. 19, 2013		53.2
R14	HP	79th school	Dec. 20, 2013		45.0
R15	CLSG	TAVAN GAN TRADE LLC	Nov. 28, 2013		54.0
R16	CLSG	TAVAN GAN TRADE LLC	Dec. 18, 2013		44.0
R17	CLSG	TAVAN GAN TRADE LLC	Dec. 23, 2013		50.9
The average value of all data					47.8
The average value of data excluding one value (R9) which is not within the range of two times of standard deviation ($\mu \pm 2\sigma$)					46.9
The average value of data excluding one value (R9) which is not within the range of two times of standard deviation ($\mu \pm 2\sigma$), and excluding nine value (R2, R3, R4, R6, R7, R10, R11, R14, R16) which is less than the abovementioned average value (46.9)					53.3

2.2.3. Conclusion on energy efficiencies of HOB from the researches

1) Boiler efficiency for the reference type HOB

It should be emphasized that catalog efficiency of boiler whose capacity ranges from 0.10 MW to 3.15 MW is no less than 75% since 2001, which is required by the Mongolian national standard, MNS 5043:2001, which implies;

- The existing old type boilers which may have lower boiler efficiency can be used continuously, however,
- Only boilers with catalog efficiency of no less than 75% can be newly installed.

Therefore, the vertical type HOB with catalog efficiency of no less than 75% is defined as the reference HOB.

Although there are some published research results regarding boiler efficiency of HOBs in Mongolia, it is not clearly stated in those documents that sample boilers have catalog efficiency of no less than 75%, and whether the values are actually measured or taken from manufacturer's specification. Therefore, actual measurement of vertical type HOBs with catalog efficiency of no less than 75% shown in Table 4 are used to determine a default value of the boiler efficiency for reference HOBs. The average value is calculated excluding one data (63.8%) which is not within the range of two times of standard deviation. Accordingly, the average value is calculated to be 46.9% by averaging 16 data. Then, another average value is calculated excluding nine more data which is less than the average value calculated above to ensure conservativeness. The obtained value of 53.3% is regarded as a default value of the boiler efficiency for reference HOBs set in a conservative manner.

The measured sample data from "*Proposed CDM new methodology:NM0144-rev*" can also be reliable since the data has been validated by DOE under the Kyoto Mechanism before being published on UNFCCC CDM website. 7 out of 16 samples shown in Table 5 meets the condition of HOB capacity scoped in the proposed methodology which is below 1.0 MW. The average value of those 7 samples is 51.0%. It should be noted that all sample boilers were installed before MNS 5043:2001 became effective, and catalog efficiency is not obtained, implying that these samples cannot be used as the boiler efficiency for reference HOBs according to its definition.

Another reliable data can be derived from boiler efficiency values assumed in the registered CDM project, Ref.0295. The values fall into the range of 34.04% - 40.0% and are validated by DOE under the Kyoto Mechanism.

As a result of comparing these data from there different sources, **it is concluded that it is conservative to determine the boiler efficiency for reference HOBs as 53.3%**, the highest value obtained in actual measurement and research on published information.

Table 5 Measured data of baseline boiler efficiency under CDM

Boiler No.	Capacity of Baseline boiler (kW)	Location	Baseline boiler efficiency (%)
1	884	Ulaanbaatar	42.0
2	1,768	Ulaanbaatar	44.0
3	872	Ulaanbaatar	43.0
4	4,885	Ulaanbaatar	53.0
5	884	Ulaanbaatar	58.0
6	884	Ulaanbaatar	57.0
7	884	Ulaanbaatar	60.0

8	3,536	Ulaanbaatar	55.0
9	884	Ulaanbaatar	43.0
10	1,768	Ulaanbaatar	59.0
11	1,326	Ulaanbaatar	50.0
12	884	Ulaanbaatar	49.0
13	1,326	Ulaanbaatar	47.0
14	5,164	Ulaanbaatar	57.0
15	1,768	Ulaanbaatar	63.0
16	1,768	Ulaanbaatar	48.0

2) Boiler efficiency for the project type HOBs

In addition to the fact that there is not enough data from published information to determine boiler efficiency for the project type HOBs, those values might as well be manufactures' specification values which tend to be higher than actual performance of the boilers.

Therefore, for the purpose of securing conservativeness of the methodology, the actual measured values are selected as **the default value for project type HOB, which is, as explained in section 2.2.2, 61.0%**. As such, the default value of the project type HOB is estimated to be much less than the values in the published documents.