ADB

Technical Assistance Consultant's Report

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Mongolia: Updating the Energy Sector Development Plan

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Prepared by E. Gen Consultants Ltd. Bangladesh in association with MVV decon GmbH, Germany, and Mon-Energy Consult, Mongolia

For Ministry of Energy, Mongolia

Asian Development Bank

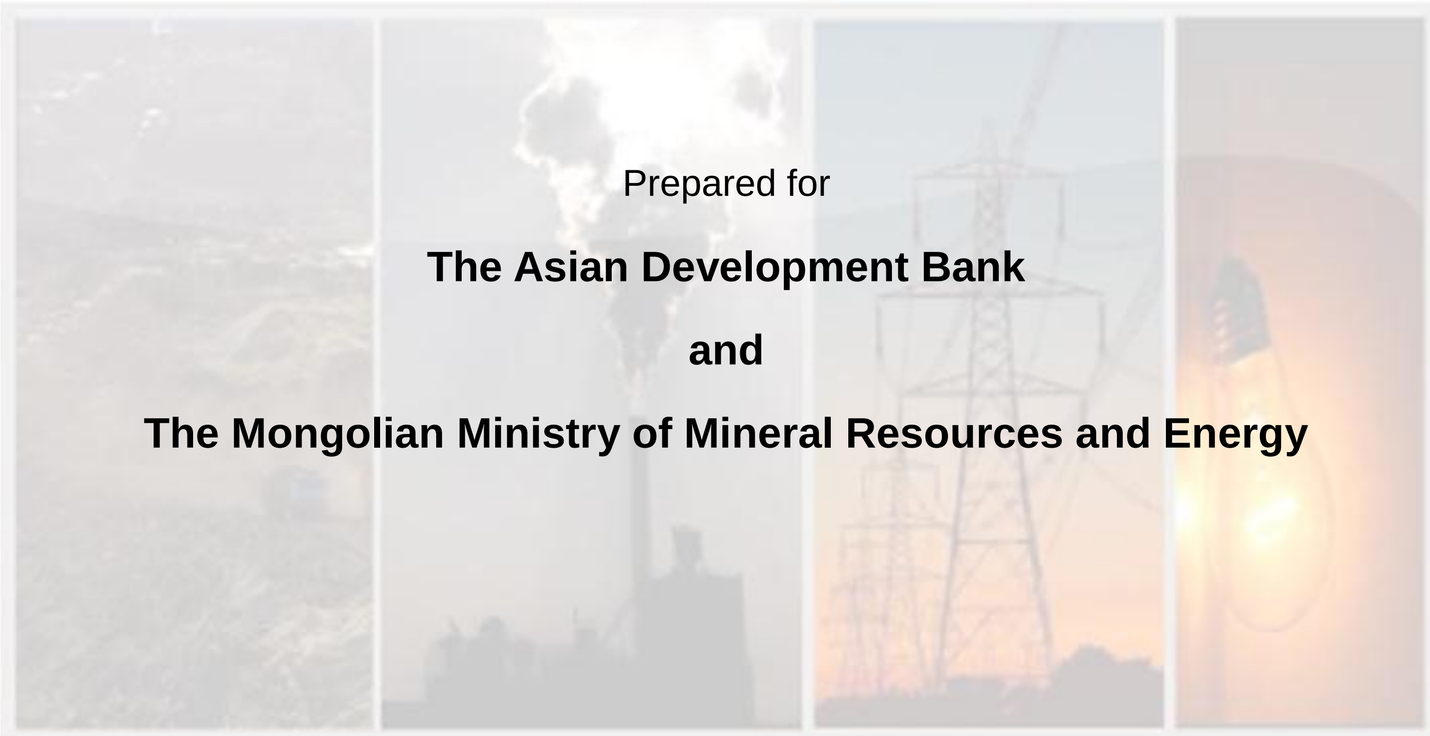
Updating Energy Sector Development Plan

Project Number: TA No. 7619-MON

FINAL REPORT

PART C: Volume - VII of X

AIMAG HEAT EXPANSION PLANS



Prepared for

The Asian Development Bank

and

The Mongolian Ministry of Mineral Resources and Energy

Prepared by

e•gen
empowering people

e.Gen Consultants Ltd.

in association with

MONENERGY CONSULT

19 October 2013

CURRENCY EQUIVALENTS

(As of April 2012)

Currency Unit	–	Tugrik (MNT)
USD 1.00	=	1,309 MNT
EUR 1.00	=	1,725 MNT
USD 1.00	=	0.759 EUR

ABBREVIATIONS

ADB	–	Asian Development Bank
AuES	–	Altai-Uliastai Energy System
CES	–	Central Energy System
CHP	–	Combined Heat Power
CO_2	–	Carbon Dioxide
CPI	–	Consumer Price Index
ERES	–	Eastern Energy System
EUR	–	European currency unit EURO
GHG	–	Greenhouse Gases
HOB	–	Heat Only Boilers
IDC	–	Interest during construction
LCOE	–	Levelized Cost of Energy
MoE	–	Ministry of Energy
MNT	–	Mongolian Tugrik
NOx	–	Nitrogen Oxides
O&M	–	Operation and Maintenance
PPA	–	Power Purchase Agreement
PV	–	Photovoltaic
SOx	–	Sulfur Oxides
USD	–	United States Dollars
VAT	–	Value Added Tax
WACC	–	Weighted Average Cost of Capital
WRES	–	Western Energy System

UNITS OF MEASURE

GCal	-	Gigacalorie (one million kilocalories)
GJ	-	Gigajoule (one thousand megajoules)
kJ	-	Kilojoule
kWh	-	Kilowatt-hour
MWh	-	Megawatt-hour
MWel	-	Megawatt electric
MWth	-	Megawatt thermal
PJ	-	Petajoule
TSC (TPU)	-	Tons of standard coal
TJ	-	Terajoule

WEIGHTS AND MEASURES

GW (giga watt)	–	1,000,000,000 calories
GJ (giga joules)	–	1,000,000,000 joules
GW (giga watt)	–	1,000,000,000 watts
kVA (kilovolt-ampere)	–	1,000 volt-amperes
kW (kilowatt)	–	1,000 watts
kWh (kilowatt-hour)	–	1,000 watts-hour
MW (megawatt)	–	1,000,000 watts
W (watt)	–	unit of active power

CONVERSION FACTORS

1 GCal	=	4.19 GJ
1 BTU	=	1.05506 kJ
1 Gcal	=	1.1615 MWh = 4.19 GJ = 1.75 steam tons/hour
1 GJ	=	0.278 MWh = 0.239 Gcal = 0.42 steam tons/hour
1 MW	=	0.86 Gcal/hour = 3.6 GJ = 1.52 steam tons/hour
1 TSC	=	7 Gcal = 29.3 GJ = 8.15 MWh

CONTENTS

I. INTRODUCTION

A. Scope

1. The justification for Aimag heating system expansion is based on a comparison of modern new heating technologies against the existing DH systems. The justification takes into account both financial and environmental considerations.

2. Centralized heating production technologies are considered in the capacity range of 5 to 75 MW. Technology options are as follows:-

- Heat Only Boilers (HOB)
- Engine CHP (Mazut)
- On-site Coal Fired CHP

3. Comparison between modern and existing systems is considered first in general way and then separately for the following Aimag town centres based on the specific data from each town centre.

4. The Aimag centres considered are as follows:-

- Altai (Govi-Altai)
- Arvaiheer (Uvurhangai)
- Bayankhongor (Bayanhongor)
- Baruun-Urt (Sukhbaatar)
- Bulgan (Bulgan)
- Zuunmod (Tuv)
- Mandalgovi (Dundgovy)
- Muren (Huvsgul)
- Ulgii (Ulgii-Bayan)
- Ondorhaan (Hentii)
- Sainshand (Domogovi)
- Suhbaatar (Seleng)
- Ulaangom(Uvs)
- Uliastai (Zavhan)
- Hovd (Hovd)
- Tsetserleg (Arhangai)
- Choir (Govy-Sumber)
- Nailakh
- Baganuur
- Choibalsan
- Dalanzadgad

5. The function of the general heat supply model is to determine if DH-based centralized production options are competitive when compared to consumers alternatives, in particular individual boiler alternatives (in this study only coal-fired individual boilers are taken into account). Also, to determine at which point heat demand and heat intensity level would justify a CHP/DH solution in Mongolia. In addition, the general approach illustrates how modern technology improves energy efficiency and reduces CO_2 emissions compared to existing inefficient systems.

6. An Aimag-specific heat supply model has been designed to determine the most suitable heat supply system for a given Aimag, from a financial and environmental point of view.

II. CENTRALIZED DISTRICT HEATING

B. Cost Assumptions

7. The default cost of coal used in financial evaluation is as follows:-

- Overground cost of MNT 23,713 ($18) for coal of 3,232 kcal/kg
- Transport cost of road transport at 250 MNT/ton, km

8. Cost assumptions for Mazut are as follows:-

- Overground cost of MNT 1,097.7 thousands per ton (844 $/ton)
- Transport cost of MNT 56,000 (equal to 200 km of transport at 280 MNT/ton, km, 0.22 USD/ton, km)

9. Fuel characteristics for Mazut and coal are presented in the following table.

Table II-1: Fuel Characteristics

Fuel	Cal value Gcal/ton	Cal value MWh/ton	Cal value MJ/kg	CEF t C/TJ	IPCC[1] CEF[2] t C/TJ	FOC	$CO_{2,\,ton}$ / TJ	$CO_{2,\,ton}$ / ton
Mazut	9.71	11.28	40.58		21.20	0.99	76.96	3.12
Coal	3.23	3.75	13.54	27.61	27.60	0.98	99.18	1.34

Sources: Consultants' analysis

10. The total costs of these fuels according to the assumptions presented above and including 200 km of transport are as follows:-

- $15 /MWhFuel for coal; and
- $79 /MWhFuel for Mazut.

11. The EPC unit costs (for heat) have been determined by benchmark analyses of each technology, taking into account capacity scale effects. An equation corresponding to a 'best fit' cost line is used to calculate the total EPC costs of heat production for both the general and Aimag-specific models.

12. The following assumptions were used to derive the costs for Mongolian markets:-

- A 40% reduction in EPC cost in relation to western cost for biomass CHP plants;
- A CHP production cost allocation on basis of heat at 20% and power at 80% of the EPC cost;
- Fuel costs calculated by using a heat rate (in cogeneration there are separate heat rates for heat and power; only the heat rate for heat production are presented); and

[1] The IPCC default values 25.8, 26.2 and 27.6 tC/TJ for bituminous coal, sub-bituminous coal and lignite, respectively, correspond to the following net calorific values: 23.5, 20 and 13.5 MJ/kg.

[2] The CEF of coals and lignite are dependent especially on the net calorific value (lower heating value). For determination the representative values of CEF values of hard or brown coals in a given European country or region, it is recommended to employ formula using the equation of CEF = 10 (a Qi + b)/Q with parameters: a = 2.334 (%C kg/MJ) and b = 5.786 (%C) corresponding to data set E.

- O&M costs were based on general industry benchmarks and vary in relation to technology choice only slightly.

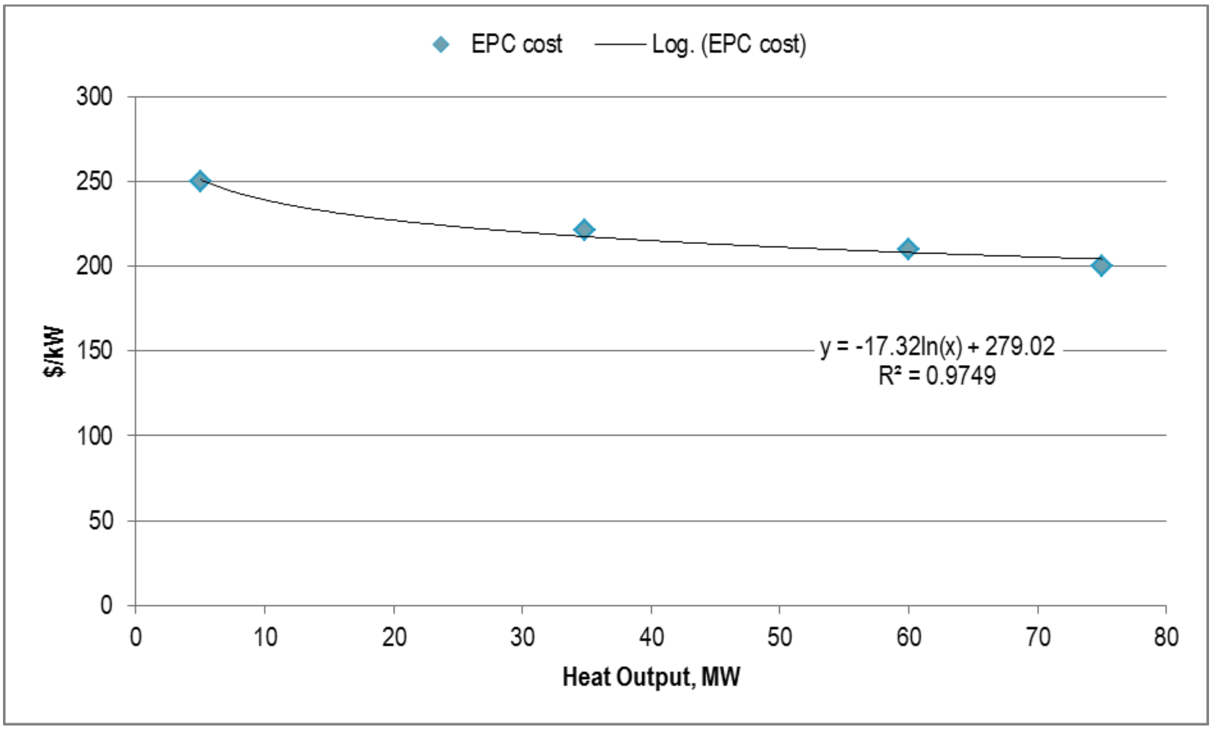
13. Total installed costs are annualized with the following assumptions.

- With 6% interest rate for all installed costs;
- 50 year calculation period for DH network;
- 20 year calculation period for centralized heating production capacity; and
- 15 year calculation period for customers' individual boilers.

C. Heat Only Boiler (HOB; Coal-fired)

14. The reference costs for HOBs were derived from a real Mongolian project comprising a HOB plant of 3 × 11.6 MW (35 MW); the total cost was 10 billion MNT. The equation shown in Figure II-2 is used to calculate EPC unit costs for different capacities as shown in Table II-3.

Figure II-2: EPC Cost for Coal – Fired Heat Only Boiler



Sources: Consultants' analysis

Table II-3: Assumptions for HOB Production

Heat Only Boiler (Coal-fired)					
Fuel capacity	MW	5.6	38.7	66.7	81.0
Heat output, hot water	MW	5.0	34.8	60.0	75.0
Boiler efficiency	%	90	90	90	90
Heat rate, DH		1.11	1.11	1.11	1.11
Total EPC cost	1,000 USD	1 625	10 000	16 380	19 500

Heat Only Boiler (Coal-fired)					
EPC Cost	USD/kW, Heat	250	221	210	200
Fixed O&M Costs	%Capital	3.0%			
Variable O&M Cost	$/MWh	2.00			

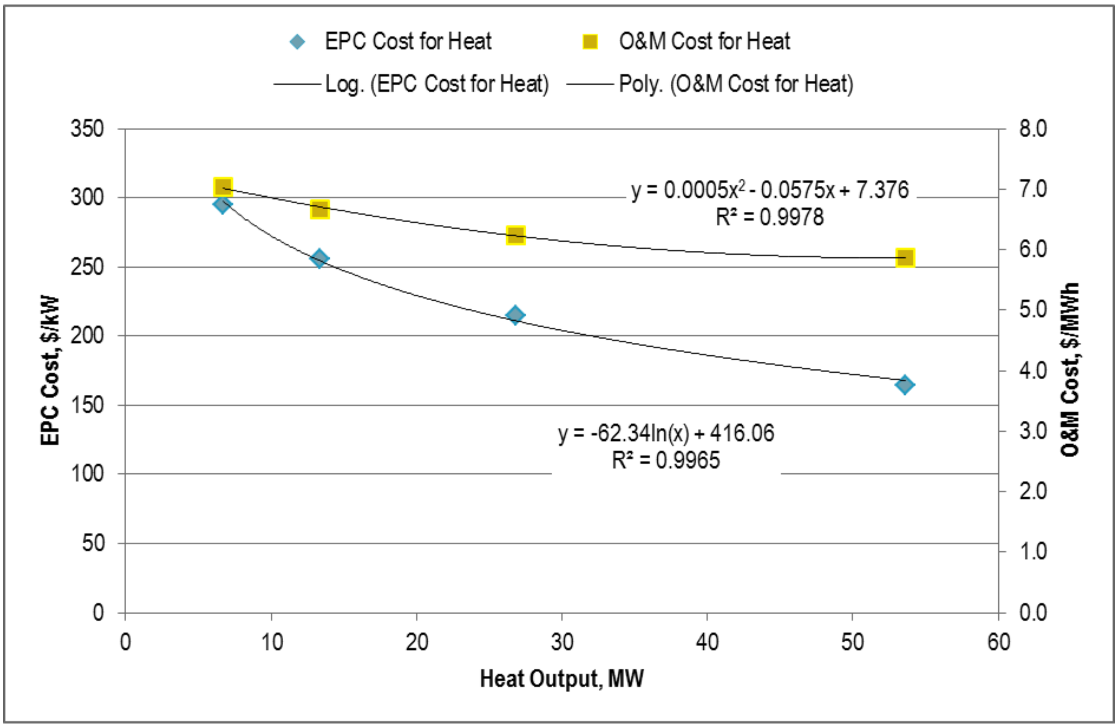
Sources: Consultants' analysis

D. Engine CHP (Mazut)

15. A diesel engine based CHP plant is an alternative to the replacement of HOBs, diesel engines or a high-cost electricity transmission connection. Diesel engines have good load following and peaking capacity properties; they start fast, demonstrate high availability and have high part-load efficiency. With these characteristics, reciprocating engines are suitable for small isolated systems. The main disadvantage is that they have relatively high emission levels of NOx and particulates when using liquid fuels such as Mazut.

16. There are four potential sources of heat in a reciprocating engine. Heat can be recovered from flue gases in heat recovery steam generator or heat exchanger; from engine jacket cooling water; from lube oil cooling; and from turbocharger cooling. Only about half of the heat can be recovered from flue gases as medium pressure steam. The rest from the cooling circuits is in the form of hot water. Overall, the temperatures are fully sufficient for space heating and domestic hot water purposes. Power to Heat ratios of diesel engine based CHP plants range from 0.6 to 1.3.

Table II-4: EPC and O&M Costs for Engine CHP



Sources: Consultants' analysis

17. A single engine 8 MWe mazut-fuelled CHP plant is assumed with a total thermal efficiency of 75% in cogeneration, and efficiency is electricity-only mode of 42%.

18. Table II-5 summarizes the technical and financial characteristics for engine based CHP

heat production. The values are based on Wartsilä's W20V32 engine type and tailored for Mongolian circumstances and Mazut fuel.

Table II-5: Assumptions for Engine CHP

Engine CHP					
No of engines		1	2	3	4
Fuel power	MW	20.38	40.90	81.22	162.53
Net power output	MWe	8.60	17.30	34.60	69.40
Heat output (60/110 °C)	MW	6.70	13.40	26.80	53.60
Power to Heat ratio		1.28	1.29	1.29	1.29
Net electrical efficiency[3]	%	42.2	42.3	42.6	42.7
Heat efficiency	%	32.9	32.8	33.0	33.0
Total thermal efficiency	%	75.1	75.1	75.6	75.7
Heat rate, net electricity		1.06	1.06	1.06	1.06
Heat rate, DH		1.68	1.69	1.67	1.66
Total EPC cost	1,000 USD	9,890	17,127	28,821	44,138
EPC cost for heat (20 % of total)	1,000 USD	1,987	3,425	5,764	8,828
EPC Cost for Heat	USD/kW, Heat	295	256	215	165
O&M Cost for heat	$/MWh	7.03	6.67	6.24	5.86

Sources: Consultants' analysis

19. The O&M cost for heat is assumed to vary moderately within the installed total capacity. The costs shown in Table II-4 are allocated for heat as 20% of the total EPC cost.

E. On-Site Coal-Fired CHP

20. EPC costs and technical output values for the two smallest plants in Table II-6 are based on the budgetary information for biomass CHP plants for western markets. Values for the largest plants are derived from the existing biomass CHP plant market in Finland.

21. Technical design values are based on backpressure turbines with a hot water temperature of 90 °C; if hot water temperature was increased, it would mainly affect the electricity output of the plant.

22. The costs in

[3] At step-up transformer outlet

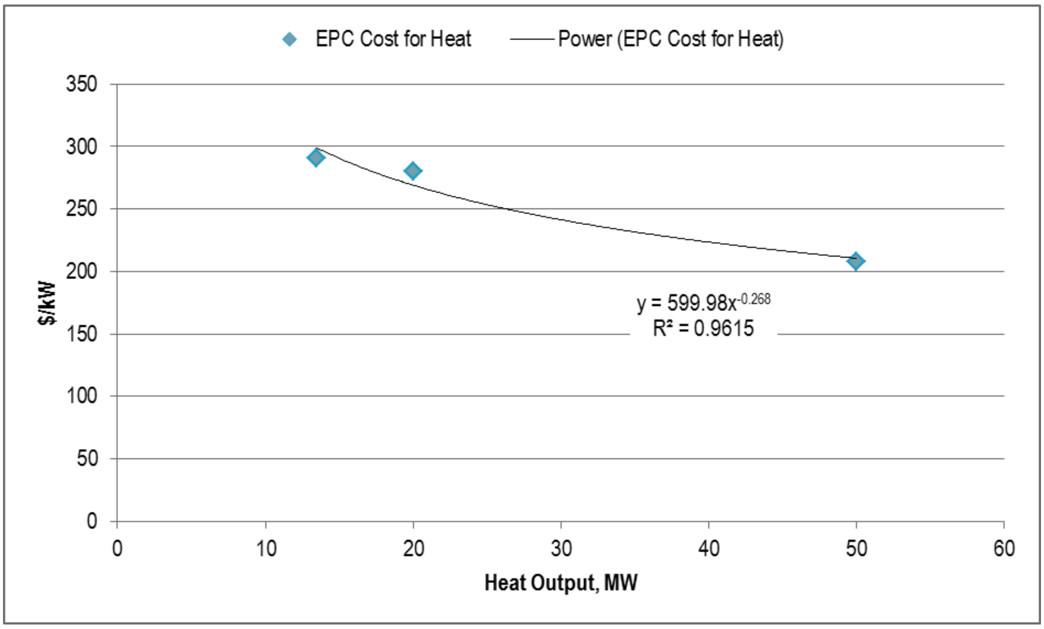
23. Table **II-6** are also allocated to heat at 20% of total EPC cost.

Table II-6: Assumptions for Coal-Fired CHP

On-site coal fired CHP				
Fuel capacity	MW	20.0	32.2	81.0
Boiler output	MW	18.0	29.0	72.5
Boiler efficiency	%	90.0	90.0	89.5
Net output	Mwe	3.8	8.0	21.0
Heat output, hot water 50/90 °C	MW	13.5	20.0	50.0
Power to Heat ratio		0.28	0.40	0.42
Total thermal efficiency incl. plant own electricity use	%	86.5	86.9	87.7
Heat rate. DH		1.11	1.11	1.12
Total EPC cost	1.000 USD	19,616	28,022	52,009
EPC cost for heat (20 % of total)	1.000 USD	3,923	5,605	10,402
EPC Cost for Heat	USD/kW, Heat	291	280	208
Fixed O&M Costs	(%Capital)	2.0%		
Variable O&M Cost	($/MWh)	1.00		

Sources: Consultants' analysis

Figure II-7: On-Site Coal-Fired CHP $/kW



Sources: Consultants' analysis

F. Individual Coal-Fired Boilers

24. Table II-8 summarizes the assumptions used for the consumer's alternative (individual coal fired boilers), namely the use of an individual boiler for heat production.

Table II-8: Individual Boiler

Boiler efficiency	85 %	
Heat rate	1,18	
Fixed O&M	4 %	/Capital
Variable O&M	3,50	$/MWh
Boiler investment	250	$/kW, every 15 years

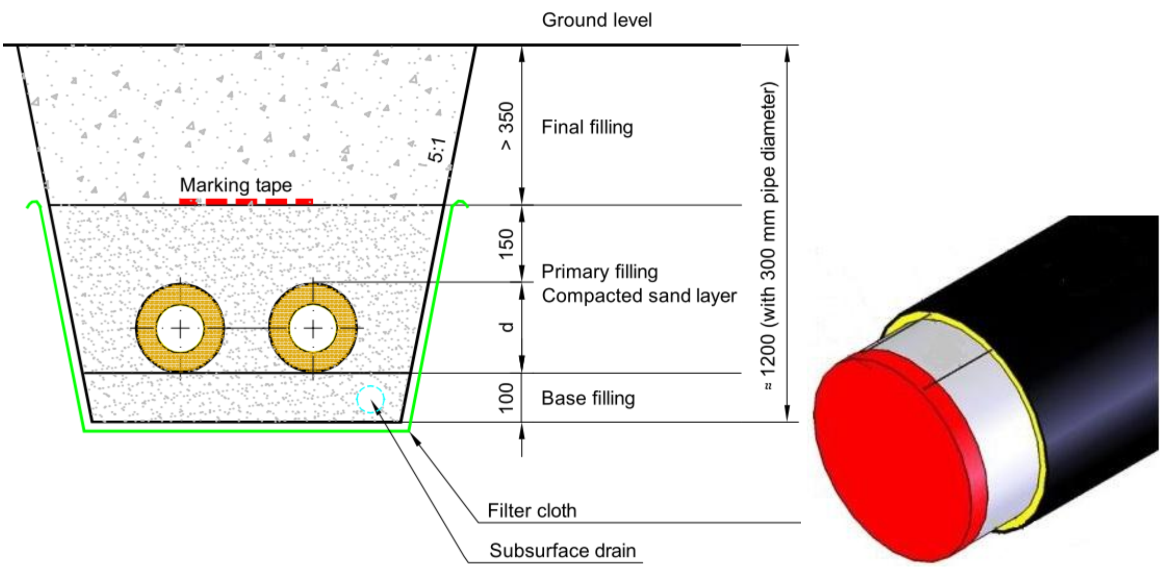
Sources: Consultants' analysis

G. District Heating Network & Consumer Substations

25. District heating pipeline costs are presented in Table II-10. Costs are based on the pre-insulated DH-pipelines' average construction costs in Finland. It has been assumed that a 40% reduction in cost would apply to the Mongolian market, compared to the market costs in Finland. Total construction costs of DH pipeline include civil engineering, installation and material.

26. All costs are per trench length including both flow and return pipelines. Figure II-9 illustrates a typical installation of district heating pipelines in a trench.

Figure II-9: Typical Installation of District Heating Pipelines in Trench



Sources: Consultant

27. District heating network weighted average pipeline cost (last column of the table) is calculated according to maximum pipe diameter of the network by the following equation:-

Price of maximum diameter × 60% + Price of one size smaller than maximum × 20% + Price of two size smaller than maximum × 20%

Table II-10: District Heating Pipeline Costs

Pipe diameter		Network Average Pipeline Cost by Maximum Diameter of the System
Mm	$/m, trench	$/m, trench
20	121.73	
25	163.11	
32	163.11	154.84
40	165.55	164.57
50	165.55	165.06
65	186.65	178.21
80	186.65	182.43
100	228.85	211.97
125	253.19	235.01
150	253.19	248.32
200	284.03	271.69
250	353.01	319.25
300	503.95	429.78
400	683.29	581.37
500	706.02	661.06

Sources: Consultants' analysis

28. O&M cost for the DH network have been assumed to be $1/m (total pipeline length) including also the O&M cost for customers' substations. The abovementioned cost is a statistical cost for Finnish DH networks, but for Mongolia a cost reduction of 40% has been applied.

29. Downstream transmission losses are assumed to be 6% in new systems.

30. Each of the consumer buildings would be connected to the DH network with a consumer substation unit, in a hydraulically separated manner. A substation unit comprises all the necessary equipment for heating connection and for domestic hot water preparation. Consumer substations typically comprise two heat exchangers – one for heating and the other for centralized, instantaneous DHW production – complete with all necessary pumps, controls and valves. A typical DH substation with main equipment is presented in Figure II-11.

31. The customers' DH substation cost at the consumer end has been assumed to be $4,000 per 600 kW (includes metering).

Figure II-11: Consumer Substation (Indirect Style)

Sources: IEA DHC Handbook

III. AIMAG HEATING SYSTEMS

H. Aimag Heating System Utilization

32. Table III-1 and Table III-2 summarizes the existing Aimag DH systems and the systems after refurbishment (when all components of the system are replaced) between years 2012 and 2020.

33. The peak utilization factor is simply calculated as production capacity on annual heat production. Annual heat production is calculated from heat consumption by using the downstream capacity loss (%), as presented in Table III-1.

34. There are some cases where the production capacity of the Aimag heating system is lower than the heat demand established by modelling. In these cases, the quality of the heat service received by consumers will be very poor during times of peak demand with room temperatures falling below 18 °C. The situation will be controlled to the extent that consumers refrain from siphoning hot water for domestic use whenever the temperature is at its lowest point during the heating season, say less than -30 °C. Nevertheless these heating systems remain a priority for capacity upgrade.

35. Rated capacity represents that modelled heating capacity required to keep room temperature at pleasing level, for example at 21 °C, at the lowest outdoor temperature during the heating season. Table III-1 represents DH systems corresponding that all components of the system are replaced with modern technology.

36. Rated capacities and demands of the heating systems are now calculated with the downstream capacity losses of 6%.

37. Heat intensities (heat demand, MW / Total pipe length of DH network, km) have also been updated compared to Table III-1, as the length of the DH network remains unchanged and because refurbishment will bring lower downstream capacity losses. In the general model, DH costs are calculated based on minimum, average and maximum heat intensity. Heat intensities are 0.85 MW/km (minimum), 2.40 MW/km (average) and 5.06 MW/km (maximum).

38. The maximum pipe dimensions of the systems have been estimated according to the updated heat intensities of Table III-2.

Table III-1: Existing Aimag Heating Systems -2012

Aimag Center	DH Network (pipe length)	DH Pipe Max Dia	Heat Intensity	Max Demand		Heat Loss		Production Capacity	Rated Capacity	Annual Production	Annual Heat Cons	Peak utilization	Annual Coal Cons
	km	DN	MW/km	Gcal/h		Gcal/h	%	Gcal/h	Gcal/h	Gcal/a	Gcal/a	h/a	tons
Baruun-Urt	5.6	200	2.09	10.1		7.4	42%	17.5	17.5	52,356	30,217	2,992	30,000
Bayankhongor	7.4	150	1.71	10.9		2.5	19%	13.4	13.4	40,753	33,150	3,041	25,900
Bulgan	7.5	150	1.05	6.8		6.6	49%	13.4	14.0	45,126	22,900	3,368	32,580
Zuunmod	24.0	200	0.95	19.7	-	3.8	-24%	15.9	25.8	51,352	63,625	3,230	50,000
Mandalgov	12.8	250	0.64	7.0		4.5	39%	11.5	16.4	32,612	19,851	2,836	19,085
Muren	19.3	150	1.11	18.5		7.7	29%	26.2	31.5	94,347	66,619	3,601	29,300
Ulgii	9.2	300	1.41	11.2		6.8	38%	18.0	25.8	53,508	33,294	2,973	31,200
Ondorhaan	17.5	150	0.64	9.6		3.6	27%	13.2	16.5	32,523	23,653	2,464	24,700
Sainshand	10.0	350	1.36	11.7		7.2	38%	18.9	30.2	55,416	34,305	2,932	35,100
Suhbaatar	6.5	400	1.80	10.1		13.4	57%	23.5	33.6	70,307	30,217	2,992	33,600
Ulaangom	3.5	250	4.12	12.4		7.6	38%	20.0	28.6	60,584	37,562	3,029	28,100
Uliastai	14.1	250	0.92	11.2		2.2	16%	13.4	18.1	43,237	36,138	3,227	34,700
Hovd	7.6	350	2.26	14.8		9.2	38%	24.0	34.3	64,322	39,665	2,680	33,600
Tsetserleg	4.5	150	2.01	7.8		2.8	26%	10.6	14.4	33,175	24,412	3,130	21,900
Choir	4.7	250	2.03	8.2		3.4	29%	11.6	13.5	22,827	16,136	1,968	16,500
Nailakh	8.8	400	4.05	30.7		3.4	10%	60.0	34.1	99,100	89,190	1,652	56,534
Baganuur	21.8	700	5.58	104.7		11.6	10%	170.0	116.3	162,700	146,430	957	65,658
Choibalsan	71.4	500	1.05	64.6		11.4	15%	93.2	76.0	187,241	159,155	2,009	284,700
Dalanzadgad	23.8	250	0.26	5.3		0.9	15%	10.9	6.2	16,021	13,618	1,470	24,359
Sum	**293**			**393.0**		**120.4**		**614.8**	**610.2**	**1,296,465**	**967,273**		**914,817**
Average	**14**	**274**	**1.82**	**18.7**		**5.7**	**28%**	**29.3**	**29.1**	**61,736**	**46,061**	**2,657**	**43,563**

Table III-2: Aimag Heating Systems After Refurbishment - 2025

Aimag Center	Heat Intensity	Increase in HI	DH Max Pipe Dia	Rated Max Demand		Rated Capacity		Downstream Capacity Loss		Annual Production	Peak utilization	Coal price	Distance to coal
	MW/km	MW/km	DN	MW	Gcal/h	MW	Gcal/h	%	Gcal/h	Gcal/a	h/a	MNT/ton	km
Baruun-Urt	2.16	-	300	14.3	12.3	15.2	13.1	6%	0.8	39,740	3,037	14,400	35
Bayankhongor	1.82	-	150	15.1	13.0	16.1	13.8	6%	0.8	42,399	3,066	12,727	90
Bulgan	1.38	0.06	150	10.1	8.7	10.7	9.2	6%	0.6	30,484	3,304	26,500	758
Zuunmod	4.63	1.78	250	52.8	45.4	56.1	48.3	6%	2.9	100,155	2,072	36,194	45
Mandalgov	0.85	0.25	300	12.9	11.1	13.7	11.8	6%	0.7	23,780	2,010	34,847	300
Muren	3.36	0.56	200	36.6	31.5	38.9	33.5	6%	2.0	102,213	3,050	70,401	217
Ulgii	3.30	1.00	400	21.8	18.8	23.2	20.0	6%	1.2	41,865	2,096	19,500	140
Ondorhaan	2.33	0.47	250	22.4	19.3	23.8	20.5	6%	1.2	44,091	2,153	23,742	59
Sainshand	2.11	0.79	400	24.9	21.4	26.5	22.8	6%	1.4	42,504	1,866	16,430	220
Suhbaatar	1.47	0.44	500	33.5	28.9	35.7	30.7	6%	1.8	68,161	2,218	27,816	630
Ulaangom	5.06	1.52	400	56.6	48.8	60.3	51.9	6%	3.1	120,138	2,316	29,770	90
Uliastai	1.29	0.33	250	21.3	18.4	22.7	19.5	6%	1.2	47,586	2,435	24,400	140
Hovd	3.23	0.97	400	29.0	25.0	30.9	26.6	6%	1.6	51,314	1,929	12,910	196
Tsetserleg	2.86	0.75	200	15.1	13.0	16.1	13.9	6%	0.8	33,132	2,388	35,000	402
Choir	2.29	0.32	250	12.6	10.8	13.4	11.5	6%	0.7	20,567	1,786	13,960	35
Nailakh	16.58	-	400	145.9	125.6	155.2	133.6	6%	8.0	388,186	2,905	-	-
Baganuur	10.06	-	700	219.4	188.9	233.4	201.0	6%	12.1	281,053	1,399	-	-
Choibalsan	1.24	-	500	88.5	76.2	94.2	81.1	6%	4.9	169,314	2,089	-	-
Dalanzadgad	0.36	-	250	8.5	7.3	9.0	7.8	6%	0.5	14,487	1,865	-	-
Sum		**10.37**		**911.7**	**785.0**	**969.9**	**835.1**		**50.1**	**1,790,958**		**442,197**	
Average	**3.33**	**0.49**	**319**	**43.4**	**37.4**	**46.2**	**39.8**	**0**	**2.4**	**85,284**	**2,280**	**21,057**	**176**

39. The average heat production peak utilization factor is 2,280 hours per annum (both years 2012 and 2013 taken into account). The average DH network maximum pipeline diameter is about 320 mm; these numbers are used in the general model.

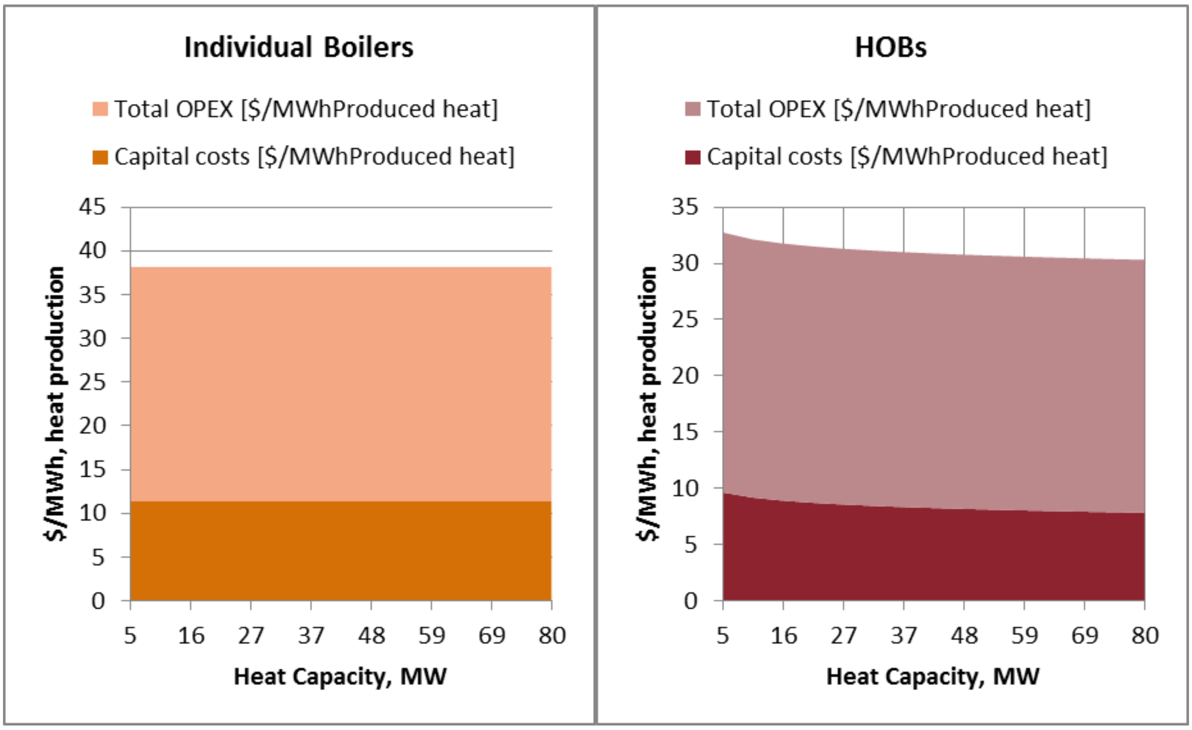
40. The coal price is calculated with the overground standard price and transmission cost. Distance from the closest coal mines for each Aimag is shown in Table III-2. The average distance from coal mines is 176km, which is used in general model to calculate the total coal price.

I. General Model

41. The total costs of production as a function of heat capacity are presented as Figure III-3 and Figure III-4. Total costs are divided into total Capex and Opex.

42. It has been assumed that for the Individual coal fired boilers (the customers' alternative) ,average unit capacity stays constant within the overall capacity range, and thus the total costs also stay constant.

Figure III-3: Total Cost of Individual Boilers and HOBs

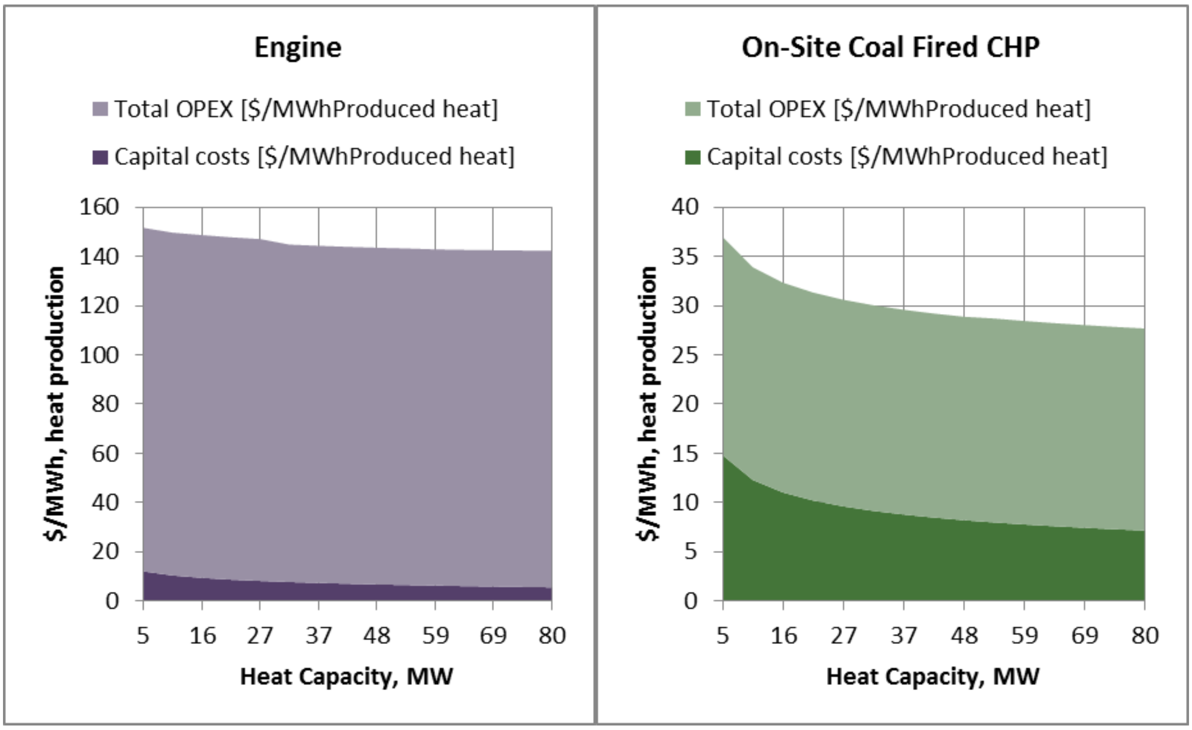


Sources: Consultants' analysis

43. Total Opex of the Engine CHP is significantly higher compared to any other production; this is due to the difference between the fuel costs of Mazut and coal, and the relatively high heat rate of Engine CHP production for heat.

44. In accordance with the assumptions used in this study, On-site Coal Fired CHP is the most economical alternative for production of heat in Aimags at the high end of the capacity range. HOBs are more cost effective at the lower end of the capacity range.

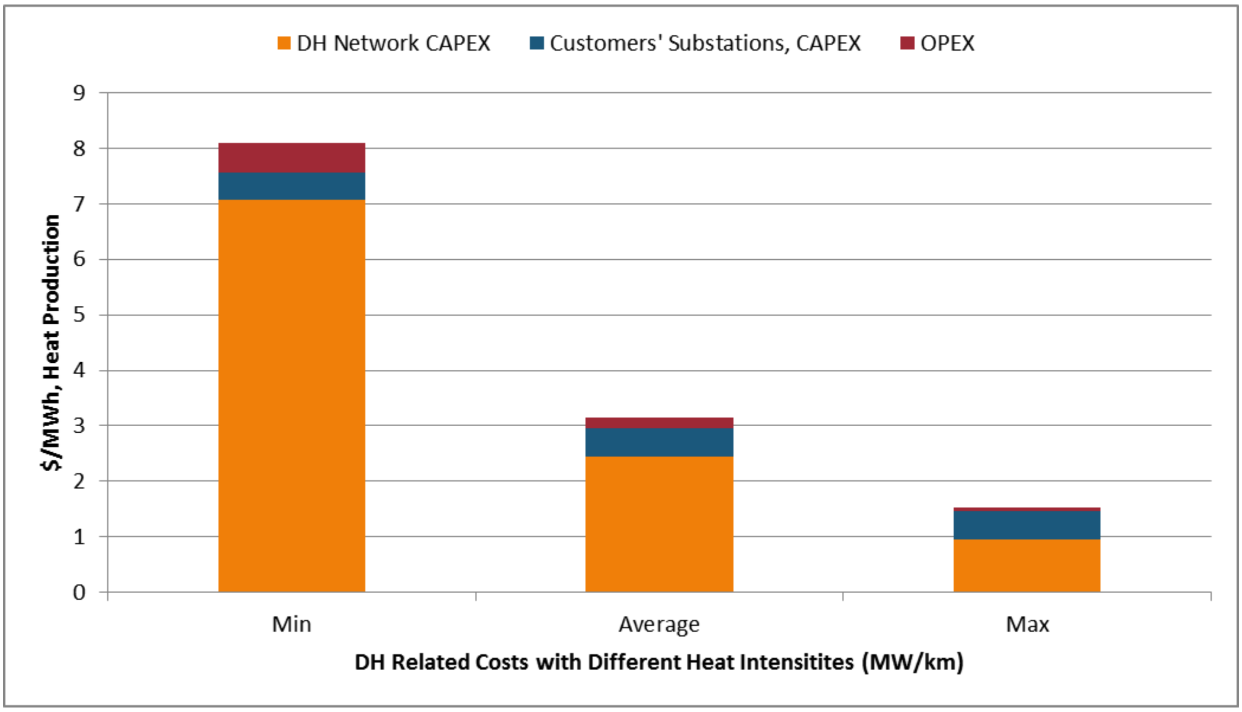
Figure III-4: Total Costs of Engine CHP and Coal-Fired CHP



Sources: Consultants' analysis

45. In Figure III-5, the total costs related to DH network with the minimum, average and maximum heat intensities, and divided into the total Capex and Opex of the DH network and customers' substations. It is clear that the costs decrease as heat intensity increases.

Figure III-5: Total Costs of DH Network and Customer's Substation by Heat Intensity



Sources: Consultants' analysis

46. The comparison of total DH system costs by heat production technology is presented in

Figure III-6 and Figure III-7. Cost curves as a function of peak heat demand of the heating system includes the total costs of production, DH network and customers' substations.

47. There is a significant difference in total costs between Engine CHP production and the other technologies, thus it is reasonable to present a separate comparison of the other technologies without the Mazut-based engine CHP.

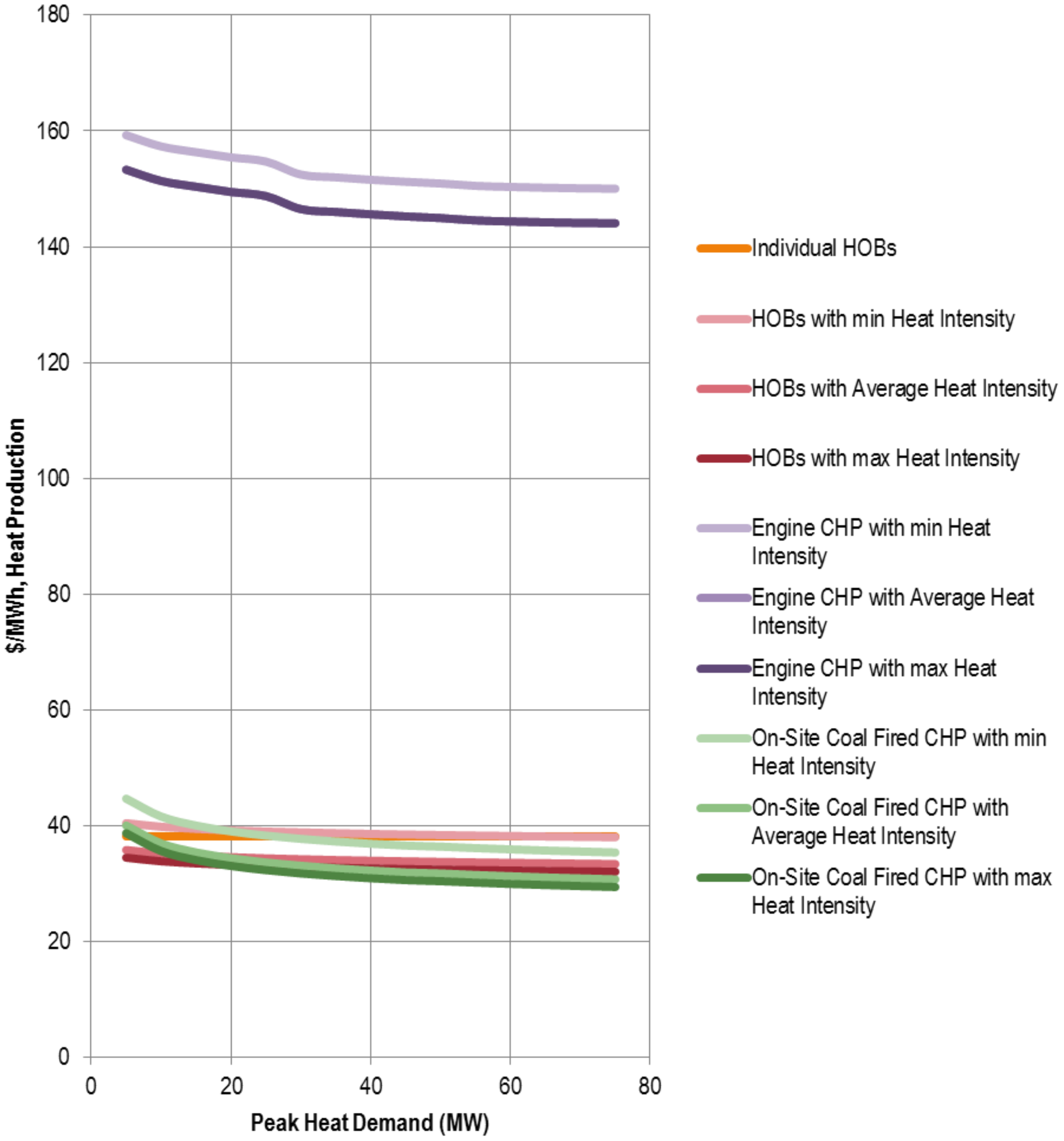
48. In Figure III-6, the financial viability between the heat production options without an Engine CHP is illustrated.

49. The greater is the heat intensity, the lower the relative cost of the DH system; it is obvious that high heat intensity favours centralized production and district heating over individual HOBs.

50. It can be seen in Figure III-7, that the breakpoint at which a CHP is justified is slightly lower than the peak heat demand of 20 MW, independent of heat intensity.

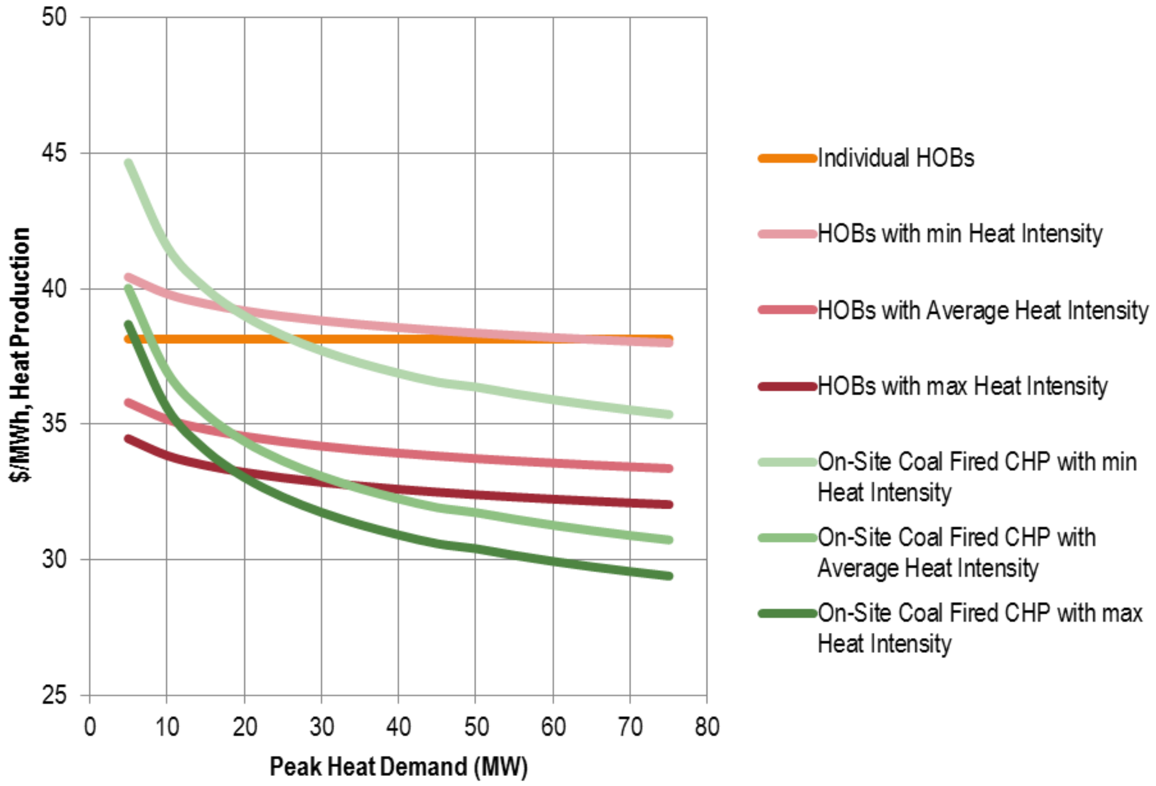
51. A CHP plant needs to be designed to a certain degree to serve both electricity and heat demands. Cost savings for both power and heat are generally achieved in cogeneration compared to separate production. The benefits of cogeneration for heat can be seen as steeper curves than for HOBs. There are also parallel benefits for power in cogeneration, which have not been modelled.

Figure III-6: Total Operating Cost of DH System



Sources: Consultants' analysis

Figure III-7: Total Costs of DH System (without Engine CHP)



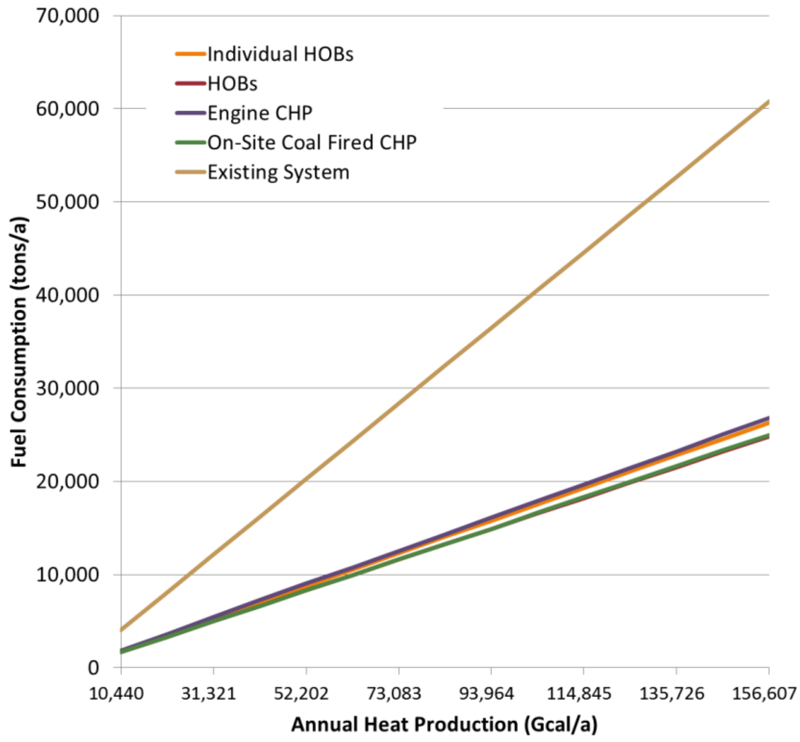
Sources: Consultants' analysis

52. Annual fuel consumption and CO2 emissions are a function of annual heat production by the technologies presented in Table III-8.

53. The annual heat production (x-axis) corresponds to the heat capacities of Figure III-3 and Figure III-4 with a peak utilization of 2,280 hours per annum. The curves for the existing system are calculated by using the average coal consumption per annual heat production of the Aimag heating systems in 2012.

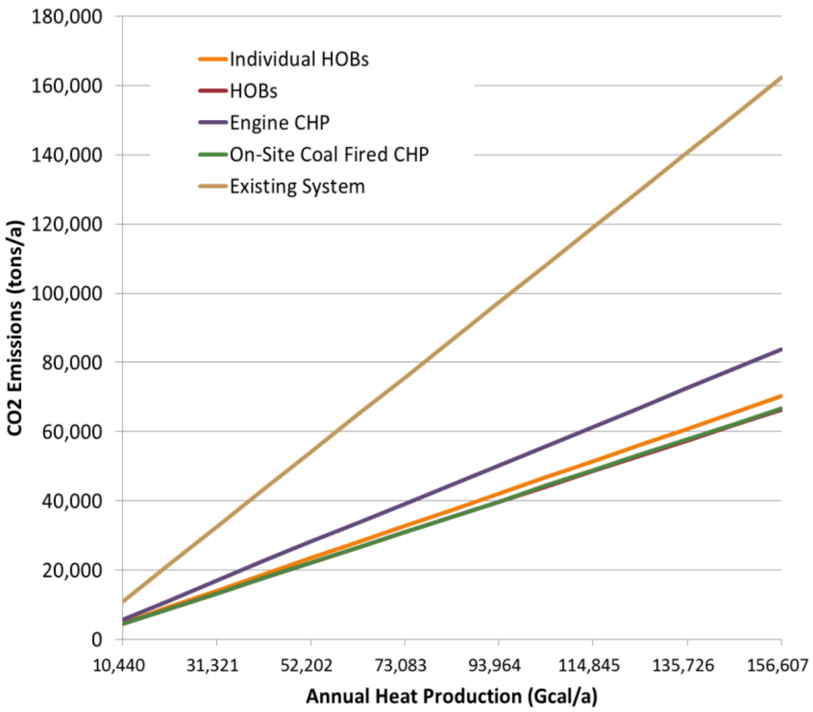
54. It can be seen from Table III-8 that the use of modern technology for heating production, would result in significantly reduced CO2 emissions.

Table III-8: Annual Fuel Consumption



Sources: Consultants' analysis

Table III-9: Annual CO2 Emissions



Sources: Consultants' analysis

J. Aimag-Specific Model

55. Appendix A contains a summary of the total annualized costs and annual CO_2-emissions separately for each Aimag. In CO_2-figures, the last column shows emissions related to coal consumption without refurbishment.

IV. CONCLUSIONS

56. The optimal heating system for each Aimag centre has been determined by a financial evaluation. The financially viable system is the system that has the lowest total annualized costs.

57. Whereas the general approach to heat supply planning does not take into account the effect of changes in the peak utilization factor, nor district heating network maximum pipeline diameter, the Aimag-specific model does consider such factors.

58. A high heat peak utilization factor favors heating systems with low heat rates (high efficiency), and thus centralized systems with lower O&M costs over small independent boilers. Moreover, economies of scale benefits highlight the difference between centralized production and individual boilers.

59. The results of specific modelling of each Aimag are presented in Table IV-1 (2012) and

60.

61. Table **IV-2** (2025).

Table IV-1: Summary Table for Aimag Town Centres in 2012

Aimag Town Centre	Peak Heat Demand	Annual Heat Consumption	Heat Intensity	Existing Heating System 2012	Most Financially Viable System in 2012	Total Installed Costs	Total reduction in O&M costs compared to system without refurbishment	Reduction in annual CO_2 emissions compared to system without refurbishment	
	MW	GCal/a	MW/km			'000s	$1,000/a	Tons/a	%
Altai	20.55	32,134	2.34	Small HOBs/DH	On-Site Coal Fired CHP	7,433	778	16,584	51%
Arvaiheer	9.90	15,002	2.25	Small HOBs/DH	HOB	3,247	372	10,359	58%
Baruun-Urt	11.73	30,217	2.09	Small HOBs/DH	HOB	4,305	529	25,449	63%
Bayankhongor	12.66	33,150	1.71	Small HOBs/DH	HOB	4,248	551	18,502	53%
Bulgan	8.25	22,900	1.10	Small HOBs/DH	Individual Boilers	2,063	4,035	32,561	74%
Zuunmod	37.13	63,625	1.55	Small HOBs/DH	On-Site Coal Fired CHP	13,201	812	35,900	53%
Mandalgov	11.59	19,851	0.91	Small HOBs/DH	Individual Boilers	2,899	966	15,927	62%
Muren	25.83	66,619	1.34	Small HOBs/DH	On-Site Coal Fired CHP	9,770	375	6,629	17%
Ulgii	18.65	33,294	2.03	Medium HOB/DH	Individual Boilers	4,661	969	25,626	61%
Ondorhaan	13.94	23,653	0.80	Small HOBs/DH	Individual Boilers	3,485	555	21,610	65%
Sainshand	21.71	34,305	2.17	Medium HOB/DH	On-Site Coal Fired CHP	9,187	1,423	30,291	64%
Suhbaatar	16.77	30,217	2.58	Medium HOB/DH	Individual Boilers	4,193	3,247	30,354	67%
Ulaangom	20.60	37,562	5.88	Medium HOB/DH	On-Site Coal Fired CHP	7,055	566	19,290	51%
Uliastai	17.57	36,138	1.25	Small HOBs/DH	HOB	6,766	1,047	28,853	62%
Hovd	24.57	39,665	3.23	Medium HOB/DH	On-Site Coal Fired CHP	9,095	1,130	25,643	57%
Tsetserleg	12.31	24,412	2.74	Small HOBs/DH	HOB	3,854	1,292	17,422	59%
Choir	11.08	16,136	2.36	Small HOBs/DH	HOB	3,692	307	14,234	64%
Nailakh	35.66	89,190	4.05		On-Site Coal Fired CHP	11,650	533	32,119	42%
Baganuur	121.61	146,430	5.58		On-Site Coal Fired CHP	30,003	424	15,860	18%
Choibalsan	75.03	159,155	1.05		Individual Boilers	18,758	4,602	304,558	80%

Aimag Town Centre	Peak Heat Demand	Annual Heat Consumption	Heat Intensity	Existing Heating System 2012	Most Financially Viable System in 2012	Total Installed Costs	Total reduction in O&M costs compared to system without refurbishment	Reduction in annual CO_2 emissions compared to system without refurbishment	
	MW	GCal/a	MW/km			'000s	$1,000/a	Tons/a	%
Dalanzadgad	6.16	13,618	0.26		Individual Boilers	1,539	393	26,058	80%
Total	**533.31**	**967,273**	**47.26**			**161,105**	**24,908**	**753,831**	**61%**

Sources: Consultants' analysis

Table IV-2: Summary Table for Aimag Town Centres in 2025

Aimag Town Centre	Peak Heat Demand	Annual Heat Production	Heat Intensity	Existing Heating System 2012	Most Financially Viable System in 2020	Total Installed Costs	Total reduction in O&M costs compared to system without refurbishment	Reduction in annual CO_2 emissions compared to system without refurbishment	
	MW	GCal/a	MW/km			'000s	$1,000/a	Tons/a	%
Altai	58.50	103,083	2.22	Small HOBs/DH	On-Site Coal Fired CHP	17,378	2,444	52,919	51%
Arvaiheer	11.88	18,919	1.25	Small HOBs/DH	Individual Boilers	2,971	487	13,108	59%
Baruun-Urt	14.29	37,356	2.16	Small HOBs/DH	HOB	5,144	653	31,462	63%
Bayankhongor	15.10	39,855	1.82	Small HOBs/DH	HOB	4,953	662	22,244	53%
Bulgan	10.07	28,655	1.38	Small HOBs/DH	HOB	3,598	5,019	40,678	74%
Zuunmod	52.77	94,146	4.63	Small HOBs/DH	On-Site Coal Fired CHP	14,007	1,178	52,867	53%
Mandalgov	12.92	22,353	0.85	Small HOBs/DH	Individual Boilers	3,230	1,087	17,935	62%
Muren	36.59	96,080	3.36	Small HOBs/DH	On-Site Coal Fired CHP	10,749	529	9,560	17%
Ulgii	21.81	39,353	3.30	Medium HOB/DH	On-Site Coal Fired CHP	8,219	1,074	30,199	61%
Ondorhaan	22.36	41,446	2.33	Small HOBs/DH	On-Site Coal Fired CHP	7,951	893	37,770	65%
Sainshand	24.87	39,954	2.11	Medium HOB/DH	On-Site Coal Fired CHP	10,378	1,655	35,279	64%
Suhbaatar	33.55	64,071	1.47	Medium HOB/DH	Individual Boilers	8,387	6,879	64,361	67%

Aimag Town Centre	Peak Heat Demand	Annual Heat Production	Heat Intensity	Existing Heating System 2012	Most Financially Viable System in 2020	Total Installed Costs	Total reduction in O&M costs compared to system without refurbishment	Reduction in annual CO_2 emissions compared to system without refurbishment	
	MW	GCal/a	MW/km			'000s	$1,000/a	Tons/a	%
Ulaangom	56.64	112,930	5.06	Medium HOB/DH	On-Site Coal Fired CHP	16,105	1,658	57,688	51%
Uliastai	21.34	44,731	1.29	Small HOBs/DH	On-Site Coal Fired CHP	8,848	1,264	35,714	62%
Hovd	29.05	48,235	3.23	Medium HOB/DH	On-Site Coal Fired CHP	10,418	1,371	31,184	57%
Tsetserleg	15.15	31,144	2.86	Small HOBs/DH	HOB	4,654	1,646	22,226	59%
Choir	12.57	19,333	2.29	Small HOBs/DH	HOB	4,186	366	17,055	64%
Nailakh	145.88	364,895	16.58		On-Site Coal Fired CHP	28,702	2,085	130,417	42%
Baganuur	219.41	264,189	10.06		On-Site Coal Fired CHP	42,772	721	28,615	18%
Choibalsan	88.51	159,155	1.24		On-Site Coal Fired CHP	41,556	4,327	303,759	79%
Dalanzadgad	8.48	13,618	0.36		Individual Boilers	2,120	401	26,058	80%
Total	**911.72**	**1,683,501**	**69.83**			**256,324**	**36,397**	**1,061,099**	**56%**

Sources: Consultants' analysis

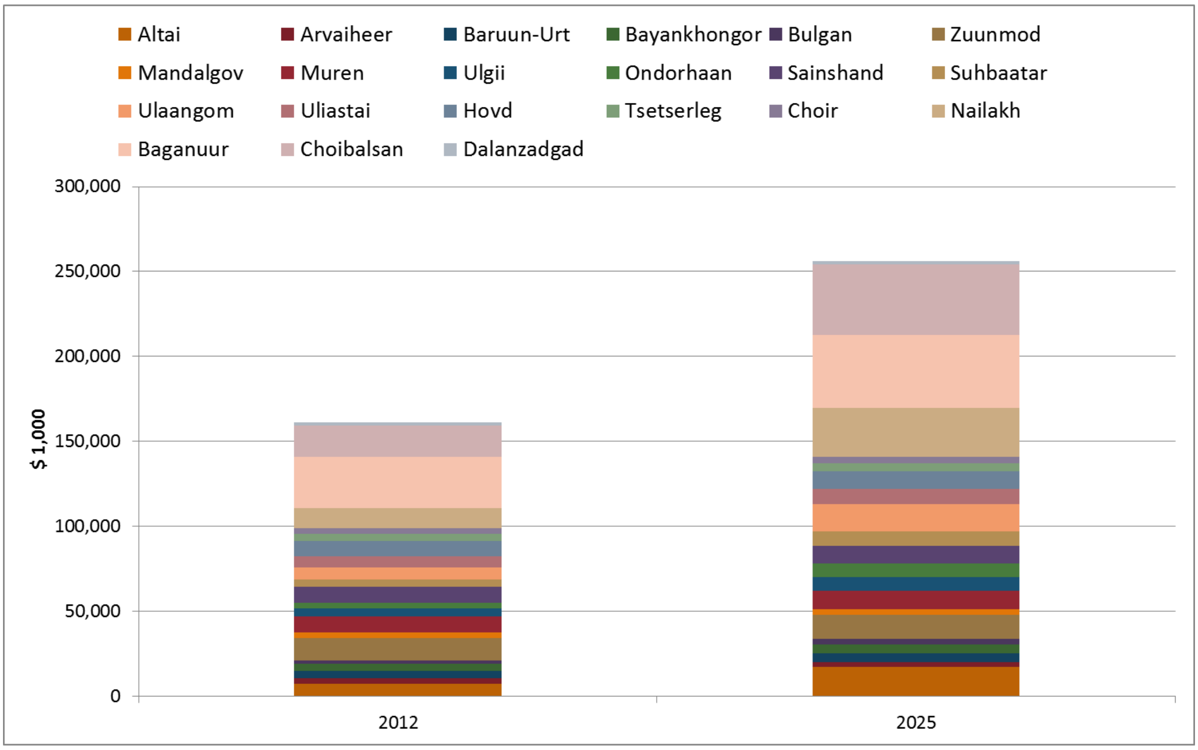
62. The results of the Aimag-specific model match with those of the general model in Figure III-7. In

63.

64. Table **IV-2**, there are five Aimags with heat demand below 20 MW that qualify for HOBs, four Aimags for individual boilers due to low heat intensities, and the rest of the Aimags with greater than 20 MW of heat demand qualify for an On-site Coal Fired CHP.

65. A total overnight cost of USD$255 million (presented in Figure IV-3 by Aimag) is required to replace existing heating systems with modern technology and to build additional capacity to meet year 2025 capacity requirements. The total investment cost has been calculated using the most financially viable systems for the Aimags.

Figure IV-3: Total Overnight Costs for all Surveyed Aimags

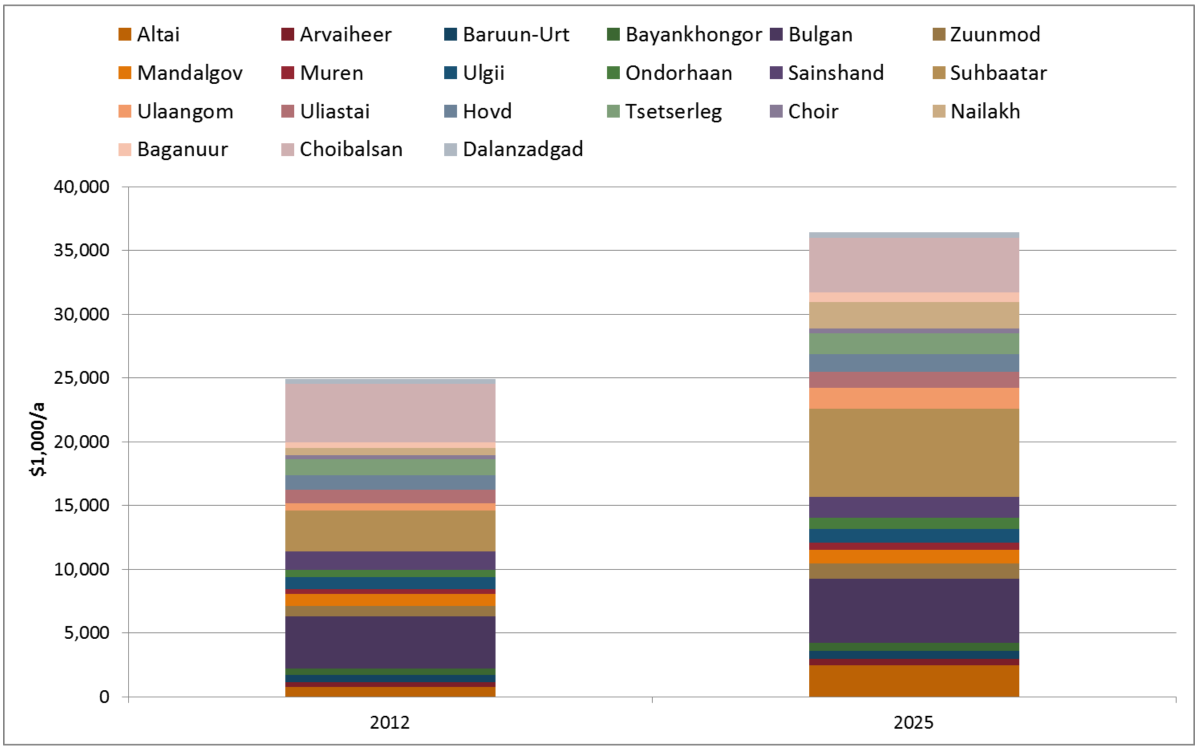


Sources: Consultants' analysis

66. In Figure IV-4, the total reduction in O&M costs compared to systems without refurbishment is presented by Aimag. The O&M costs cover fuel costs and other variable and fixed operation and maintenance cost; it has been assumed that the latter O&M costs for modern technology are 25% lower compared to the existing systems.

The calculated savings in Opex compared to systems without refurbishment is USD$25 million in 2012 and USD$36 million in 2025 respectively.

Figure IV-4: Efficiency - Total Reduction in O&M Costs

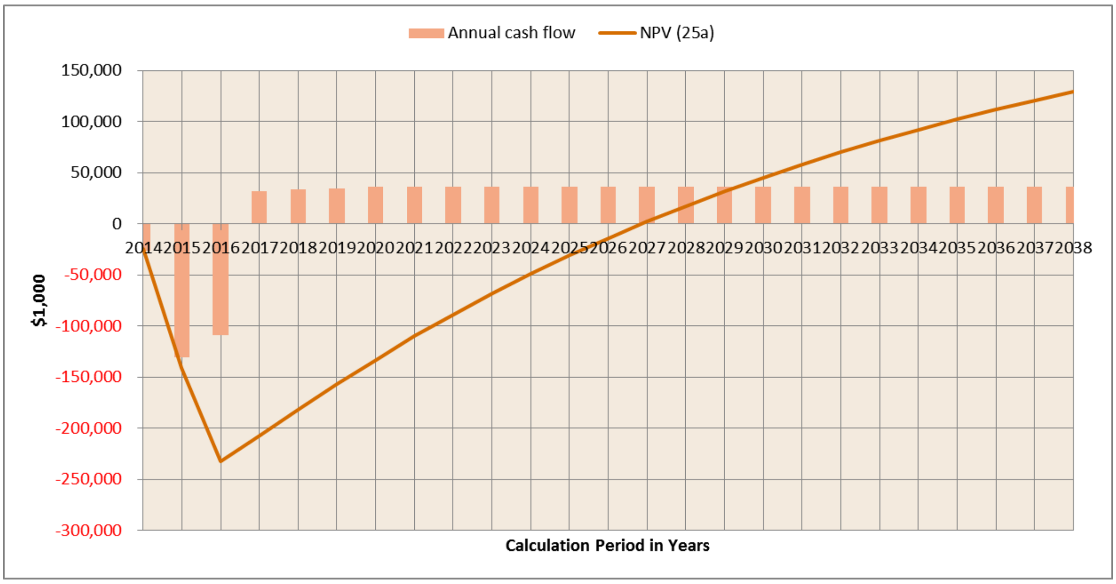


Sources: Consultants' analysis

67. In Figure IV-5, the annual cash flow and accumulated net present value are presented on the basis of a 25 year calculation period starting from year 2014. A three year construction period has been assumed for all heating systems; the share of the total investment cost for the first year is 10%, for second year 50% and for the last year 40%. It has been assumed that cost savings in Opex start accruing after the construction period, starting from the fourth year (2017). The savings in Opex has been interpolated between years 2012 and 2025.

68. A payback period of 10 years has been determined for a discount rate of 6%.

Figure IV-5: Heating System Cash Flow



Sources: Consultants' analysis

69. The increase in heat demands in the considered Aimags is shown in Figure IV-6; there are three Aimag town centres with a distinctly rapid increase (Altai, Zuunmod and Ondorhaan), and thus these Aimags should be given priority for construction. A CHP is justified for each of these Aimags.

70. The level of investment required to replace existing systems with modern technologies is indicative because further detailed feasibility study would be required before investing. However, the investment is not highly dependent on the heating technology due to fact that investment costs between the different options are fairly equal.

71. If individual boilers are selected as the most viable system, financing could nevertheless be arranged by and Energy Services Company (ESCO).

Figure IV-6: Increase in Heat Demands in Aimag Town Centres

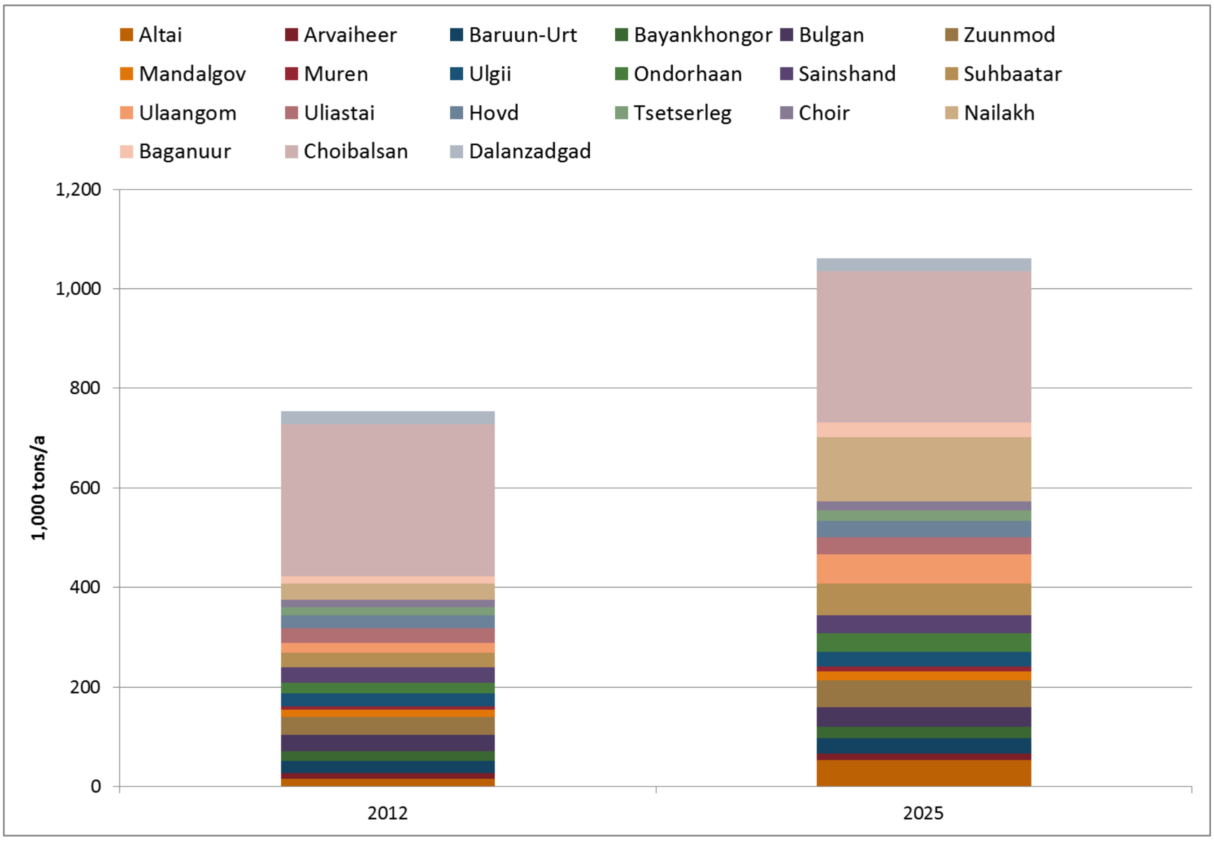
Aimag Town Centre	Increase from 2012 to 2025 MW		Heat Intensity from 2012 to 2025 MW/km	Most Financially Viable System in 2025
Altai	37.94	185%	-0.12	On-Site Coal Fired CHP
Arvaiheer	1.98	20%	-1.00	Individual Boilers
Baruun-Urt	2.56	22%	0.07	HOB
Bayankhongor	2.44	19%	0.11	HOB
Bulgan	1.82	22%	0.28	HOB
Zuunmod	15.64	42%	3.08	On-Site Coal Fired CHP
Mandalgov	1.33	11%	-0.06	Individual Boilers
Muren	10.75	42%	2.02	On-Site Coal Fired CHP
Ulgii	3.16	17%	1.28	On-Site Coal Fired CHP
Ondorhaan	8.42	60%	1.53	On-Site Coal Fired CHP
Sainshand	3.16	15%	-0.06	On-Site Coal Fired CHP
Suhbaatar	16.77	100%	-1.11	Individual Boilers
Ulaangom	36.04	175%	-0.83	On-Site Coal Fired CHP
Uliastai	3.77	21%	0.04	On-Site Coal Fired CHP
Hovd	4.48	18%	-0.00	On-Site Coal Fired CHP
Tsetserleg	2.84	23%	0.12	HOB
Choir	1.49	13%	-0.07	HOB
Nailakh	110.23	309%	12.53	On-Site Coal Fired CHP
Baganuur	97.80	80%	4.49	On-Site Coal Fired CHP
Choibalsan	13.47	18%	0.19	On-Site Coal Fired CHP
Dalanzadgad	2.32	38%	0.10	Individual Boilers
Total	**378.41**	**71%**		

Sources: Consultants' analysis

72. The reduction in annual CO2 emissions for the refurbished heating systems is compared to the systems without refurbishment in Figure IV-7. The total annual reduction is around 1 million tons of CO2 at the coal consumption level expected in 2025.

Figure IV-7: Reduction in Annual CO2 Emissions

(Compared to Systems without Refurbishment)



Sources: Consultants' analysis

V. APPENDIX A: AIMAG HEATING ANNUALIZED COSTS & CO_2

K. Altai

Figure V-1: Total Annualized Costs Divided into Cost Items

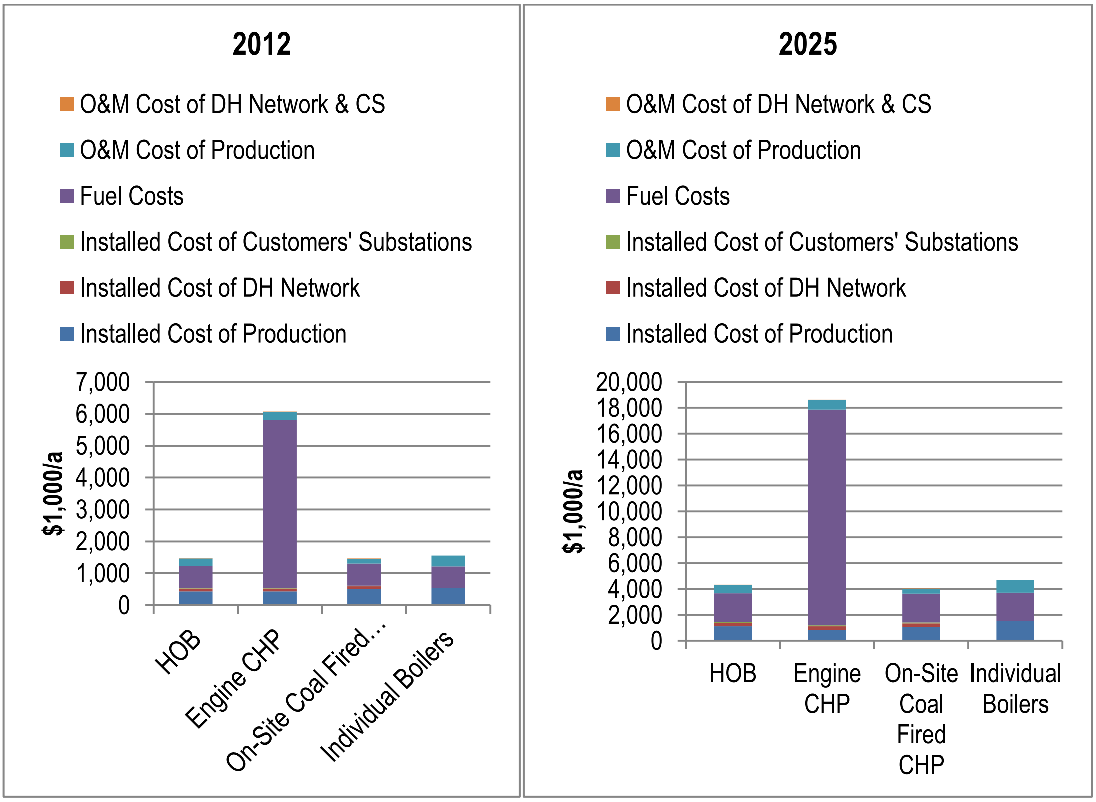
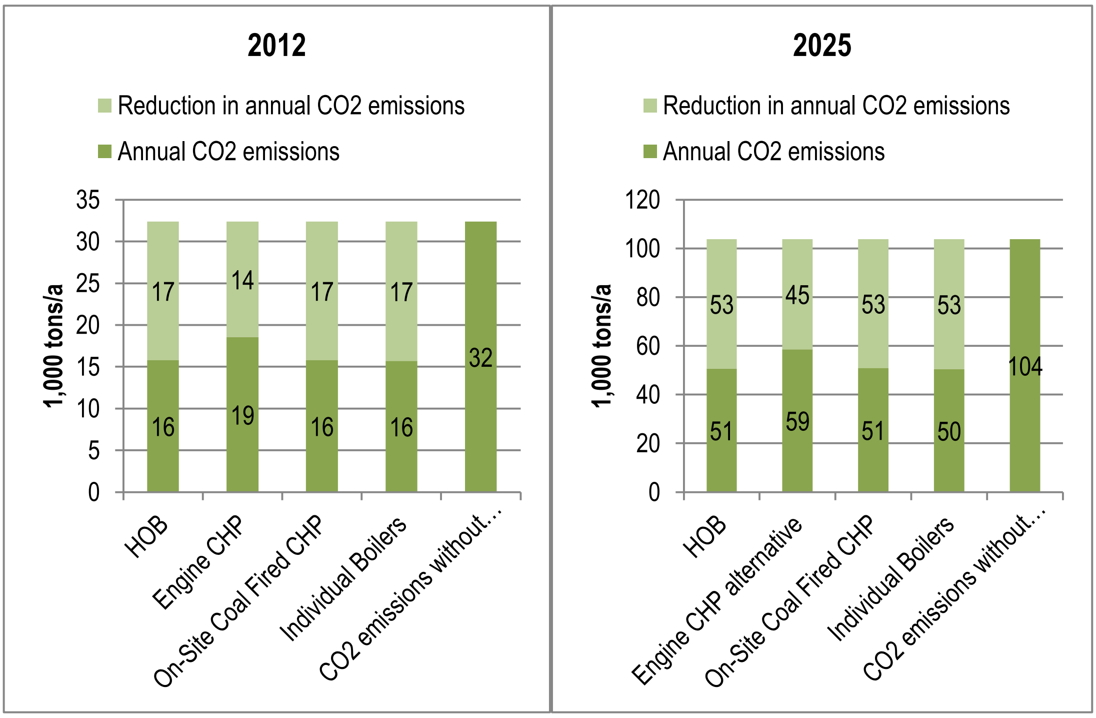


Figure I-2: Annual CO2 Emissions



L. Arvaiheer

Figure I-3: Total Annualized Costs Divided into Cost Items

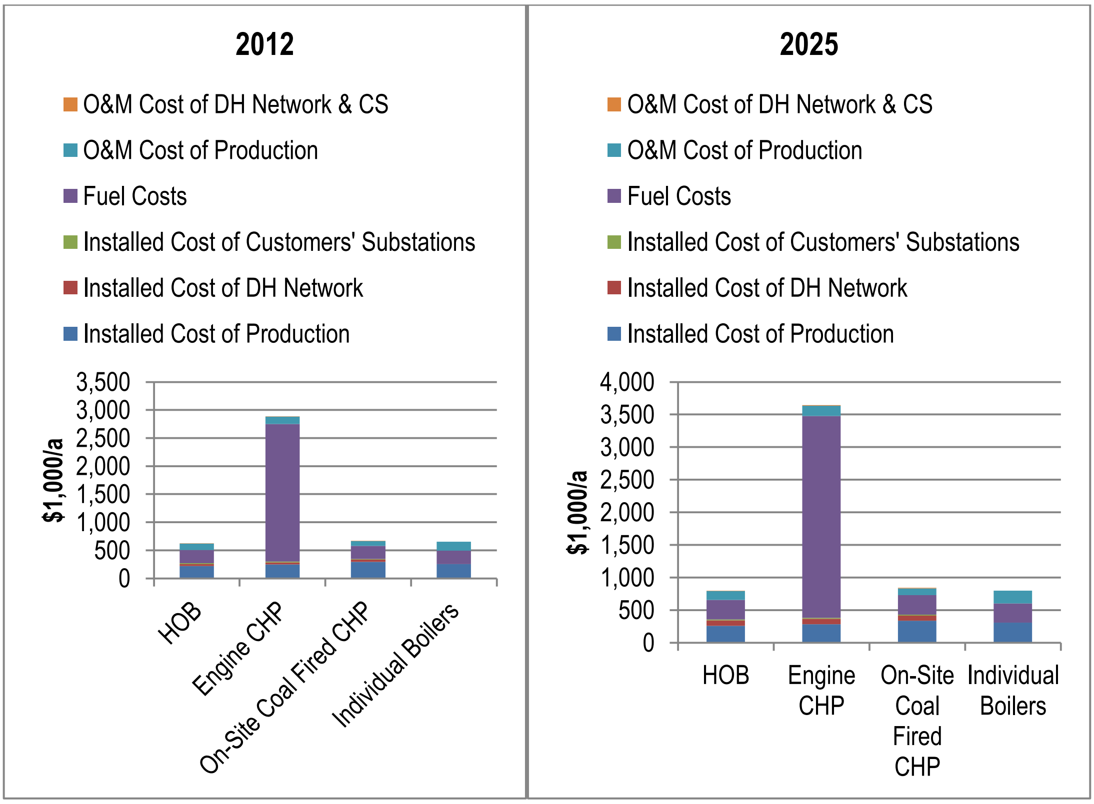
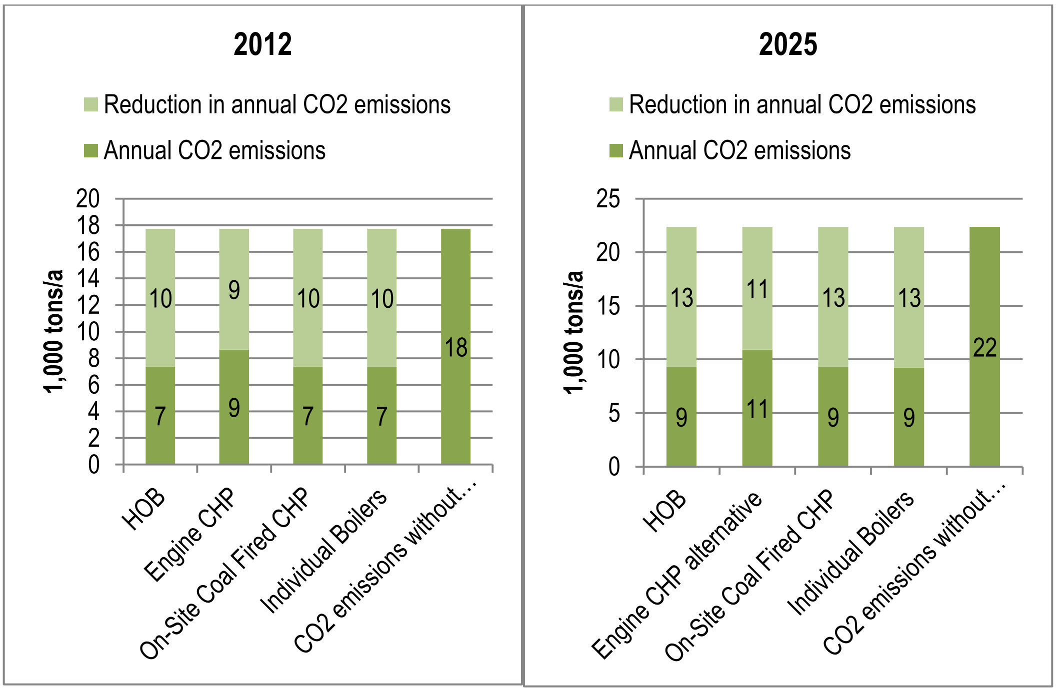


Figure I-4: Annual CO2 Emissions



M. Baruun-Urt

Figure I-5: Total Annualized Costs Divided into Cost Items

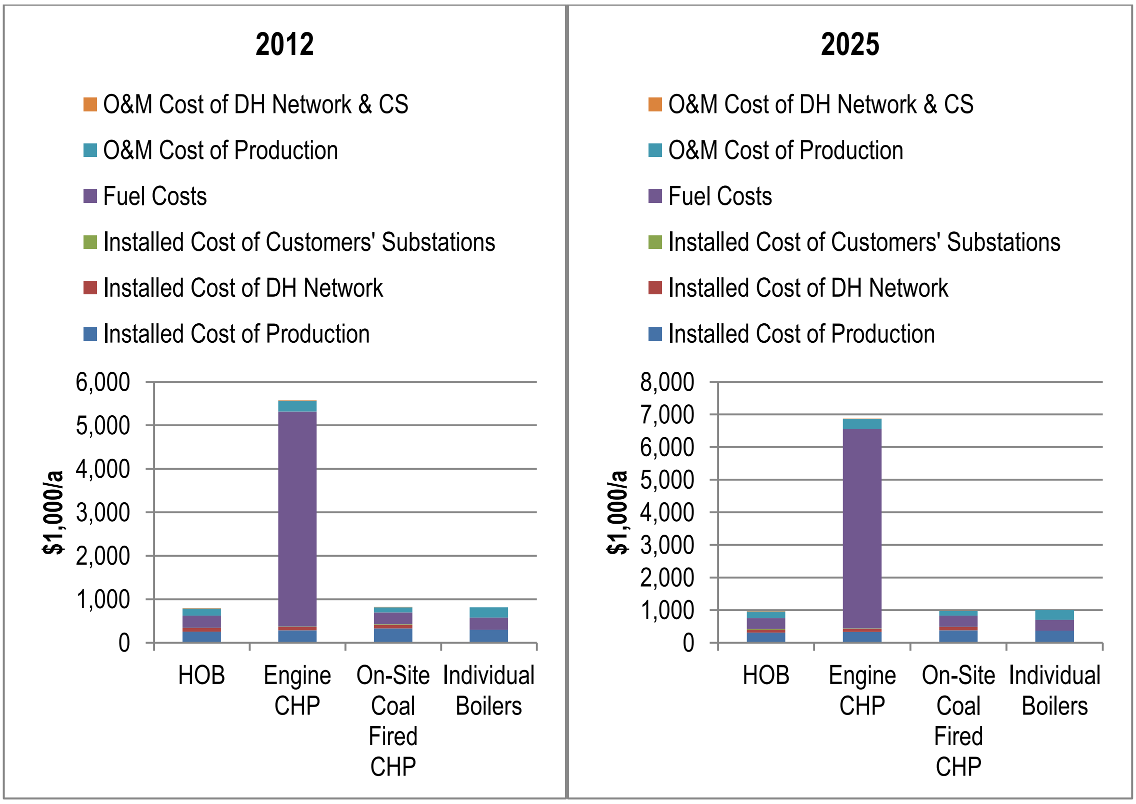
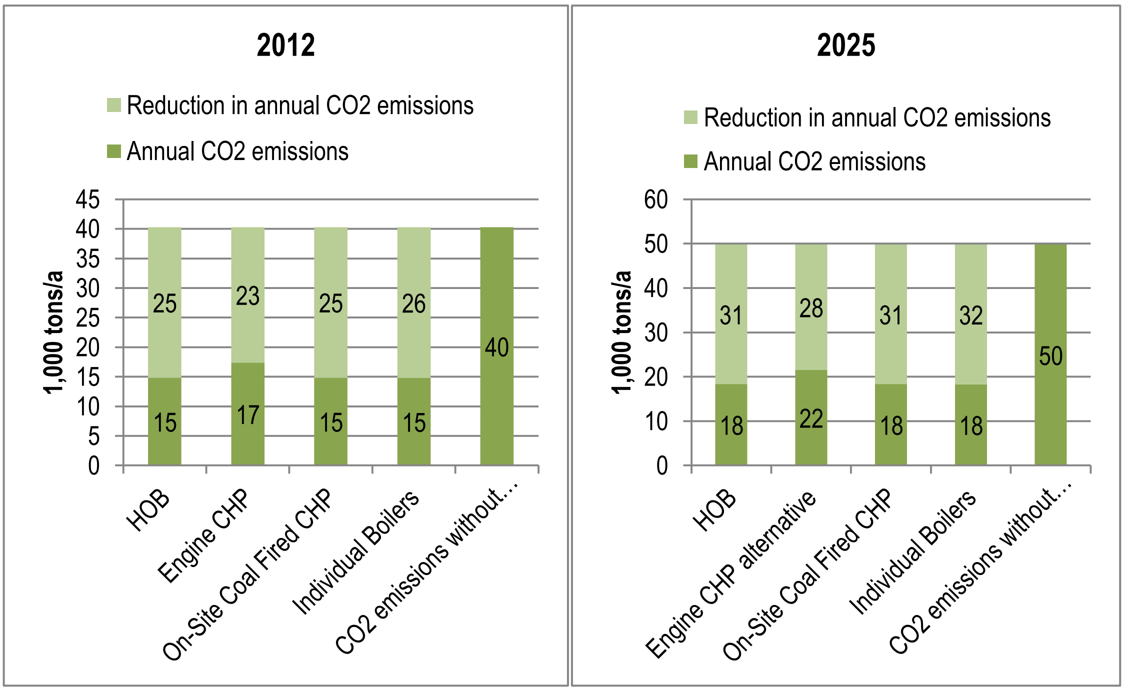


Figure I-6: Annual CO2 Emissions



N. Bayankhongor

Figure I-7: Total Annualized Costs Divided into Cost Items

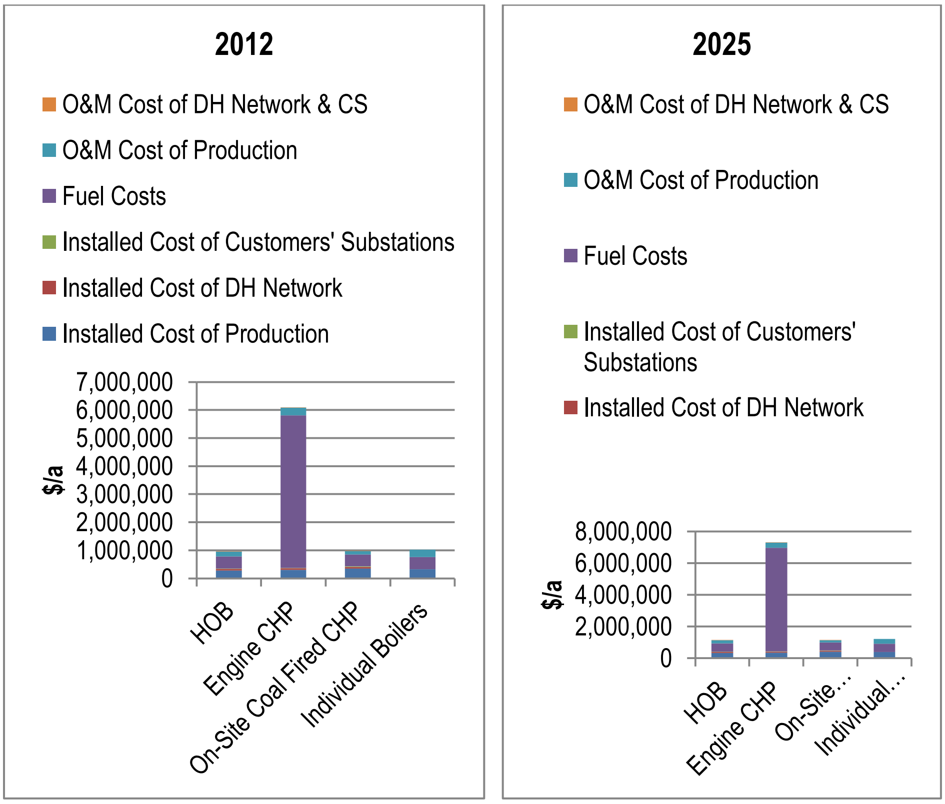
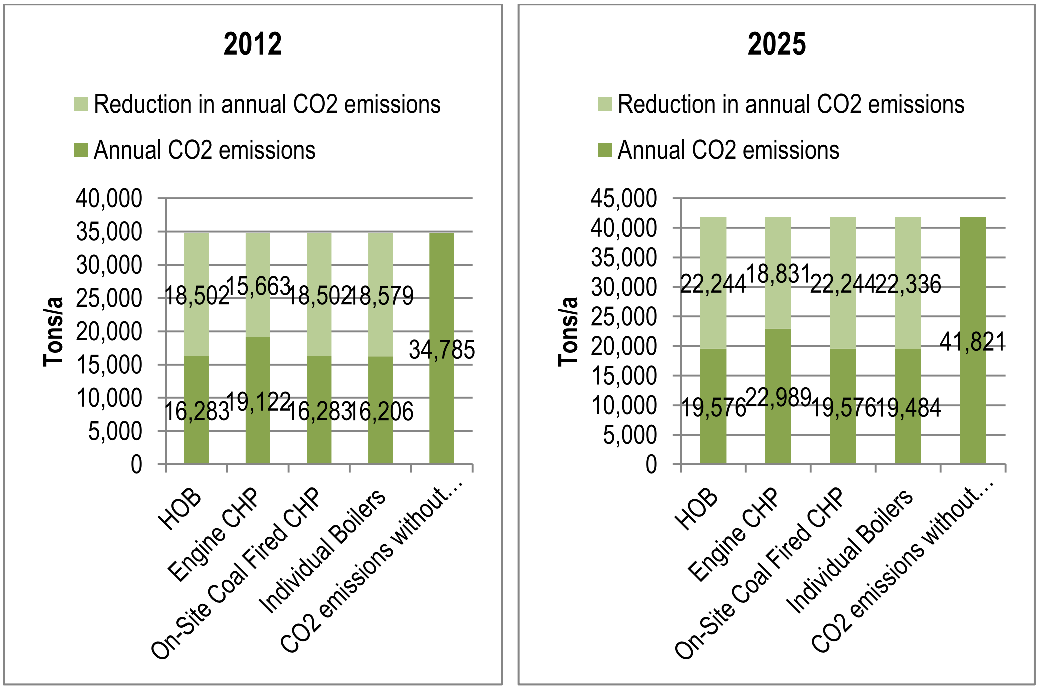
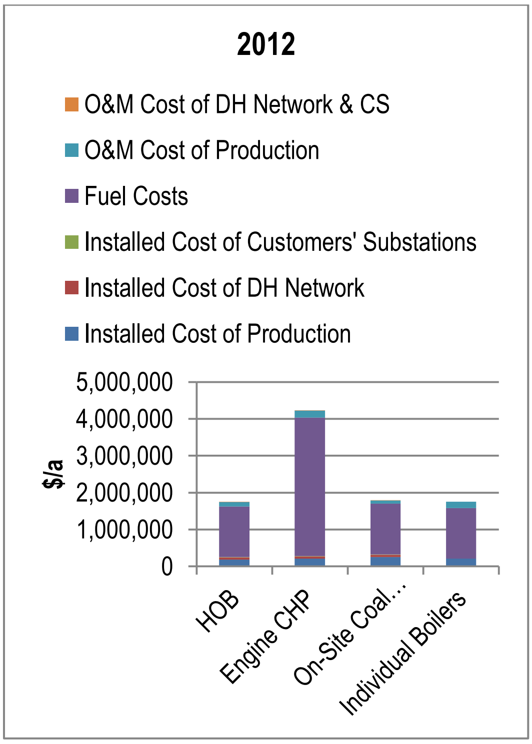


Figure I-8: Annual CO2 Emissions



O. Bulgan

Figure I-9: Total Annualized Costs Divided into Cost Items



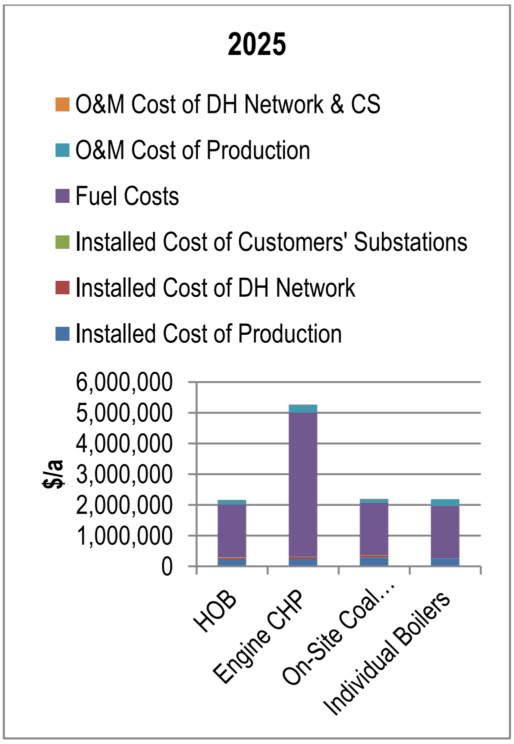
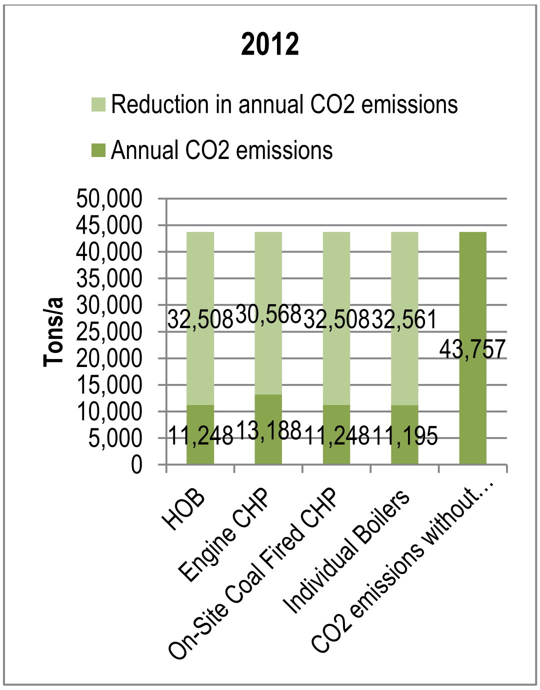
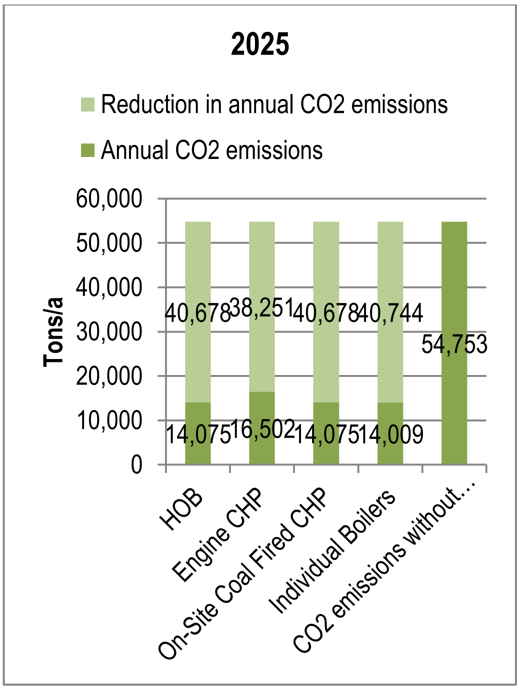


Figure I-10: Annual CO2 Emissions





P. Zuunmod

Figure I-11: Total Annualized Costs Divided into Cost Items

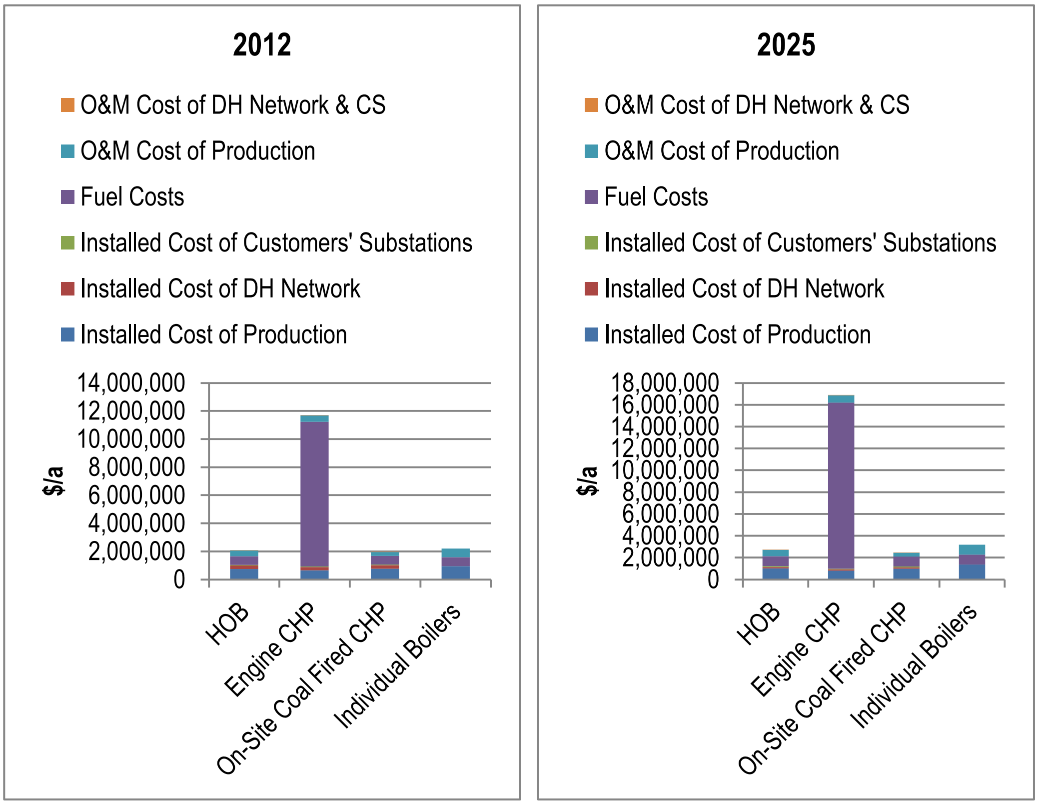
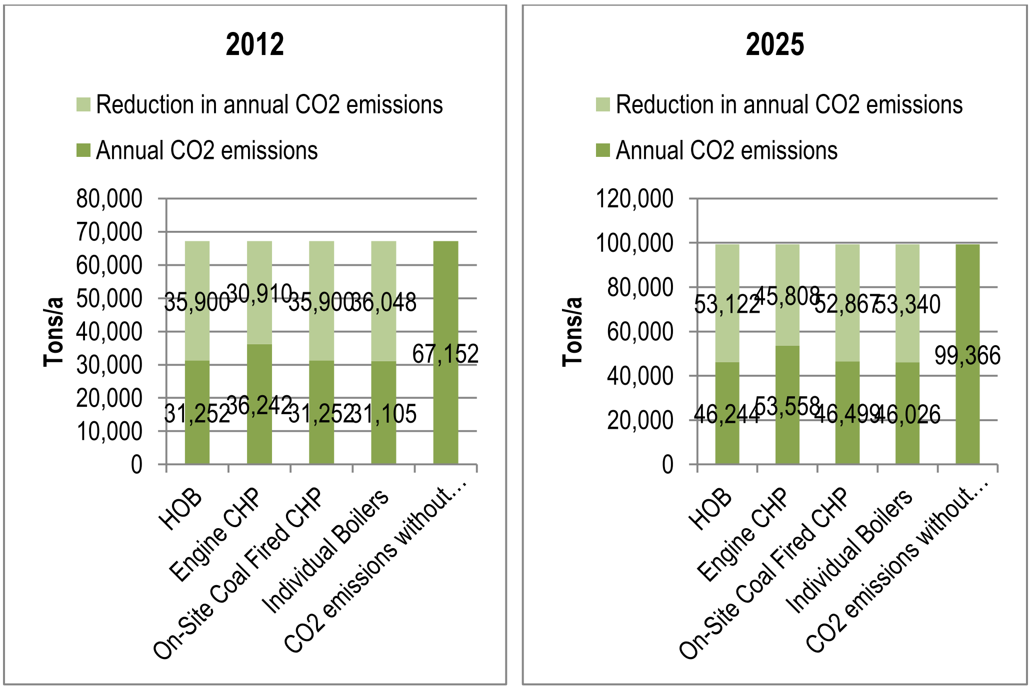


Figure I-12: Annual CO2 Emissions



Q. Mandalgovi

Figure I-13: Total Annualized Costs Divided into Cost Items

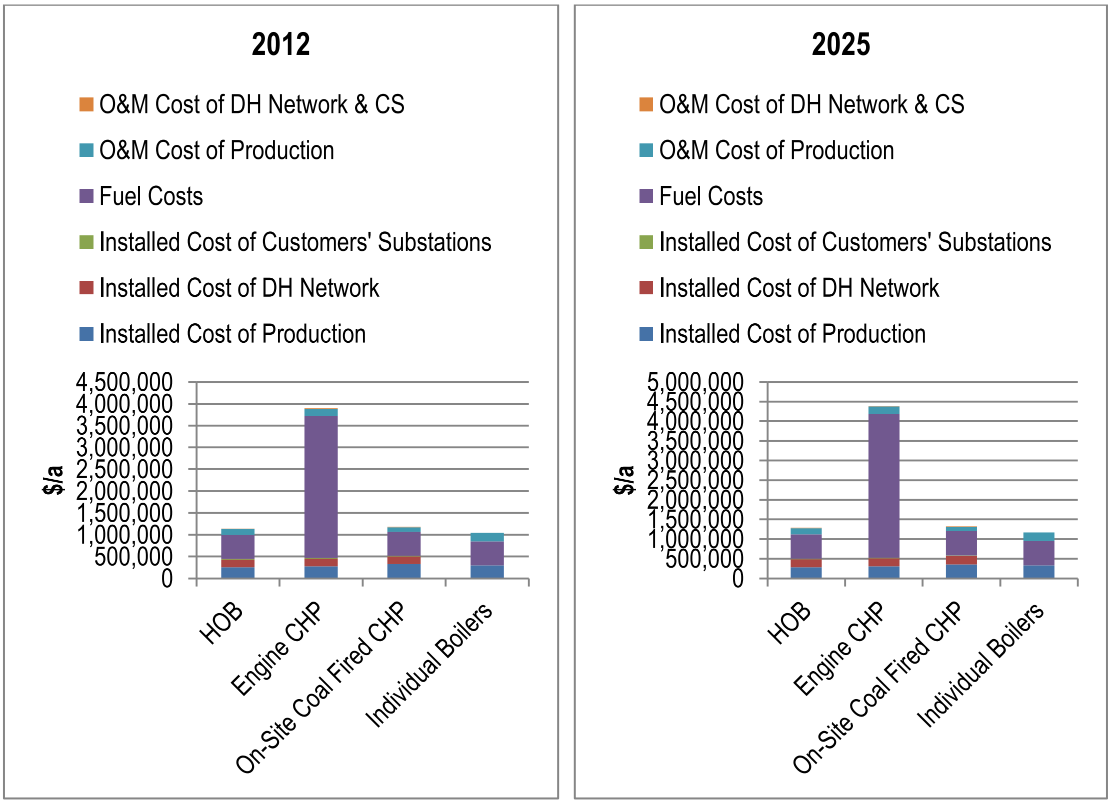
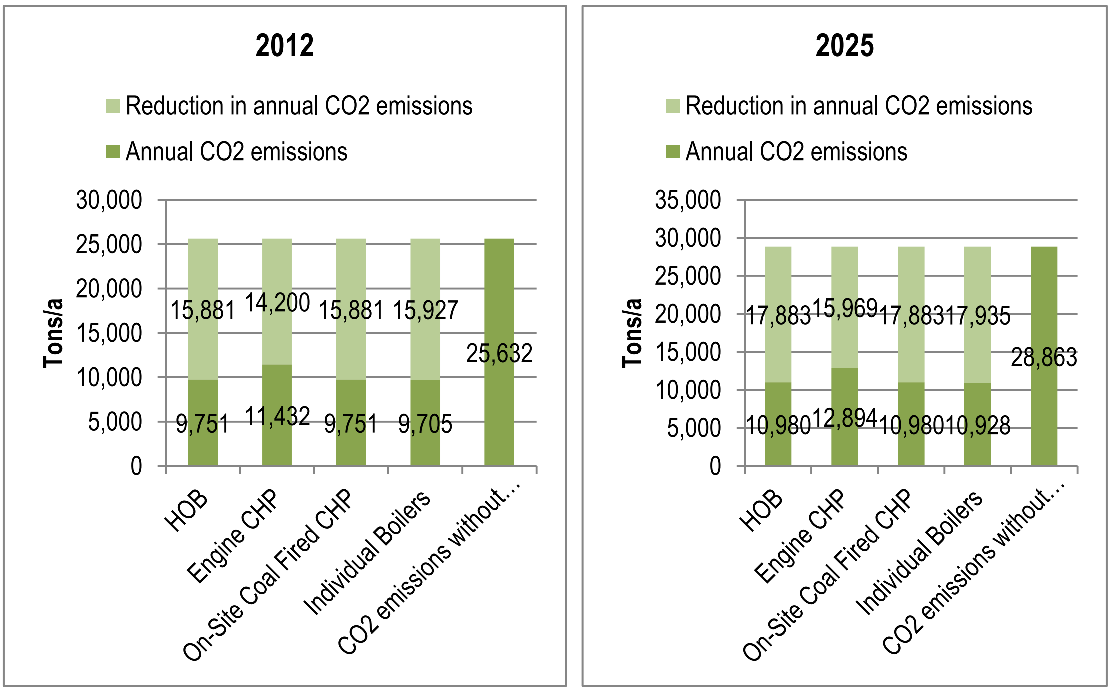


Figure I-14: Annual CO2 Emissions



R. Muren

Figure I-15: Total Annualized Costs Divided into Cost Items

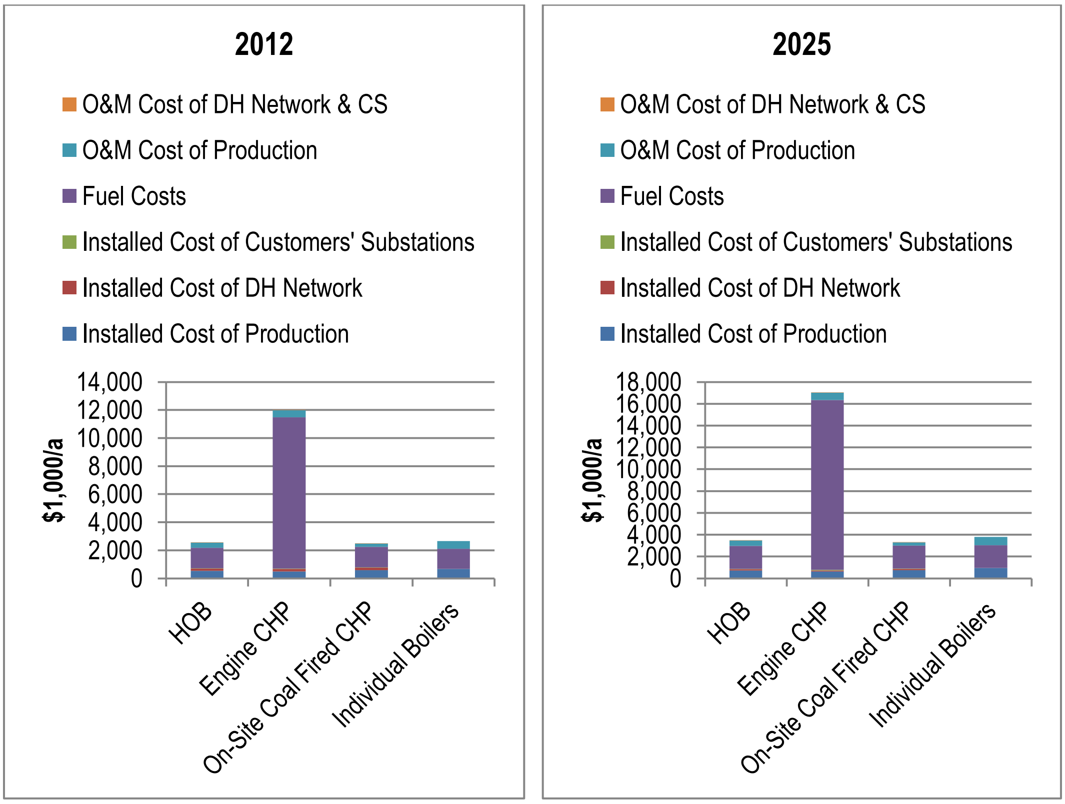
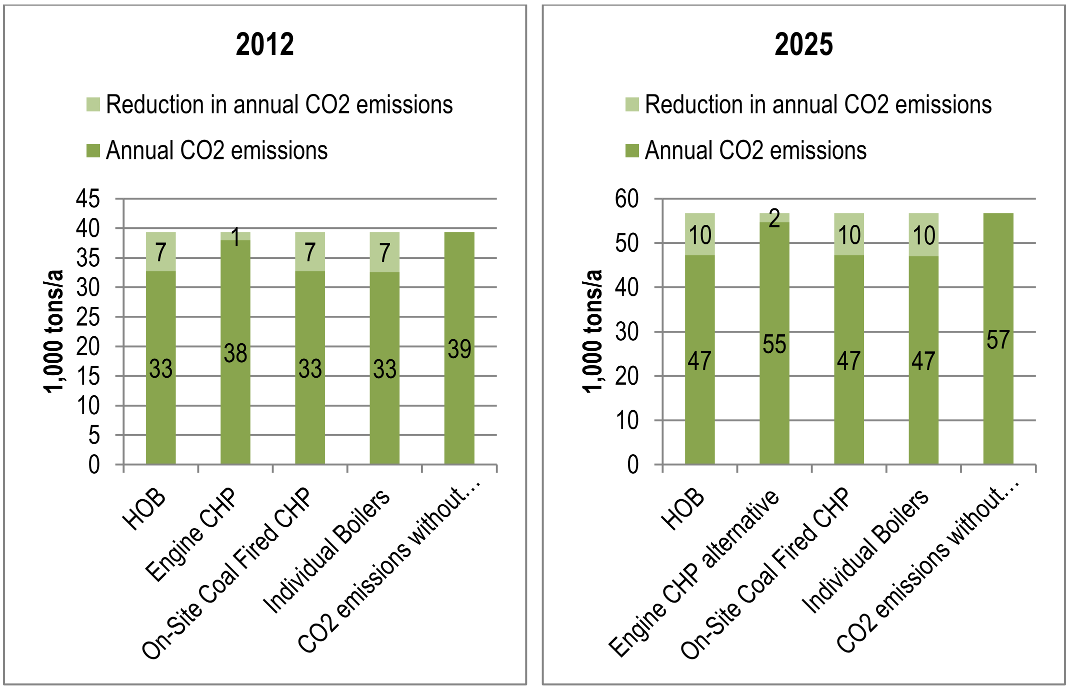


Figure I-16: Annual CO2 Emissions



S. Ulgii

Figure I-17: Total Annualized Costs Divided into Cost Items

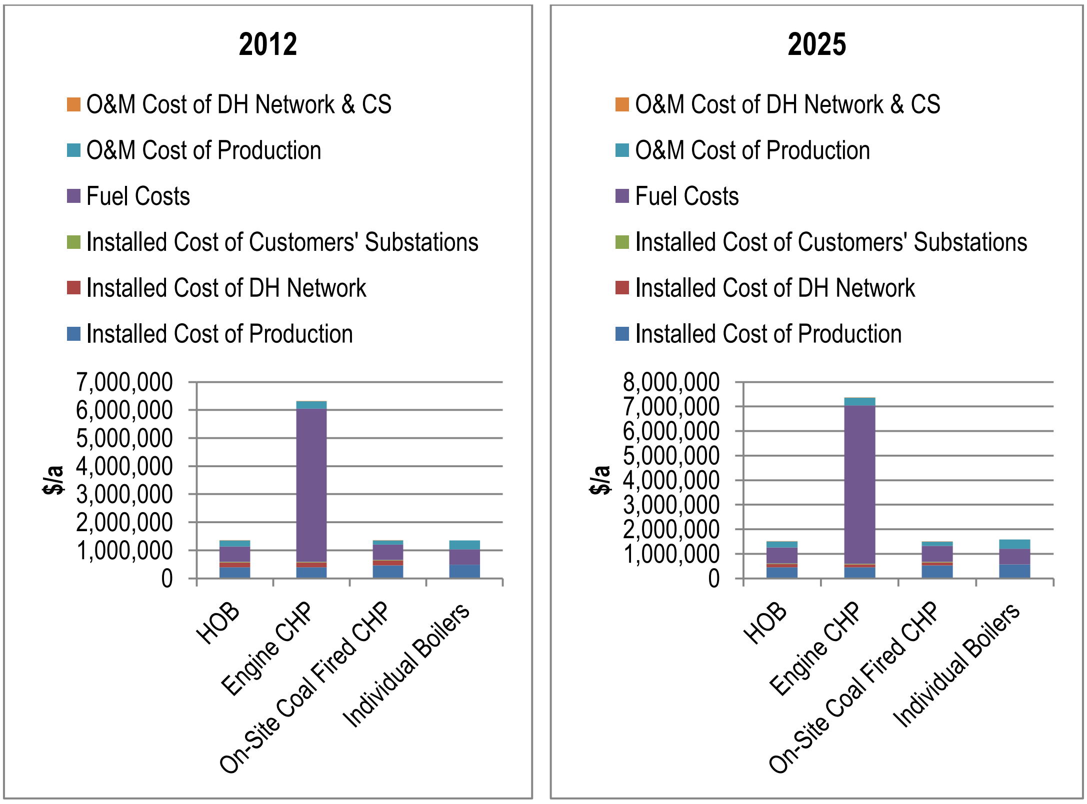
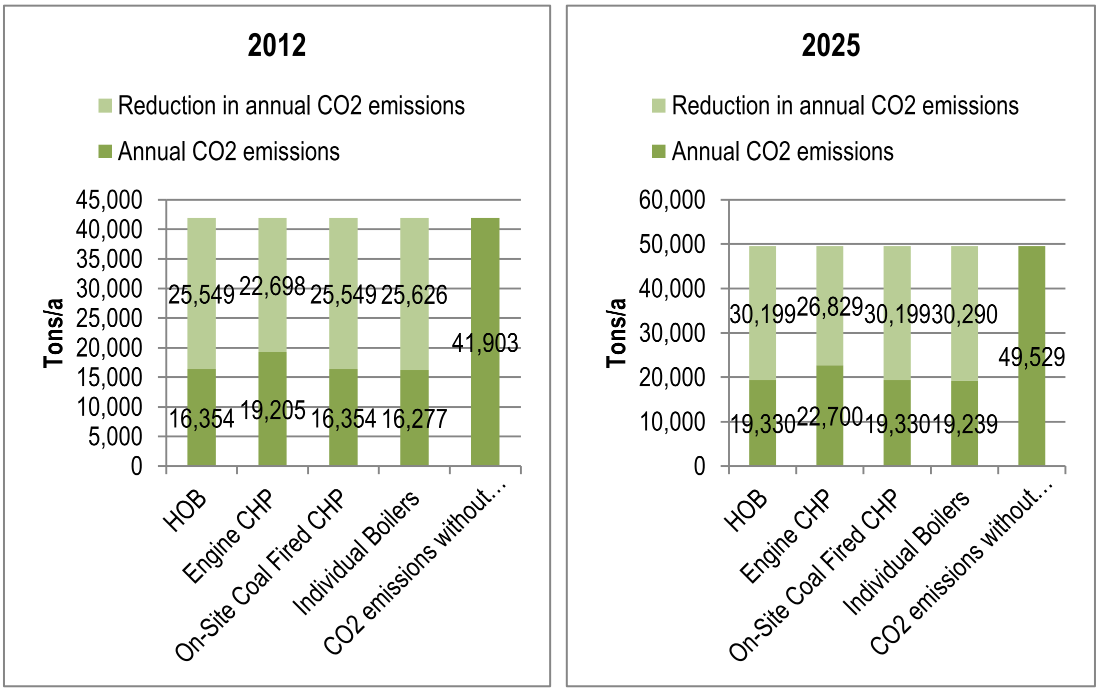


Figure I-18: Annual CO2 Emissions



T. Ondorhaan

Figure I-19: Total Annualized Costs Divided into Cost Items

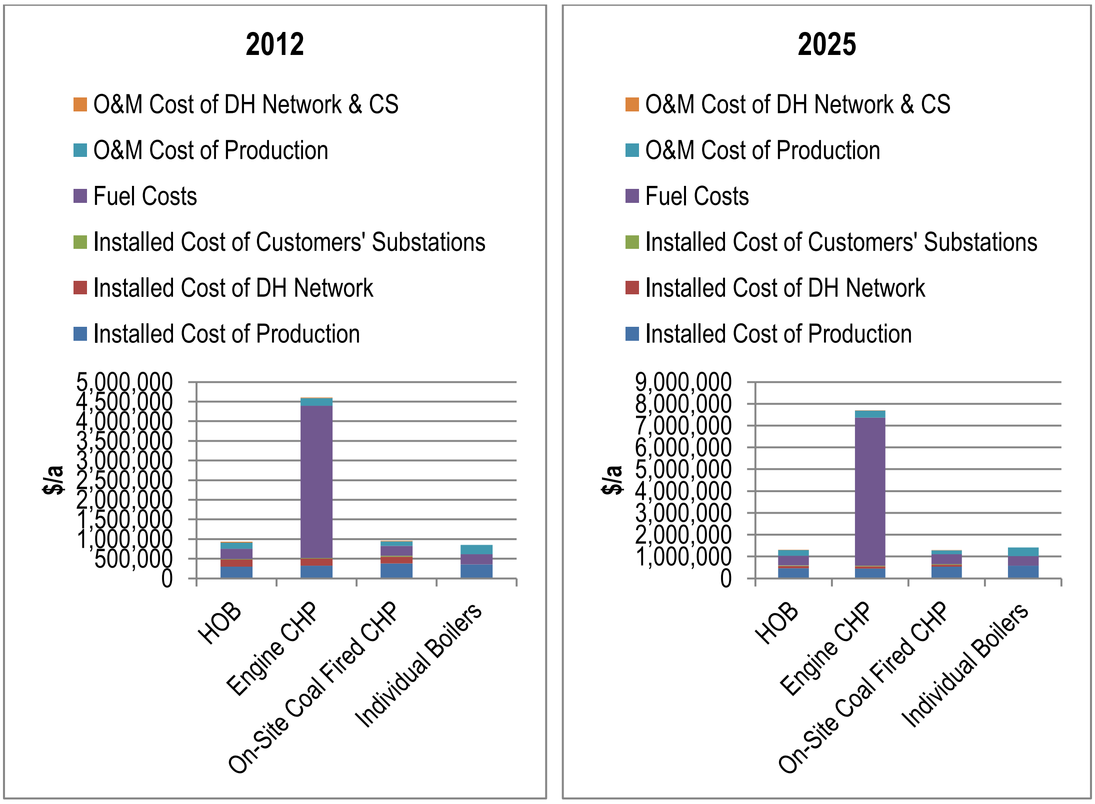
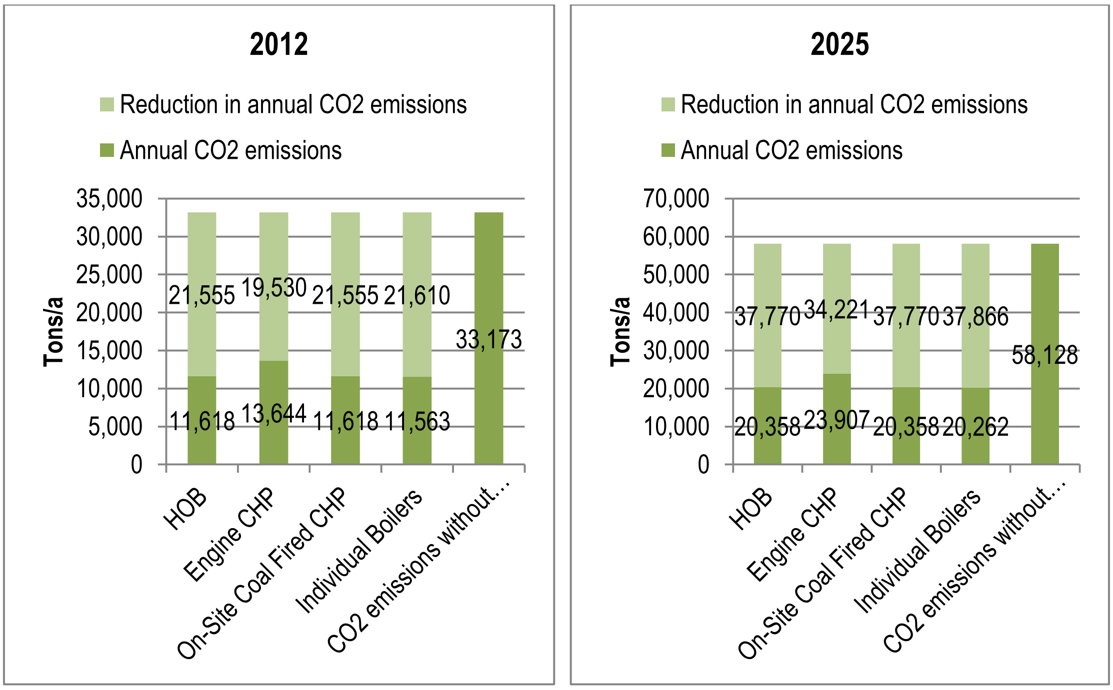


Figure I-20: Annual CO2 Emissions



U. Sainshand

Figure I-21: Total Annualized Costs Divided into Cost Items

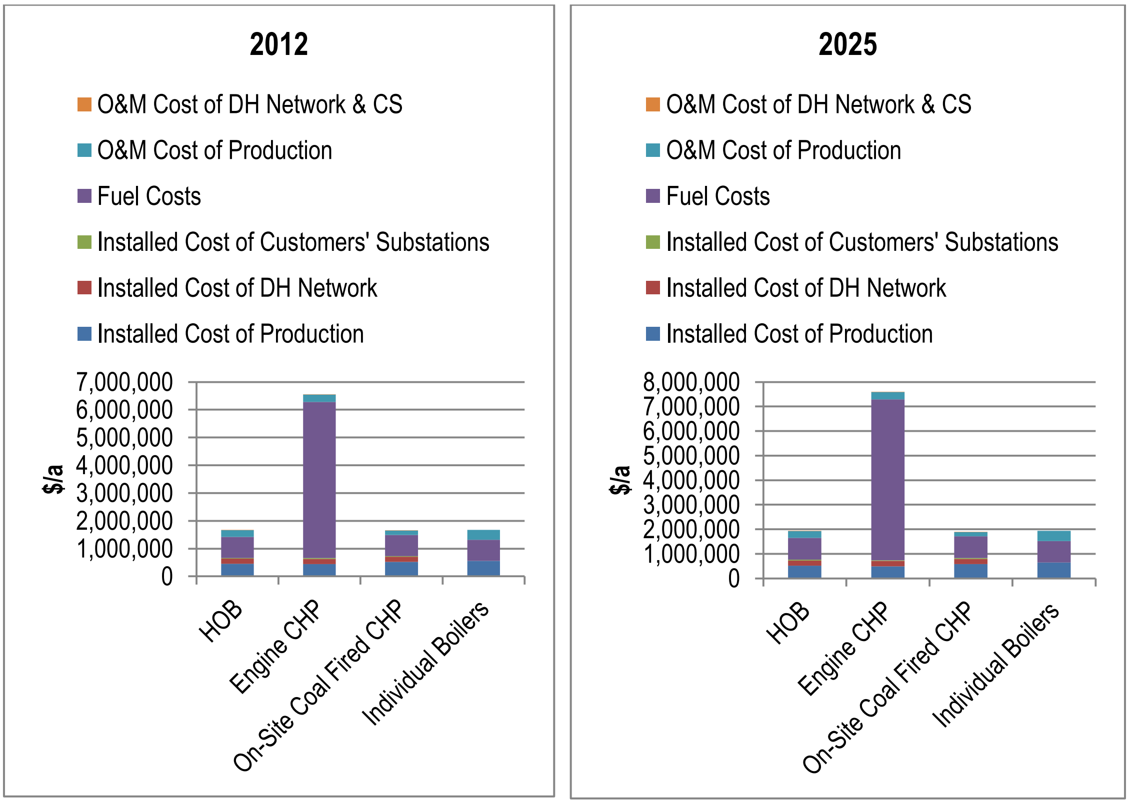
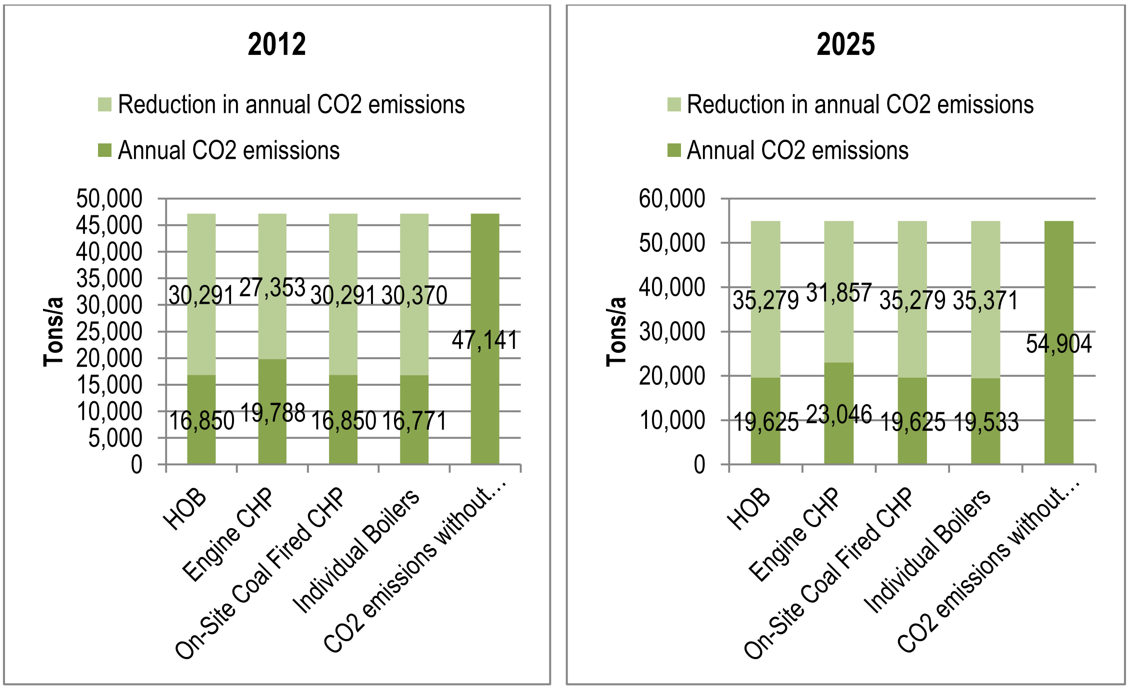
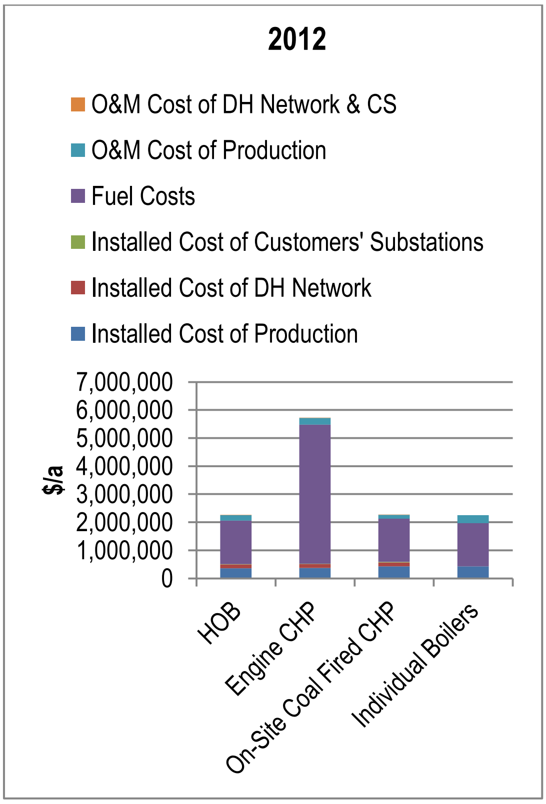


Figure I-22: Annual CO2 Emissions



V. Suhbaatar

Figure I-23: Total Annualized Costs Divided into Cost Items



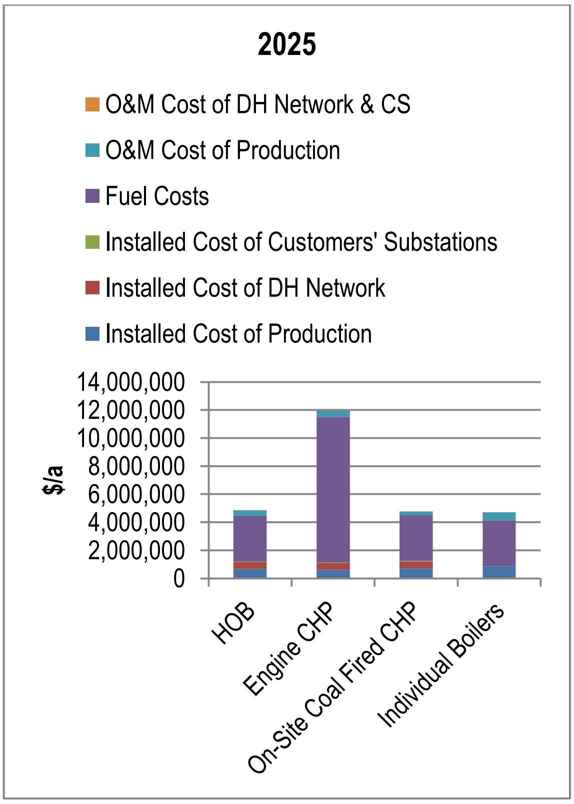
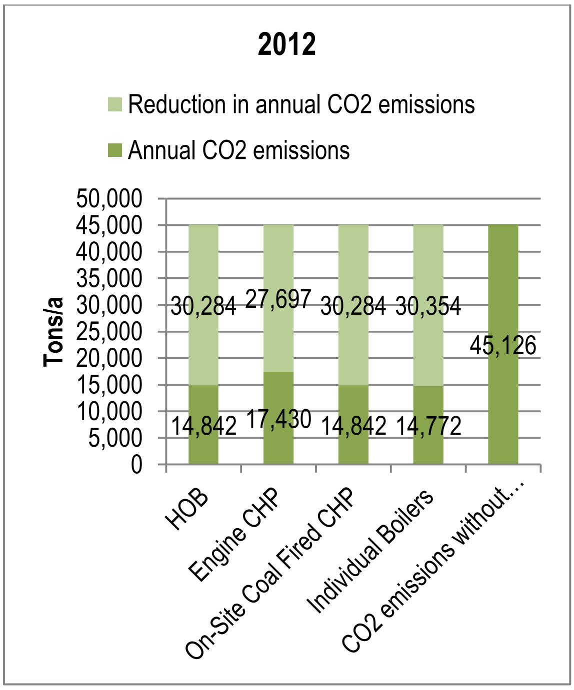
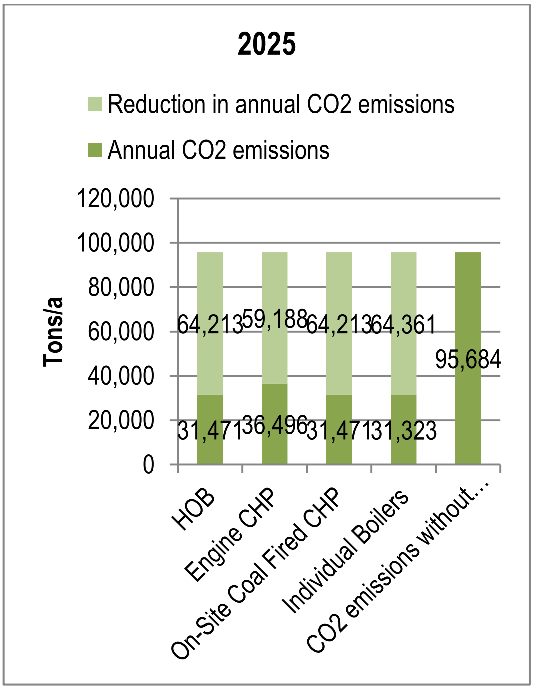


Figure I-24: Annual CO2 Emissions





W. Ulaangom

Figure I-25: Total Annualized Costs Divided into Cost Items

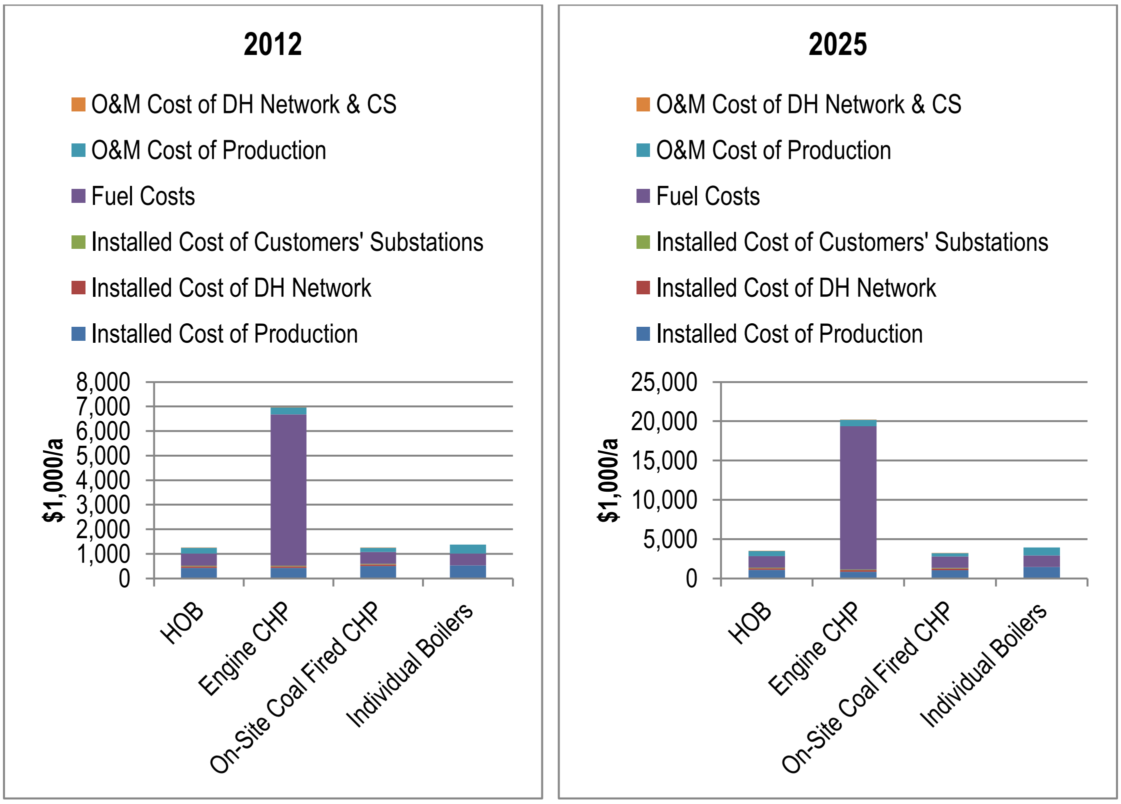
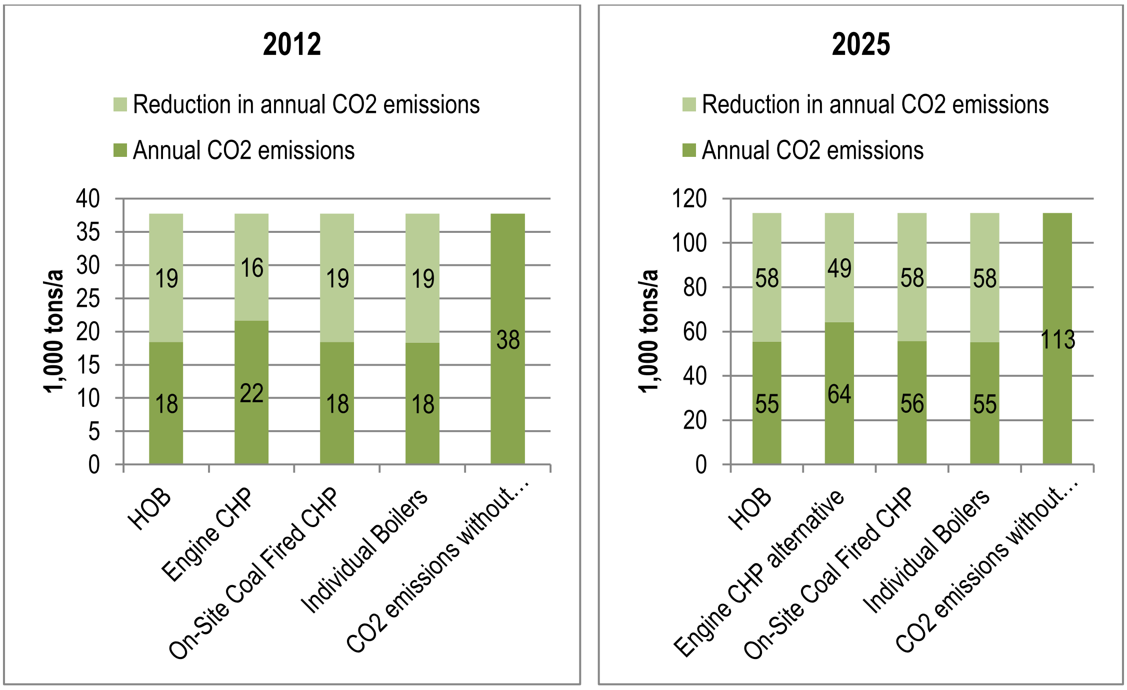


Figure I-26: Annual CO2 Emissions



X. Uliastai

Figure I-27: Total Annualized Costs Divided into Cost Items

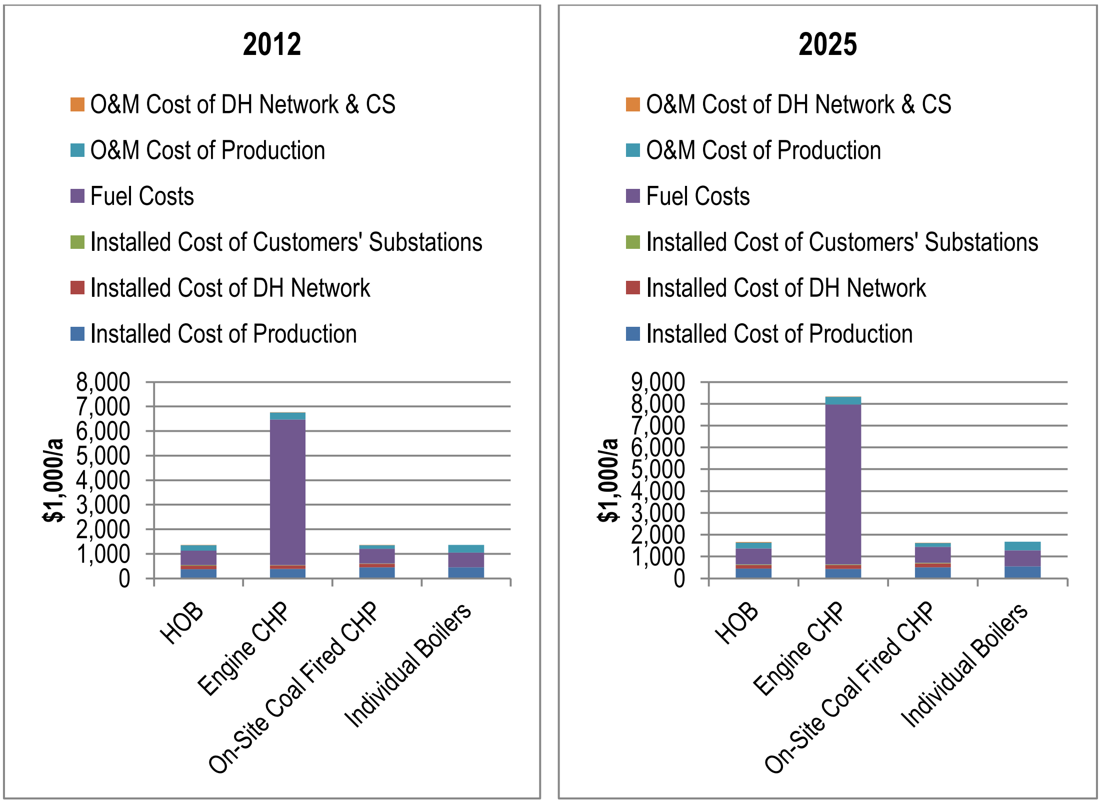
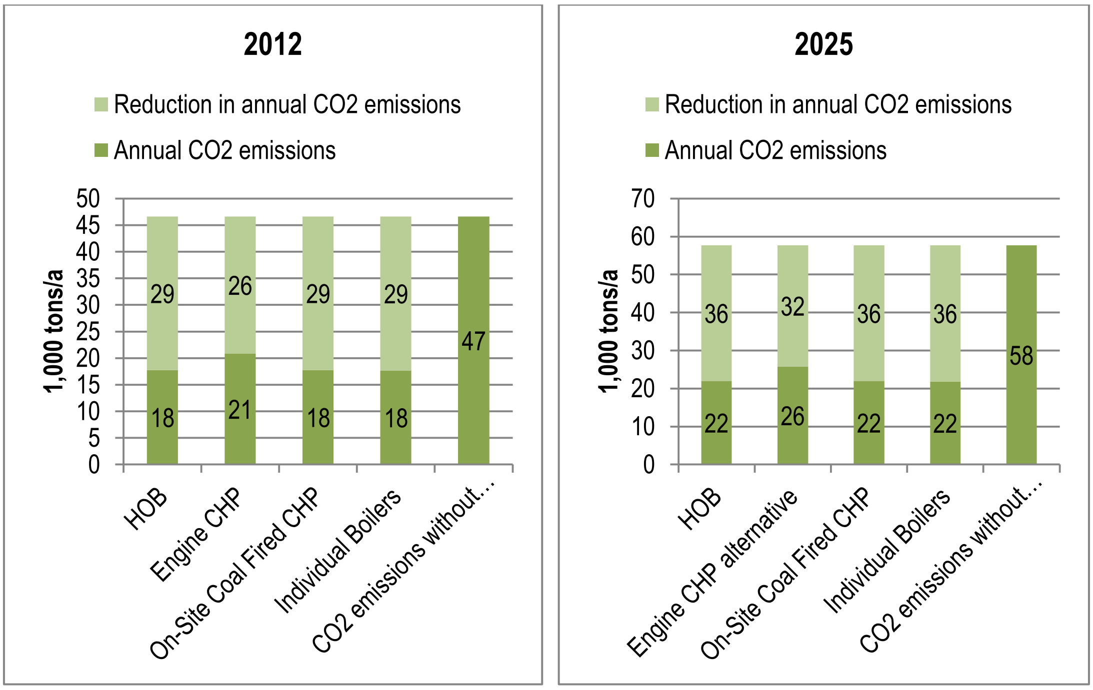


Figure I-28: Annual CO2 Emissions



Y. Hovd

Figure I-29: Total Annualized Costs Divided into Cost Items

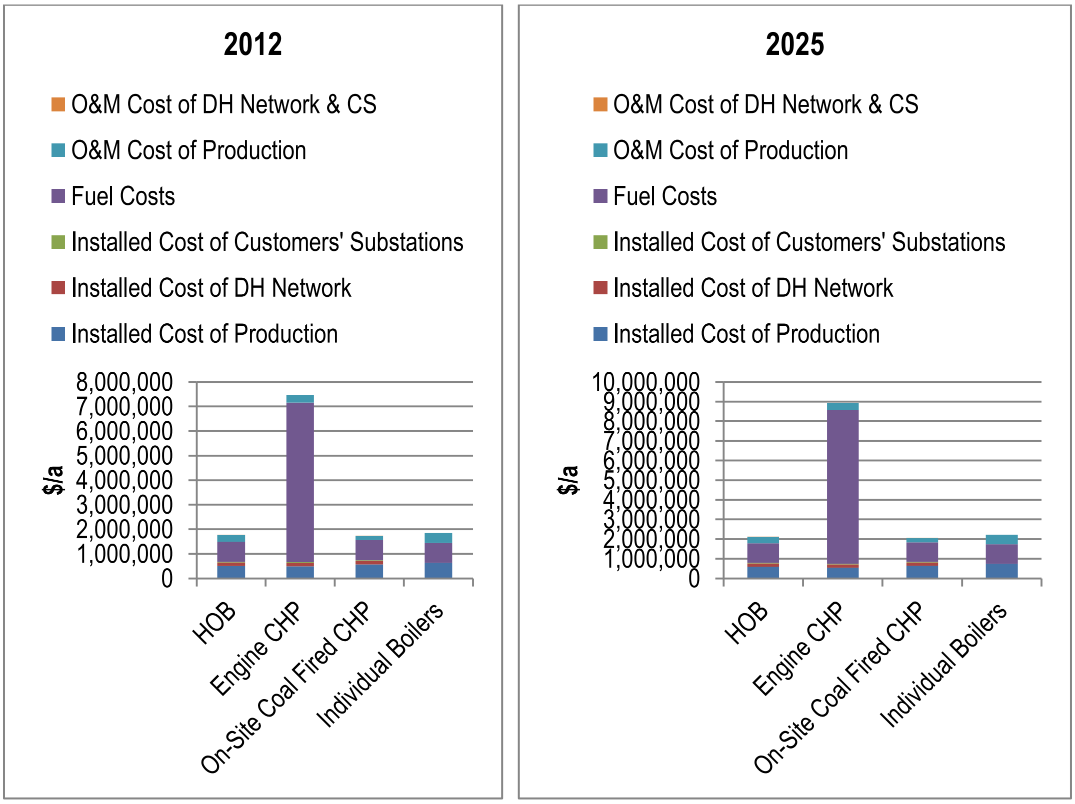
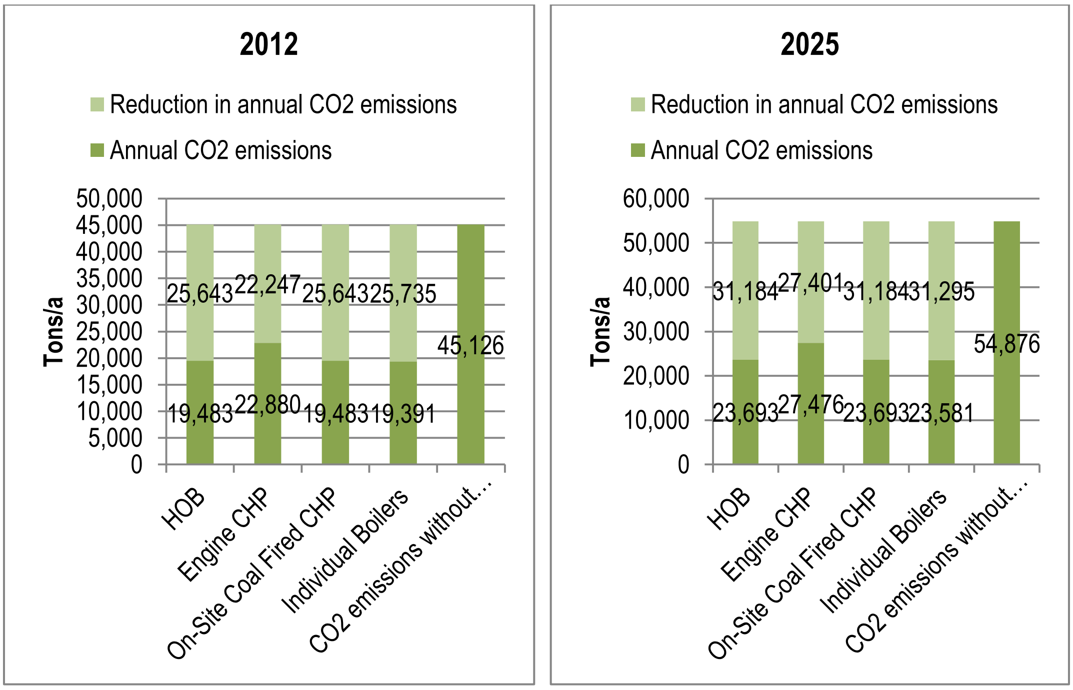


Figure I-30: Annual CO2 Emissions



Z. Tsetserleg

Figure I-31: Total Annualized Costs Divided into Cost Items

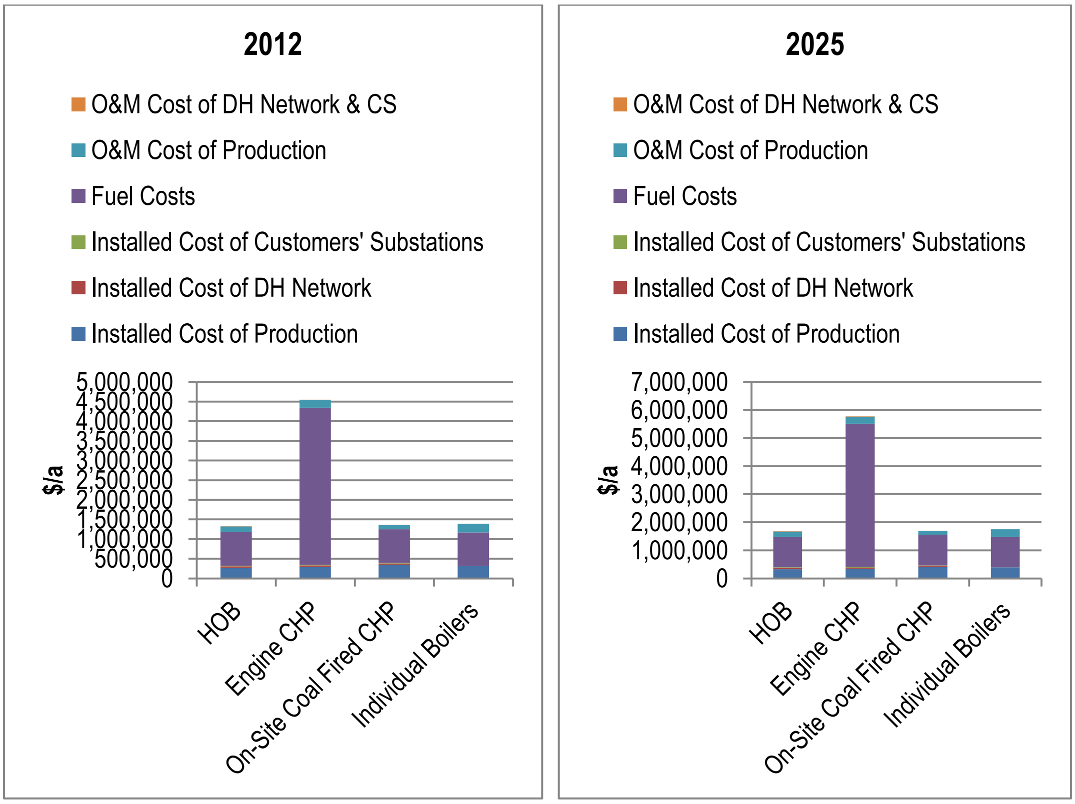
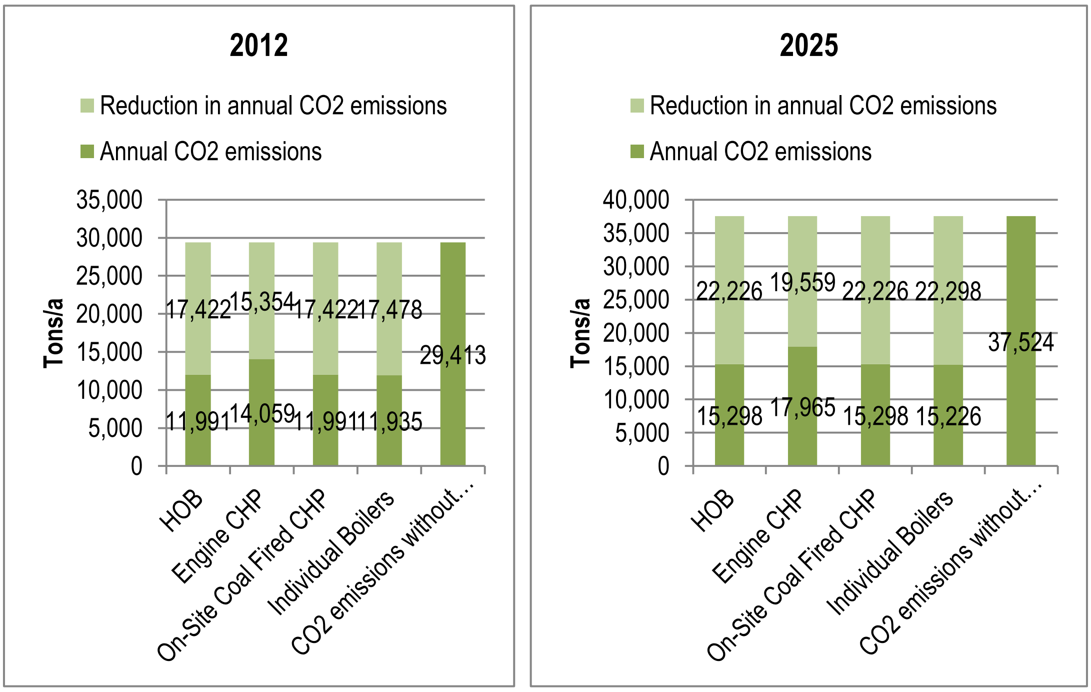


Figure I-32: Annual CO2 Emissions



AA. Nailakh

Figure I-33: Total Annualized Costs Divided into Cost Items

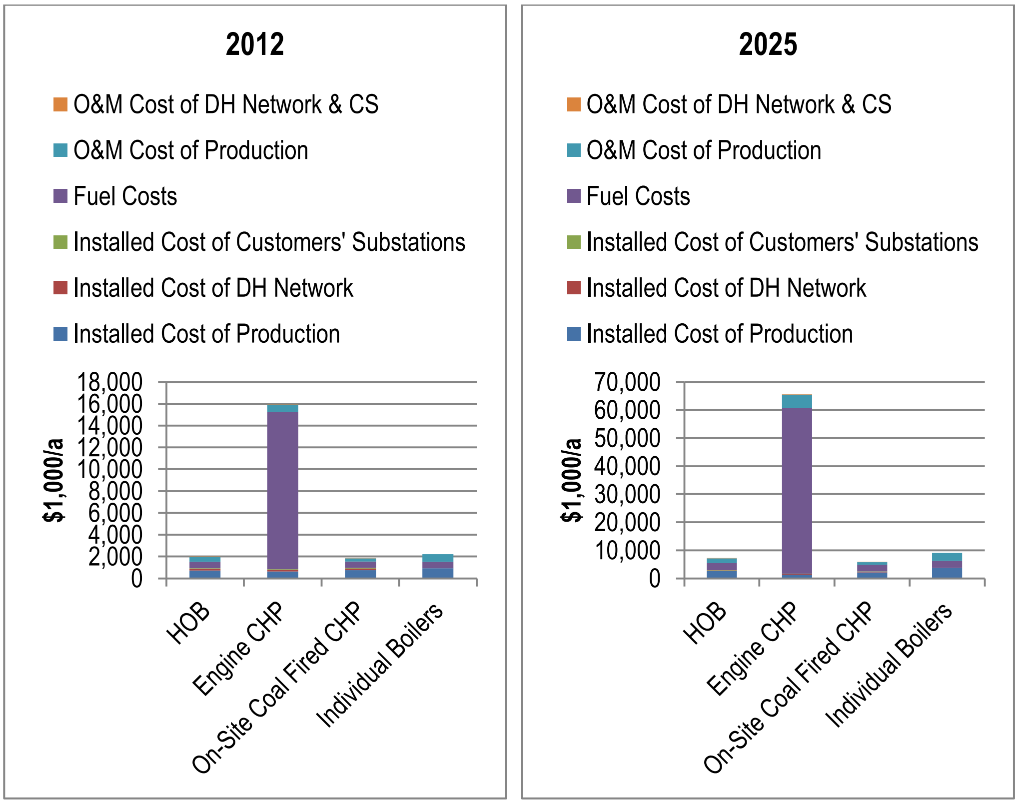
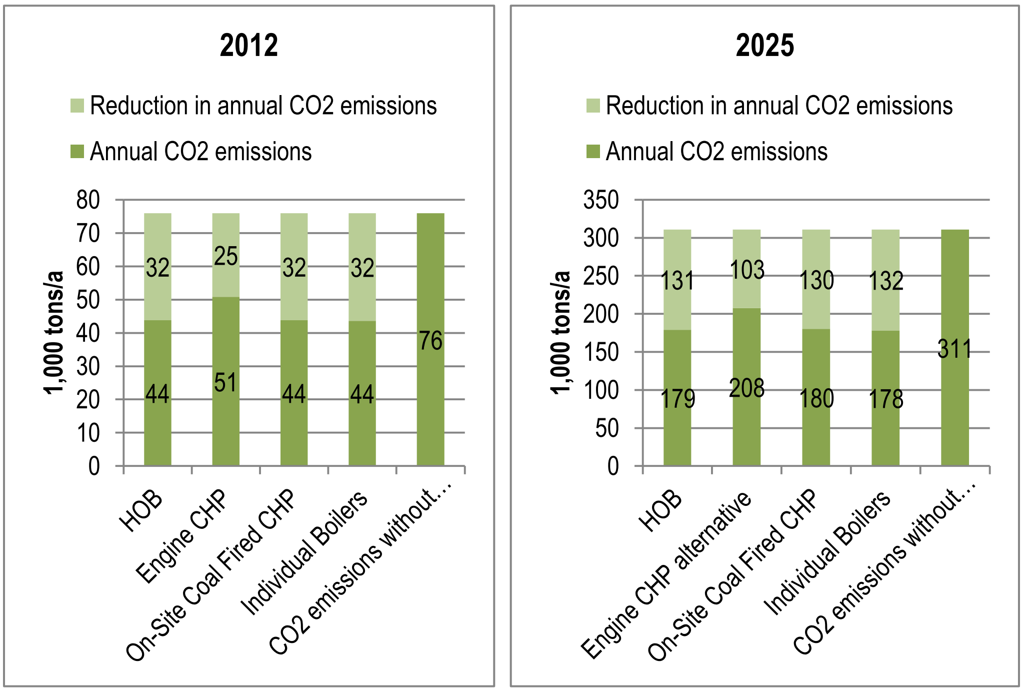


Figure I-34: Annual CO2 Emissions



BB. Choir

Figure I-35: Total Annualized Costs Divided into Cost Items

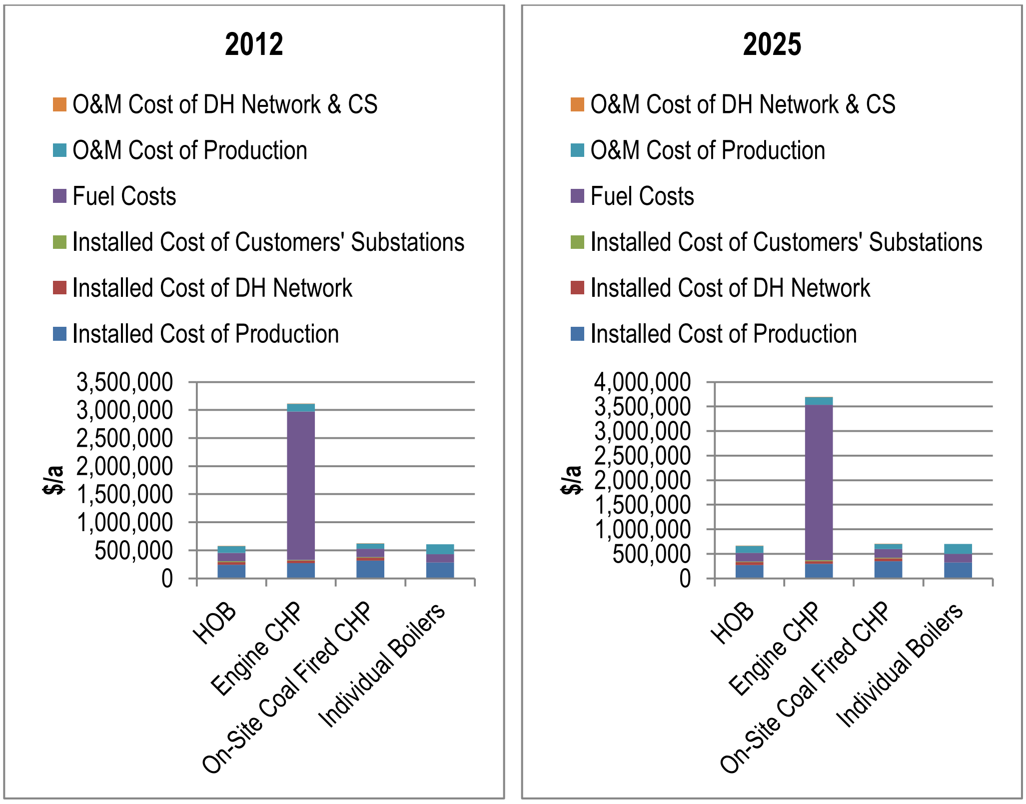
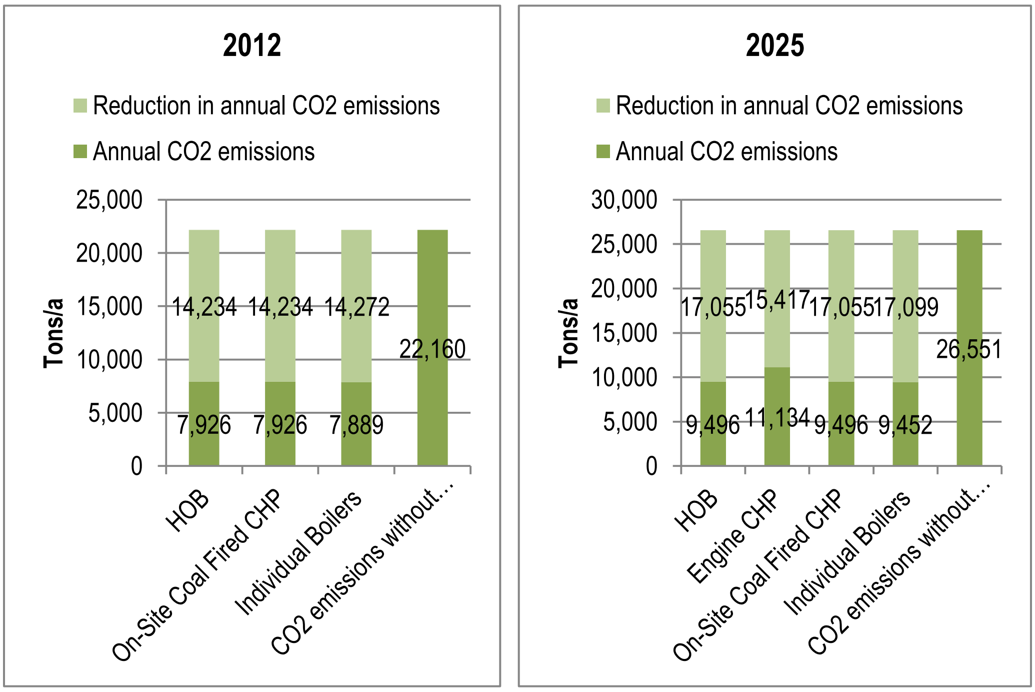


Figure I-36: Annual CO2 Emissions



CC. Baganuur

Figure I-37: Total Annualized Costs Divided into Cost Items

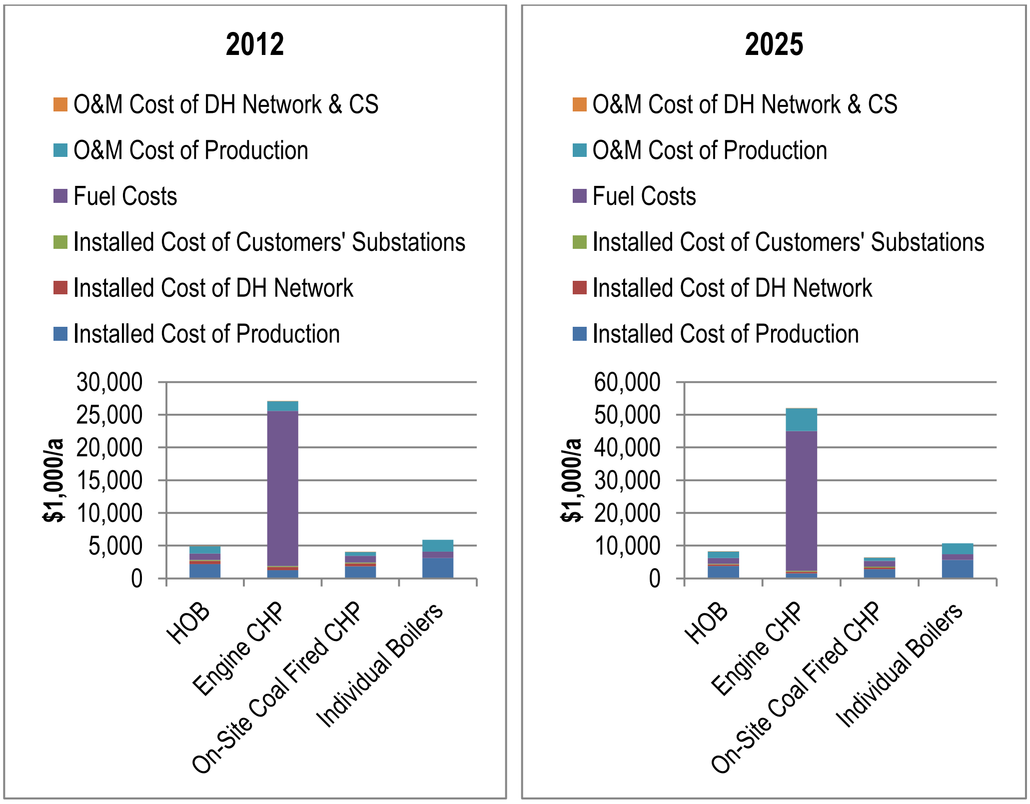
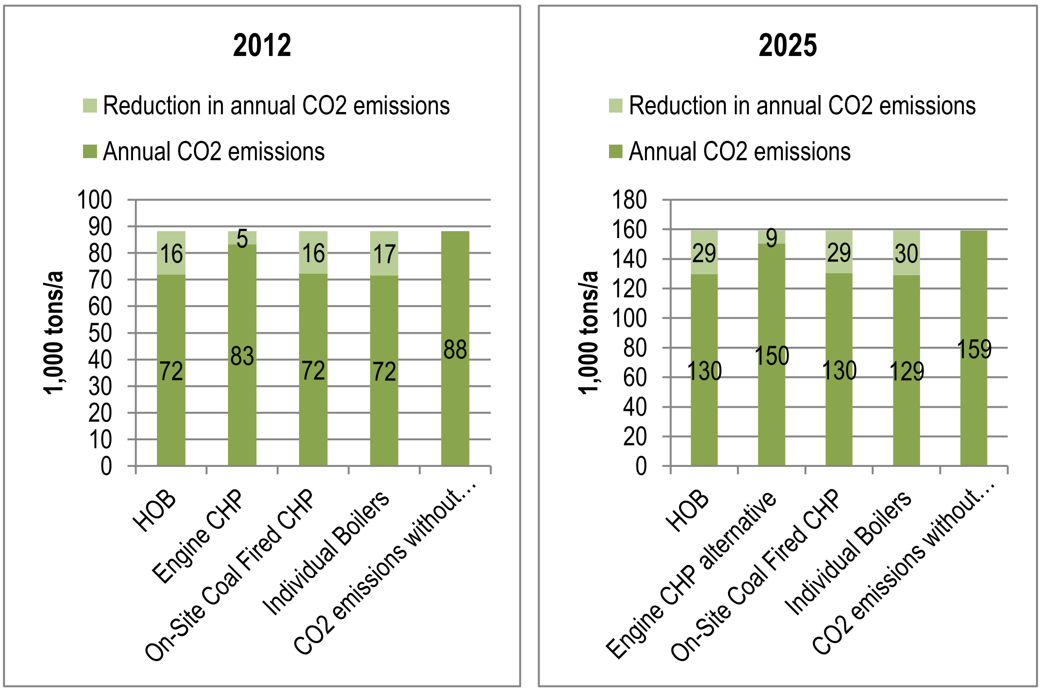


Figure I-38: Annual CO2 Emissions



DD. Choibalsan

Figure I-39: Total Annualized Costs Divided into Cost Items

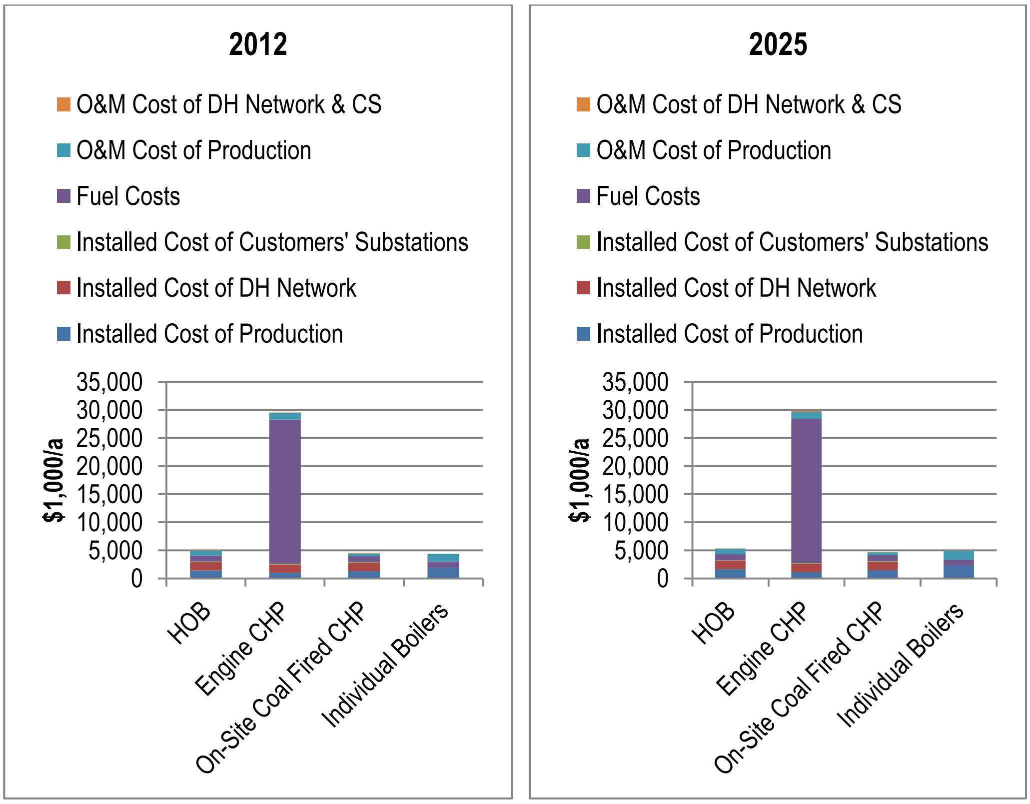
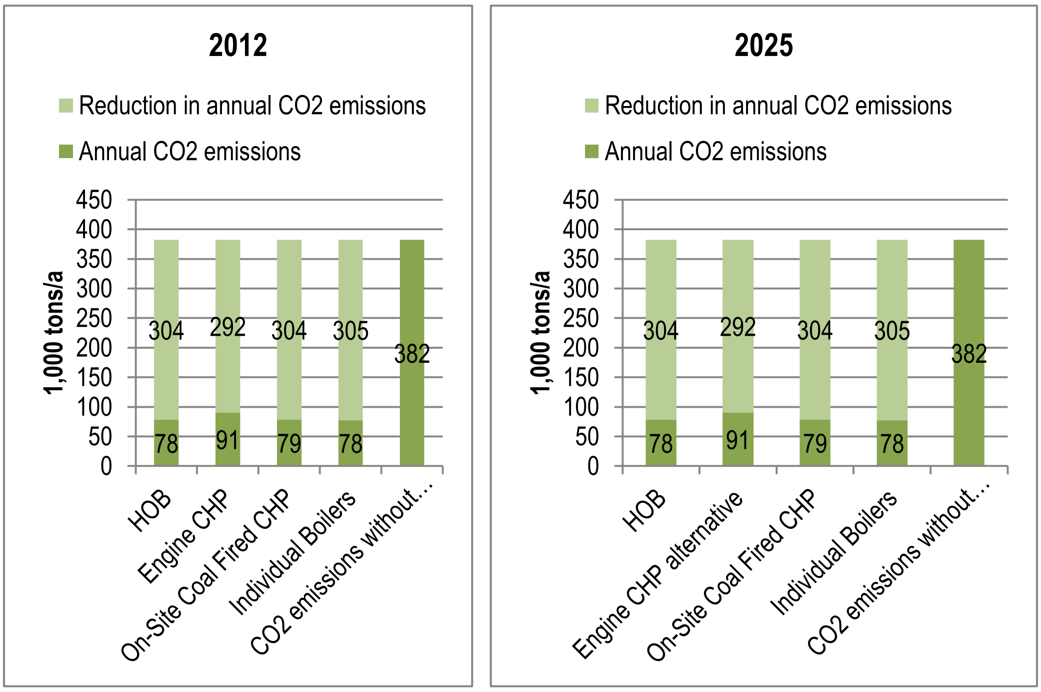


Figure I-40: Annual CO2 Emissions



EE. Dalanzadgad

Figure I-41: Total Annualized Costs Divided into Cost Items

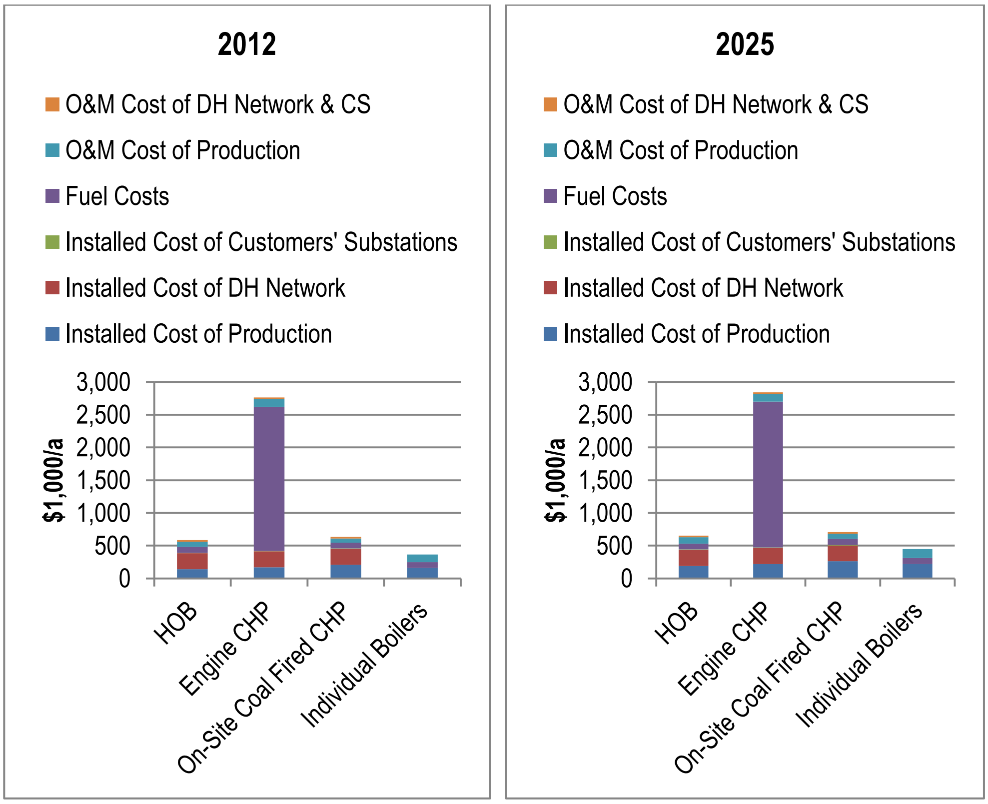


Figure I-42: Annual CO2 Emissions