COVER

01

Quantification of GHG Emissions

The Direct (Scope-1) and Indirect (Scope-2) GHG emissions from various sources TPS have been quantified in this chapter. **The GHG emissions quantified from each source in the existing units are discussed below.**

1.1 Direct Emissions

The GHG emissions quantified from the existing units for the Direct (scope 1) category are elucidated in this section. As mentioned in earlier section, Direct (Scope 1) emissions include the **GHG emissions from the sources owned or controlled by the industry.**

1.1.1 Stationary Combustion

The stationary combustion indicates the combustion of any type of fuel associated with non-movable activities. During the assessment period, the identified stationary sources include fuel combustion in boilers, diesel generator (DG) sets, and LPG consumption in townships as shown in Table 3-1.

Table 3-1 Stationary combustion units within the premises of TPS

Sr. No.	Source	Total Count	Location of the source	Fuel used for combustion
1	Boiler	3	Unit 1,2,3	Coal, FO, LDO
2	DG Set	3	Unit 4,5,6	HSD
3	Canteen	1	Aurora TPS	LPG
4	Residential Block	1	Aurora TPS	LPG

1.1.1.1 GHG Emissions by Fuel Combustion in Boilers

At Auraora TPS, three types of fuels used in boilers for electricity generation. **Coal is used as the primary fuel, while FO and LDO are used as auxiliary fuels for initial ignition purposes.** The combustion of these fuels leads to GHG emissions namely CO2, CH4, and N2O in the environment, with CO2 accounting for the majority of the GHG emissions (ICCA, 2021).The CO2 emissions from the combustion of coal in boilers were quantified based on carbon content in the coal (ICCA, 2021). The following equation was used to calculate CO2 emissions.

1.1.1.1.1 GHG Emissions due to Coal Combustion

According to the data provided by the TPS personnel, the total coal consumption in the FY 2023-24 for Units- 3, 4, and 5 was 1000, 1100, and 1200 tons respectively. The GHG emissions released due to coal combustion along with the month-wise quantity of coal combusted are shown in Table 3-2. The total emissions in terms of CO2e are shown in Table 3-3

$$\text{Emissions}\left(\frac{\text{Tons}}{\text{month}}\right)\ \text{Total Fuel consumption}\left(\frac{\text{Tons}}{\text{month}}\right) * \text{CC} * \ 1.2/32$$

Where:

Emissions = Mass of carbon emitted

Total fuel consumption = Mass of fuel used

CC = Carbon of the fuel, in units of mass of carbon per mass of fuel

1.2/32 = Ratio of molecular weight

Table 3-2: GHG emissions due to coal consumption in Units - 3, 4, and 5

Month	Unit 3				Unit 4				Unit 4			
	Coal Consumption (Tons/month)	GHG Emissions (Tons/month)			Coal Consumption (Tons/month)	GHG Emissions (Tons/month)			Coal Consumption (Tons/month)	GHG Emissions (Tons/month)		
		CO_2	CH_4	N_2O		CO_2	CH_4	N_2O		CO_2	CH_4	N_2O
Apr-23	7108	90429	4.33	0.86	14355	14696	9.39	4.70	12126	16626	5.92	1.49
May-23	7456	94857	4.55	0.90	14312	14652	9.37	4.68	10607	14543	5.18	1.30
Jun-23	5551	70614	3.38	0.67	16445	16835	10.76	5.38	12037	16504	5.88	1.48
Jul-23	6353	80814	3.87	0.76	17046	17450	11.15	5.58	12071	16551	5.90	1.48
Aug-23	6903	87822	4.21	0.83	15700	16072	10.27	5.14	11993	16443	5.86	1.48
Sep-23	6192	78768	3.78	0.75	16056	16437	10.51	5.25	11697	16038	5.71	1.44
Oct-23	6270	79769	3.82	0.75	13787	14114	9.02	4.51	11677	16010	5.70	1.44
Nov-23	2084	26507	1.27	0.25	13653	13977	8.93	4.47	10922	14975	5.34	1.34
Dec-23	6115	77791	3.73	0.74	13151	13463	8.61	4.30	10360	14204	5.06	1.27
Jan-24	3397	43214	2.07	0.41	15589	15959	10.20	5.10	11120	15247	5.43	1.37
Feb-24	6515	82878	3.97	0.78	11057	11319	7.23	3.62	9749	13367	4.76	1.20
Mar-24	6891	87663	4.20	0.83	13409	13727	8.77	4.39	8177	11212	3.99	1.01
Total (Tons/year)	70834.74	901124	43.19	8.52	74560	178701	114	57	32535	181722	65	45.64

It can be observed from the above table that CO2 emissions are higher as compared to CH4 and N2O emissions. The CO2 emission from **Units -3, 4, and 5** were estimated as **901124, 178701, 181722 tons/year** respectively.

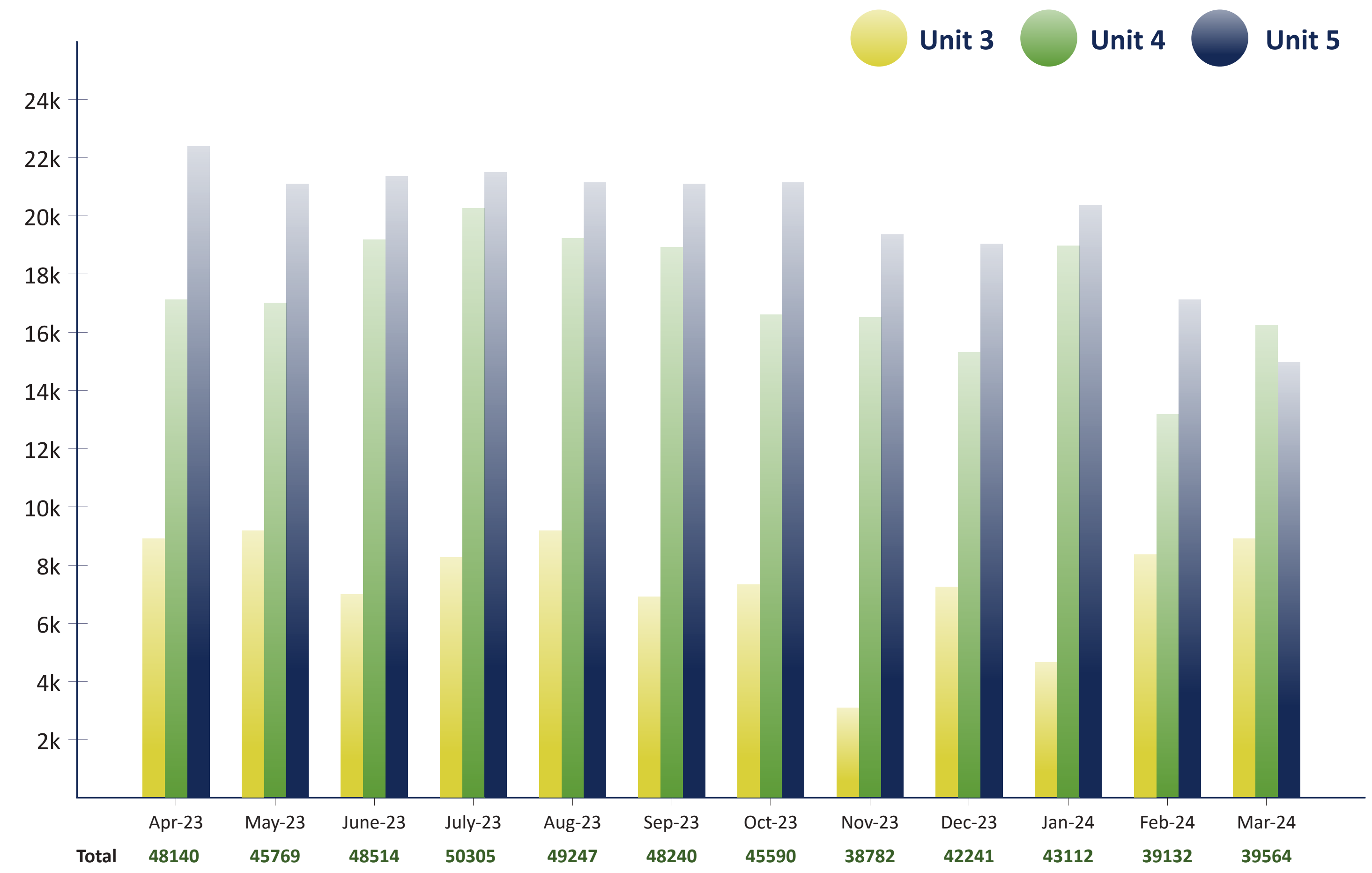


Table 3-3: CO2e emission due to coal consumption in Units - 3, 4, and 5

Total GHG Emission from Boilers due to Fuel Combustion

The fuel-wise and unit-wise GHG emissions from the boilers attached to Units - 3, 4, and 5 are shown in Table 3-8. The emissions in terms of CO2e are shown in Table 3-4.

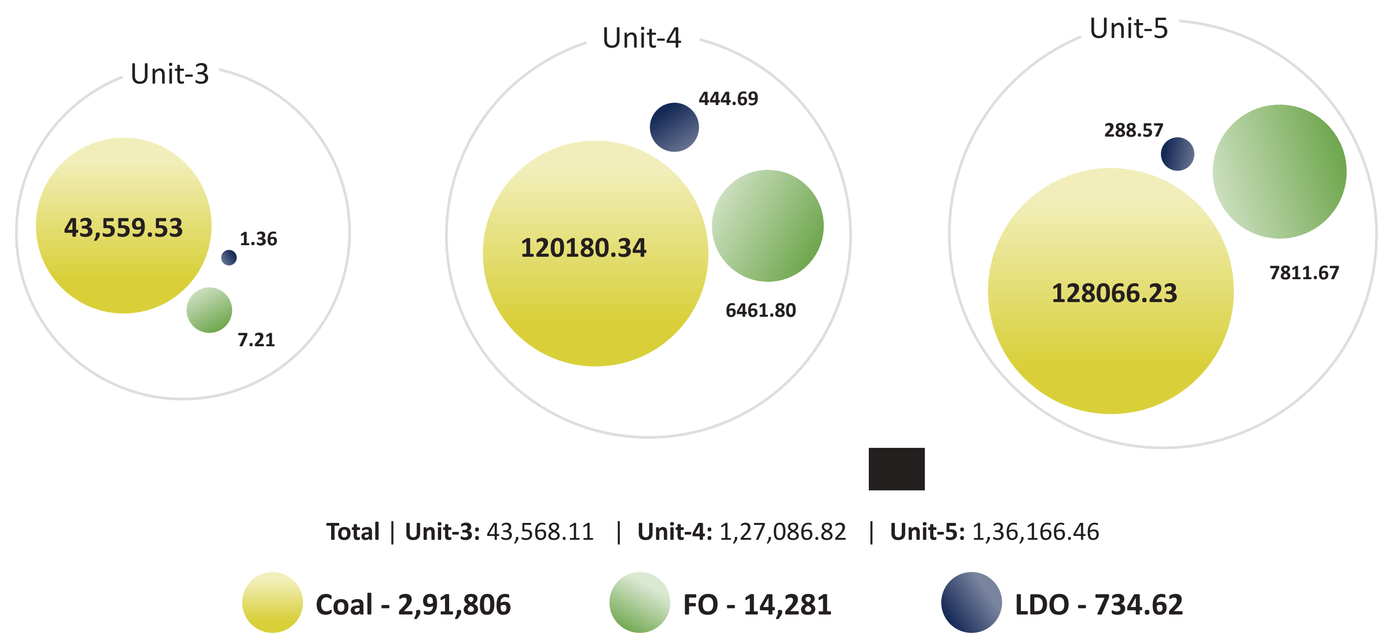


Table 3-4: Total CO2e emission due to fuel consumption in boilers

1.1.2 Mobile Combustion

The mobile combustion source pertains to fuel combustion associated with mobile activities, including vehicular movement within the study area. The vehicle movement within the plant run on either petrol or diesel, and the combustion of these fuels results in direct emissions of GHGs, including CO2, CH4, and N2O. The GHG emissions and CO2e emissions from mobile sources (on-road and off-road vehicles) were estimated and are shown in Table 3-8.

Mobile Source Category	Category of Vehicle	Classification of Vehicle	Type of Fuel	CO_2 (Tons/year)	CH_4 (Tons/year)	N_2O (Tons/year)	CO_2e (Tons/year)
On- road Vehicles	Fire Tenders	HDV	Diesel	17.70	1.77E-04	6.89E-04	14.12
	Cars	LDV	Diesel	7.26	1.35E-03	7.36E-04	5.90
			Petrol	5.15	1.82E-04	8.43E-05	4.09
	Ambulance	MDV	Diesel	18.97	2.36E-04	9.18E-04	15.17
	Total (Tons/year)			49.08	1.95E-03	2.43E-03	39.27
On- road Vehicles	Dozers	HDV	Diesel	40.07	3.47E-02	2.77E-02	227.67
	Locomotives			98.64	6.76E-02	1.88E-02	550.18
	Hydra			0.15	1.33E-04	1.06E-04	0.88
	Payloader			0.62	5.34E-04	4.26E-04	3.50
	Total (Tons/year)			139.48	0.10	0.05	782.23
Total (Tons/year)				188.56	0.10	0.05	821.50

Table 3-8: GHG and CO2e emissions from mobile sources

It can be observed from the above table that CO2e emission due to off-road vehicles was found to be **782.23 tons/year**, whereas CO2e emission from on-road vehicles was **39.27 tons/year.**

The total CO2e emission from mobile sources was **821.50 tons** per year.

1.1.3 Total GHG Emissions from Existing Units

The total GHG emission of the TPS is as shown in Table 3-11.

Category	Sources	Operation/ Activity	Fuel Type	GHG Emissions CO_2 (Tons/year)	CH_4 (Tons/year)	N_2O (Tons/year)	CO_2e (Tons/year)
Direct Emissions (Scope – 1)	Stationary Combustion	Fuel combustion in the boiler	Coal	1261547	222.19	111.16	538634
		DG Set	HSD	6557.06	0.52	0.03	3881.09
		Fuel combustion in DG set	LPG	199.8	0.01	0	158.49
	Total Emissions from Stationary Combustion			1930140	149.39	103.15	1294214
	Total Emissions from Mobile Combustion			188.56	0.1	0.05	821.5
	Total Emissions from Wastewater Treatment Plants			-	0.02	1.96E-03	1.18
	Total Emissions from Refrigeration & Air-conditioning Equipment				-		327.34
	Sub-Total - Direct Emissions			**3198632.4**	**372.23**	**214.392**	**1838038**
Indirect Emission (Scope – 2)	Emissions due to Consumption of Grid Electricity			5676	-		5676
Total Emissions (Direct and Indirect)				**3204308.4**	**372.23**	**214.392**	**1843714**

Table 3-11: Category wise total GHG emissions in terms of CO2e from existing unit

02

1 Net Carbon Footprint of Thermal Power Station

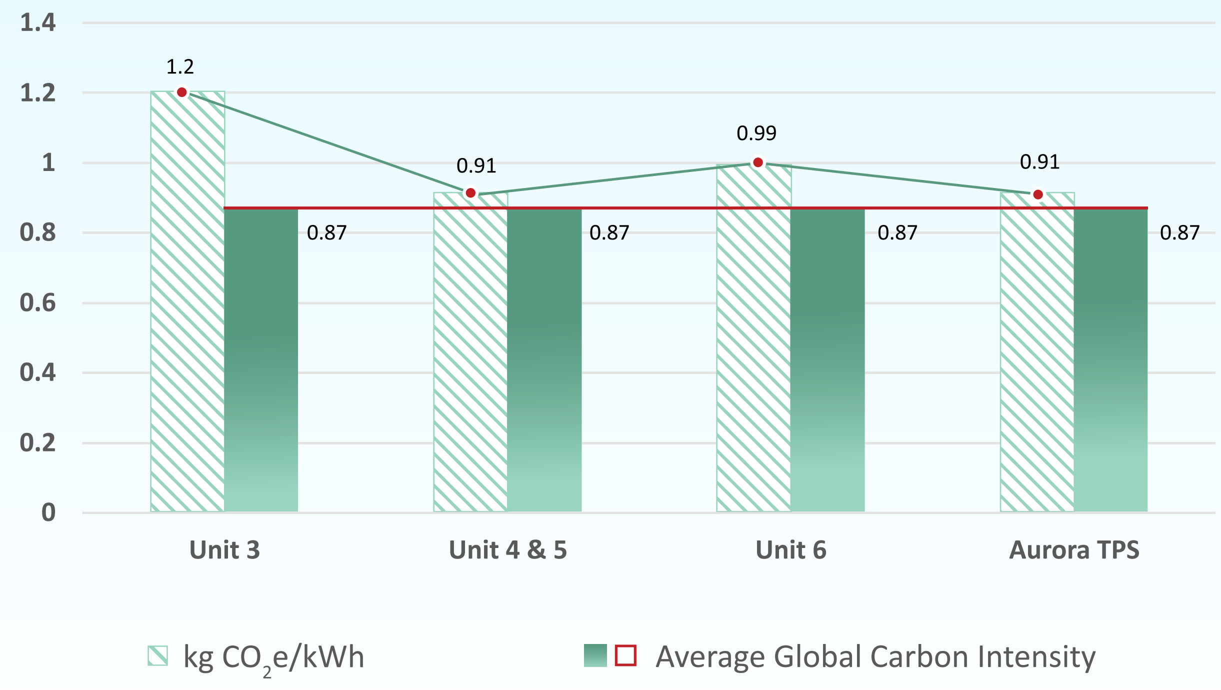
For the year 2023-24, the total CO2e emission (Scope 1 & Scope 2) from Aurora TPS was found to be 4,15,164.68 tonnes CO2e per year. The amount of carbon sequestered annually was found to be 30,768.73 tonnes CO2e. Therefore, the net carbon footprint of TPS was found to be 3,84,395.95 tons CO2e per year.

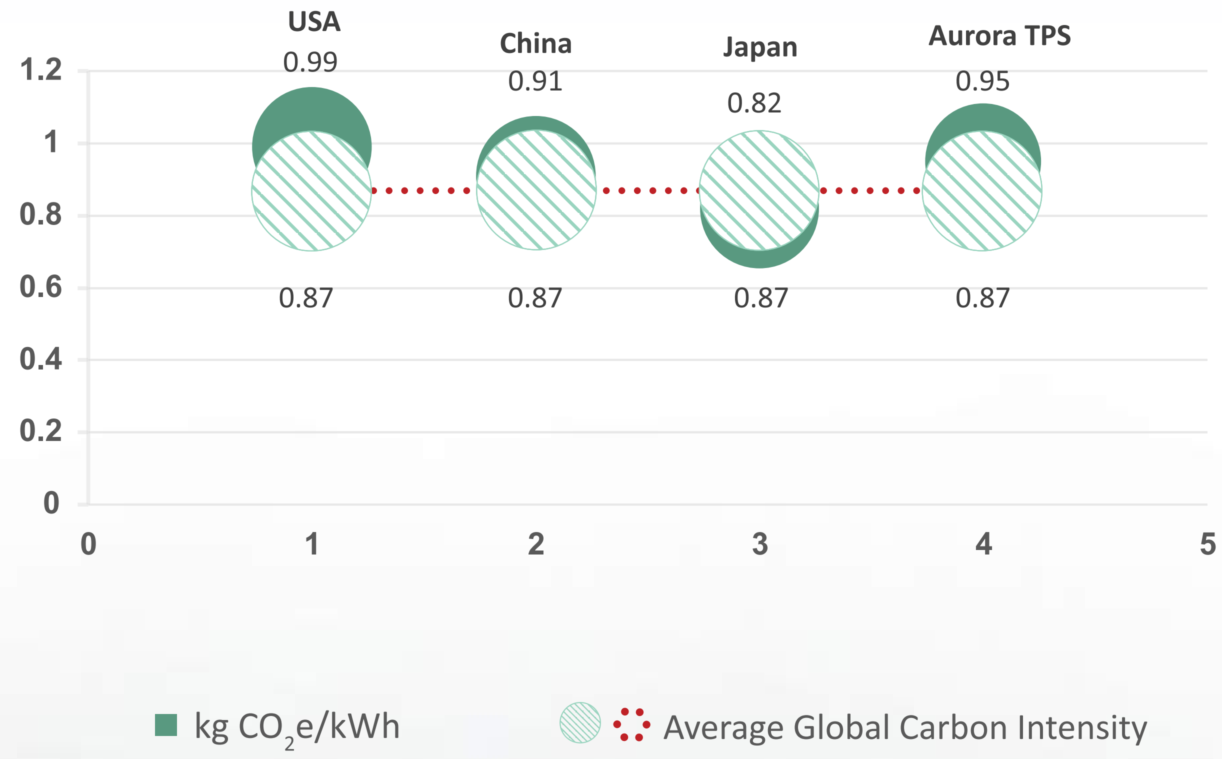
2.1 GHG Emission Intensity Per kWh of Electricity Generation

The GHG emission in terms of CO2e per kWh of electricity generation from Unit 3, Units 4 & 5, Unit 6 and overall TPS are presented in the Figure 5-1. The comparison of GHG emission intensity of Aurora TPS with other coal power plants has been shown in the Figure 5-2.

The GHG emission intensity of Aurora TPS was found to be 0.91 kg CO2e/kWh of electricity generation, which is 4% higher than average GHG emission intensity of global coal-based power plants.

Aurora TPS had 4% higher GHG emission intensity compared to GHG emission intensity of coal power plants in USA. The GHG emission intensity of Aurora TPS was 4% higher compared to the coal power plants in China and 14% higher compared to coal power plants in Japan.





03

Control Scenarios to Reduce Carbon Footprint

Thermal power stations (TPS) are significant contributors to carbon emissions due to their dependence on fossil fuels for electricity. Reducing their carbon footprint is crucial for climate change mitigation and regulatory compliance. Key strategies include improving operational efficiency, adopting cleaner technologies, and integrating advanced emission reduction systems, such as optimized combustion processes, upgraded equipment, lower-carbon fuels, and carbon capture and storage (CCS).

For the year 2023-24, Aurora TPS had a total CO2e emission (Scope 1 & 2) of 415,164.68 tonnes CO2e annually, with 30,768.73 tonnes CO2e sequestered, resulting in a net carbon footprint of 384,395.95 tonnes CO2e per year. To reach net-zero emissions, control scenarios are planned in three phases: Phase 1 (2024-2033), Phase 2 (2034-2043), and Phase 3 (2044-2050). These scenarios outline steps to reduce emissions and enhance carbon offsetting, with detailed estimations provided in the following section.

3.1 Control Scenarios for Reduction at Source

The control scenarios for reduction at source that shall be implemented in phases in order to control emissions at the source are elucidated in this section.

The control scenarios were developed based on the total coal consumption across all units for FY 2023-2024. Depending on feasibility, the TPS can choose to apply the control measures to either a single unit or all units within the recommended phase.

3.1.1 Control Scenario – I: Switch to Lower Carbon Fuels

Switching to lower-carbon fuels is a pivotal strategy for reducing the carbon footprint of thermal power stations (TPS). This approach involves replacing traditional fossil fuels, like coal and oil, with fuels that have a lower carbon content or are renewable. By making this shift, TPS can significantly decrease their greenhouse gas emissions and contribute to a cleaner energy landscape.

Phase 1
Year 2024-2033

In Phase 1, it was considered that the TPS would adopt **7% fuel** replacing **20769 tons** of coal per year.

Phase 1
Year 2024-2033

In Phase 3, it was considered that the TPS would achieve an additional **6% fuel** replacing **35273 tons** of coal per year, thus by 2050, a total of **20% biomass** cofiring will be achieved.
The net CO_2e emitted from the Aurora TPS in the present scenario and the phase-wise percentage reduction in CO_2e with respect to net CO_2e after accounting CH_4 and N_2O emissions from biomass cofiring are presented in Table 6-1.

Phase 1
Year 2024-2033

In Phase 2, it was considered that the TPS would achieve an additional **7% fuel** replacing **27331 tons** of coal per year, i.e. by the year 2043, the TPS will achieve a total of **14% biomass** cofiring.

Table 6-1 Control Scenario I and respective percentage reduction in emissions of CO_2e

Control Scenario - I Switch to Lower Carbon Fuels	Control Measure	% of Coal Replaced	Reduction in CO_2e Emissions w.r.t BAU Scenario	
			tons/year	%
BAU scenario - Net CO_2e emissions (tons/year)			384395.95	
Phase 1- Year 2024 to 2033	Considering 7% fuel used	11.97%	20769	5.40%
Reduced CO_2e emission after Phase - 1 (tons/year)			363627	
Phase 2- Year 2034 to 2043 (Including Phase- 1)	Considering 14% fuel used [Phase 1 (7%) + Phase 2 (7%)]	23.95%	27331	7.11%
Reduced CO_2e emission after Phase - 2 (tons/year)			357065	
Phase 3- Year 2044 to 2050 (Including Phase- 1 & 2)	Considering 20% fuel used [Phase 1 (7%) + Phase 2 (7%) + Phase 3 (6%)]	34.21%	35273	9.17%
Reduced CO_2e emission after Phase - 3 (tons/year)			349123	

It can be observed from the above table that after adopting furl co-firing in phases, the TPS can achieve a reduction of **20769 tons/year (5.40%), 27331 tons/year (7.11%)** and **35273 tons/year (9.17%)** in net CO2e emissions by the year **2033, 2043 and 2050,** respectively.

3.2 Control Scenario for Carbon Offsetting

Carbon offsetting is the process of reducing GHG emissions or sequestering CO2 from the atmosphere for compensating the emissions that occur elsewhere. A few initiatives that can be implemented by organizations for carbon offsetting include the implementation of renewable energy (such as solar technology, wind technology, Bio-CNG plant), tree plantation, mangrove plantation, etc.
Aurora TPS shall adopt the above-mentioned carbon offsetting activities to compensate for their net carbon footprint. All these carbon offsetting measures are discussed in this section.

3.2.1 Carbon Offsetting Case I: Installation of Renewable source within TPS

In this control scenario, it was considered that the TPS would install renewable energy source in the plant and colonies. The phase-wise measures considered under Control Scenario for the installation of renewable energy source are as follows:

Phase 1
Year 2024-2033

In Phase 1, it was considered that the TPS would replace 10% of conventional energy source with renewable energy source within the colonies and TPS.

Phase 1
Year 2034-2043

In Phase 1, it was considered that the TPS would replace additional 20% of conventional energy source with renewable energy source within the colonies and TPS.

Phase 1
Year 2044-2050

In Phase 1, it was considered that the TPS would replace additional 25% conventional energy source with renewable energy source within the colonies and TPS. The reductions in CO2e emission from TPS on adopting carbon offsetting Case – I (renewable energy source) are presented in Table 6-2.

Table 6-2 Carbon offsetting case I and respective percentage reduction in emissions of CO_2e

Control Scenario: Case I (Renewable energy source)	Control Measure	Reduction in CO_2e Emissions w.r.t BAU Scenario	
		tons/year	%
BAU scenario - Net CO_2e emissions (tons/year)		3,84,395.95	
Phase 1- Year 2024 to 2033	Installation of 10% of renewable energy source	12930	3.36%
Reduced CO_2e emission after Phase - 1 (tons/year)		3,71,465.95	
Phase 2- Year 2034 to 2043 (Including Phase- 1)	Installation of additional 20% renewable energy source	15660	4.07%
Reduced CO_2e emission after Phase - 2 (tons/year)		3,68,735.95	
Phase 3- Year 2044 to 2050 (Including Phase- 1 & 2)	Installation of additional 25% renewable energy source	18820	4.89%
Reduced CO_2e emission after Phase - 3 (tons/year)		3,65,575.95	

It can be observed from the above table that after adopting furl co-firing in phases, the TPS can achieve a reduction of 20769 tons/year (5.40%), 27331 tons/year (7.11%) and 35273 tons/year (9.17%) in net CO2e emissions by the year 2033, 2043 and 2050, respectively.

3.3 Summary of Control Scenarios

Control scenarios developed for the year 2024-2033 (Phase 1), 2034-2043 (Phase 2) and 2044-2050 (Phase 3) to achieve the net-zero target of the Aurora TPS are summarized below.

Scenarios	Phase -1			Phase -2		
BAU scenario - Total CO_2e emissions						
	Description	Reduction in CO_2e Emissions	% Reductions (w.r.t BAU)	Description	Reduction in CO_2e Emissions	% Reductions (w.r.t BAU)
Reduction due to control at source (A)						
Switch to Lower Carbon Fuels	7% of total lower carbon fuel used	20,769	5.40%	Additional 7% lower carbon fuel used	27,331	7.11%
Increase in Energy Efficiency	5% Increase in Energy Efficiency	64,454	16.77%	Additional 5% increase in energy efficiency	79,114	20.58%
Integrate Renewable Energy Sources	25% of integrating renewable energy sources	5,942	1.55%	Integrating renewable energy sources in all the remaining sources	8,520	2.22%
Total Reduction at Source (In each Phase)	Phase-1	91,165	23.72%	Phase-2	1,14,965	29.91%
Total Reduction at Source (By end of each Phase)				Phase- 1 + 2	2,06,130	53.62%
Net CO_2e Emission after Reduction at Source (By end of each Phase)	Phase -1	2,93,231		Phase - 1 + 2		

Scenarios	Phase -1			Phase -2		
Carbon offsetting (B)						
Installation of Renewable energy sources	Installation of 10% of renewable energy source	12,930	3.36%	Installation of additional 20% renewable energy source	15,660	4.07%
Trees Plantation	Plantation of total 5.0 lacs trees for next 10 years	2,290	0.60%	Additional plantation of total 5.0 lacs trees for the next 10 years	7,418	1.93%
Improve Plant Maintenance	Improve Plant Maintenance	3,330	0.87%			
Total Reduction by Carbon Offsetting (In each Phase)	Phase-1	18,550	4.83%	Phase-2	23,078	6.00%
Total Reduction by Carbon Offsetting (By end of each Phase)				Phase- 1 + 2	41,628	10.83%
Total Reduction by Control at Source & Carbon Offsetting (A+B) (In each Phase)	Phase-1	1,09,715	28.54%	Phase-2	1,38,043	35.91%
Total Reduction by Control at Source & Carbon Offsetting (A+B) (By end of each Phase)				Phase- 1 + 2	2,47,758	64.45%
Net CO_2e Emission After Control Scenarios at Source & Carbon Offsetting	Phase -1	2,74,681		Phase - 1 + 2	1,36,638	

The reduction in the net CO_2e emissions with the phase-wise implementation of these scenarios along with their percentage reduction for all the phases are mentioned in Table 6-3.

Phase -1			Total (Phase -1 + 2 + 3)		
			3,84,396		
Description	Reduction in CO_2e Emissions	% Reductions (w.r.t BAU)	Description	Reduction in CO_2e Emissions	% Reductions (w.r.t BAU)
Reduction due to control at source (A)					
Additional 6% lower carbon fuel used	35,273	9.18%	20% of lower carbon fuel used	83,373	21.69%
Additional 5% increase in energy efficiency	85,457	22.23%	15% increase in energy efficiency	2,29,025	59.58%
100% renewable energy sources integrated	-	-	100% renewable energy sources integrated	14,462	3.76%
Phase-3	1,20,730	31.41%	-		
Phase- 1 + 2 + 3	3,26,860	85.03%	-	3,26,860	85.03%
Phase - 1 + 2 + 3	57,536		57,536		

Phase -1			Total (Phase -1 + 2 + 3)		
Carbon offsetting (B)					
Installation of additional 25% renewable energy source	18,820	4.90%	Installation of 55% renewable energy sources	47,410	12.33%
Additional plantation of total 2.0 lacs trees for the next 6 years	7,923	2.06%	Plantation of a total 12 lacs trees	17,631	4.59%
	-	-	Improve Plant Maintenance	3,330	0.87%
Phase-3	26,743	6.96%	-		
Phase- 1 + 2 + 3	68,371	17.79%	-	68,371	17.79%
Phase-3	1,47,473	38.36%	-		
Phase- 1 + 2 + 3	3,95,231	102.82%	-	3,95,231	102.82%
Phase - 1 + 2 + 3	-10,835		-10,835		