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APPLICATION OF THE MONITORING, REPORTING AND VERIFICATION SYSTEM FOR GREENHOUSE GAS EMISSIONS IN THE REPUBLIC OF SERBIA: A CASE STUDY OF THE „ISTOK" DISTRICT HEATING PLANT IN NOVI SAD

Research paper

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Abstract: Reliable greenhouse gas reporting requires traceable fuel consumption data, consistent calculation factors and a documented assessment of measurement uncertainty. This paper examines these elements at the „Istok" district heating plant in Novi Sad using its monitoring plan, supporting annexes and annual emission report for 2025. Carbon dioxide emissions are calculated from fuel consumption, net calorific value, emission factor and oxidation factor. Natural gas consumption amounted to 4,696,998 Nm^3, corresponding to 9,770.45 t CO_2; the reported contribution of the emergency diesel generator was 0.10 t CO_2. The combined expanded uncertainty of natural gas activity data was reproduced as 2.06%, below the 2.5% threshold of the applied tier. The turbine meter accounts for approximately 94.1% of the combined variance. The results illustrate how existing commercial and metrological documentation can support a transparent calculation, while identifying reference-condition consistency, metrological evidence and documented auxiliary-fuel estimates as practical priorities. The assessed uncertainty concerns gas quantity and does not represent the complete uncertainty of annual emissions.
Key words: MRV, district heating, carbon dioxide, activity data, measurement uncertainty

INTRODUCTION

The development of monitoring, reporting and verification (MRV) provides the data foundation for climate policy and the assessment of emissions from industrial installations. In Serbia, the framework for the first reporting cycle was established through the Law on Climate Change, the Regulation on Types of Activities and Greenhouse Gases, and the Rulebook on Monitoring and Reporting of Greenhouse Gas Emissions (Republic of Serbia, 2021, 2022, 2023). Monitoring for the first annual cycle began in 2025. The present study concerns this reporting framework and does not assess emissions trading or carbon pricing.
Čepić and Petrović (2026) discussed the introduction of MRV in Serbia and the practical difficulties encountered by operators, including data selection, calculation factors and uncertainty assessment. These issues are relevant even to conventional combustion installations. A correct emission equation alone cannot ensure reliable reporting if fuel quantities, reference conditions or supporting records are inconsistent.
The objective of this paper is to present a compact quantitative case study of the „Istok" district heating plant. The contribution is an installation-specific reconciliation of the reported emissions, reproduction of the activity data uncertainty calculation and interpretation of the relative metering contributions. The analysis uses existing documentation and requires no additional experimental programme.

DESCRIPTION OF THE INSTALLATION AND MONITORING METHODOLOGY

The „Istok" plant, operated by JKP Novosadska toplana, is located in Novi Sad and supplies heat to Podbara, Rotkvarija and part of the city centre. Its two hot-water boilers are K3 (VKLM-50, 58.15 MW) and K4 (RHV 58, 58 MW), giving a documented combined boiler capacity of 116.15 MW. Each boiler has a separate stack, designated EP1 and EP2. Natural

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gas is the sole boiler fuel; the boilers cannot use an alternative fuel. A separate 100 kVA diesel generator provides emergency electricity (JKP Novosadska toplana, 2026b).
The monitoring boundary includes natural gas combustion in both boilers (source stream F1) and diesel combustion in the emergency generator (F2). F1 is classified as the major source stream and F2 as de minimis. Emissions are determined by the standard calculation-based method, without continuous CO_2 measurement at the stacks. Consequently, separate stacks do not require separate fuel-based emission totals for the purpose of this installation-level assessment.
Purchased natural gas quantities are taken from JP Srbijagas invoices and equal consumption because there is no gas storage at the plant. The supplier's metering chain consists of turbine flow meter MI1 and electronic volume corrector MI2. MI1 measures gas volume and MI2 corrects it to the applicable reference conditions. They are two components of one metering chain, rather than independent supply lines. Both belong to the supplier and are subject to national legal metrological control (JKP Novosadska toplana, 2026b).
Gas net calorific value (NCV) and emission factor (EF) are based on the supplier's monthly gas-quality reports for GMRS Novi Sad, with analyses performed by its accredited gas laboratory. The monitoring methodology converts NCV from 15 °C to 0 °C at 101,325 Pa using the factor 1.0554. Gas volumes and volumetric NCV must therefore be expressed on the same basis. The annual report applies tier 3 to gas activity data, NCV and EF. The oxidation factor (OF) is 1. Diesel uses the reported estimate of 0.0313 t and default NCV and EF values (JKP Novosadska toplana, 2026a, 2026b).

METHODOLOGY FOR EMISSION CALCULATION AND UNCERTAINTY ASSESSMENT

For each fuel and reporting interval, carbon dioxide emissions are calculated as follows:

$$E = Q \times NCV \times EF \times OF \quad (1)$$

Here E is emission (t CO_2), Q is fuel quantity, NCV is expressed in TJ per quantity unit, EF in t CO_2/TJ, and OF is dimensionless. For gas quantities in Nm^3 and NCV in MJ/Nm^3, the product Q × NCV is multiplied by 10^{-6} to obtain TJ. For diesel, Q is in tonnes and NCV is 0.043 TJ/t. Annual emissions are the sum of the fuel contributions.
Monthly gas calculations retain the relevant monthly factors. For an equivalent annual calculation, NCV is weighted by gas volume and EF by the corresponding energy input. This preserves the sum of the monthly emissions; multiplying two independently calculated arithmetic averages would not generally do so. The published annual factors are used to check consistency with the annual report, while the monthly table retains the precision of the supplied methodology.
The uncertainty assessment reproduces Annex 4 of the monitoring plan. That annex applies route CT-1 to supplier-owned instruments under legal metrological control and enters 2.00% for MI1 and 0.50% for MI2 as expanded, in-service uncertainties. For uncorrelated inputs expressed at the same coverage factor, the combined relative expanded uncertainty is:

$$U(Q) = \sqrt{[U(MI1)^2 + U(MI2)^2]} \quad (2)$$

The annex reports a coverage factor k = 2; the equivalent combined standard uncertainty is obtained by dividing the result by two. The calculation assumes that the two contributions are uncorrelated. The numerical results therefore reproduce the documented assessment, rather than a new calibration-based determination. Individual certificates and their coverage assumptions were not supplied for independent examination. Maximum permissible errors and certificate uncertainties should be identified correctly and their use justified when the supporting metrological records are reviewed.
No reduction by the square root of the number of months is applied: recurring use of the same instruments does not establish independent monthly errors. The assessment covers

annual gas quantity only. Uncertainty in NCV, EF and their possible correlation is outside the quantitative scope because the required analytical uncertainty data are unavailable. A separate numerical uncertainty budget is not reported for the de minimis diesel stream.

RESULTS AND DISCUSSION

Table 1 brings together the consumption, calculation factors and emissions reported for 2025. Gas volumes refer to 0 °C and 101,325 Pa. OF is 1 for both fuels (JKP Novosadska toplana, 2026a, 2026b).

***Table 1**. Fuel consumption, calculation factors and CO2 emissions in 2025*

Period / fuel	Quantity Nm^3	NCV MJ/Nm^3	EF t CO_2/TJ	Emission t CO_2
Jan	201,310	37.379	55.6	418.4
Feb	231,933	37.391	55.6	482.2
Mar	998,873	37.380	55.6	2,076.0
Apr	708,367	37.401	55.6	1,473.0
May	0	37.686	55.7	0.0
Jun	0	37.748	55.7	0.0
Jul	0	37.788	55.7	0.0
Aug	0	37.563	55.6	0.0
Sep	243	37.694	55.7	0.5
Oct	1,068,711	37.503	55.6	2,228.4
Nov	513,665	37.406	55.5	1,066.4
Dec	973,896	37.407	55.6	2,025.5
Gas annual	4,696,998	37.42010	55.58907	9,770.45
Diesel annual	0.0313 t	43.0 MJ/kg	74.1	0.10
Total	**—**	**—**	**—**	**9,770.55**

Note. Monthly values retain source precision and sum to 9,770.4 t CO_2. Annual gas factors are weighted. The annual total is 9,770.55 t CO_2, shown as 9,770.6 in Annex 3 and rounded to 9,771 in the annual report.

The annual gas volume of 4,696,998 Nm^3 corresponds to approximately 175.76 TJ. Applying the annual NCV and EF gives 9,770.454 t CO_2, consistent with the reported 9,770.45 t CO_2. Diesel contributes approximately 0.001% of the displayed total. Its inclusion remains necessary for completeness, but gas determines the scale of the installation's emissions.
Figure 1 shows the monthly distribution of gas-related emissions. October has the highest reported value (2,228.4 t CO_2), followed by March and December. These three months account for approximately 64.8% of annual gas emissions. No gas consumption is reported from May to August. The unusually low January and February values compared with March should be checked against dispatch and operating records before attributing the distribution solely to outdoor temperature.

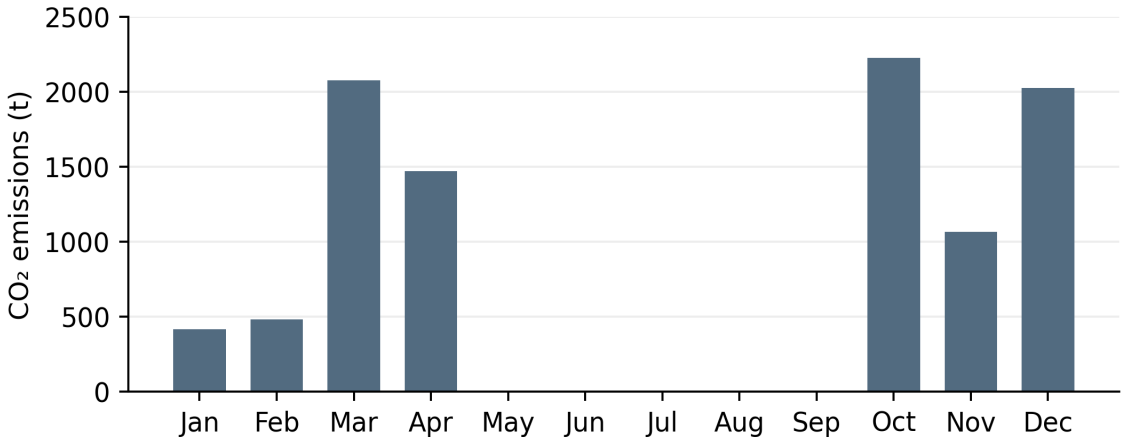


***Fig. 1**. Monthly CO_2 emissions from natural gas at „Istok" in 2025*

***Table 2**. Reproduction of the natural gas activity data uncertainty assessment*

Component / indicator	Value	Interpretation
MI1 turbine meter	2.00%	Expanded input; 94.1% of variance
MI2 volume corrector	0.50%	Expanded input; 5.9% of variance
Combined standard uncertainty	1.03%	Equivalent value at k = 1
Combined expanded uncertainty	2.06%	Result at k = 2; uncorrelated inputs
Applied tier 3 threshold	2.50%	Headroom: 0.44 percentage points

Source: Authors' calculation from Annex 4 (JKP Novosadska toplana, 2026b). Variance shares are each squared input divided by the sum of both squared inputs.

The combined result is below the 2.5% threshold for the applied activity data tier 3. The monitoring plan lists tier 2, with a 5.0% threshold, as the required tier. Thus, the documented assessment supports the higher applied tier, subject to the validity of its metrological inputs. The gas meter accounts for 94.1% of combined variance, making its documentation and performance the first priority in maintaining the metering assessment.

As a simple sensitivity interpretation, a 2.06% change in annual gas quantity would change calculated gas emissions by approximately 201 t CO_2 when all factors are held fixed. This is the emission effect of the activity data component, not a complete confidence interval for the annual emission inventory. If the two metering contributions were fully positively correlated, their combined value would be 2.50%, leaving no margin below the applied threshold. This conditional comparison shows why the correlation assumption should be documented.

Data consistency is equally important. The 15 °C to 0 °C NCV conversion changes the numerical volumetric value by 5.54%, which exceeds the assessed 2.06% metering uncertainty. Mixing gas volume and NCV reference conditions could therefore create a systematic calculation error larger than the metering component. A consistent unit convention and an independent check of spreadsheet formulas are practical controls with immediate value.

The supplied risk assessment identifies meter and corrector failures, missing calibration documentation, reading and data-entry errors, and incorrect calculation factors. It proposes checks against production records, timely acquisition of metrological documentation and review by a person independent of data entry. These measures address traceability and processing errors that are not represented by the numerical uncertainty budget (JKP Novosadska toplana, 2026b).

Two documentation issues warrant clarification. First, the supplied monitoring plan records tier 2b for gas NCV and EF, whereas the annual report records tier 3 based on laboratory analyses. This does not affect the reproduced arithmetic, but the stated tiers and supporting

evidence should be reconciled. Second, the diesel estimate uses 4.67 operating hours and 80 kW. The cited European Commission (2021) example specifies rated thermal input for this approach. Since the plant description gives a 100 kVA generator, the basis of the 80 kW value needs confirmation. If it is electrical output, fuel input cannot be established without accounting for efficiency and load. The reported 0.10 t CO_2 is retained here as a documented estimate, not independently validated fuel consumption.

CONCLUSION

The „Istok" case demonstrates a practical use of existing monitoring documentation to connect annual CO_2 emissions with activity data quality. Natural gas consumption of 4,696,998 Nm^3 yielded 9,770.45 t CO_2 in 2025. Together with the reported diesel contribution of 0.10 t CO_2, the displayed annual fuel values sum to 9,770.55 t CO_2. The calculation using the published annual gas factors reproduces the reported gas emission.
The activity data uncertainty assessment gives 2.06% at k = 2 under the documented assumption of uncorrelated meter and corrector contributions. This is below the applied 2.5% tier threshold, with the turbine meter contributing 94.1% of combined variance. The result concerns gas quantity; it should not be presented as the total uncertainty of reported emissions.
The approach is readily applicable to comparable gas-fired heating plants with supplier invoices, gas-quality data and documented metering systems. Practical priorities are to maintain metrological evidence, align gas reference conditions, reconcile factor-tier descriptions and substantiate emergency-generator fuel estimates. These targeted checks improve reporting reliability without requiring a complex additional monitoring programme.

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