DEVOTION Journal of Research and Community Service
Volume 5, Number 7, July 2024
e-ISSN: 2797-6068 and p-ISSN: 2777-0915

# EMISSION INVENTORY OF CENTRAL PROCESSING PLANT IN THE OIL AND GAS INDUSTRY IN CENTRAL SULAWESI

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**KEYWORDS**
Inventory GHG Emission, Oil and Gas Industry, Central Processing Plant

**ABSTRACT**

The Central Processing Plant (CPP) in Central Sulawesi, Indonesia, is one of the largest oil and gas industries in the world. This study aims to determine the magnitude of the greenhouse gas emission load and identify the operational facilities that produce the highest GHG emissions from CPP Donggi. The study results show an emission inventory for 2021 is 7.609ton CO2-eq per year or 365.78 tonnes of CO2 per TJ in 2021, for 2022 is 8.084ton C2Eq/355.50 tonnes CO2/TJ, and dan for 2023 is 7.565ton. The three highest carbon emission-generating facilities are the Gas Turbine Generator, Acid Gas Removal Unit, and Oil Heater. The research contributes to understanding the scale and distribution of greenhouse gas emissions from a specific industrial source and aids in directing efforts for emission reduction.

## INTRODUCTION

Climate change is caused by an increase in global average temperature, mainly due to the accumulation of greenhouse gases in the atmosphere (Chaturvedi, 2021). The main greenhouse gases are carbon dioxide and methane (Sreenivas et al., 2016). The causes and impacts of climate change vary worldwide, depending on geography and human activities. Carbon dioxide ($CO_2$), the main driver of climate change, is generated from natural processes and human activities, primarily from burning fossil fuels (Lin & Tan, 2021). It is emitted from various sources such as oil and gas industries (Bello et al., 2023) and power plants (Wilberforce et al., 2019). Monitoring and assessing $CO_2$ emissions from all potential sources are crucial to understanding its accumulation in the atmosphere and its impacts. The impact of climate change from $CO_2$ emissions is predicted to worsen in the coming decades, with effects such as rising sea levels, loss of sea ice, glacier and ice sheet melting, increased intensity of heat waves, and shifts in the geographic range of plants and animals (Yao et al., 2023). Climate change impacts are mainly caused by the interaction of solar energy with greenhouse gases such as carbon dioxide, methane, nitrous oxide, and fluorinated gases in the Earth's atmosphere. Climate change affects natural disasters, natural resources, economic sectors, and communities including living standards, gender, and health (Erfian, 2024). Due to climate change, all stakeholders are committed to reducing greenhouse gas emissions and adapting to the impacts of climate change (World Bank Group, 2021).

Greenhouse gas inventory provides periodic data and information on the levels, status, and trends of greenhouse gas emissions from various sources (and carbon sinks, including carbon storage) (Indonesia, 2011). The purpose of this inventory is to provide regular information on the levels, status, and trends of greenhouse gas emissions and absorptions, including $CO_2$ reduction, at the national, state, and city/district levels. The inventory includes additions and improvements to the IPCC Guidelines ratified by Indonesia in Minister of Environment and Forestry Regulation No. 73 of 2017. This regulation explains the implementation procedures, institutional arrangements, source categories, data collection and updating mechanisms, analysis processes, and greenhouse gas inventory reporting procedures. The principles that must be met to conduct a greenhouse gas emissions inventory are transparency, accuracy, completeness, consistency (Menteri Lingkungan Hidup dan Kehutanan, 2017).

A greenhouse gas emissions inventory was conducted in the oil and gas industry using different guidelines, such as the one published by the American Petroleum Institute in 2021. The API guideline used was the Compendium of Green House Gas Emission Methodologies for the Oil and Natural Gas Industry in 2021, which is based on the calculation of natural gas processes. It is important to identify emission sources when calculating greenhouse gas emissions. One of potential activity with a high greenhouse gas emissions is the natural gas purification process or Central Processing Plant (CPP) in the oil and gas industry. Inventory greenhouse gases need calculated in CPP Donggi in Central Sulawesi, Indonesia. It is vital due to its significant $CO_2$ gas potential from operate CPP Donggi. CPP Donggi is one of key energy role Indonesia. In-depth research on emission inventory is essential to understand the environmental impact of operational activities and achieve the Net Zero Emission target by 2050. The inventory is aimed at determining the amount of greenhouse gas emissions and identifying facilities with the highest emissions from operate CPP. This research serves as a strategic step towards improving sustainability and reducing the carbon footprint of CPP Donggi.

The purpose of this study is to determine the magnitude of the greenhouse gas emission load and identify the operational facilities that produce the highest GHG emissions from the CPP in Central Sulawesi. The research contributes to understanding the scale and distribution of greenhouse gas emissions from a specific industrial source and aids in directing efforts for emission reduction.

## RESEARCH METHOD

The research method begins with a review of previous literature to understand past research references, providing a foundation for further study. Various sources, including books, scientific journals, guidelines from organizations like IPCC, API, and government regulations, are used to gather information on greenhouse gas emissions and emission inventories. Emission inventories are compiled based on operational production processes that adhere to international standards such as IPCC and API guidelines. Operational activities at CPP Donggi are identified based on API standards, ensuring compliance with operational requirements. Emissions are calculated for $CO_2$ and $CH_4$ gases using emission factors from the American Petroleum Institute. Data from 2021 to 2023 is utilized for emission inventories, including gas production and equipment data such as Gas Turbin Generator (GTG), Oil Heater, Reboiler Dehydration (DHU), Main Flare, Acid Flare, Thermal Oxidation (TOX) Incinerator, and gas sales.

## RESULT AND DISCUSSION

Identification of emission-generating operational activities will be conducted based on the 2021 American Petroleum Institute standards. Operational activities refer to the types of natural gas processing activities. Raw natural gas is produced from gas wells and consists of a mixture of hydrocarbons, mainly ethane, propane, butane, and pentane. According to the 2021 American Petroleum Institute standards, a field survey was conducted to verify the operational facilities at CPP Donggi. The field survey results identified several emission-generating activities. GHG emissions in the operational process of CPP Donggi occur due to three main activities, fuel combustion for primary processes, gas waste disposal, and vented gas during the process.

**(a)** **(b)** **(c)**

**Figure 1.** The Gas Turbin Generator (a). The Oil Heater (b). The DHU Reboiler (c).

Emissions from the primary combustion process occur at three facilities: the GTG, the oil heater, and the DHU reboiler. The first combustion process, which takes place in the GTG unit, generates electricity for CPP Donggi operations. The second combustion process, occurring in the oil heater unit, produces heat for the AGRU regeneration process. The final combustion process generates heat to separate moisture present in the main gas purification process. Emissions from gas waste disposal combustion occur at three facilities: the acid flare, the main flare, and the TOX incinerator. Combustion is used for treating waste gas containing $H_2S$, a highly toxic gas hazardous to humans. Inhaling air with an H2S concentration of 0.1% or 1000 ppm can cause immediate paralysis of the respiratory system and death. The reaction of $H_2S$ with water can damage piping systems due to corrosion (Koyanbayev et al., 2022). Although preferred, gas flaring still harms public health, potentially causing cancer, asthma, chronic bronchitis, blood disorders, and other diseases (Davoudi et al., 2013). Therefore, it is essential to implement mitigation strategies to reduce gas flaring operationally (Blundell & Kokoza, 2022; Orisaremi et al., 2022). The TOX incinerator's emissions result from the incomplete sulfur capture process in the Biological Sulfur Recovery Unit (BSRU), mixed with emissions from the main AGRU process.

**(a)** **(b)** **(c)**

**Figure 2.** Main Flare (a). Acid Flare (b). TOX Insinerator (c).

Emissions from gas release during the main process occur at the AGRU facility, which removes acid gases, including $H_2S$ and $CO_2$, at CPP Donggi. Chemical absorption with amine solvents is widely used for acid gas removal in the gas processing industry. The AGRU process uses chemical absorbers in the form of amine solvents, which absorb acid gases and are regenerated with heat in the oil heater pipes, triggering the desorption reaction and regenerating the solvents for reuse in the AGRU process (Cho et al., 2015).

**Figure 3.** Acid Gas Removal Unit.

This emission inventory calculates emissions based on $CO_2$, $CH_4$, and $N_2O$ gases. The inventory of emissions is determined by multiplying the emission-producing activity by the emission factor. The emission factor is defined as the value representing the relationship between the amount of pollutant released into the atmosphere and the activity associated with that release (Susanto, 2024). Greenhouse Gas (GHG) emission inventories are often reported as Carbon Equivalent or Carbon Dioxide Equivalent ($CO_{2\text{-eq}}$), where all GHGs are converted to an equivalent basis relative to $CO_2$. This equivalent form is commonly referred to as Global Warming Potential (GWP). GWP measures a compound's ability to trap heat in the atmosphere over a specific period compared to the effect of an equal mass of $CO_2$ released over the same period (American Petroleum Institute, 2021). GWP values quantify the amount of energy absorbed by one ton of a gas over a specified period (typically 100 years) relative to one ton of CO2. The higher the GWP value, the greater its impact on surface warming (Lazuardi, 2024). The inventory is conducted according to emission factors provided in the 2021, American Petroleum Institute standards, using data from 2021, 2022, and 2023.

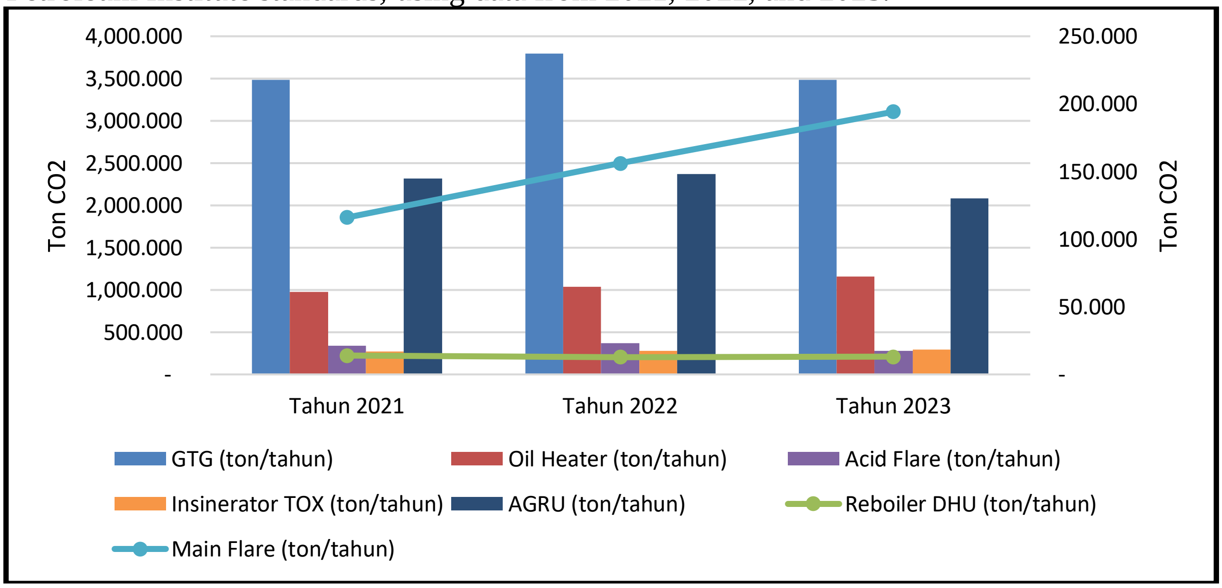



**Figure 4.** Graph $CO_2$ Green House Gas Emissions

In 2021, the operational equipment with the highest $CO_2$ emissions were the GTG combustion unit (46%), the AGRU processing unit (31%), the Oil Heater combustion unit (13%), the acid flare (5%), the TOX incinerator (4%), the main flare (2%), and the DHU reboiler (0.2%). In 2022, the equipment order remained similar: the GTG combustion unit (47%), the AGRU processing unit (30%), the Oil Heater combustion unit (13%), the acid flare (5%), the TOX incinerator (3%), the main flare (2%), and the DHU reboiler (0.2%). In 2023, the equipment order remained similar: the GTG combustion unit (46%), the AGRU processing unit (28%), the Oil Heater combustion unit (15%), the acid flare (4%), the main flare (3%), the TOX incinerator (4%), and the DHU reboiler (0.2%). Based on the emission inventory calculations from 2021 to 2023, the potential $CO_2$ emissions from CPP Donggi operations were 7.518 tonnes in 2021, 8.024 tonnes in 2022, and 7.496 tonnes in 2023, with an average of 7.679 tons of $CO_2$ per year.

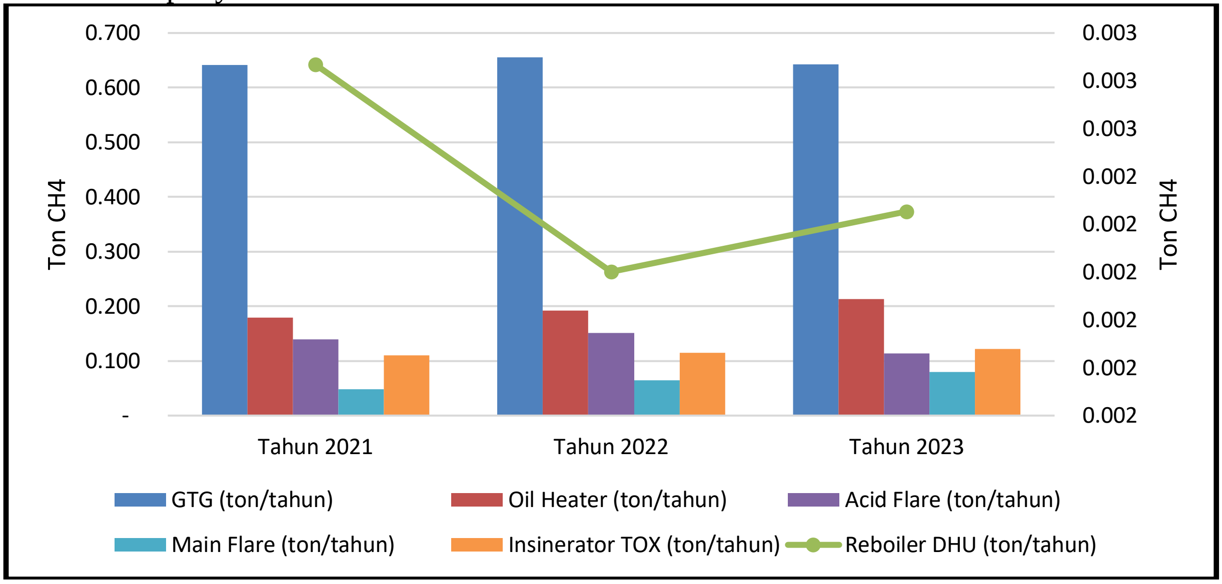



**Figure 4.** Graph CH4 Green House Gas Emissions

In 2021, the operational equipment sequence generating the highest methane ($CH_4$) emissions at CPP Donggi was: GTG combustion unit 57%, Oil Heater combustion unit 16%, acid flare 12%, TOX incinerator 10%, main flare 4.0%, and DHU reboiler 0.2%. By 2022, this sequence remained largely consistent with: GTG combustion unit 56%, Oil Heater combustion unit 16%, acid flare 13%, TOX incinerator 10%, main flare 5%, and DHU reboiler 0.2%. In 2023, the sequence was: GTG combustion unit 55%, Oil Heater combustion unit 18.0%, acid flare 10%, TOX incinerator 10%, main flare 7%, and DHU reboiler 0.2%. Based on the emission inventory calculations from 2021 to 2023, the potential methane ($CH_4$) emissions from CPP Donggi were 1,121 tonnes $CH_4$ in 2021; 1,179 tonnes $CH_4$ in 2022; and 1,173 tonnes $CH_4$ in 2023, with an average of 1,158 tonnes CH4 per year.

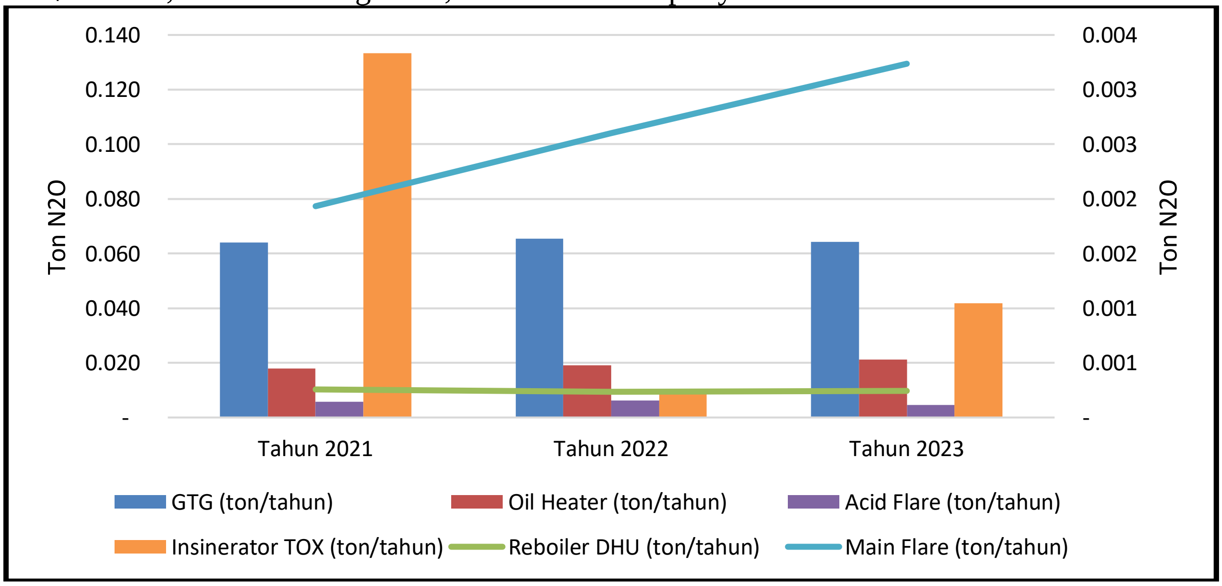
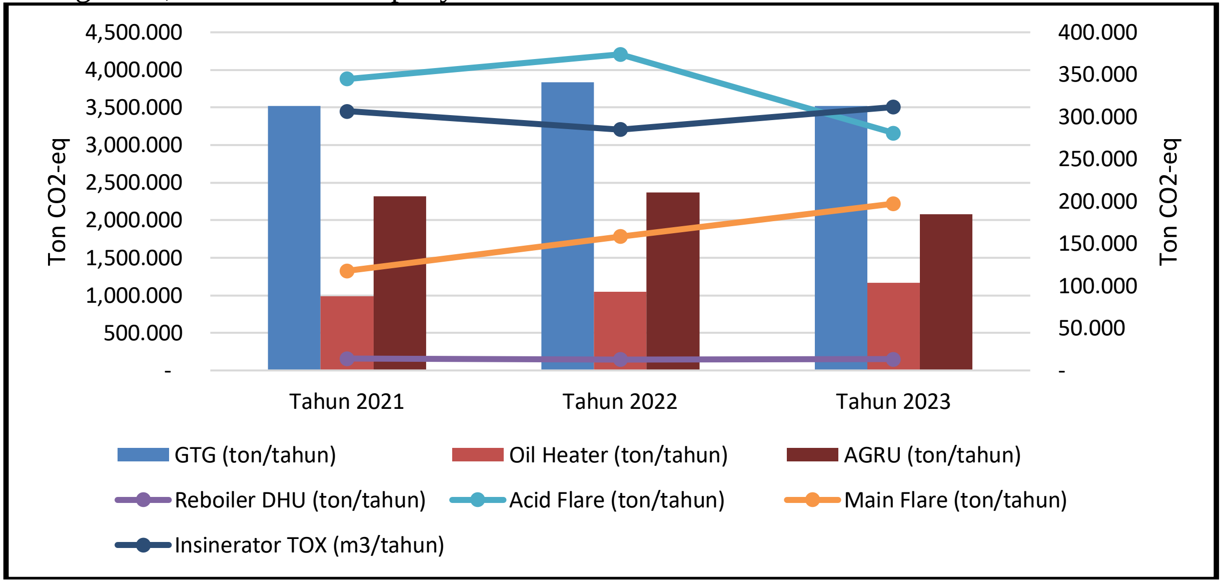



**Figure 5.** Graph $N_2O$ Green House Gas Emissions

In 2021, the operational equipment sequence generating the highest emissions of $N_2O$ at CPP Donggi was as follows: TOX incinerator unit 60%, GTG combustion unit 29%, Oil Heater combustion unit 8%, acid flare 3%, main flare 1%, and DHU reboiler 0.1%. By 2022, this sequence shifted to: GTG combustion unit 63%, Oil Heater combustion unit 18%, TOX incinerator unit 10%, acid flare 6%, main flare 3%, and DHU reboiler 0.2%. In 2023, the sequence was: GTG combustion unit 47%, TOX incinerator unit 31%, Oil Heater combustion unit 16%, acid flare 3%, main flare 2%, and DHU reboiler 0.2%. Based on the emission inventory calculations from 2021 to 2023, the potential $N_2O$ emissions from CPP Donggi were 0,223 tonnes $N_2O$ in 2021; 0,104 tonnes $N_2O$ in 2022; and 0,135 tonnes $N_2O$ in 2023; with an average of 0,154 tonnes N2O per year.




Based on the emission inventory from 2021 to 2023, the potential $CO_{2\text{-eq}}$ emissions from the operational activities at CPP Donggi are as follows: 7.609 tonnes $CO_{2\text{-eq}}$ or 365.78 tonnes $CO_{2\text{-eq}}$ per TJ in 2021, 8.084 tonnes $CO_{2\text{-eq}}$ or 355.50 tonnes $CO_{2\text{-eq}}$ per TJ in 2022, and 7.564 tonnes $CO_{2\text{-eq}}$ or 376.05 tonnes $CO_{2\text{-eq}}$ per TJ in 2023, with an average of 7.752 tonnes $CO_{2\text{-eq}}$ per year or 365.35 tonnes $CO_{2\text{-eq}}$ per TJ. The operational equipment contributing the highest emissions based on the inventory results include GTG combustion units, AGRU units, Oil Heater units, Acid Flares, TOX Incinerators, Main Flares, and DHU reboilers.

After understanding GHG emissions from the operations of CPP Donggi, strategic plans were taken to reduce GHG emissions. Emission reduction can be achieved through energy efficiency programs or mitigation programs such as decarbonization. Energy efficiency can be implemented at each emission source, such as load priority selection in GTG operations, optimizing GTG operations from three units to two units with one unit on standby. Additionally, the combustion process of waste gas at the main flare, acid flare, and TOX incinerator can be optimized by using waste gas as operational fuel or through adjustable choke at the well. Climate change mitigation efforts aim to reduce carbon in the atmosphere, known as decarbonization (Wang et al., 2020).

Decarbonization programs should be implemented quickly and comprehensively due to the increasing impact of climate change. Decarbonization plans can be achieved with several technological options, one of which is carbon capture and storage technology (Hurlbert & Osazuwa-Peters, 2023). According to the Intergovernmental Panel on Climate Change (IPCC, 2022), efforts to reduce carbon emissions and activities related to lowering carbon concentration in the atmosphere across all sectors are needed to limit global warming to 2°C. This indicates the need for rapid, comprehensive, and realistic decarbonization steps, one of which is the implementation of Carbon Capture Utilization and Storage (CCUS) technology. The implementation of CCUS technology must be supported by various aspects, including economic analysis (support for research and development, government incentives, and carbon pricing), technical aspects (process efficiency, new material development, operation, and maintenance), administration (CCUS policy enforcement), CCUS commercialization, and financial analysis (Dubey & Arora, 2022).

## CONCLUSION

The study results show an emission inventory for 2021 is 7.609ton $CO_{2-eq}$ per year or 365.78 tonnes $CO_{2-eq}$ per TJ.year, for 2022 is 8.085ton $CO_{2-eq}$ per year or 355.50 tonnes $CO_{2-eq}$ per TJ.year, dan for 2023 is 7.565ton $CO_{2-eq}$ per year 376.05 tonnes $CO_{2-eq}$ per TJ.year and the three highest carbon emission-generating facilities being the Gas Turbine Generator, Acid Gas Removal Unit, and Oil Heater. The impact of GHG emissions from the operations of CPP Donggi is evident. Emission reduction mitigation programs can be implemented through energy efficiency measures and decarbonization programs such as implemented CCUS Technology. The authors are grateful to PT Pertamina EP Donggi Matindok Field and the Laboratory of Air Pollution Control and Climate Change, Department of Environmental Engineering, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia, for their support, funding, and provision of secondary data during this research.

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