Bitcoin Mining: Lower Emissions than Flaring Gas

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Introduction

As we build out the infrastructure for Bitcoin mining globally, critics of Bitcoin tout the negative environmental impact and high energy consumption from Bitcoin production. It is true - the production of Bitcoin is an energy-intensive process, so we must shift the production to more emissions-neutral sources. This paper will discuss the real and credible emissions reductions the energy industry can make by using Bitcoin mining as an alternative to flaring gas.

The scenario-based study demonstrates that mining Bitcoin from oilfield gas instead of flaring gas:

- Reduces Volatile Organic Compound (VOC) emissions by 98%
- Reduces Carbon Monoxide (CO) emissions by 69%
- Reduces Nitrogen Oxides (NO_x) emissions by 43%
- Reduces GHG emissions (in the form of CO_2 equivalents) by 28%.

What is Flaring

Across the energy value chain, and throughout many modern industries, flaring is used as a method to destroy gas so that the hydrocarbons are broken down and do not cause harm to humans or the environment. The combustion process itself is a source of "criteria" pollutants as regulated by the US EPA, including Nitrogen Oxides (NO_x), Carbon Monoxide (CO), particulate matter ("soot"), and remaining undestroyed Volatile Organic Compounds (VOCs). Additionally, a primary byproduct of the combustion of hydrocarbons is CO_2, a greenhouse gas. Flaring is highly regulated in the US for all industries by the US Environmental Protection Agency (EPA) and state-implemented air permitting programs.

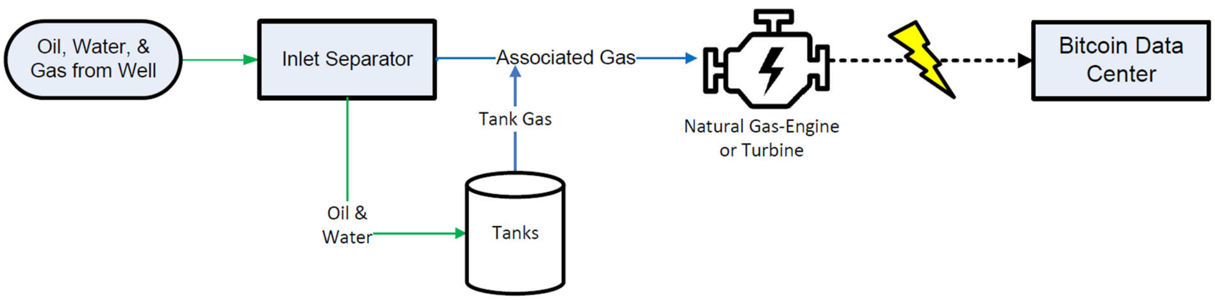
If gas is flared, it is wasted and has no use….it is money and energy lit on fire. According to the Global Gas Flaring Tracker Report, 142 billion cubic meters of upstream gas were flared globally in 2020.[1]

[1] https://www.worldbank.org

Flared Gas Bitcoin Mining

As discussed in our previous whitepapers, the concept of mining Bitcoin from flared gas is that we can take the waste gas stream that would be routed to a flare and instead feed it to a power generation source (a natural gas generator or turbine) to generate electricity that is used to power Bitcoin data centers (or ASICs). An example process flow diagram is presented in Figure 1.

Figure 1. Upstream Oil and Gas Bitcoin Mining Process Flow



Sending the gas to a Bitcoin mining engine in lieu of a flare has operational benefits, including:

- The heat content of the gas is used to create power instead of being wasted to the atmosphere. This fosters energy efficiency on a large scale.
- As regulations continue to discourage gas flaring in the oilfield, Bitcoin mining is an immediate solution to reduce or eliminate flaring outright.
- The gas becomes an asset, not a waste.

Emissions Base Case Scenario

This study scenario is based on 7,100 SCF/hr of waste gas at a natural gas processing facility that is currently routed to a flare.

The first case calculates potential emissions from combustion of that gas in a flare. The second case routes that same gas to a Capstone microturbine to generate electricity for Bitcoin production. These calculations are based on standard emissions estimation methodologies recommended by the US EPA, not in-stack source testing.

Flare Emissions

Potential emissions from the flare are calculated using pre-approved EPA methodology from AP-42 Chapter 13.5 calculations and factors for products of combustion CO and NO_x, PM_{10}, $PM_{2.5}$, and GHG emission factors from AP-42, Table 1.4-1 and 1.4-2 based on the maximum expected flow rate and heating value of the waste stream routed to the flare.[2] The flare operates with a control efficiency of 98% for all VOC constituents. It is assumed that the stream is steady and is flared 8,760 hours/year

[2] For more information on EPA AP-42 emission factors: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors

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The emissions summary is presented below, and additional information is presented in the Appendix.

Total Emissions from Flare		
Pollutant	**tons per year (tpy)**	**Notes**
Total VOC	**9**	Post-control VOC
Total NO_x	**2**	NO_x from combustion
Total CO	**7**	CO from combustion
Total PM_{10}	**0.25**	PM from combustion
Total $PM_{2.5}$	**0.25**	PM from combustion
CO_2	**3,742**	Includes CO_2 from initial waste stream + products of combustion
CH_4	**5**	Post-control methane
N_2O	**0.07**	N_2O from combustion
Total CO_2e	**3,886**	tpy
Total CO_2e	**3,525**	metric tonne/year

Turbine Emissions

Engine/turbine emissions are calculated per EPA AP-42 methodology, according to fuel type and engine type, and vendor-specific emission factors. The gas flow rate equates to an estimated power rating of 500 kWh for this scenario. Vendor-specific emission factors for NO_x (9 ppm), CO (1 lb/MWhe), VOC (0.1 lb/MWhe), and CO_2 (1,330 lb/MWhe) were used for the emissions calculations, again assuming a runtime of 8,760 hr/year. This microturbine is selected specifically for its low-NO_x emissions guarantees.

The emissions summary is presented below, and additional information is presented in the Appendix.

Total Emissions from Turbines	
Pollutant	**Emissions (tpy)**
NO_x	**1**
CO	**2**
VOC	**0.2**
CO_2	**2,784**
CO_2 (metric tonne/year)	**2,525**

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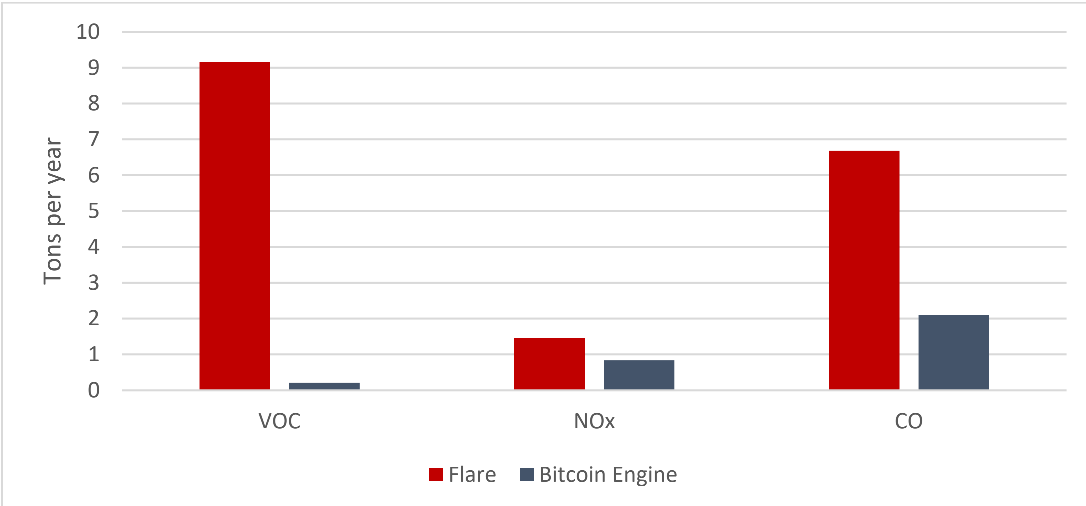
Emissions Comparisons

The total emissions from the microturbine are less than those from flaring for all evaluated pollutants.

Criteria Pollutants

Figure 2 presents criteria pollutant-specific emissions estimates for the two scenarios.

Figure 2. Criteria Pollutant Reductions from Bitcoin Mining Flared Gas

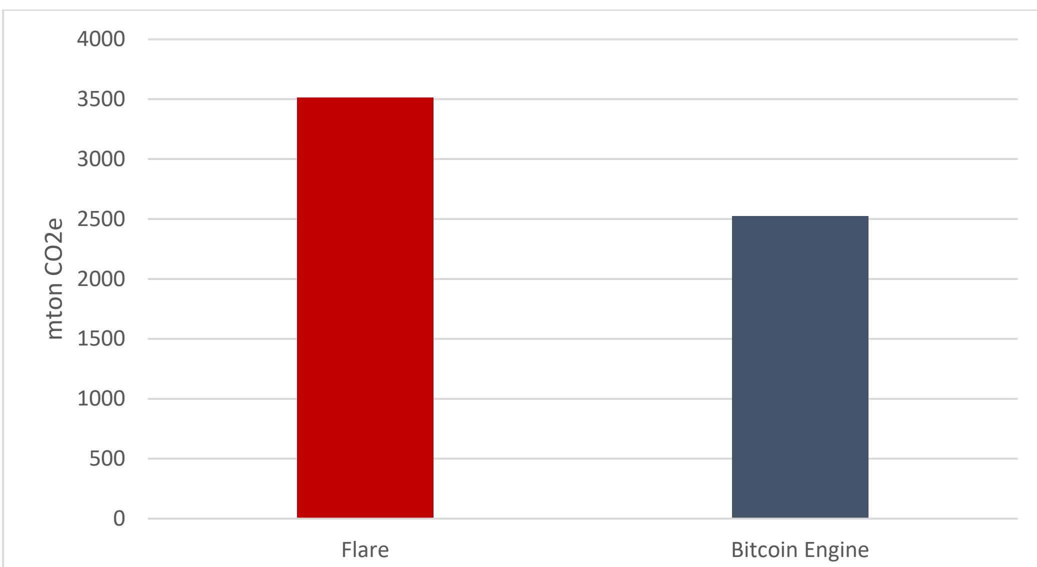


- Mining Bitcoin instead of flaring reduces potential VOC emissions by **98**%
- Mining Bitcoin instead of flaring reduces potential CO by **69**%
- Mining Bitcoin instead of flaring reduces potential NO_x emissions by **43**%.

Greenhouse Gas

Figure 3 presents total metric tons of CO_2 equivalents for the two scenarios.

Figure 3. GHG Reductions from Bitcoin Mining Flared Gas



Mining Bitcoin instead of flaring reduces GHG emissions by **28**%.

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Conclusions

In this study, using the waste gas to mine Bitcoin instead of flaring it significantly reduces emissions for criteria pollutants and greenhouse gases.

If designed correctly incorporating low-emitting turbines or engines, Bitcoin mining is a pollution abatement option for the operator who is currently flaring waste gases.

The emissions scenarios presented herein are real and credible emission reduction options for operators who are currently flaring oilfield gas. Putting the heat content of the wasted gas to work is not only an emissions reduction option but also an energy efficiency improvement and a source of revenue.

A Green Path-Forward for Bitcoin

Mining Bitcoin from off-grid energy sources reduces Bitcoin's overall strain on global electrical grids. If we mine all the global upstream gas that is currently flared, we can eliminate over 100 million metric tons of CO_2e emissions a year without using any additional sources of energy to do so.

Further, if we capture the emissions from the turbines/engines and sequester them underground, that is completely carbon-neutral Bitcoin from a source of energy that is currently wasted.

About the Author

Kat Galloway is the founder and president of Bright Sky Environmental, LLC and Artemis Energy, Inc. With nearly 20 years of environmental consulting and air permitting experience focused on the energy industry, her goal is to help oil and gas companies develop and operate assets in accordance with environmental regulations. As ESG protocols emerge, she helps her clients identify emissions reductions opportunities to deliver impactful environmental results to shareholders. She may be reached at Kat@ArtemisEnergy.us

Bright Sky Environmental is a leading consultancy for oil and gas air permitting and compliance as well as air permitting for Bitcoin mining operations. www.BrightSkyENV.com

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Artemis Energy is a Bitcoin mining company whose goal is to reduce air emissions from facilities across the energy value chain. The company's goal is to Mine with Purpose. www.artemisenergy.us

Appendix - Flare Emissions Calculations

Maximum Annual Flare Emission Rates			
Waste Flare Stream	Waste stream emissions[a]	Destruction Efficiency	Flare Exhaust (controlled)
Component	(tpy)	(%)	(tpy)
Hydrogen	46.26	0%	**46.26**
Nitrogen	620.06	0%	**620.06**
Oxygen	64.11	0%	**64.11**
CO2	14.68	0%	**14.68**
Methane	247.66	98%	**4.95**
Ethane	231.02	98%	**4.62**
Ethylene	130.32	98%	**2.61**
Propylene	44.31	98%	**0.89**
Propane	109.14	98%	**2.18**
Isobutene	48.94	98%	**0.98**
Butane	43.77	98%	**0.88**
Pentane	81.49	98%	**1.63**
Total	**1681.78**	--	**763.86**
Total VOC	**457.98**	--	**9.16**
Annual Hours (Hrs)	8,760		
Heating Value HHV (Btu/scf)[a]	694		
Volumetric Flow (scf/hr)[a]	7,091		
Volumetric Flow (MMscf/yr)	62.12		
Heat Release (MMBtu/year)[a]	43109.31		

Component	Emission Factor	Emission Factor Units
NO_X	0.068	lb/MMBtu
CO	0.31	lb/MMBtu
PM_{10}	7.60	lb/MMscf
$PM_{2.5}$	7.60	lb/MMscf

GHG emissions factors [c,d]		
Component	Emission Factor	Emission Factor Units
GHG CO_2 Factor	120,000	lb/MMscf
GHG N_2O Factor	2.2	lb/MMscf
GWP CO_2 Equivalent	1	
GWP CH_4 Equivalent	25	
GWP N_2O Equivalent	298	

Total Emissions from Flare		
	(tpy)	Notes
Total VOC	**9.16**	Post-control VOC
Total NOx	**1.47**	NOx from combustion
Total CO	**6.68**	CO from combustion
Total PM_{10}	**0.24**	PM from combustion
Total $PM_{2.5}$	**0.24**	PM from combustion
CO_2	**3,741.71**	Includes CO_2 from initial waste stream + products of combustion
CH_4	**4.95**	Post-control methane
N_2O	**0.07**	N_2O from combustion
Total CO_2e	**3,885.91**	tpy
Total CO_2e	**3,525.24**	metric tonne/year

Footnotes:

[a] Midstream base-case waste gas to flare speciation.

[b] Flare CO and NOx emission factors from AP-42, Table 13.5-1 & 13.5-2, February 2018. PM_{10} and $PM_{2.5}$ emission factors from AP-42, Table 1.4-1 and 1.4-2, July 1998.

[c] Greenhouse Gas Factors from AP-42, Table 1.4.2 Emission Factors for Criteria Pollutants and Greenhouse Gases from Natural Gas Combustion.

[d] Global Warming Potentials from Table A-1 of Subpart A of Part 98 for Mandatory Greenhouse Gas Reporting.

Equations used:

A. *(Controlled VOC emissions, lb/hr or tpy) = (Uncontrolled VOC Emissions, lb/hr or tpy) x (1 - Destruction Efficiency)*

B. *(NOx, CO, PM, GHG emissions, tpy) = (Emission Factor, lb/MMscf) x (Flow rate, scf/yr) / (1,000,000 scf/MMscf) / (2,000 lb/ton)*

OR

(NOx, CO, PM, GHG Emissions, tpy) = (Emission Factor, lb/MMBtu) x (Flow rate, scf/yr) x (Heat Value, Btu/scf) / (1,000,000 Btu/MMBtu) / (2,000 lb/ton)

Turbine/Engine Emissions Calculations

Engine Fuel consumption (BTU/kWh)[a]:	10,300
Engine Available fuel (scf/hr):	7,091
Fuel Assumed HHV (BTU/scf):	694
Engine scf/kKh:	14.84
Available Power (kWh)	477.78

Pollutant	Emission Factor[a] (lb/MWhe)	Available Power (MW)	Emissions (lb/hr)	Emissions (tpy)
NOx	0.4	0.48	0.19	**0.84**
CO	1	0.48	0.48	**2.09**
VOC	0.1	0.48	0.05	**0.21**
CO_2	1330	0.48	635.45	**2,783.27**
CO_2 (metric tonne/year)				**2,524.94**

Footnotes:

[a.] Capstone Technical Reference 410065 for C200S.

Equations used:

A. *(Pollutant Emissions, lb/hr) = (Pollutant Emission Factor, lb/MWhe) x (Engine Power, MW)*

B. *(Pollutant Emissions, tpy) = (Pollutant Emissions, lb/hr) x (8,760 Hours of Operation per Year, hr/yr) / (2,000 lb/ton)*

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