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P2_5 The Doorway to Hell

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Abstract

We investigate the Darvaza crater, an open-air natural gas fire located in Turkmenistan known locally as the "Doorway to Hell". We estimate the power output of the gas fire to be $\sim 45\,\mathrm{MW}$, calculating that it could supply 2.6% of Turkmenistan's power requirements. We also estimate the total CO_2 emissions over the lifetime of open air combustion at the crater to be $\sim 10^7$ Tonnes.

Introduction

The Darvaza Oil field in Turkmenistan was first identified in 1971 by Soviet engineers, with drilling operations beginning later the same year [1]. Shortly into preliminary drilling, a natural gas pocket was discovered underneath the surface resulting in the ground collapsing to form the crater. To prevent the release of poisonous gases into the area, the gas in the crater was ignited with the expectation the gas would burn off in a few weeks. It still burns to this day. This paper investigates the energy released by the ongoing gas fire and the potential benefits of capturing this for providing electrical power.

Theory and Method

Firstly, we determined the surface area of the crater as this is the location of combustion. The crater has a diameter of 70 metres [2] and a maximum depth of 30 metres [3]. Assuming the crater can be modelled as a hemisphere, the area exposed can be calculated from using equation (1).

$$A = 2\pi r h \tag{1}$$

Using the previously mentioned values of height and radius, the exposed area of the crater was calculated as 6597 m^2. The rate of gas being released from beneath the surface was found online to be $365\,\mathrm{mg\,m^{-2}\,s^{-1}}$ [4]. The molecular mass of methane is 16 atomic mass units. This mass value can be converted in moles using equation (2) shown below.

$$\text{number of moles} = \frac{\text{mass}}{\text{molecular mass}} \tag{2}$$

Where the substance mass is given in grams and the molecular mass is given in Atomic Mass Units. Therefore, this rate of gas release corresponds to $0.0228\,\mathrm{moles\,m^{-2}\,s^{-1}}$. It is assumed all of the gas released from the ground is undergoing complete combustion. The complete combustion of methane gas with oxygen releases $891\,\mathrm{kJ\,mol^{-1}}$ [5]. (3) shown below.

$$P = \Delta H \times \delta N \tag{3}$$

Where P is the power output of the flame, ΔH is the energy released from the complete combustion of 1 mole and $\delta\,\mathrm{N}$ is the number of moles burning per second. Applying this to the gas released produces a power from the fire of $20.3\,\mathrm{kW\,m^{-2}}$. Multiplied across the entire area of the crater produces a total power of the Darvaza gas crater of 134 MW.

Results and Discussion

Currently, no useful work is being extracted from this heat. The construction of a steam turbine and boiler/condenser above the gas crater could be used to drive a generator to produce electrical power. A modern steam turbine can expect an efficiency of extracting energy from steam of 33% [6]. This would result in 44.7 MW of electrical power being generated for the people of Turkmenistan.

The total energy consumption of Turkmenistan is 15.09 billion kWh per year [7]. This correlates to a constant power consumption of 1722 MW. If the energy released from the Darvaza gas crater could be harnessed by a modern steam turbine it could meet 2.6% of the nations energy needs. This would mean less fossil fuels would need to be burned elsewhere.

The combustion of methane with oxygen releases 2.75kg of carbon dioxide per 1kg of methane fuel [8]. Over the near 50 year lifetime of the Darvaza gas crater, 3,796,784 Tonnes of methane fuel has been released and undergone complete combustion. This has resulted in a total lifetime production of 1.044×10^7 Tonnes of carbon dioxide being released into the atmosphere. For comparison the average UK automobile releases 1.735 Tonnes of carbon dioxide into the atmosphere per year [9]. This means the lifetime emissions of the Darvaza gas crater equals the emissions of a single average UK car usage annually for 2,188,348 years.

Conclusion

This paper investigated the energy output of the Darvaza gas crater from the complete combustion of methane gas escaping from beneath the surface. We determined that this energy, if harnessed by the people of Turkmenistan, could power 2.6% of their national energy requirements. Not only would this be efficient but it would also allow for a reduction in the burning of fossil fuels elsewhere and significantly reduce carbon emissions. However, as the structure has now become somewhat of a tourist attraction, it will likely continue to burn in open air for the foreseeable future.

References

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