Homework 2 Solar Power for Africa

In class we briefly discussed the solar chimney which has been produced at pilot plant scale in Spain and recently commercialized in Arizona. The concept is to cover a large field with black rocks, put up a polymer sheet (UV stabilized LDPE) over the rocks and direct the hot air to a chimney in the center of the site that contains a turbine to generate electricity. The University of Botswana and the Botswana Technology Centre (BOTEC) collaborated to produce small-scale solar chimneys for villages in Southern Africa. The specifications for the Spanish Solar Chimney and the Botswana Solar Chimney are given below:

Location	Stack Diameter, m	Stack Height, m	Ground-Level Internal Temperature, °C (K)	Temperature at Top of Stack, °C (K)
Spain	8.5	250	68 (341)	10 (283)
Gaberone, Botswana (BOTEC)	2	12	60 (333)	25 (298)

For a chimney the pressure differential is given (with a few assumptions https://en.wikipedia.org/wiki/Flue-gas_stack) as, ΔP in Pa,

$$\Delta P = 0.0342 A H \left(\frac{1}{T_o} - \frac{1}{T_i}\right) \qquad (1)$$

and the flow rate, Q in m^3/s, is given as,

$$Q = 0.675\, A \sqrt{2gH\frac{T_i - T_o}{T_i}} \qquad (2)$$

where A is in meter^2, H in meters, $g = 9.81$ m/s^2, and T is in K.

a) Calculate the pressure differential and the flow rate from the two solar chimneys.
b) Make an assessment on the viability of the Botswana chimney. (Note that the cut-in speed for a typical wind turbine is 10 mph and most are designed to operate at 30 mph with a maximum (cut-out) speed of 45 mph. (2.24 mph = 1 m/s))
c) What would a minimum stack height be for a reasonable power source based on the Botswana design?
d) Suspended wires can hum in the wind due to an effect called vortex shedding (https://en.wikipedia.org/wiki/Vortex_shedding). An oscillatory vibration that can match the frequency of the structure can result from a blunt object in a rapid airflow. The plains of Spain have a constant breeze and often are subject to intense winds. Explain how this may have led to the demise of the Spanish Solar Chimney which was constructed of low weight and somewhat flimsy rigid materials (plastic).
e) How could vortex shedding be avoided? (Look at the Wiki page for the answer)
f) What is your assessment of the use of solar chimneys in the developing world based on this analysis.