Question 1:

Dear Cheap Astronomy – *Is solar or nuclear better for a future Mars base?*

A common theme on Cheap Astronomy, with regards to space exploration is that just because we can do it, doesn't mean we will do it, since any billion dollar investment is going to require some kind of return on investment, whether that be an actual monetary return or political capita, or whatever. And even then, if there's a major risk of people dying and/or the mission failing it probably won't get off the ground in the first place.

So, for a while now we've been running with the line that establishing a base on Mars would be problematic if it's going to rely on solar panels for electrical power generation, since Mars has somewhat unpredictable months-long dust storms. So, on balance the best option is to go nuclear.

But a recent 2022 study compared two scenarios of a six person crewed mission landing on Mars, establishing a base, staying for 480 days and then returning to Earth. The mission would draw on in situ resources, primarily water and CO2 for the purposes of staying alive, generating power and making large volumes of methane to fuel the journey home.

The solar versus nuclear comparison, is of course just a mathematically modelled comparison, where the energy requirements are calculated and then the different energy options' capacity to meet those requirements are compared. The study concluded with the headline finding that the solar power option would be better at equatorial regions, but if you move the base towards the poles, the nuclear option starts looking better.

But now let's go beyond the headlines – for example, what does better actually mean. After all both options are scaleable – if you want to get more power from solar, you just add more panels and if you want more power from nuclear you can get a bigger reactor or more fuel throughput. So what the study actually mean by better is about the ratio of the payload mass you have to fly Mars and the subsequent energy output that's achievable from that mass. As you'd expect, solar panels are low mass – but you have to include an energy storage solution, otherwise there'd be no power at night, not to mention during the dust storms. It turns out the best energy storage solution (again based on payload mass) is a water electrolysis solution, where you divert some of your daytime solar-generated power to electrolyzing water into hydrogen and oxygen, which can later be recombined back into water just using traditional fuel cell technologies, which generates electricity, heat and more water.

Of course if you go nuclear, that will run 24/7 so you won't need to be so reliant on energy storage. The 2022 study works of specs for NASA's Kilopower nuclear fission reactor, pleasing named the Kilopower Reactor Using Stirling Technology or KRUSTY. So if you flew KRUSTY to Mars it would be outcompeted by the solar option if the base was established near the equator, but it wins out for a base established near the poles. The overall finding suggests there's not that much difference between the options and let's remember the mission is dependent on in situ resource utilization, notably water, where most of the known water sources on Mars are polar. So, in that respect, KRUSTY starts looking pretty good.

But let's take a deep breath here, if you did land on Mars and your only way off again was to generate a large volume of methane from in situ resources then one of the many things you would want is some certainty about is a reliable energy supply. So really, the best solution is probably to establish some redundancy, where you fly both the nuclear and solar systems, so if one breaks down you just switch to the other. It's a lot more mass to fly, but you are less likely to die, so what the heck. Once you do have a reliable energy source with redundancy options, all you then have to do is manufacture rocket fuel from local resources to get home again – and what could possibly go wrong with that.

Question 2:

Dear Cheap Astronomy – *Can we look forward to a cloud city on Venus?*

Having a cloud city on Venus is at least as likely as having a surface city on Mars – both of which are probably less likely than having a surface city on the Moon or a solar orbiting space station city at the Earth-Sun Lagrange points 4 or 5.

The attraction of having a cloud City on Venus is that, at 50 kilometres above the surface there's one Earth atmosphere of pressure and enough atmosphere above you to get as much radiation protection as you would on Earth's surface, while also letting through as much solar flux for energy as you would get on Earth. The super-rotation of Venus' upper atmosphere means a floating structure at 50 kilometres altitude would circle the planet every four Earth days, so you would get days and nights of about 48 hours long – which with sufficient battery storage would give an ample amount of solar power generation and good temperature regulation. Of course, there are risks associated with being at altitude rather than being on solid ground, but in Venus' case those risks are not that bad. A balloon of breathable air will float in Venus dense CO2 atmosphere just like a hydrogen balloon would do in Earth's atmosphere. So rather than living in a gondola that's hanging from a balloon, the gondola itself can be the balloon and the high external pressure means there's no risk of explosive decompression if the hull is punctured, there will just be a slow leak that you'll have ample time to fix. And if your gondola has a balcony, you could actually walk outside without a pressure suit, just with an oxygen mask – although the possibility of contact with traces of sulphuric acid in the atmosphere might make you think twice. Being fifty kilometres above the surface of a planet with about 90 per cent of Earth's surface gravity means the gravity on the deck of your Venus gondola would nearly 90 per cent of Earth's surface gravity too. After all, you are not orbiting the planet in free fall, you're just floating buoyant within Venus' gravity-bound atmosphere. And while you could fall over your balcony railing and die, that could happen to you on Earth too.

So there's a lot of nearly-Earth aspects to Venus' cloud top environment – with respect to temperature, pressure and gravity. By comparison, Mars has less to offer, it's colder, the atmosphere is so thin it lets the nasty space radiation through, but is still able to whip up global dust storms which could render your solar panels useless. On the plus side, with Mars you are on the planet's surface and able to walk around even if it's in a pressure suit, which could have some psychological benefits. And being on the surface, maybe there's mining to be done, if

there is anything in Mars rocks that's worth mining. And what both Mars and even the Moon have a little bit of, and what Venus completely lacks, is water.

For example, with the Moon we think there are exploitable pockets of water in shadowed areas near the poles, though it's unlikely we are talking huge volumes that would be sufficient to maintain a long-term colony. Mars certainly has more water than the Moon, mainly at the poles along with some patchy underground deposits elsewhere, so there a self-sustaining long-term colony might be theoretically possible if water could be shipped from the poles to the colony. This can't be a straight forward matter of pipes and pumps like on Earth, since the water at the source would be ice and would just freeze en route unless you kept the pipes permanently warmed. So, it's probably easier to have some kind of railway to truck solid ice blocks which could then be thawed back at the base.

Of course, this isn't a podcast about Mars colonisation options, we're just saying that it remains to be seen if full reliance on endemic Martian water is an economically viable option. So, given that any extra-terrestrial colony in the near future is going to be reliant on supplies being shipped in, the case for a cloud city on Venus looks relatively good, mainly on the basis of Venus' proximity to Earth and the generous solar radiation available for power generation.

Nonetheless, the Moon wins out on the basis of proximity to Earth and a Moon base could get continuous solar power generation if it is situated near the poles, which is the current plan. But after the Moon, Venus might be a real option – so a Venus cloud city is certainly an idea worth floating.