the stratosphere – or perhaps in low Earth orbit – and act to absorb sunlight by the photoelectric effect; the absorbed energy is then thermally re-radiated, with ~half escaping into space. In the second, metallic "nets" of ultra-fine mesh-spacing are employed to reflect solar photons of optical wavelengths into space.[33] In the third, optimized metallic-walled balloons – similar in concept to ones with which children play – are self-deployed into the stratosphere from ground level, where they serve to scatter insolation.[34] Each of these approaches involves total masses of the order of

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phase-space volumes of the two types of transitions). For *scattering unit* design purposes, an effective photoelectric cross-section of 10^{-17} cm^2 is a reasonable estimate (taking into account finite solar spectral width requirements and considering that the solar spectral intensity falls rapidly above even the lowest-energy single-element photo-edge, that of Cs metal at a photon wavelength ~0.37 μm), and assuming that all photons with energies above the photo-edge interact with this cross-section. Likewise, note that a multiple alkali-metal alloy system can lower this photoedge to an effective 2 eV threshold (e.g., as the tri- and quad-alkali-metal-alloy photocathodes of commercial photodetection devices routinely do). A sheet of this material of a few dozen atoms thicknesses – ~100 Å – would then represent an extinction length for blue-green photons, and would have a mass-density of $\leq 3\times10^{-6}$ gm/cm^2. Then, assuming that *scattering units* comprised of such 10^{-6} cm-thick sheeting would absorb half the incident solar spectrum and that the corresponding scattering system would sun-shield 0.01 of the Earth's disc continuously, the minimum mass-budget of an efficiently implemented *scattering system* comprised of such ultra-thin sheets of photoelectric absorber/thermal re-radiator would be $(2)(10^{-2})(1.2\times10^{18}\ cm^2)(3\times10^{-6}\ gm/cm^2)\sim7\times10^{10}$ gms ~ 70,000 tons. If deployed either in the atmosphere or in LEO, individual *scattering units* could be effective only ≤50% of the time, so that ≥140,000 tons would be required to fully implement such a *scattering system*.

The constituent materials of every efficient photoelectric absorber for solar-spectrum radiation inherently are readily oxidizable, particularly in the highly (photo)reactive upper atmosphere, so that only LEO deployment of such systems appears feasible – unless ≥two-fold mass penalties are paid for protective jacketing, e.g., SiO_2 . In addition to having a relatively large mass budget for a space-deployed system, such an absorption/re-radiation module in space would have the active momentum-management requirements characteristic of any space-based *scattering system*; this additional complexity would trade off against the multi-decade lifetimes (and thus far lower annualized costs) implicit in LEO deployment.

[33]The scattering system of this approach is comprised of a set of single-layer screens which scatter incident sunlight through ~π/2 rad, and whose conducting elements must be ~1 skin-depth in longitudinal extent, or ≥200 Å, by ~300 Å in transverse width, spaced at $\leq 3\times10^{-5}$ cm distances in both dimensions; packaging mass for protection against stratospheric oxidation would be comparatively small, if metal having a thin protective oxide, such as Al, is used. Such a high-angle *scattering system* would have electrically conducting 'wire' elements massing a total of ~15,000 tons; averaging random orientation and diurnal availabilities drives this up by ~2π, to ~90,000 tons. (Overhead mass for deployment and operation would, of course, be additional, although, in fractional terms, it would be smaller, as the scattering screens would be much stronger, due to their thicker conducting members.)

[34]Thin-walled helium-filled balloons are routinely employed to lift multi-ton payloads to 30-50 km altitudes, and maintain them there for multi-day intervals (limited mostly by the durability-against-photooxidation of the balloon's plastic wall). It thus seems entirely reasonable to consider ultra-thin metallic-walled balloons, partially inflated with a suitable lifting-gas, e.g., H_2, as sunlight-backscattering 'stratostats', for they can be expected to have very long stratosphere residence times (probably limited by micrometeoritic puncture-rates). A wall thickness of ~0.02 μm of e.g., Al, is ~1 skin-depth at the 8×10^{14} Hz frequencies characteristic of mid-visible solar radiation and thus suffices to (predominantly) backscatter the blue end of the incident solar spectrum; however, it is ≤0.2 skin-depth at $2\text{-}3\times10^{13}$ Hz and thus is nearly transparent to Earth thermal emissions in the 8-14 μm wavelength atmospheric pass-band. Each of these balloons thus constitutes a 'micro anti-greenhouse': it passes space-directed low-frequency photons emitted by the Earth but reflectively backscatters-into-space the high-frequency ones incoming from the Sun.