Is it worthwhile to add PV panels to operate lights to make up for the light lost due to shading in a vertical greenhouse, or warehouse/plant factory?

Preliminaries:

1. Assume: A close-to-worst case of natural light - Ithaca, NY, solar climate.
2. Assume: PV panels with typical solar/electrical conversion efficiency, mounted at the optimal yearly tilt angle and azimuth.
3. Assume: Grid storage is used as needed for electrical energy (net metering.)
4. Assume: Crops such as lettuce will be grown using a Daily Light Integral (DLI) of 17 mol/m^2.
5. Assume: Three-day DLI averaging is not imposed for greenhouse production.
6. Assume: Luminaire efficacy equals 7.2 mol/kWh, which is better than typical HPS lighting.
7. A modern greenhouse will permit 70% of the yearly light need to come from the sun. This value is based on simulations as well as operating experience in the Ithaca climate. Sunnier locations show a higher percentage (e.g., 85% from natural light in Harford, CT.)
8. Nearly 100% of the DLI must come from supplemental lighting in a facility such as a warehouse or multi-storied vertical greenhouse.
9. In Ithaca, over a year, a typical commercial PV system can provide 250 kWh/m^2-yr.*

Calculations:

1. In any system, 17*365 = 6205 mol/m^2-yr of light is needed.
2. In a closed system (plant factory), 6205/7.2 = 860 kWh/m^2-yr for supplemental light is needed.
3. In a closed system (plant factory), 860/250 = 3.44 m^2 of panel per m^2 of growing area is needed.*
4. In a modern CEA facility, 0.3*6205 = 1860 mol/m^2-yr must come from the lights.
5. In a modern CEA facility, 1860/7.2 = 260 kWh/m^2-yr is needed.
6. In a modern CEA facility, 260/250 = 1.04 m^2 of panel per m^2 of growing area is needed.*
7. In a modern CEA facility in a sunnier location, 0.15*6205 = 930 mol/m^2-yr must come from the lights.
8. In a modern CEA facility in a sunnier location, 930/7.2 = 129 kWh/m^2-yr is needed.
9. In a modern CEA facility in a sunnier location, 129/250 = 0.52 m^2 of panel per m^2 of growing area is needed.*

Conclusions based on Assumptions:

1. In Ithaca, operating supplemental lights using photovoltaics will require a PV panel area approximately equal to the area of greenhouse plant production.
2. In a sunnier location, operating supplemental lights using photovoltaics will require a panel area approximately equal to half the area of greenhouse plant production.
3. In a closed system (plant factory), operating supplemental lights using photovoltaics will require a panel area nearly three and a half times the area of greenhouse plant production.
4. A more realistic comparison will be less optimistic about using PV because the typical luminaire efficacy is likely to be less than 7.2 mol/kWh, and 3-day DLI averaging can be imposed in a greenhouse (saves roughly 3% of the supplemental lighting need in a year.)

*PV systems in a sunnier location will generate more than 250 kWh/m^2-yr, and the required panel areas will be somewhat smaller, but the relative advantages/disadvantages will be similar. For example, data for Sayville, NY (Long Island) predicts a typical PV panel should generate approximately 290 kWh/m^2-yr.

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