# Quantifying Energy Savings from Potential Green and Biosolar Roof Retrofits for Pennovation Data Center

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## Abstract

The goal of this research was to determine if there is tangible energy savings as a result of installing a green roof and a biosolar roof to Pennovation Center to mitigate data center emissions. The assessment was made by quantifying the energy saved and comparing this to the building’s already white roof. The net present value (NPV) of the project, as well as data center and green roof governance, are discussed to determine how to further incentivize the University's Information Systems and Computing (ISC) Department and Facilities and Real Estate Services (FRES) to collectively retrofit data centers with these sustainability measures. Google Earth Pro imagery and a building site visit showed that about 37% of the roof could be feasibly retrofitted. Results from ASU Global Climate Research Center’s Green Roof Energy Calculator and NPV find that the total annual energy savings for Pennovation with a green roof is a negligible 0.23% of the building’s approximate current emissions. The project has a negative NPV of about -$492,000. Similarly, the number of solar panels that would be necessary to power the data center’s cooling, ignoring server electricity usage, would require utility scale solar and could not feasibly be powered with solar panels on the roof alone. Therefore, as Penn considers methods for achieving carbon neutrality by 2042, it is not advisable, at this time, that the University pursue either of these projects because emissions reductions are negligible for the green roof, and the biosolar roof is not technically feasible. If the green roof project almost doubled in size, Philadelphia would forgive about 20% of the cost to build in tax relief, so the area Pennovation could dedicate to greening should be revisited as Penn considers this option.


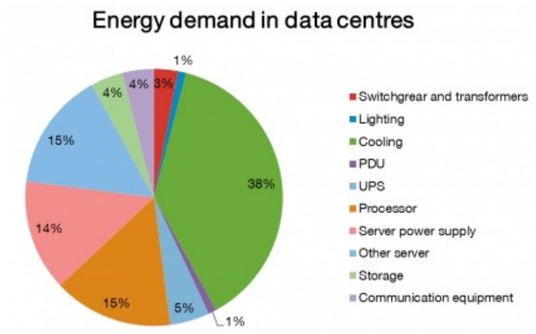


Figure 1: Pie chart showing the myriad uses of energy in data centers (Reproduced from Kohler, 2020))

## Conclusion

- ASU Green Roof Energy Calculator and NPV find total annual energy savings for the Pennovation data center with green roof is .23% of building’s approx. current emissions; green roof has negative NPV of ~ -$492,000
- Biosolar is currently infeasible given the current size of roof area available and today’s panel efficiency
- Neither project is currently advisable for Penn, as ways to reduce emissions across campus are considered


Figure 2: Where green and biosolar roofs could be placed, leaving service zones and buffers from the roof edge, highlighted in green (Google Earth Pro)

## Roof site visit and Google Earth Pro imagery reveal only 37% of roof can be viably greened.

Figure 3: View from center roof of unavailable lower roof area

Figure 4: View of upper roof

Figure 5: Center roof cooling equipment

Imagery from March 21, 2023 building site visit shows available and unavailable roof space to vegetate. The foreground of Figure 2 is available to vegetate, while the lower roof in the background is unavailable. Figure 3 shows large available roof area on the upper roof. Figure 4 depicts the data center’s large cooling equipment on the center roof, also visible in Figure 1. Other obstacles like satellites and signage would have to be avoided by green roof project.

## Assessing emissions reductions with ASU Global Climate Research Center Green Roof Calculator and Net Present Value show projects are not worthwhile at this time.

| Data Point | Data and Units |
|---|---|
| State in which building is located | Pennsylvania |
| City in which building is located | Philadelphia |
| Total roof area | 2,542 square meters |
| Type of building | New office |
| Growing media depth (2-30cm) | 15cm |
| Leaf Area Index (.5-5) | 5 |
| Is the green roof irrigated? | No |
| Percentage of roof which the green roof covers | 37% |
| Type of roof covering the remaining roof area | White (albedo= .65) |
| Electricity price | $.15/kWh |

Figure 6: Summary of data applied to ASU Calculator

| Data Point | Data and Units |
|---|---|
| Annual Energy Savings Compared to White Roof | 4896.2kWh |
| Total Energy Cost Savings | $734.43 |
| Annual Average sensible heat flux to urban environment | 6W/square meter |
| Annual precipitation | 1005.2mm |
| Annual net runoff | 654.5mm |

Figure 7: Summary of Results from ASU Calculator

NPV = (.15*4896.2)/(1+.1)^10-492,500 = **$-492,216.85**
Rational actors do not invest in projects with negative NPV


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## Biosolar Feasibility

- Data centers utilize more electricity and generate more emissions than entire countries, 70 billion kWh of energy annually, $7 billion in energy use, enough energy to power 7 million households.
- 70 billion kWh of power would require 2x solar panels as we had in 2016 to generate that much energy.
- Energy demand for a data center is 100x greater than that of a normal office.

## Green Roof Feasibility

- Green roofs are vegetated swaths of previously exposed roof which can mitigate the urban heat island effect by reflecting light which would otherwise be absorbed by a dark roof.
- Evapotranspiration which occurs on green roofs produces a cooling effect.
- Extensive green roof is better suited for Pennovation’s purpose than an intensive roof because it is cheaper, and results in insulation and stormwater benefits.


Figure 8: Aesthetic Differences between extensive and intensive green roofs (Reproduced from Ramcon Roofing, 2011)

## Limitations

- ASU Green Roof Energy Calculator is a simplified, though useful, model, therefore some assumptions are not entirely accurate, like the “new office” distinction.
- Intermittent reliability of solar panels is not well suited for data centers due to the need for constant connectivity, so batteries or backstop electrical power are also necessary.
- Potential co-benefits of green roofs include lower ambient air temperatures/reduced heat island effect, stormwater runoff mitigation, aesthetics, and urban biodiversity which NPV does not capture.

## Future Directions

1. Complete analysis for another campus building with more roof area available
2. Investigate how much of Pennovation Center’s electricity could be powered with rooftop solar
3. Calculate the reduction in PWA Stormwater Charge to University as a result of implementing the green roof