Problem 1 (50pts)

In class we examined the total land area required to “power” California with renewable energy. Repeat this calculation for Arizona.

For Arizona, the approximate Peak Solar Hour daily average is approximately 6.6 hours\(^1\). This for the Phoenix area, and the probable sites for large solar farms will be further to the west and probably have a higher PSH value. Nevertheless, this is a reasonable estimate for the desert portion of the state.

Therefore the average insolation is approximately:

\[
I_{\text{avg}} = PSH \cdot 1 \text{kW} / m^2 = 6.6 \text{kWh} / m^2 / \text{day}
\]

Using the conversion factor between sq meters and acres, we get:

\[
I_{\text{avg}} = \left[6.6 \text{kWh} / m^2 / \text{day}\right] \cdot \left[4046 m^2 / \text{acre}\right] = 26.7 \text{ MWh} / \text{day}
\]

Again, assuming that a current solar farm will an overall conversion efficiency of approximately 20\%, then the solar farm on an annual basis could generate electricity of roughly:

\[
E_{\text{solar}} = \left[26.7 \text{ MWh} / \text{acre} / \text{day}\right] \cdot \left[0.20\right] \cdot \left[365 \text{days} / \text{year}\right] = 1.95 \text{GWh} / \text{acre} / \text{year}
\]

The Arizona electricity consumption (in 2017) was approximately 106 TWh/year\(^2\), so the acreage for all the solar farms to produce this electricity, therefore:

\[
A_{\text{solarfarm}} = \frac{106 \text{ TWh/year}}{1.95 \text{ GWh/acre/year}} = 54,300 \text{ acres}
\]

This can also be converted to square miles:

\[
A_{\text{solarfarm}} = 54,300 \text{ acres} = \frac{54,300 \text{ acres}}{640 \text{ acres/sq.mi}} = 85 \text{ sq mi}
\]

The total land area of Arizona is about 114,000 sq mi\(^3\), so the solar land area would represent only 0.07\% of the total.
(2) Problem 2 (50pts)

In class we examined the total land area required to “power” California with renewable energy. Repeat this calculation for Massachusetts

For Massachusetts, the approximate Peak Solar Hour daily average is approximately 3.8 hours\(^1\). This for the Boston area, and again the probable sites for large solar farms will be further to the west and probably have a higher PSH value. Nevertheless, this is a reasonable estimate for the entire state. Therefore the average insolation is approximately:

\[
I_{\text{avg}} = PSH \cdot 1kW / m^2 = 3.8kWh / m^2 / \text{day}
\]

Using the conversion factor between sq meters and acres, we get:

\[
I_{\text{avg}} = \left[3.8kWh / m^2 / \text{day}\right] \cdot \left[4046m^2 / \text{acre}\right] = 15.4 \text{ MWh / day}
\]

Again, assuming that a current solar farm will an overall conversion efficiency of approximately 20%, then the solar farm on an annual basis could generate electricity of roughly:

\[
E_{\text{solar}} = \left[15.4 \text{ MWh / acre / day}\right] \cdot \left[0.20\right] \cdot \left[365\text{days / year}\right] = 1.12\text{GWh / acre / year}
\]

The Massachusetts electricity consumption (in 2017) was approximately 32TWh/year, so the acreage for all the solar farms to produce this electricity, therefore:

\[
A_{\text{solarfarm}} = \frac{32 \text{ TWh / year}}{1.12 \text{ GWh / acre / year}} = 28,600 \text{ acres}
\]

This can also be converted to square miles:

\[
A_{\text{solarfarm}} = 28,600 \text{ acres} = \frac{28,600 \text{ acres}}{640\text{acres / sq.mi}} = 45 \text{ sq mi}
\]

The total land area of Massachusetts is about 7838 sq mi, so the solar land area would represent 0.57% of the total.
I have also recalculated the values for California, using the references that had been
employed with the Arizona and Massachusetts calculations.

For California, the approximate Peak Solar Hour daily average is approximately 5.9
hours\(^1\). This is for the Riverside area, and again the probable sites for large solar
farms will be further to the east and probably have a higher PSH value.

Nevertheless, this is a reasonable estimate for the entire state. Therefore the average insolation is approximately:

\[ I_{avg} = PSH \cdot 1kW / m^2 = 5.9kWh / m^2 / day \]

Using the conversion factor between sq meters and acres, we get:

\[ I_{avg} = [5.9kWh / m^2 / day] \cdot [4046m^2 / acre] = 23.9 \ MWh / day \]

Again, assuming that a current solar farm will an overall conversion efficiency of
approximately 20%, then the solar farm on an annual basis could generate
electricity of roughly:

\[ E_{solar} = [23.9 \ MWh / acre / day] \cdot [0.20] [365days / year] = 1.74GWh / acre / year \]

The California electricity consumption (in 2017) was approximately 206 TWh/year, so the acreage for all the solar farms to produce this electricity, therefore:

\[ A_{solarfarm} = \frac{206 \ TWh / year}{1.74 \ GWh / acre / year} = 118,400 \ acres \]

This can also be converted to square miles:

\[ A_{solarfarm} = 118,400 \ acres = \frac{118,400 \ acres}{640acres / sq.mi} = 185 \ sq \ mi \]

The total land area of California is about 163,707 sq mi, so the solar land area would represent 0.11% of the total.
References

[1] https://www.wholesalesolar.com/solar-information/sun-hours-us-map
