- **Back of envelope calculation/estimate of scale and impact, or any related calculations to establish the scope of the problem or proposed research.**
    - **Heating Energy Consumption**
        - Equations
            - Heating up the building from outdoor temperature to 72 degrees Fahrenheit: $Q = mc\Delta T$
            - Maintaining the heat of the building for 15 hours (the longest that the building is open for on a given day): $Q = \frac{kA(T_h - T_c)t}{d}$
        - Assumptions
            - All steam energy listed in the BEE goes to the building's heating
            - We can approximate the heating demand by treating the library as one giant volume, rather than dividing it into individual floors (essentially this means there is minimal insulation between the floors)
            - The basement is the same shape as each other floor (to simplify initial calculations)
            - We can estimate the energy consumption of the heating demand by assuming the temperature outside of the library is a consistent 40 degrees Fahrenheit (this is meant to account for the building's insulation, wind outside of the library, and the fluctuating temperatures throughout the year)
            - The energy consumption of the library is approximately the same for each day of the year (also to simplify initial calculations).
        - Calculations
            - Heating the building's interior from exterior temperature (40 degrees Fahrenheit) to desired temperature (72 degrees Fahrenheit)
                - m (mass of the air in the building) = 24806.25 kg
                    - m = V (volume of the building) * p (density of the air)
                    - V = 90 m * 15 m * 15 m = 20250 m^3
                    - p = 1.225 kg/m^3
                - c (specific heat of air) = 1015 J/(kg * degrees Celsius)
                - ΔT (change in temperature of the air in the building) = 18 degrees Celsius
                    - ΔT = T_h (desired interior temperature) - T_c (exterior temperature)
                    - T_h = 72 degrees Fahrenheit (22.2 degrees Celsius)
                    - T_c = 40 degrees Fahrenheit (4.4 degrees Celsius)
                - Ideal energy consumption (if all the assumptions are true and we do not worry about other complex factors): Q = 0.45 billion J / day

- Maintaining the library's temperature at 72 degrees Fahrenheit for 15 hours (8 AM - 11 PM)
    - k (thermal conductivity of the library's brick wall) = 0.84 W/(m * degrees Celsius)
    - A (surface area of all of the library's exterior surfaces) = (90 m * 15 m) * 4 [for each wall] + (15 m * 15 m) * 2 [for the ceiling and floor] = 5850 m^2
    - T_h - T_c = 18 degrees Celsius (found in the previous calculation for temperature)
    - d (thickness of the library's exterior wall) = 1 ft (0.3048 m)
    - t (time that we wish to maintain the temperature) = 15 hr (54000 s)
    - Ideal energy consumption: Q = 15.7 billion J / day
- Comparison
    - Library's steam energy consumption (as of 2015, according to the BEE) = 36.2 billion J / day
        - 12,537,649 KBtu of steam/year
        - 1 year = 365 days
        - 1 Btu = 1055.06 J
    - Total ideal energy consumption: 0.45 + 15.7 = 16.1 billion J / day
    - Ratio of reality to ideal = 2.25 times as much energy used for heating as ideal

- **Lighting Energy Consumption**
    - Assumptions
        - All electricity going to the library is used for lighting
            - We are not accounting for the energy consumed by elevators as of now
        - For now, we will approximate that each floor has the equivalent of 100 light bulbs, and there are 28 floors (including the basement and the main level), so there are 2800 bulbs total
            - For calculation simplicity and to account for outliers, I will round this to 3000 bulbs
        - Our calculations are for lighting the building for 15 hours, rather than 24 hours
    - Calculations
        - Compact fluorescent light bulbs (CFLs)
            - It is reasonable to assume that all of the library's bulbs are CFLs, given that it was built in 1972, after the CFL was beginning to be popular, but before the LED became popular
            - Power consumption for a 1200 lumen light bulb (about right in the middle of the typical lumen range for a bulb) is around 20 W [W = J / s]

            - Even if we ran every bulb in the building for 24 hours, then the total energy consumption per day of all of the lights (assuming they were average CFLs) would be around 3.24 billion J / day
                - 15 hours = 54000 s
            - If these bulbs were run for 24 hours instead, their energy consumption would total to around 5.18 billion J / day
        - Incandescent light bulbs
            - It is unlikely that a large amount of (or even really any at all) the bulbs in the library are incandescent because they were starting to be replaced by CFLs in the early 1900s, and the library was built in 1972
            - Power consumption for a 1200 lumen bulb is around 75 W
            - For calculation sake, if every bulb in the building is incandescent, the total energy consumption per day would be around 12.2 billion J / day
                - 15 hours = 54000 s
            - Taking one step further, let's assume we have extremely bright bulbs (2700+ lumens) which are equivalent to 150 W each. This would lead to a total energy usage of 24.3 billion J / day. You may be wondering why I went this far, but check out the comparison
    - Comparison
        - The library consumes around 45.6 billion J / day in electricity
            - 15,761,719 KBtu of electricity/year
        - CFLs are more efficient than incandescent bulbs (a 75 W incandescent = a 20 W CFL) and LEDs are even more efficient than CFLs (a 75 W incandescent = a 12 W LED)
        - Where does all of this extra electricity consumption come from?
            - Energy draw from outlets?
            - Elevators?
            - Motion sensors and timers for library isle lights?

- Ideal situation thermodynamic calculation
- Cost of fluorescent versus LED lights
    - Finances and energy
- Average occupancy over the course of each day in the library
- How much power the metering devices would consume
    - Bluetooth connection or wifi connection - how do we control them remotely?