Storing Heat in a Water Tank

For comparison, here's a corresponding calculation of the rate that we have to supply heat to a water tank to compensate for its losses. Call this rate Q (watts). We'll consider a cylindrical water tank of radius r m and height h m covered with a layer of insulation t m thick and of conductivity k W/m.K and containing water at a uniform temperature ΔT degrees above reference.

Thinking first about the energy stored in the tank, the volume of the tank is $V = \pi r^2 h$ m^3. The tank will be most efficient in terms of heat loss if it approximates a sphere as closely as possible but we want the water to stratify which necessitates a taller tank, so we'll take $h = 4\,r$ giving

$$V = 4\pi r^3$$

The heat energy E stored in a tank is given by $E = \rho c V \Delta T$ joules or $E = \frac{\rho c V \Delta T}{3{,}600{,}000}$ kWh where c = 4184 J/kg.K is the specific heat of water and ρ = 1000 kg/m^3 is the density of water. Rearranging to solve for V gives

$$V = 3{,}600{,}000 \frac{E}{\rho c \Delta T} = \frac{3{,}600{,}000}{1000 \times 4184} \times \frac{E}{\Delta T} = 0.86 \frac{E}{\Delta T}$$

and for r we obtain

$$r = \sqrt[3]{\frac{0.86}{4\pi} \times \frac{E}{\Delta T}} = \sqrt[3]{0.0685 \frac{E}{\Delta T}}$$

David O suggested a figure of 5000 kWh storage at a temperature difference of 5 K. We'll work out r for three different values of ΔT for reasons we'll discuss below:

ΔT	5	15	70
r	4.1	2.8	1.7

Now let's consider the rate of heat loss from the tank. This depends on the surface area A, which is given by $2\pi r^2 + 2\pi r h = 2\pi r(r+h)$ or $10\pi r^2$

We'll just add the insulation thickness to the radius to calculate the effective area for heat loss; this gives a conservative answer. The formula is $Q = \frac{k A}{t} \Delta T$ watts, where t (m) is the insulation thickness and k is its thermal conductivity. So using the values of ΔT and r from above, we can work out the heat loss for a range of insulation thicknesses and materials.

	ΔT	5	15	70	K
	V	866	276	62	m^3
	r	4.1	2.8	1.7	m
	k				
100 mm PU	0.021	582	832	1496	W
100 mm EPS	0.033	914	1308	2351	W
300 mm PU	0.021	213	317	616	W
300 mm EPS	0.033	335	498	968	W

Water tanks are different to storing heat underground in that the tanks can potentially be inside the building. So the heat losses can be over the same temperature differential as the useful energy storage. Plus some of the heat losses can be used to heat the building, with clever design.