Answer Key: Homework Assignment #1

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1. Obviously this will vary by person. I had to measure three things before I could start calculations: length of shower, temperature of shower, and water flow. I measured length of shower at 11 minutes, temperature (using a thermometer) at 108 degrees F, and filled up a 16 oz. container in 6 seconds. 16 oz. (or 1 pint) in 6 seconds equates to 110 pints in 11 minutes. 1 BTU equals 1 pint up one degree, so 110 pints up 58 degrees is 6,380 BTUs. At 3,413 BTUs per KWH, this shower was 1.87 KWH. Obviously, generation, storage, and transmission of hot water (especially if electrical heat is used) is not perfectly efficient, so my energy use for this shower was likely well in excess of this figure.

2. There is a fair deal of estimation here and your answer will also vary depending on your weight. While your estimates don't need to be exact, they do need to be close.

   a. I measured the distance and height gain from Cool Beans 2 to Cool Beans 1 both "by hand" and by using Google Earth and a GPS device. The horizontal distance between the two points is roughly 300 meters by both measures. In terms of vertical distance, GPS did not provide precise enough estimates to use while Google Maps provided a measure of about 32 meters. "By hand," there are 150 steps between the two points averaging roughly 6 inches each for a vertical rise of 75 feet plus an additional amount for any uphill portions not covered by stairs. This comes to 25 meters or a bit more, so let's call it about 30 meters total or 100 feet total.

   I am 155 pounds (exactly the same weight as when I graduated from college in 1991 I might add). 300 meters = 984 feet. (984 feet)(10 c /foot per 100 lbs)(155 lbs/100) = 15,255 (little) calories or 15.255 kc (food calories). (15.255kc)(.001163 KWH/kc) = 0.0177 KWH for the horizontal portion.

   For the vertical portion, for my body I am lifting 155 pounds by 100 feet for a total of 15,500 foot pounds. (15,500 ft-pounds)(.0000003766 KWH/foot-pound) = 0.0058 KWH for the vertical portion. Total KWHs used = 0.0235 KWHs. Notice how much less this is than the energy you used in your shower.

   b. I takes me 3 minutes and 45 seconds to make the walk, or 225 seconds, or 225/3600 = 0.0625 hours. Since I generate 23.5 watt hours in .0625 hours, this would be 23.5/.0625 = 376 watts.

   c. I can climb the 12 - 7 3/4 inch stairs in my house in 1.75 seconds. Since I weigh 155 pounds, that is (7.75)(155) =1,201.25 foot-pounds in 1.75 seconds or 1,201.75(60)/1.75 = 41,186 foot-pounds per minute. Since 1 horsepower = 33,000 foot-pounds/minute, this is 41,186/33,000 = 1.248 horsepower. 1 horsepower = 746 watts, so 1.248 horsepower = 931 watts.

   Now one may wonder how it is possible that I am stronger than a horse. While "steroids" is an obvious answer, the real reason is that in short people can produce lots of power, but a horse could keep up this rate of output over an extended period. I couldn't keep up this rate of climb for a large number of flights.

3. Again this will vary. In my bedroom of my house I have a clock radio, a fish tank, several lamps and overhead lights, an overhead fan, my laptop computer and power supply, an ethernet router and a wireless router and power strip, cordless phone and charger, and an iPod docking station.

Fish tank (5 gallon)	45w	24 hrs/day	30 days/month	= 32,400 wh
Bedside lamps	80w	3 hrs/day	30 days/month	= 7,200 wh
Overhead light 1	27w	1 hr/day	30 days/month	= 810 wh
Overhead light 2	130w	1 hr/day	10 days/month	= 1,300 wh
Closet light	80w	.5 hr/day	30 days/month	= 1,200 wh
Routers	20w	24hrs/day	30 days/month	= 14,400 wh
Clock radio	10w	24 hrs/day	30 days/month	= 7,200 wh
iPod docking station	20w	1 hrs/day	5 days/month	= 100 wh
Cordless phone	3w	24 hrs/day	30 days/month	= 2,160 wh
Laptop	40w	1.5 hrs/day	30 days/month	= 1,800 wh
Laptop charger	2w	24 hrs/day	30 days/month	= 1,440 wh
Total				= 70,010 wh

So, I use roughly 70KHW per month in my bedroom. (I'm not sure how close this really is to the true amount, but my average monthly electricity usage is about 1,000 KWH for my whole house. Since I have an electric water heater, this estimate would mean I use roughly 10% of my total electricity (other than for hot water) in the bedroom which probably isn't too far off.

4. a. At peak capacity of 600KW, the turbine should be able to produce 600(24)(365) = 5,256,000 KWH. Since it is expected to produce only 1,100,000 KWH, the turbine is only about 21% efficient. By comparison, a well-run nuclear plant runs at over 90% of capacity.

b. $NPV = \sum_{t=0}^{\infty} \frac{(B_t - C_t)}{(1+r)^{\wedge}t}$

@ r = 2%, benefits = $1,919,078, costs = $1,700,000, NPV = $ 219,078
@ r = 3%, benefits = $1,711,643, costs = $1,700,000, NPV = $ 11,643
@ r = 4%, benefits = $1,535,588, costs = $1,700,000, NPV = $-164,412

c. @ r = 2%, B/C ratio = $1,919,078 / $1,700,000 = 1.129
@ r = 3%, B/C ratio = $1,711,643 / $1,700,000 = 1.007
@ r = 4%, B/C ratio = $1,535,588 / $1,700,000 = 0.903

d. Based on the answers in part b., one can tell it must be just above 3%. Using guess and verify or Goal Seek, IRR = 3.06%.

e. @ r = 2%, the sum of benefits exceeds $1.7 million for the first time in year 22.
@ r = 3%, the sum of benefits exceeds $1.7 million for the first time in year 25.
@ r = 4%, the sum of benefits never exceeds $1.7 million. The payback time exceeds the working life of the turbine.

Note that payback period can sometimes also be solved analytically. The equation for an annuity is $NPV = P [1 - (1+r)^{-t}] / r$. P = 1.1 million KWH(8.936 cents/KWH) = $98,256.

At the payback period the NPV needs to equal the $1.7 million initial cost.

For the case of a discount rate = 2%, $1700000 = 98256[1 - (1.02)^{-t}] /.02$ and solve for t.
$0.34589 = [1 - (1.02)^{-t}] \Longrightarrow (1.02)^{-t} = 0.65411 \Longrightarrow -t \ln(1.02) = \ln (0.65411)$
$t = - \ln(0.65411)/\ln(1.02) = 21.44$
This procedure could be repeated for any combination of discount rate and annual benefits.

f. @ r = 2%, benefits = $3,196,244, costs = $1,700,000, NPV = $1,496,244
@ r = 3%, benefits = $2,850,759, costs = $1,700,000, NPV = $1,150,759
@ r = 4%, benefits = $2,557,538, costs = $1,700,000, NPV = $ 857,538

g. @ r = 2%, B/C ratio = $3,196,244 / $1,700,000 = 1.880
@ r = 3%, B/C ratio = $2,850,759 / $1,700,000 = 1.677
@ r = 4%, B/C ratio = $2,557,538 / $1,700,000 = 1.504

h. Based on the answers in part h., one can tell it must be above 4%. Using guess and verify or Goal Seek, IRR = 8.33%.

i. @ r = 2%, the sum of benefits exceeds $1.7 million for the first time in year 12.
@ r = 3%, the sum of benefits exceeds $1.7 million for the first time in year 13.
@ r = 4%, the sum of benefits exceeds $1.7 million for the first time in year 14.

j. This simply requires the use of Goal Seek with cost per KWH as the variable.
@ r = 2%, the sum of benefits = $1.7 million at a cost of 7.916 cents/KWH.
@ r = 3%, the sum of benefits = $1.7 million at a cost of 8.875 cents/KWH.
@ r = 4%, the sum of benefits = $1.7 million at a cost of 9.893 cents/KWH.

k. Holy Cross would normally have to pay for both generation and distribution of any electricity it purchases. If it now generates electricity locally, it avoids both costs, so it is saving the full 14.883 cents/KWH. On the other hand, if National Grid generates power, it still has to distribute it so for it to install wind turbines, wind has to beat the cost of generation alone at 8.936 cents/KWH.

l. This grant lowers the cost to Holy Name to $1.115 million from $1.7 million.
@ r = 2%, benefits = $3,196,244, costs = $1,115,000, NPV = $2,081,244
@ r = 3%, benefits = $2,850,759, costs = $1,115,000, NPV = $1,735,759
@ r = 4%, benefits = $2,557,538, costs = $1,115,000, NPV = $1,442,538

m. @ r = 2%, the sum of benefits exceeds $1.115 million for the first time in year 8.
@ r = 3%, the sum of benefits exceeds $1.115 million for the first time in year 8.
@ r = 4%, the sum of benefits exceeds $1.115 million for the first time in year 9.

n. Since the real discount rate = interest rate - inflation, if inflation for energy is higher than other goods, then one should use a lower real discount rate than one might use for other goods.

o. This project appears to have positive net benefits over a range of interest rates and a range of prices for electricity. Therefore, Holy Cross should certainly consider such a project, especially if it too can receive subsidies to cover a portion of the cost like Holy Name did.

Obviously, costs and benefits aside from the electricity itself should be considered.

5. a. Since the cost of electricity and light bulbs is being held constant over time, we want to use a discount rate that subtracts out inflation. Therefore, we want to use a real discount rate rather than a nominal discount rate. Real discount rates are generally around 1%-5%, so 12% is far outside this range. Furthermore, even as a nominal discount rate 12% is rather high. There are essentially no examples of risk-free rates of return that average 12%. Thus, this is almost certainly too high a discount to use.

b. I have chosen not to discount the first year of bulbs or electricity. The NPV equations are shown below. As can been seen, florescents are much cheaper to use.

	Nominal Incandescent		Flourescent	
Year	Bulbs	Elec.	Bulbs	Elec.
0	$ 1.00	$ 23.10	$ 2.50	$ 6.16
1	$ 1.00	$ 23.10	$ -	$ 6.16
2	$ 1.00	$ 23.10	$ -	$ 6.16
3	$ 1.00	$ 23.10	$ -	$ 6.16
4	$ 1.00	$ 23.10	$ -	$ 6.16
	$ 5.00	$ 115.50	$ 2.50	$ 30.80
	Total	**$ 120.50**	**Total**	**$ 33.30**

	Discounted Incandescent		Florescent	
Year	Bulbs	Elec.	Bulbs	Elec.
0	$ 1.00	$ 23.10	$ 2.50	$ 6.16
1	$ 0.89	$ 20.63	$ -	$ 5.50
2	$ 0.80	$ 18.42	$ -	$ 4.91
3	$ 0.71	$ 16.44	$ -	$ 4.38
4	$ 0.64	$ 14.68	$ -	$ 3.91
	$ 4.04	$ 93.26	$ 2.50	$ 24.87
	Total	**$ 97.30**	**Total**	**$ 27.37**

c. Probably the biggest issue is that of status quo bias. Other factors might include light quality or fixture compatibility. Also, florescents have their greatest advantage in applications where the lights are used frequently. In low use applications like attics or closets, one may never use the bulbs long enough to accrue significant energy savings.