Economic Analysis

Homework

2017

PS2: Economic analysis problem set

1. a) Calculate the net present value of your education at Cornell 10 years after graduation assuming $40,000 cost per year followed by what you expect to earn upon graduation.
   b) Compare this to what you would expect to earn over 14 years if you entered the workforce instead of Cornell. (Hint, you can modify the simple examples part of the spreadsheet on blackboard to carry out these two calculations).

2. a) Calculate the change in the NPV for the base case mine (8% discount, 1 million/year exploration tax incentive) if the government gave an exploration tax credit of $1.5 million per year instead of $1 million per year. (Hint, appropriately adjust the tax discount multiplier.)
   b) What is the change in IRR?
   c) Plot the NPV vs time when the discount rate equals the internal rate of return. (Hint: Use the spreadsheet and the plot will appear on the associated excel sheet.)
   d) Explain why the shape of the curve is expected.

3. Tabulate the NPV of 350 MWe power plants in the "Electrical Costs unitized" spreadsheet on Blackboard assuming a discount rate of 8%, a tax rate of 30%, and an electricity sales price of 8₵/kWh. Use the base capacity factors, construction, and fuel costs in that spreadsheet (from the 2005 OECD Electrical Generation Costs Projections pdf), and assume a 40 year plant life. Comment on what your results tells you.

4. In 2005 solar electricity generation was much more expensive than the other alternatives because of its capacity factor and high cost of construction, but from the discussion in lecture the cost of solar has dropped dramatically because of a strong decrease in construction cost, an increase in capacity factor, and a decrease in operations and maintenance. How much could the capacity factor be increased above that assumed in the spreadsheet? (Search in the OECD pdf, look at what MacKay has to say, and look at the web).

5. From the lecture material (see links) construction costs for Solar Photovolaics may have dropped from $4000/kW$_e$ to $1500/kW$_e$, and O&M may be ~0.2₵/kWh rather than 0.48 ₵/kWh. Make a table showing the levelized cost of the base case of ($4000/kW$_e$, O&M=0.48 ₵/kWh, capacity=20%, discount=10%, life=40y) and sequential changes in the base case: (a) increase capacity factor to 24%, (b) decrease O&M to 0.2 ₵/kWh, (c) decrease the discount rate to 7%, and (d) then to 4%, (e) decrease the construction costs to $1500/kW$_e$, and (f) then to $1170, and then the impact of increasing the discount rate for this case to 7 and then 10%. You will find the lowest levelized cost is 3.95 ₵/kWh. From this analysis how certain are you that this is a good estimate.

6. What are the costs left out of your spreadsheet analysis?

1. a) Calculate the net present value of your education at Cornell 10 years after graduation assuming $40,000 cost per year followed by what you expect to earn upon graduation.
b) Compare this to what you would expect to earn over 10 years if you entered the workforce instead of Cornell.
c) What will your comparative situation be 20 years out? How much higher will your salary be?
d) Do you think the NPV calculation captures how what your comparative lifestyle will be 10 or 20 years from starting Cornell?

start	70			start	30	
raise/yr	1.06			raise/yr	1.04	
		discount rate		0.1		
period	cash flow	PVIF	PV		cash flow	PV
0	-40		-40		30.00	30.00
1	-40	0.909	-76.36		31.20	58.36364
2	-40	0.826	-109.42		32.45	85.18017
3	-40	0.751	-139.47		33.75	110.534
4	70	0.683	-91.66		35.10	134.5048
5	74.20	0.621	-45.59		36.50	157.1682
6	78.65	0.564	-1.19		37.96	178.5954
7	83.37	0.513	41.59		39.48	198.8538
8	88.37	0.467	82.82		41.06	218.0073
9	93.68	0.424	122.54		42.70	236.116
10	99.30	0.386	160.83		44.41	253.2369
11	105.25	0.350	197.72		46.18	269.424
12	111.57	0.319	233.27		48.03	284.7281
13	118.26	0.290	267.52		49.95	299.1975
14	125.36	0.263	300.53		51.95	312.8776
15	132.88	0.239	332.35		54.03	325.8116
16	140.85	0.218	363.00		56.19	338.04
17	149.30	0.198	392.54		58.44	349.6015
18	158.26	0.180	421.00		60.77	360.5323
19	167.76	0.164	448.43		63.21	370.8669
20	177.82	0.149	474.87		65.73	380.6378

See NPV homework excel spreadsheet

a) NPV 10 years out = 160,000
(you could educate another student)

b) Cornell has cost you $93k (=$253-$160) 10 years out, but you have over 2x the salary.

c) You are $94k better off (NPV) 20 years out and have a 2.7 fold greater salary

d) Your feelings 10 or 20 years out may be more due to your greater income than whether your education was a good investment

2. a) Calculate the change in the NPV for the base case mine (8% discount, 1 million/year exploration tax incentive) if the government gave an exploration tax credit of $1.5 million per year instead of $1 million per year. (Hint, appropriately adjust the tax discount multiplier.)
b) What is the change in IRR?

	Discount	NPV 50 yrs $millions	IRR
Tax incentive 1	8%	$13.8	14%
Tax incentive 1.5	8%	$16.7	16.7%

a) NPV has changed by $2.9 million (to $16.7 from $13.8 million.
b) IRR has changed by 2.7% (from 14% to 16.7%).

Mining Base Case

year	$ millions exp/inc	$ millions tax	PVIF	NPV Tax	$ millions NPV			
1	$ (2.0)	$ 1.0	0.926	$ 1.39	$ (0.46)	disc =	8%	
2	$ (2.0)	$ 1.0	0.857	$ 2.67	$ (0.89)	tax incentive mul =	1.5	
3	$ (2.0)	$ 1.0	0.794	$ 3.87	$ (1.29)	tax mul	1	
4	$ (2.0)	$ 1.0	0.735	$ 4.97	$ (1.66)			
5	$ (2.0)	$ 1.0	0.681	$ 5.99	$ (2.00)	total income	$ 267.6	
6	$ (2.0)	$ 1.0	0.630	$ 6.93	$ (2.31)	Net Income	$ 125.1	
7	$ (2.0)	$ 1.0	0.583	$ 7.81	$ (2.60)	Tax	$ (142.5)	
8	$ (2.0)	$ 1.0	0.540	$ 8.62	$ (2.87)			
9	$ (18.0)	$ -	0.500	$ 8.62	$ (11.88)	NPV	$ 16.7	47%
10	$ (21.0)	$ -	0.463	$ 8.62	$ (21.60)	NPV Tax	$ (19.1)	53%
11	$ 10.0	$ (1.2)	0.429	$ 8.11	$ (17.83)			
12	$ 18.0	$ (4.0)	0.397	$ 6.52	$ (12.27)	IRR=14.034%		
13	$ 18.0	$ (5.8)	0.368	$ 4.38	$ (7.79)	no tax and no tax incentive IRR = 16.9%		
14	$ 16.5	$ (6.3)	0.340	$ 2.24	$ (4.31)	no tax incentive IRR= 10.8%		
15	$ 15.8	$ (7.0)	0.315	$ 0.03	$ (1.54)			

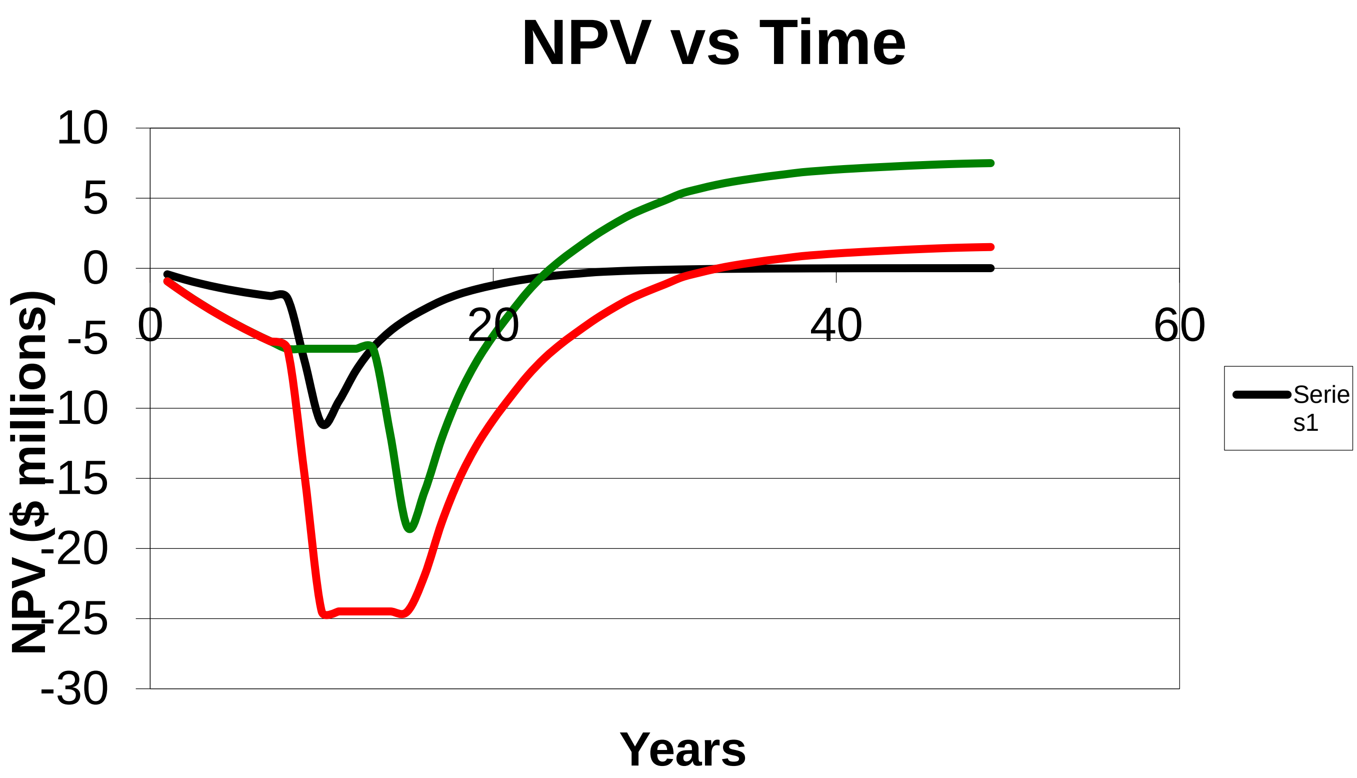
See NPV-simple and mine examples_2013 excel spreadsheet

Mining Base Case

IRR

year	$ millions exp/inc	$ millions tax	PVIF	NPV Tax	$ millions NPV			
1	$ (2.0)	$ 1.0	0.857	$ 1.29	$ (0.43)	disc =	16.7%	
2	$ (2.0)	$ 1.0	0.734	$ 2.39	$ (0.80)	tax incentive mul =	1.5	
3	$ (2.0)	$ 1.0	0.629	$ 3.33	$ (1.11)	tax mul	1	
4	$ (2.0)	$ 1.0	0.539	$ 4.14	$ (1.38)			
5	$ (2.0)	$ 1.0	0.462	$ 4.83	$ (1.61)	total income	$ 267.6	
6	$ (2.0)	$ 1.0	0.396	$ 5.43	$ (1.81)	Net Income	$ 125.1	
7	$ (2.0)	$ 1.0	0.339	$ 5.93	$ (1.98)	Tax	$ (142.5)	
8	$ (2.0)	$ 1.0	0.291	$ 6.37	$ (2.12)			
9	$ (18.0)	$ -	0.249	$ 6.37	$ (6.61)	NPV	$ 0.0	3%
10	$ (21.0)	$ -	0.213	$ 6.37	$ (11.09)	NPV Tax	$ (0.3)	97%
11	$ 10.0	$ (1.2)	0.183	$ 6.15	$ (9.48)			
12	$ 18.0	$ (4.0)	0.157	$ 5.52	$ (7.29)	IRR=14.034%		
13	$ 18.0	$ (5.8)	0.134	$ 4.75	$ (5.65)	no tax and no tax incentive IRR = 16.9%		
14	$ 16.5	$ (6.3)	0.115	$ 4.02	$ (4.47)	no tax incentive IRR= 10.8%		

2. c) Plot the NPV vs time when the discount rate equals the internal rate of return. (Hint: Use the spreadsheet and the plot will appear on the associated excel sheet.)
d) Explain why the shape of the curve is expected.



c) Black curve is the case where discount rate = IRR
d) Expected because by definition the IRR is the discount rate at which the NPV at the mine life is zero.

3. Tabulate the NPV of 350 MWe power plants in the spreadsheet (disc rate 8%, 30% tax). Comment on what this tells you.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Power source		(note 1 kW-yr= 8.76E3 kWh)			Coal	Tbl 3.10		$40 for 2000 lb			$44.00 1 metric ton	
2	Overnight construction cost [$/kWe]				Tbl 3.10, fig 3.1	$1,161	$1161/kWe-yr		0.014 GJ/t				
3	blue=used in calc	cost in ¢/(kWh/y) (cost 1y of kWh prodn)				13.25	¢/kWh		61.6 ¢/GJ				
4		construction time [yrs]				4	yrs Tble 3.1		130 ¢/GJ tbl 3.3 = 62¢/GJ + 68¢/GJ delivery				
5	cost growth	1.30%		costs					0.47 ¢/kW_{th}h		at 44% conv=		1.06 ¢/kWh
6	construction (investm)	¢/(kWh/y)		% Investment		Tbl 3.14	1.950	53.3%					
7	costs->	¢/(kWh/y)		% O&M	$/MWh/10 = ¢/kWh		0.660	18.0%					
8	overnight constr cost	¢/(kWh/y)		% Fuel			1.050	28.7%					
9	cost multiplier	1.00		plant life [yrs]		40							
10	% Tax			30%									
11	sales price of power [¢/kWh]			8		85.0%	capacity factor						
12	Levelized cost of power production [¢/kWh]					4.25	[¢/kWh] determined at 0% tax, NPV(life)=0						
13						NPV	NPV tax		NPV	NPV tax			
14	NPV at 20y [¢/(kWh/yr)]			NPV tax @20 y		8.931	-8.78		[$/MWe]	[$/MWe]			
15	NPV at 40y [¢/(kWh/yr)]			NPV tax @40 y		12.789	-10.43	¢/kWh					
16	NPV at life plant [¢/(kWh/yr)]			NPV tax @life		12.789	-10.43		1.12	-0.91	$/$W_e$-yr		
17												350 MWe plant	
18	discount rate		10%			Costs	Revenue	Tax	NPV tax	NPV	NPV	$ 392.1	
19	year	PVIF				all in ¢/kWh/yr					NPV tax	$ (319.9)	
20	0	1.0000				-3.313	0	0	0	-3.313		millions	
21	1	0.9091				-3.313	0	0	0.00	-6.325			
22	2	0.8264				-3.313	0	0	0.00	-9.064			
23	3	0.7513				-3.313	0	0	0.00	-11.553			

Coal

	350 MWe plant
NPV	$ 392.1
NPV tax	$ (319.9)
	millions

Gas

	350 MWe plant
NPV	$ 340.9
NPV tax	$ (232.0)
	millions

Wind

	350 MWe plant
NPV	$ (28.4)
NPV tax	$ (152.8)
	millions

Solar Thermoele

	350 MWe plant
NPV	$ (1,476.1)
NPV tax	$ 203.1
	millions

Solar PV

	350 MWe plant
NPV	$ (1,076.88)
NPV tax	$ (10.60)

Nuclear

	350 MWe plant
NPV	$ 195.2
NPV tax	$ (320.6)
	millions

Micro Hydro

	350 MWe plant
NPV	$ 153.6
NPV tax	$ (339.4)
	millions

CHP

	350 MWe plant
NPV	$ 269.86
NPV tax	$ (294.63)

Tells you wind and solar not economic
Nuclear, MicroHydro and CHP less "

4. How much could the capacity factor be increased above that assumed in the spreadsheet? (Search in the OECD pdf, look at what MacKay has to say, and look at the web).

Capacity factor = ratio of actual output to output at full capacity.

- OECD (2005) projects solar PV could achieve capacity factor of 24% (from 20% assumed)

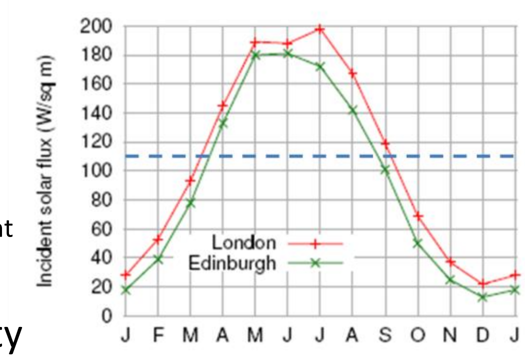
1. Incident energy:

$110\ W/m^2$

Incident avg/inc clds

1000x0.32x0.34

inc=mid-day incident



2. Efficiency of conversion to electricity

MacKay's rules of thumb

Power per unit land or water area	
Wind	$2\ W/m^2$
Offshore wind	$3\ W/m^2$
Tidal pools	$3\ W/m^2$
Tidal stream	$6\ W/m^2$
Solar PV panels	$5–20\ W/m^2$
Plants	$0.5\ W/m^2$
Rain-water (highlands)	$0.24\ W/m^2$
Hydroelectric facility	$11\ W/m^2$
Solar chimney	$0.1\ W/m^2$
Concentrating solar power (desert)	$15\ W/m^2$

MacKay, 2009, Sewha, p177

MacKay p39: "Typical solar panels have an efficiency of about 10%; **expensive ones 20%.** (Fundamental physical laws omit the efficiency of photovoltaic systems to **at best 60%** with perfect concentrating mirror or lenses, and **to 45%** without concentration. A mass produced device with efficiency **greater than 30% would be remarkable**.) The average power delivered by a south-facing 20% efficient photovoltaic panels in Britain would be

$$20\% \times 110\ W\ m^{-2} = \mathbf{22\ W\ m^{-2}}.$$

OECD (2005): Max conversion to electricity efficiency is 32% in the lab (p. 166). Inverters to AC now 90-95% efficient.

Cornell 11 acre solar farm **$6.4\ W\ m^{-2}$**
Long Island 200 acre solar farm **$6.2\ W\ m^{-2}$**

5. Make a table showing the levelized cost for:

$4000/kW$_e$ O&M=0.48 ₵/kWh capacity=20% discount=10% life=40y

24%

0.2 ₵/kWh

7%

4%

$1500

$1170

7%

10%

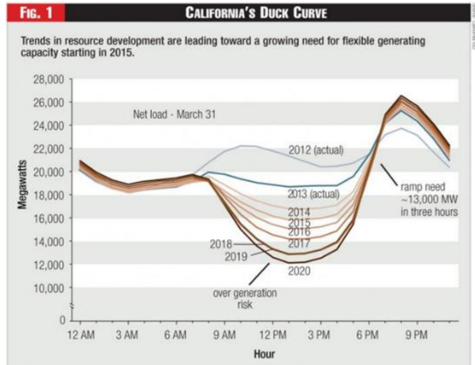
Solar Photovoltaic (USA-2)

Construction [$/kW$_e$]	O&M [₵/kWh]	Capacity [%]	Discount [%/y]	Plant Live [y]	Levelized cost [₵/kWh]
$4000	0.48	20	10	40	27.3
		24			22.8
				25	24.5
	0.20			40	20.0
			7		15.85
			4		10.95
$1500					4.75
$1170					3.95
			7		5.35
			10		7.0

6. What are the costs left out of your spreadsheet analysis?

1. Energy Storage

2. Polution

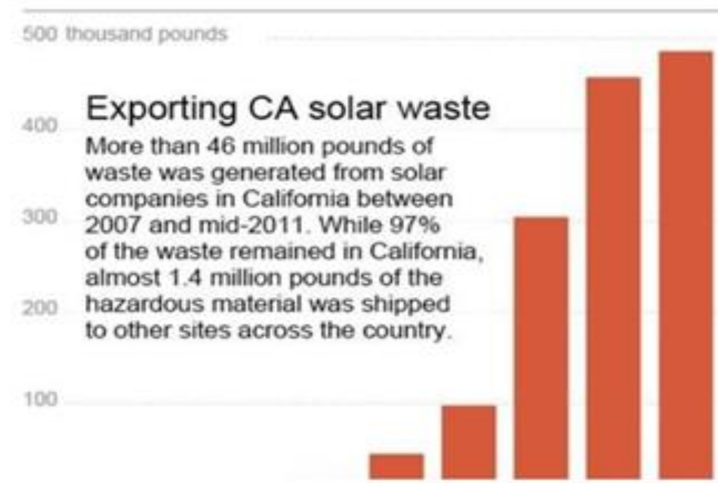


Chinese Protesters Accuse Solar Panel Plant of Pollution

Protesters and police officers faced off on Saturday at a plant in the Chinese province of Zhejiang. The unrest began Thursday.

By SHARON LaFRANIERE
Published: September 18, 2011

The dirty side of clean solar energy



AP 2/10/13 | By Jason Dearen

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Images from Doug Lee
State Assembly Candidate Long Island

MailOnline

January 29, 2011
by Simon Parry in China and Ed Douglas in Scotland

In China, the true cost of Britain's clean, green wind power experiment: Pollution on a disastrous scale

This toxic lake poisons Chinese farmers, their children and their land. It is what's left behind after making the magnets for Britain's latest wind turbines... and, as a special Live investigation reveals, is merely one of a multitude of environmental sins committed in the name of our new green Jerusalem.

The lake of toxic waste at Baotou, China, which as been dumped by the rare earth processing plants in the background.

Rare earth processing turned a lake into toxic mud pond

3. Land impact

visual

4. Habitat dissection

Service roads