

ELG4126- Sustainable Electrical Power Systems- DGD

# Economics of Distributed Resources

Maryam Parsa

DGD 02- Jan14<sup>th</sup>, 2013

Winter 2013



# REVIEW from DGD 01- Jan 7<sup>th</sup>

- Standard Residential Rates

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Tier Level	Winter: November–April		Summer: May–October	
Tier I	First 620kWh	7.378¢/kWh	First 700kWh	8.058¢/kWh
Tier II	621–825	12.995¢/kWh	701–1000	13.965¢/kWh
Tier III	Over 825	14.231¢/kWh	Over 1000	15.688¢/kWh

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- Residential Time-Of-Use (TOU) Rates

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	November–April		May–October	
On-peak	7–10 A.M., 5–8 P.M.	8.335 ¢/kWh	2–8 P.M.	19.793 ¢/kWh
Off-peak	All other times	7.491 ¢/kWh	All other times	8.514 ¢/kWh

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# REVIEW from DGD 01- Jan 7<sup>th</sup>



- Demand Charges

	Winter Oct–May	Summer June–Sept
Energy charges	\$0.0625/kWh	\$0.0732/kWh
Demand charges	\$7/mo-kW	\$9/mo-kW

- Load Factor

$$\text{Load factor (\%)} = \frac{\text{Average power}}{\text{Peak power}} \times 100\%$$

# Example 1: Calculating a Simple Residential Utility Bill



- Q: Customer subject to the rate structure in Table 1 uses 1200 kWh/mo during the summer.
  - What would be the total cost of electricity
  - What would be the value (¢/kWh) of an efficiency project that cuts the demand to 900 kWh/mo?
- *Answer:*
  - The total monthly bill includes 700 kWh @ 8.058¢, 300 kWh @ 13.965¢, and 200 kWh @ 15.688¢, for a total of
$$700 * \$0.08058 + 300 * \$0.13965 + 200 * \$0.15688 = \$129.68 / \text{mo}$$
  - If the demand is reduced to 900 kWh/mo, the bill would
$$700 * \$0.08058 + 200 * \$0.13965 = \$84.34 / \text{mo}$$
  - Savings per kWh is  $(\$129.68 - \$84.34) / 300 \text{ kWh} = \$0.1511 / \text{kWh}$



## Example 2: PVs, TOU Rates, and Net Metering

- Q: Based on the table below, for a 30-day month in the summer, find the electric bill for the customer if the TOU rates of Table 2 apply.

	PV supply	Demand
On-peak	10kWh	2kWh
Off-peak	10kWh	18kWh
Total	20kWh/day	20kWh/day

- Answer:*
  - On-peak credits =  $8 \text{ kWh/day} * \$0.19793 / \text{kWh} * 30 \text{ day/mo} = \$47.50$
  - Off-peak bill =  $8 \text{ kWh/day} * \$0.08514 / \text{kWh} * 30 \text{ day/m} = \$20.43/\text{m}$
  - Net bill =  $\$20.43 - \$47.50 = - \$27.07\text{mo}$

## Example 3: Impact of Demand Charges



- Q: During the summer, a small commercial building that uses 20,000 kWh per month has a peak demand of 100 kW
  - The monthly bill?
  - How much does the electricity cost for a 100-W computer that is used 6h a day for 22 days in the month? The computer is turned on during the period when the peak demand is reached for the building. How much is that in ¢/kWh?

(Based on Table 3)



## Example 3: Impact of Demand Charges

*Answer:*

- Monthly bill = energy charges + demand charges
  - Energy charge =  $20,000 \text{ kWh} * \$0.0732/ \text{ kWh} = \$1464/ \text{ mo}$
  - Demand charge =  $100 \text{ kW} * \$9/ \text{ mo-kW} = \$900/ \text{ mo}$
  - For a total of  $\$1464 + \$900 = \$2364/ \text{ mo}$
- The computer uses  $0.10 \text{ kW} * 6 \text{ h/ d} * 22 \text{ day/ mo} = 13.2 \text{ kWh/ mo}$ 
  - Energy charge =  $13.2 \text{ kWh/ mo} * \$0.0732/ \text{ kWh} = \$0.97/ \text{ mo}$
  - Demand charge =  $0.10 \text{ kW} * \$9/ \text{ mo-kW} = \$0.90/ \text{ mo}$
  - Total cost =  $\$0.97 + \$0.90 = \$1.87/ \text{ mo}$
  - Per kilowatt-hour basis:  $(\$1.87/ \text{ mo}) / (13.2 \text{ kWh/ mo}) = \$0.142/ \text{ kWh}$

## Example 4: Impact of Ratcheted Demand Charges on an Efficiency Project



- Q: A customer's highest demand for power comes in August when it reaches 100 kW. The peak in every other month is less than 70 kW. A proposal to dim the lights for 3 h during each of the 22 workdays in August will reduce the August peak by 10 kW. The utility's energy charge is 8¢/kWh and its demand charge is \$9/kW-mo with an 80% ratchet on the demand charges.
  - a. What is the current annual cost due to demand charges?
  - b. What annual savings in demand and energy charges will result from dimming the lights?

## Example 4: Impact of Ratcheted Demand Charges on an Efficiency Project



*Answer:*

a)

- At \$9/kW-mo, the current demand charge in August will be

$$\text{August} = 100 \text{ kW} * \$9/ \text{ kW-mo} = \$900$$

- For the other 11 months, the minimum demand charge will be based on 80 kW, which is higher than the actual demand:

$$\text{Sept–July demand charge} = 0.8 * 100 \text{ kW} * \$9/ \text{ kW-mo} * 11 \text{ mo} = \$7920$$

- So the total annual demand charge will be

$$\text{Annual} = \$900 + \$7920 = \$8820$$



## Example 4: Impact of Ratcheted Demand Charges on an Efficiency Project



*Answer:*

b)

- August =  $90 \text{ kW} * \$9/ \text{ kW-mo} = \$810$
- Sept–July =  $0.8 * 90 \text{ kW} * \$9/ \text{ kW-mo} * 11 \text{ mo} = \$7128$
- Total annual demand charge =  $\$810 + \$7128 = \$7938$
- Annual demand savings =  $\$8820 - \$7938 = \$882$
- August energy savings =  $3 \text{ h/d} * 10 \text{ kW} * 22 \text{ days} * \$0.08 = \$52.80$
- Total Annual Savings =  $\$882 + \$52.80 = \$934.80$

- Notice that the demand savings is 94.4% of the total savings!

## Example 5: Impact of Load Factor on Electricity Costs



- Q: Two customers each use 100,000 kWh/mo. One (customer A) has a load factor of 15% and the other (customer B) has a 60% load factor. Using a rate structure with energy charges of \$0.06/kWh and demand charges of \$10/kW-mo, compare their monthly utility bills.
- *Answer:* They both have the same energy costs:  $100,000 \text{ kWh/mo} * \$0.06/\text{kWh} = \$6000/\text{mo}$ . Based on the load factor formula we have:
  - $\text{Peak(A)} = (100,000 \text{ kWh/mo}) / (15\% * 24 \text{ h/day} * 30 \text{ day/mo}) * 100\% = 925.9 \text{ Kw}$ , Costing = \$9259/mo
  - $\text{Peak(B)} = (100,000 \text{ kWh/mo}) / (60\% * 24 \text{ h/day} * 30 \text{ day/mo}) * 100\% = 231.5 \text{ Kw}$ , Costing = \$2315/mo
  - The total monthly bill for A with the poor load factor is nearly twice as high as for B (\$15,259 for A and \$8315 for B)

# Journal Paper of the first week



Maria Isabel Blanco, “*The Economics of Wind Energy*”,  
Renewable and Sustainable Energy Reviews, Elsevier, 2009



uOttawa

# DGD 02- Outline



- **Energy Economics**
  - Simple Payback Period
  - Initial (Simple) Rate-Of-Return
  - Net Present Value (NPV)
  - Internal Rate of Return (IRR)



# Energy Economics- Introduction



- Different ways to determine the energy efficient projects:
  - The capital cost of equipment
  - The operation and maintenance costs
  - The fuel costs, ...
- In this DGD:
  - We just want to know whether the project deserves further, more careful, analysis or not



# DGD 02- Outline



- Energy Economics
  - **Simple Payback Period**
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# Simple Payback Period

- One of the most common ways to evaluate the economic value of a project:

$$\text{Simple payback} = \frac{\text{Extra first cost } \Delta P(\$)}{\text{Annual savings } S(\$/\text{yr})}$$

- Example.
  - An energy-efficient air conditioner that costs an extra \$1000 and which saves \$200/yr in electricity would have a simple payback of 5 years.
- Period of time required for the return on an investment to "repay" the sum of the original investment
- e.g. a \$1000 investment which returned \$500 per year would have a two year payback period





# Simple Payback Period

- Advantage:
  - The easiest to understand of all economic measures
- Disadvantage:
  - Does not take into account the “Time Value of Money”
  - Simple payback period: makes an investment look worse than it is
  - One of the least convincing ways to present the economic advantages of a project, individuals prefer very short payback periods rather than considering the energy investment products
  - One of the most misleading measures since it doesn’t include anything about the longevity of the system
    - e.g. Two air conditioner, both 5 year payback periods, one lasts for 20 years the other lasts only 5 years!



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## Initial (Simple) Rate-Of-Return

- Inverse of Simple Payback Period:

$$\text{Initial (simple) rate of return} = \frac{\text{Annual savings } S \text{ (\$/yr)}}{\text{Extra first cost } \Delta P \text{ (\$)}}$$

- The initial rate of return makes the investment look too good!
- A useful function as a convenient “minimum threshold” indicator. If the investment has an initial rate of return below the threshold, there is no need to proceed any further.



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# Net Present Value (NPV)



- Problem of “Simple Payback Period” and “Initial Rate of Return”:
  - Too simple!
- More serious analysis:
  - Take into account the time value of money
    - e.g. One dollar in 10 years before now was more precious than today!
- Solution:
  - The present worth analysis in which all future costs are converted into an equivalent present value or present worth.





# Net Present Value (NPV)

- Investment today:  $P$
- Annual interest:  $i$
- Future amount of money:  $F$
- Period of the plan project:  $n$

$$F = P (1 + i)^n$$

- The relationship between a future amount of money  $F$  and what it should be worth to us today  $P$

$$P = \frac{F}{(1 + i)^n}$$

- The interest term  $i$  is usually referred to as a discount rate  $d$

# Net Present Value



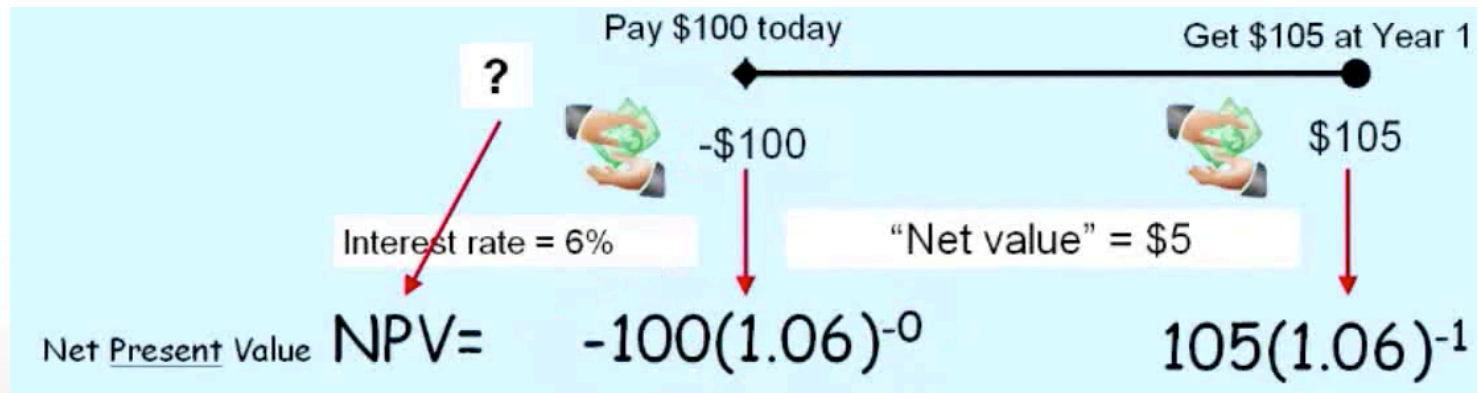
- Net:
  - Usually the result different amounts combined
  - EX:
    1. at restaurant: Food: \$100, Discount: -\$15  
Final Bill: \$85 NET!
    2. Pay Today \$100 to a friend and get back \$105 after a year  
Net value: \$5





# Net Present Value

- EX continued: Assume Bank: interest rate: %6
  - Present value formula at year 1:  $\$105(1.06)^{-1}$
  - Present value formula at year 0:  $\$100(1.06)^{-0}$



$$NPV = -\$100(1.06)^{-0} + \$105(1.06)^{-1} = -\$0.94$$

You will lose 94 cents with this deal!

If NPV is + you WIN if NPV is – you Lose!

# Net Present Value (NPV)



- Example: If an efficiency investment is projected to save \$1000 in fuel in the fifth year, and the best alternative investment is one that would have earned 10%/yr interest, the present worth of that \$1000 would be

$$P = \frac{F}{(1 + d)^n} = \frac{\$1000}{(1 + 0.10)^5} = \$620.92$$

- *That person should be willing to spend as much as \$620.92 today in order to save \$1000 worth of energy 5 years from now*
- **The higher the discount rate, the less valuable a future payoff becomes**



# Net Present Value (NPV)



- Example:
- Ask from an inexperienced person (e.g. student) whether he prefers \$621 today or \$1000 in 5 years?!
  - Probably he prefers \$621 today. He expects to have a lot more money after 5 years, so \$1000 then wouldn't mean nearly as much as \$621 today.
  - His personal discount rate is probably much higher than 10%
- Defining an appropriate discount rate: VERY difficult





# Net Present Value (NPV)

- Frequently, a distributed generation or efficiency investment will deliver financial benefits year after year
- Present Value Function (PVF):
  - Present value:  $P$
  - Stream of annual cash flows:  $A$
  - Plan period:  $n$  years
  - Discount rate:  $d$
- For a series of  $n$  annual \$1 amounts that start 1 year from the present, PVF is the summation of the present values

$$P = A \cdot PVF(d, n)$$

$$PVF(d, n) = \frac{1}{1+d} + \frac{1}{(1+d)^2} + \dots + \frac{1}{(1+d)^n} = \frac{(1+d)^n - 1}{d(1+d)^n}$$



# Net Present Value (NPV)



- Unit of PVF: YEAR
- Life Cycle Cost:
  - The present value of all costs, present and future
- Net Present Value:
  - When comparing two investments
  - The present value or life cycle cost of each will be computed and compared
  - Difference between the two life cycle costs will called Net Present Value of the lower cost alternative





## Simplified Way to Calculate NPV

- The net present value calculation can be simplified by comparing the present value of all of those future fuel savings  $\Delta A$  with the extra first cost of the more efficient product  $\Delta P$ :

NPV = Present Value of Annual Savings – Added First Cost of Better Product

$$\text{NPV} = \Delta A * \text{PVF}(d,n) - \Delta P$$



# Example 1. Net Present Value of an Energy-Efficient Motor



- Q: Two 100-hp electric motors are being considered, “good” and “premium.”
  - The good motor: draws 79 kW, costs \$2400
  - The premium motor: draws 77.5 kW, costs \$2900

The motors run 1600 hours per year with electricity costing \$0.08/kWh. Over a 20-year life, find the net present value of the cheaper alternative when a discount rate of 10% is assumed.

# Example 1. Net Present Value of an Energy-Efficient Motor



- *Answer:*
- Annual electricity cost:
  - $A(\text{good}) = 79 \text{ kW} * 1600 \text{ h/yr} * \$0.08 / \text{kWh} = \$10,112 / \text{yr}$
  - $A(\text{premium}) = 77.5 \text{ kW} * 1600 \text{ h/yr} * \$0.08 / \text{kWh} = \$9920 / \text{yr}$
- The present value factor for these 20-year cash flows with a 10% discount rate is:

$$PVF(d, n) = \frac{(1 + d)^n - 1}{d(1 + d)^n} = \frac{(1 + 0.10)^{20} - 1}{0.10(1 + 0.10)^{20}} = 8.5136 \text{ yr}$$

# Example 1. Net Present Value of an Energy-Efficient Motor



- *Answer:*
- The present value of the two motors, including first cost and annual costs
  - $P(\text{good}) = \$2400 + 8 .5136 \text{ yr} * \$10,112 /\text{yr} = \$88,489$
  - $P(\text{premium}) = \$2900 + 8 .5136 \text{ yr} * \$9920 /\text{yr} = \$87,354$
- The premium motor is the better investment with a net present value of
  - $\text{NPV} = \$88,489 - \$87,354 = \$1,135$
- **OTHER SOLUTION:**
  - $\text{NPV} = \Delta A * \text{PVF}(d,n) - \Delta P$
  - $\text{NPV} = (\$10,112 - \$9920)/\text{yr} * 8.5136 \text{ yr} - (\$2900 - \$2400) = \$1135$

# DGD 02- Outline



- Energy Economics
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  - Net Present Value (NPV)
  - **Internal Rate of Return (IRR)**



# Rate of Return, Internal Rate of Return



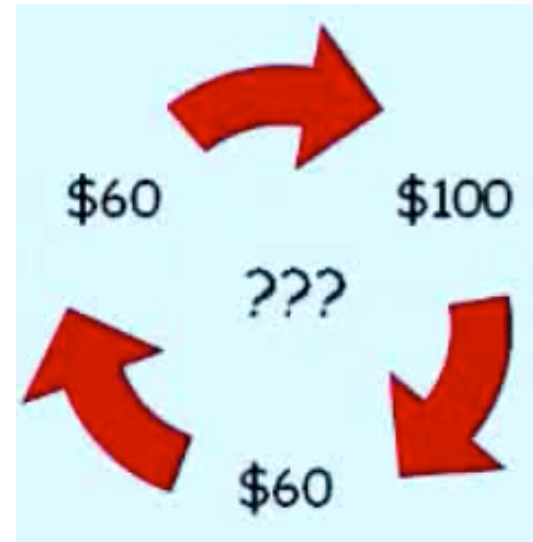
- Rate of return:
  - Speed that money come back to you
  - Written as % per year
- EX:
  - Invest \$100 today
  - Get Back \$3 every year, forever
  - Rate of return is 3% per year





# Rate of Return, Internal Rate of Return

- EX:
  - Invest \$100 today
  - Get back \$60 after one year
  - Get back another \$60 after two years
  - And then STOPS!
- The rate of return is now HIDDEN
  - They call it INTERNAL Rate of Return
- Using Present Value Formula:
  - For a series of n annual \$1 amounts that start 1 year from the present, PVF is the summation of the present values



$$PVF(d, n) = \frac{1}{1+d} + \frac{1}{(1+d)^2} + \dots + \frac{1}{(1+d)^n}$$





# Rate of Return, Internal Rate of Return

$$-100(1+r)^{-0}+60(1+r)^{-1}+60(1+r)^{-2}$$

We still don't know the rate  $r$ !

- Solve  $r$ :  $-100(1+r)^{-0}+60(1+r)^{-1}+60(1+r)^{-2}=0$ 
  - NOT TRADITIONAL WAY!
  - GUESS using Trial and Error
    1. Guess:  $r=14\% \rightarrow -1.2=0!$
    2. Guess:  $r=12\% \rightarrow 1.4=0!$
    3. Guess:  $r=13\% \rightarrow 0.09=0 \text{ ☺}$
- IRR: 13%





## Internal Rate of Return (IRR)

- It is the most persuasive measure of the value of an energy-efficiency or distributed-generation project
- It is the trickiest to compute
- Allows the energy investment to be directly compared with the return that might be obtained for any other competing investment.
- **IRR is the discount rate that makes the net present value of the energy investment equal to zero**



## Internal Rate of Return (IRR)

- In the simple case of a first-cost premium  $\Delta P$  for the more efficient product, which results in an annual fuel savings  $\Delta A$ , it is the discount rate that makes the net present value be zero:

$$NPV = \Delta A * PVF(IRR, n) - \Delta P = 0$$

- Introduced before that:  $\Delta P/\Delta A$  is Simple Payback Period

$$PVF(IRR, n) = \frac{\Delta P}{\Delta A} = \text{Simple payback period}$$

- Solving the above equation is not straight forward, Table 1 gives the estimated value.





# Table 1. Present Value Function to Help Estimate the Internal Rate of Return <sup>a</sup>

Life (years)	9%	11%	13%	15%	17%	19%	21%	23%	25%	27%	29%	31%	33%	35%	37%	39%
1	0.92	0.90	0.88	0.87	0.85	0.84	0.83	0.81	0.80	0.79	0.78	0.76	0.75	0.74	0.73	0.72
2	1.76	1.71	1.67	1.63	1.59	1.55	1.51	1.47	1.44	1.41	1.38	1.35	1.32	1.29	1.26	1.24
3	2.53	2.44	2.36	2.28	2.21	2.14	2.07	2.01	1.95	1.90	1.84	1.79	1.74	1.70	1.65	1.61
4	3.24	3.10	2.97	2.85	2.74	2.64	2.54	2.45	2.36	2.28	2.20	2.13	2.06	2.00	1.94	1.88
5	3.89	3.70	3.52	3.35	3.20	3.06	2.93	2.80	2.69	2.58	2.48	2.39	2.30	2.22	2.14	2.07
6	4.49	4.23	4.00	3.78	3.59	3.41	3.24	3.09	2.95	2.82	2.70	2.59	2.48	2.39	2.29	2.21
7	5.03	4.71	4.42	4.16	3.92	3.71	3.51	3.33	3.16	3.01	2.87	2.74	2.62	2.51	2.40	2.31
8	5.53	5.15	4.80	4.49	4.21	3.95	3.73	3.52	3.33	3.16	3.00	2.85	2.72	2.60	2.48	2.38
9	6.00	5.54	5.13	4.77	4.45	4.16	3.91	3.67	3.46	3.27	3.10	2.94	2.80	2.67	2.54	2.43
10	6.42	5.89	5.43	5.02	4.66	4.34	4.05	3.80	3.57	3.36	3.18	3.01	2.86	2.72	2.59	2.47
15	8.06	7.19	6.46	5.85	5.32	4.88	4.49	4.15	3.86	3.60	3.37	3.17	2.99	2.83	2.68	2.55
20	9.13	7.96	7.02	6.26	5.63	5.10	4.66	4.28	3.95	3.67	3.43	3.21	3.02	2.85	2.70	2.56
25	9.82	8.42	7.33	6.46	5.77	5.20	4.72	4.32	3.98	3.69	3.44	3.22	3.03	2.86	2.70	2.56
30	10.27	8.69	7.50	6.57	5.83	5.23	4.75	4.34	4.00	3.70	3.45	3.22	3.03	2.86	2.70	2.56

<sup>a</sup>Enter the row corresponding to project life, and move across until values close to the simple payback period,  $\Delta P/\Delta A$ , are reached. IRR is the interest rate in that column. For example, a 10-year project with a 5-year payback has an internal rate of return of just over 15%.



# Internal Rate of Return (IRR)

- Example for Table 1:
  - If the premium air conditioner costs an extra \$1000 and saves \$200 per year in electricity, so  $\Delta P/\Delta A = \$1000/(\$200/\text{yr}) = 5.0$  years.
  - With a lifetime of 10 years, Table 1 suggests that it would have an IRR of just over 15%. If it lasts 20 years, its IRR would be between 19% and 21%. To find the exact value would require iteration on main formula below or interpolation in Table 1.

$$\text{PVF}(\text{IRR}, n) = \frac{\Delta P}{\Delta A} = \text{Simple payback period}$$



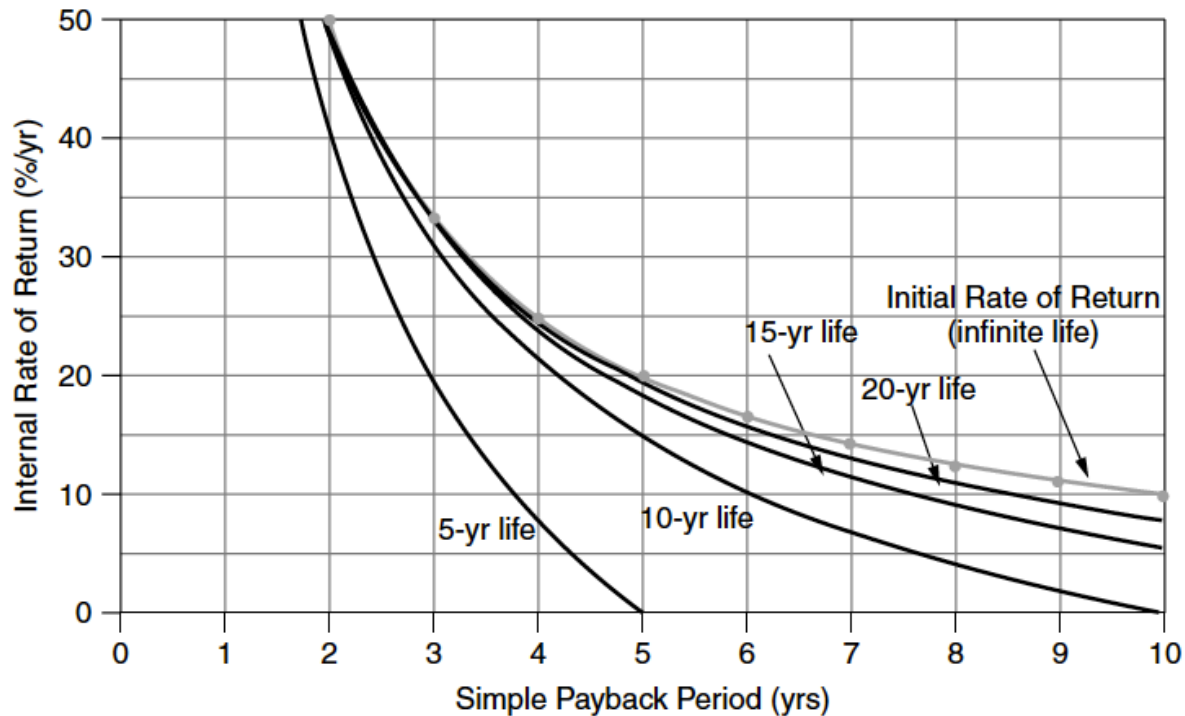


# Internal Rate of Return (IRR)

- Other advantage of Table 1:
  - Determining the IRR when the decision maker wants an energy payback, with interest, within a certain number of years.
  - e.g. a motor costs an extra \$500 and saves \$192/yr:  
It's simple payback period:  $\Delta P / \Delta A = \$500 / \$192 = 2.60$  years. Assuming a 20-year life and using Table 1, the internal rate of return is between 37% and 39% (it is actually 38.34%). Suppose management decides that it wants to earn all of its extra \$500 investment back sooner—in 5 years, for example—with interest. That is equivalent to saying the efficiency device has only a 5-year life. Table 1 indicates that the investment would still earn, almost 27% compounded annual interest. That's a pretty good investment!



# Internal Rate of Return (IRR)



Internal rate of return as a function of the simple payback period, with project life as a parameter. When the lifetime greatly exceeds the simple payback, IRR approaches the initial rate of return.



## Journal Paper of the second week



Md Ruhul Kabir, et al., “*Comparative life cycle energy, emission, and economic analysis of 100 kW nameplate wind power generation*”, Renewable Energy, Elsevier, 2012

