SOLAR
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Life Cycle Cost Analysis

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What will be discussed?

- What is Life Cycle Cost Analysis
- LCC Methodology
- Using Excel for Calculations
- Case Study and Results
- Sensitivity Analysis

Acknowledgement: This presentation builds on the material provided in the Siemens Solar Basic PV Technology Course.

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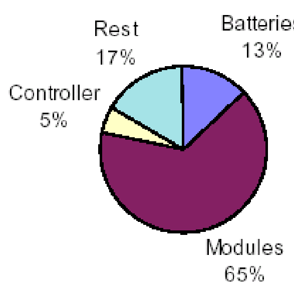
Initial Cost of Solar Electric System



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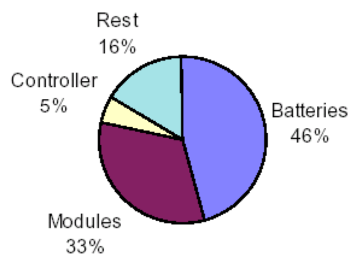
20 Year Life Cycle Cost of Solar Electric System



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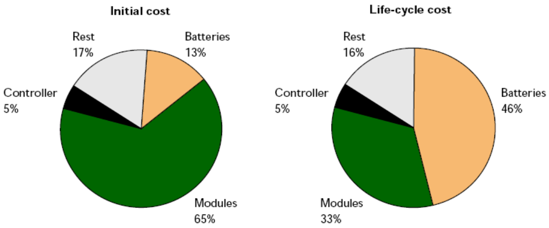
Comparison Initial and LCC



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Financial Analysis

There are a number of different analyses that may be applied to compare costs:

- Life Cycle Cost (LCC) analysis
- Cash-flow analysis
- Benefit-cost ratio
- Pay-back period

(Cash-flow analysis, Benefit-cost ratio, Pay-back period:) financial benefits have to be known

The advantage of the LCC analysis is that it is familiar to economists and other decision makers and that it provides a means to include the time preference or 'opportunity cost' of money.

What is Life Cycle Cost Analysis?

Levelized Cost of Energy (LCOE)

Life Cycle Cost (LCC) analysis is a tool used to compare the ultimate delivered costs of technologies with different cost structures.

$$\frac{\text{Capital Cost + Operating Cost during the project life}}{\text{total of kWh provided during the project life}}$$

Assumed that:

1. The kWh produced is equal for different technologies
2. The service that is provided by the different technologies are equal

LCC gives a value in cost per kWh, no matter what technology is used to deliver the electricity, so that costs of different technologies can be compared on an equal basis.

Cost Structure

Three different types of costs should be analysed

1. Capital Costs: costs that are made at the start of the project.
   Generator, PV Modules, BOS, Line extension, Batteries
2. Recurring Costs: costs that are incurred every year of operation.
   Fuel, Maintenance, Loan payments
3. Non-recurring Costs: costs that only happen every once in a while.
   Generator replacement, battery replacement

Economic Factors

Life Cycle Term (Term)
The length of "term" of the analysis is chosen to be the service life of the longest lived component.

Discount Rate (DR)
This is the factor that describes the changing value of money over time. It is basically equivalent to the amount of money you could make with your capital if you chose to invest it in a bank or other investment.

Fuel & General Escalation (FE & GE)
Cost Escalation accounts for the fact that components and services traditionally get more expensive over time.

Net Present Value (NPV)
The net present value of future costs can be regarded as the amount of capital that should be reserved at the time of investment to cover all future costs.

Example NPV Calculation (1)

1. Calculation of Present Value:

A full tank of fuel for a generator costs P100 today. It will need to be replaced next year. If the discount rate is 10%, then the amount of money needed today to pay for P100 of fuel next year will be given by:
Present Value = 1/(1+0.10) X P100 = P90.91

So P90.91 is the present value of the future P100 needed to pay for the fuel in one year. If the P90.91 was put aside this year and "invested" at the discount rate of 10%, then in one year we would have P100.

Example NPV Calculation (2)

2. Calculation of Escalation

If there is price escalation happening as well, then the future cost of the tank of fuel will be slightly higher than the price today. If the price escalation of diesel fuel is 5%, then the price in one year will be given by:

FV = (1 + 0.05) X P100 = P105.00

So you would need to have P105.00 after one year to pay for the fuel.

Example NPV Calculation (3)

3. Calculation of NPV
The **NPV** of next year's fuel will be the escalated price discounted back to the present. This involves combining the two formulas above.
NPV = (1 + 0.05)/(1+0.10) X P100 = P95.45

So the **NPV** of the tank of fuel to be purchased next year is P95.45 in today's money. Putting this much aside today will increase in value at the discount rate of 10% and be enough to cover the escalated price of P105.00 that will be needed one year from now.

LCC Analysis Methodology

The basic life cycle cost analysis method is as follows:

1. Calculate the initial (capital) cost of the system;
2. Calculate the annual recurring fuel cost, then multiply by a factor which accounts for the discount rate (DR), fuel escalation rate (FE) and life cycle term (term);
3. Calculate the annual recurring maintenance cost, then multiply by a factor which accounts for the discount rate, non-fuel general escalation rate (GE) and life cycle term;
4. Determine the schedule for each non-recurring cost and multiply the cost by a factor to account for the discount rate and escalation rate in the year of occurrence;
5. Add these four costs together and divide by the total number of kWh produced to determine levelized cost of energy.

Non-quantifiable costs are not included !

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Recurring Fuel Costs

$$LCCFuelCost = AnnFuelCost * \left\{ \left(\frac{1+FE}{DR-FE} \right) \times \left(1 - \left(\frac{1+FE}{1+DR} \right)^{Term} \right) \right\}$$

where

AnnFuelCost	is the annual fuel expenditure
FE	represents Fuel Escalation
DR	represents Discount Rate, and
Term	is the life cycle term

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Recurring Maintenance Costs

$$LCCMaintCost = AnnMaintCost * \left\{ \left(\frac{1+GE}{DR-GE} \right) \times \left(1 - \left(\frac{1+GE}{1+DR} \right)^{Term} \right) \right\}$$

where

AnnFuelCost	is the annual non-fuel expenditure
GE	represents General Escalation
DR	represents Discount Rate, and
Term	is the life cycle term

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Non-Recurring Costs

$$LCCReplCost = \sum \left[ItemCost * \left\{ \left(\frac{1+GE}{1+DR} \right)^{RY} \right\} \right]$$

where

ItemCost	is the nonrecurring expenditure in present day costs
GE	represents General Escalation
DR	represents Discount Rate, and
RY	is the "Replacement Year"

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Life Cycle Energy Cost

$$LCC\$ / kWh = \frac{CapitalCosts + LCCFuelCost + LCCMaintCost + LCCReplCost}{Term * 365 * kWh / d}$$

where

LCC$/kWh	is the life cycle cost per kWh energy
LCCFuelCost	is calculated above
LCCMainCost	is calculated above
LCCReplCost	is calculated above
Term	is the life cycle cost term, and
kWh/d	is the daily kWh output of the system

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Life Cycle Energy Cost

$$LCC\$ / kWh = \frac{CapitalCosts + LCCFuelCost + LCCMaintCost + LCCReplCost}{Term * 365 * kWh / d}$$

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Financial Functions in Excel

$$NPV = \sum_{i=1}^{n} \frac{values_i}{(1+rate)^i}$$

Syntax

NPV(discount rate,value1,value2, ...)

Value1, value2, ... must be equally spaced in time and occur at the end of each period.

Example of LCC analysis in Excel

		Variables	Units	0	1	2	3	4	5	6	7	8	9	10
1-a	**SHS Electrification**													
	Discount rate SHS	15%												
	Number of Households (HH)	50												
	Size of SHS	50	Wp											
	Annual electricity consumption	3,650	kWh/y		3,650	3,650	3,650	3,650	3,650	3,650	3,650	3,650	3,650	3,650
	Investment cost for SHS	96.30	P/Wp	240,750										
	Battery replacement cost	500	P/Battery				25,000			25,000			25,000	
	Operation & Maintenance cost	500	P/Village/m		6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
	Agent fee cost	5%			1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
	Head office cost	276	P/HH/y		13,800	13,800	13,800	13,800	13,800	13,800	13,800	13,800	13,800	13,800
	Life Cycle Cost		P											
	Life Cycle Cost per kWh		P/kWh											

Example of LCC analysis in Excel

		11	12	13	14	15	16	17	18	19	20	residual value	**NPV at year 0**
1-a	**SHS Electrification**												
	Discount rate SHS												
	Number of Households (HH)												
	Size of SHS												
	Annual electricity consumption	3,650	3,650	3,650	3,650	3,650	3,650	3,650	3,650	3,650	3,650		**73,000**
	Investment cost for SHS												**240,750**
	Battery replacement cost		25,000			25,000			25,000			-8,333	**91,479**
	Operation & Maintenance cost	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000		**37,556**
	Agent fee cost	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200		**7,511**
	Head office cost	13,800	13,800	13,800	13,800	13,800	13,800	13,800	13,800	13,800	13,800		**86,379**
	Life Cycle Cost												**463,675**
	Life Cycle Cost per kWh												**6.35**

Case Study

Rural electrification technologies using Solar Home Systems in Botswana in comparison with:

- Grid extension
- PV-minigrids
- Diesel minigrids
- Battery charging stations

General Assumptions

- Quantity of energy produced is the same for all technologies.
- Discount rate is 15% and is constant over the lifetime of the technology.
- Inflation is constant over time and equal for all costs.
- Linear depreciation of capital cost of technologies over system lifetime.
- 100% system availability.
- A load factor of 100% is assumed for all technologies (technology generates electricity at full power capacity).

Assumptions for Grid

- Capital costs are based on fixed cost per kilometre installed times the number of installed kilometres
- Capital and connection costs are depreciated over 25 years lifetime
- Connection cost is the same for all users in a village (average connection cost)
- In-house wiring is not included

Assumptions for SHS

- 200Wh of energy is available per 50Wp solar panel per day
- An average size of SHS is assumed
- Capital cost includes installation
- Capital cost varies linear with installed Wp
- One battery of 100Ah per 50Wp installed solar panel is assumed
- Operation and maintenance of SHS is a fixed amount per village
- Panels and balance of system lifetime is 20 years
- Battery lifetime is 3 years

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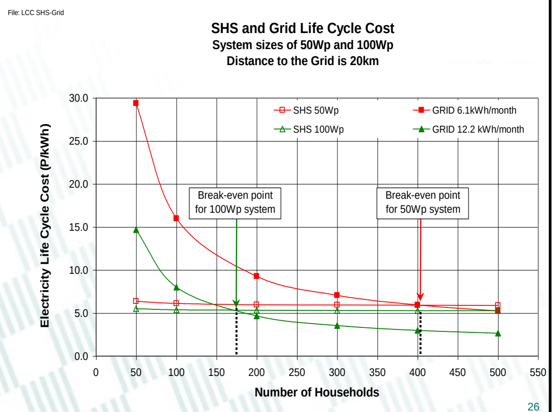

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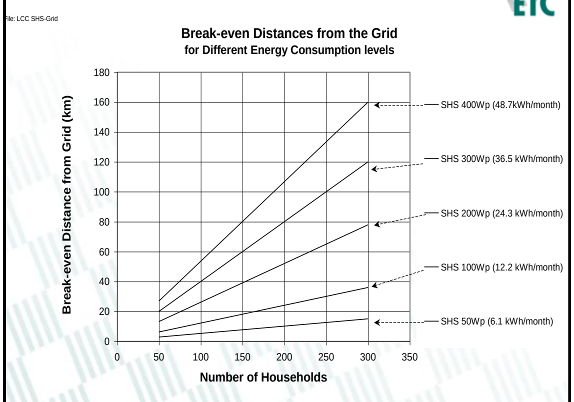

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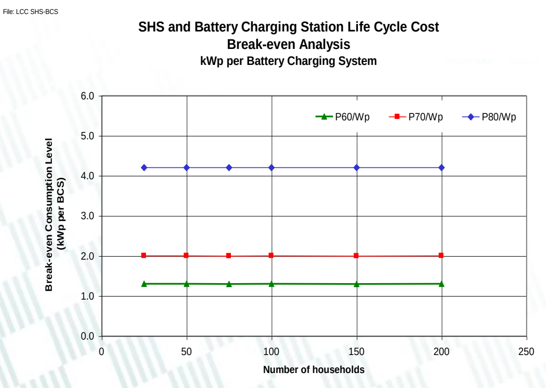

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Conclusions

LCC per kWh of the different technologies depends very much on the number of kWh generated (number of households that consume electricity and the amount of electricity that an individual household consumes).

If there is a main electric grid close by ***and*** there is sufficient energy demand, extension of the electric grid is the most cost effective option, when compared to other electrification options.

SHS become competitive with grid extension, even a few kilometres from the main electric grid (50 households, 50Wp per household energy demand), with the cost of connection to the grid being the most important parameter that determines the break-even point.

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Conclusions

VAT has little effect on the LCC and also because it is unlikely to get SHS components VAT exempted, it is not worth the effort.

PV-minigrids are cost effective compared to SHS for systems that are larger than approximately 10kWp if connections costs are low (less than P2000 average connection cost), that is when the household density is high. The break-even point depends very much on the average connection cost.

Based on the assumptions made, diesel-minigrids are a more cost-effective solution than PV or LPG-minigrids.

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Conclusions

PV-minigrids are cost effective in comparison to grid if the number of households is small and the loads are small and where there is a high density of households (average connection cost less than P2000) because of the high sensitivity towards connection costs.

Below sizes of minigrids of 10 kWp it is more cost effective to use SHS.

Battery Charging Stations compete with SHS starting at BCS system sizes of approximately 2kWp, depending on the capital cost of the BCS and the salary cost of the person who operating the BCS.

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Life Cycle Cost Analysis of Solar vs Diesel Pumps

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Solar <=> Diesel Pump Comparison

Cost Effectiveness over 10 years				
		Total Pumping Head		
		50 m	100 m	150 m
Litres per day	5.000	Solar	Solar	Solar
	7.000	Solar	Solar	Solar
	8.000	Solar	Solar	Solar
	12.000	Solar	Solar	Diesel
	15.000	Solar	Solar	Diesel
	16.000	Solar	Solar	Diesel
	24.000	Solar	Diesel	Diesel
	40.000	Solar / Diesel	Diesel	Diesel
	50.000	Diesel	Diesel	Diesel
	80.000	Diesel	Diesel	Diesel

Cheaper to buy | PB = 1 yr | PB = 5 yrs | PB = 10 yrs

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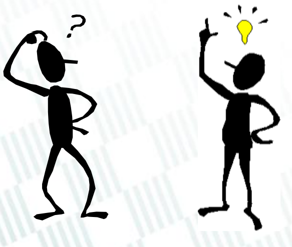
QUESTIONS ?



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