Renewable Energy technologies

Sustainable Energy Solutions to reduce poverty in South Asia

Choosing right RET solutions

Presented at the

INFORSE South Asian Capacity Building National Workshop of NGOs on RETs for Poverty Reduction

and

Seminar on Decentralized Power/Electricity Generation

held at Dhaka from Jan 23 to 24, 2008

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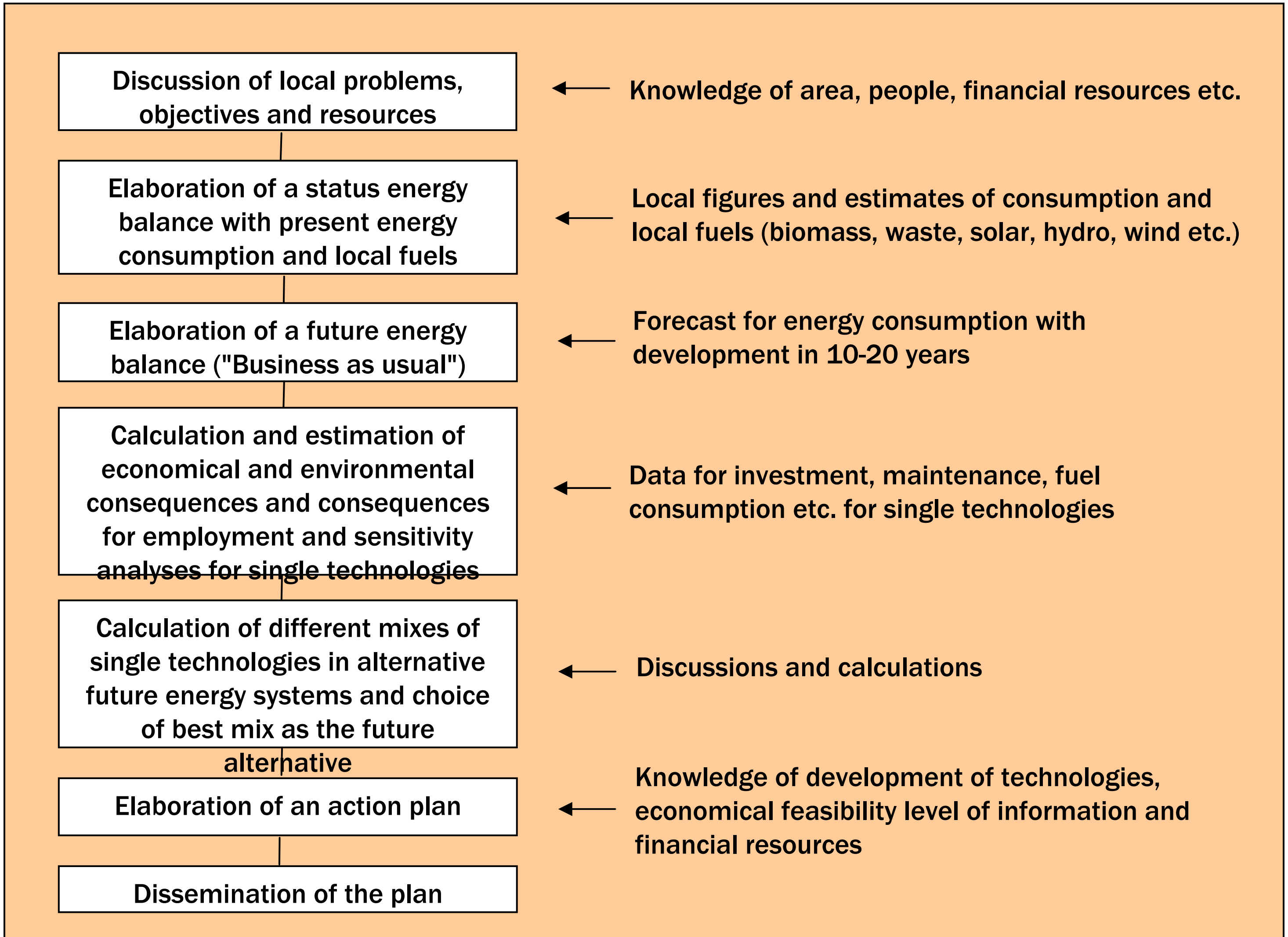
How they can spend money and time for energy supply more efficient in the future?

In this way they can:

- Get energy services cheaper than before. Thus there will be more money for consumption.
- Creation of new work places (this gives a rise in welfare if some people are unemployed) producing energy producing equipment and using renewables and local fuels in stead of importing fuels into the village. Local labour force and local fuels will then replace purchased fuels and salaries will stay in local business
- Reducing the environmental problems and thus reduction of health problems, such as less smoke in the kitchen.
- Developing technologies, learning to use new technologies and achieving new skills.

To choose the right solutions they need to calculate and estimate the consequences for the options they have. This can be done in a number of steps as given in box



Discussion of Local Problems and Resources

The best energy solutions differ widely from place to place, depending on local problems and resources. The process must start with discussions on local problems for development, involving those that will be covered by the proposals, local leaders, local business and administration etc.

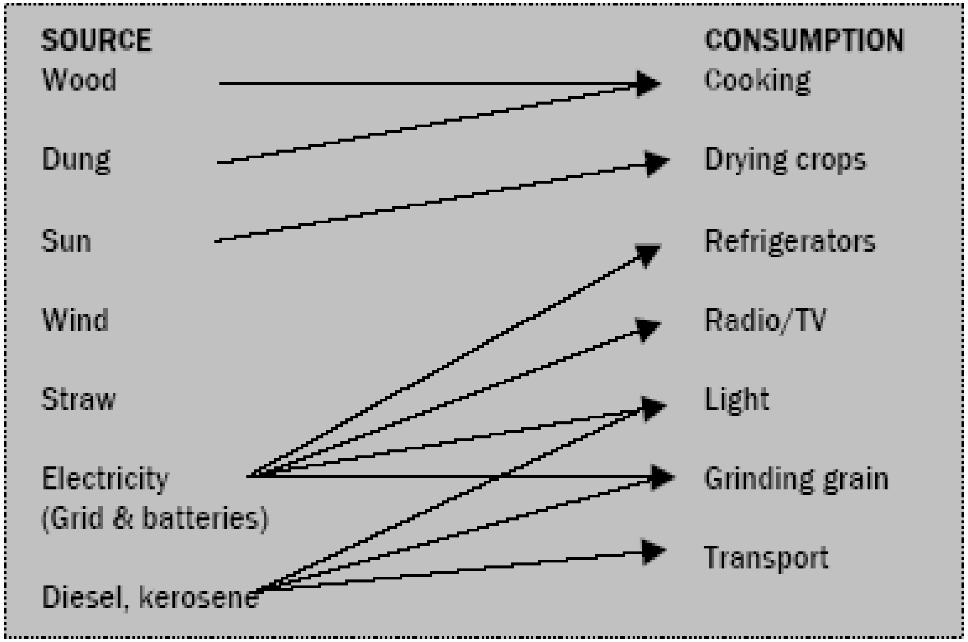
It is important to discuss:

- What are the main current and potential problems regarding energy supply (e.g. expensive energy, unstable supply, smoke from cooking, etc.)?
- For whom the proposals and plans are made?
- Which consequences are needed to analyze?
- What are environmental problems in the area (such as deforestation, lack of fuel wood, drought, etc.)?
- What are major social problems in the area (illnesses, food shortage, illiteracy, etc.)?
- What are available financial resources and people's ability to pay for energy?
- What are main objectives for development in the area (such as increased employment, increased local independence of energy imports, stop environmental degradation, improved village facilities, improved security, etc.)?
- The discussions should lead to conclusions for each issue and pave the way for the next phases of the development.

Status of Energy Balance and Local Energy Resources

The “energy balance” of a village or family is the abbreviation used for energy consumption and sources. All types of energy are converted to same unit for comparison, and estimates of efficiency are included. Examples of sources and consumption are shown in box aside.

Each arrow shows the present flow of energy. Some sources have many uses, such as electricity, while other sources have no current use such as wind and straw. When the energy flows are found, their size should be found as precise as practical possible. This could be as shown in next



50 families collect 4 kg wood daily for cooking, 200 kg/day = 72 t/year	**= 324,000 kWh/year**
30 families use 2 kg dry dung daily for cooking, 60 kg/day = 22 t/year	**= 65,000 kWh/year**
25 families use 1 kg agricultural residues for cooking, 25 kg/day, 9 t/y.	**= 36,000 kWh/year**
5 families use one gas bottle (14,5 kg gas) per year for cooking, 72 kg/year	**= 800 kWh/year**
50 families use 4 batteries per month each (2 D-size, 2 AA-size), 2400 /year	**= 36 kWh/year**
5 families use 25 kWh/month of grid electricity each, 50 kWh/month	**= 1500 kWh/year**
Health clinic +village head's office uses 75 kWh/month grid electricity	**= 900 kWh/year**
Village grinder use 400 kWh during the season	**= 400 kWh/year**
45 families use 2 ltr/month kerosene for light each, 1080 ltr/year	**= 10,800 kWh/year**
Village grinder uses 1000 ltr. diesel per year at power outage	**= 10,000 kWh/year**
A tractor in the village use 6000 ltr/year	**= 60,000 kWh/year**

Information on energy contents, conversion and light efficiency

Energy Contents			
Wood	4.5	kWh/kg	Dry soft wood with less than 15% moisture. Hard wood: 15% higher
Dung	3	kWh/kg	Dry dung cake, wet dung lower
Straw	4	kWh/kg	Dry straw from cereal
Charcoal	7	kWh/kg	Typical
Kerosene	10	kWh/ltr	
Diesel	10	kWh/ltr	
Petrol	9	kWh/ltr	equal to about 12 kWh/kg
Gas (LPG in bottles)	12.7	kWh/kg	
Coal	6	kWh/kg	Hard coal, typical. Brown coal and lignite are lower

Conversion factors		
1 kg oil equivalent	10	kWh
1000 Btu (British thermal Unit)	0.293	kWh
1 MJ (Mega Joule)	0.28	kWh

Next step is to divide use of electricity into use for light, radio/TV, etc.

Division of electricity consumption into end-uses							
Electricity (kwh/y)	**Light**	**Radio/TV**	**Refrigerator**	**Grinder**	**Water pump**	**Total**	**Costs**
Batteries	**18**	**18**				**36**	**42000**
Households with grid*	**1168**	**332**				**1500**	**18000**
Clinic etc.	**500**		**400**			**900**	**10800**
Agriculture (grinder)				**400**		**400**	**4800**
Total	**1686**	**350**	**400**	**400**	**0**	**2836**	**75600**

Then an energy balance for the village can be made

Various sources of light for use in a village

Light efficiency and consumption, typical	Wick lamps	Hurricane lamps	Pressure lamps	Gas lamps	Light bulbs (incandescent)	Halogen lamps	LED (white)	CFL lamps	Light tubes
Efficiency, lumen/w	0.1	0.15	1	1	6-18	14-25	22-38	40-60	50-60
Efficiency, relative	0.2%	0.3%	1.7%	1.7%	10-30%	23-40%	37-63%	60-100%	80-100%
Light given (lumen)	15	30	1400	200	500	400	100	550	1800
Power consumption (Watt)**	150	200	1400	200	40	20	3	9	36
Consumption, 4 hrs*	0.06 ltr k.	0.08 ltr k.	0.56 ltr.k.	0.13 m^3 b.	0.16 kWh	0.08 kWh	0.012 kWh	0.036 kWh	0.14 kWh

*** 4 hours are typical daily consumption for most lamps for household use, k=kerosene, b=biogas with an energy content of 6 kWh/m3**

***Sources*: ESD - http://www.eurorex.com/ugtoges/light.htm, and Danish information on efficient lighting**

**** The power consumption are examples, other wattages are also available for most lamps**

Present energy consumption	families	Use/family		Use/year	Energy content	Energy use/year
	number	kg/day	kg/day	kg/year	kWh/kg	kWh/year
Families in village	50					
Wood	50	4	200	72000	4.5	324000
Dung	30	2	60	21600	3	64800
Agri-waste/Straw	25	1	25	9000	4	36000
Gas bottles (14,5 kg/bottle)	5	0.04	0.2	72	12.7	914
	families	no./month	Use/month	Use/year	kwh/battery	kwh/year
Batteries D-Size	50	2	100	1200	0.025	30
Batteries AA-size	50	2	100	1200	0.005	6
Grid electricity use	families	kWh/month	kWh/month	kWh/year		kWh/year
Household use	5	25	125	1500		1500
		kWh/month		kWh/year		kWh/year
Clinic & office		75		900		900
Village grinder				400		400
Oil/kerosene use	Number	ltr/family/ month	ltr/month	ltr/year	kWh/ltr	kWh/year
Household kerosene	45	2	90	1080	10	10800
Village grinder				1000	10	10000
Tractor	1			6000	10	60000

Costs of various energy forms						
Batteries, D-Size	20	Rs/piece	Local*	25%	Bought**	100%
Batteries, AA-Size	15	Rs/piece	Local*	25%	Bought**	100%
Grid electricity	12	Rs/kWh	Local*	0%	Bought**	100%
Firewood	1	Rs/kg.	Local*	100%	Bought**	10%
Dung, agri-waste	non, it is not sold		Local*		Bought**	0%
Bottled (LPG) gas	20	Rs/kg.	Local*	0%	Bought**	0%
Kerosene	25	Rs/ltr	Local*	0%	Bought**	100%
Diesel	25	Rs./ltr	Local*	0%	Bought**	100%

***Fraction of income that stays in village as profit, payment for collection of wood etc.**
****Fraction of fuel that is bought, the rest is just collected and used without payments**

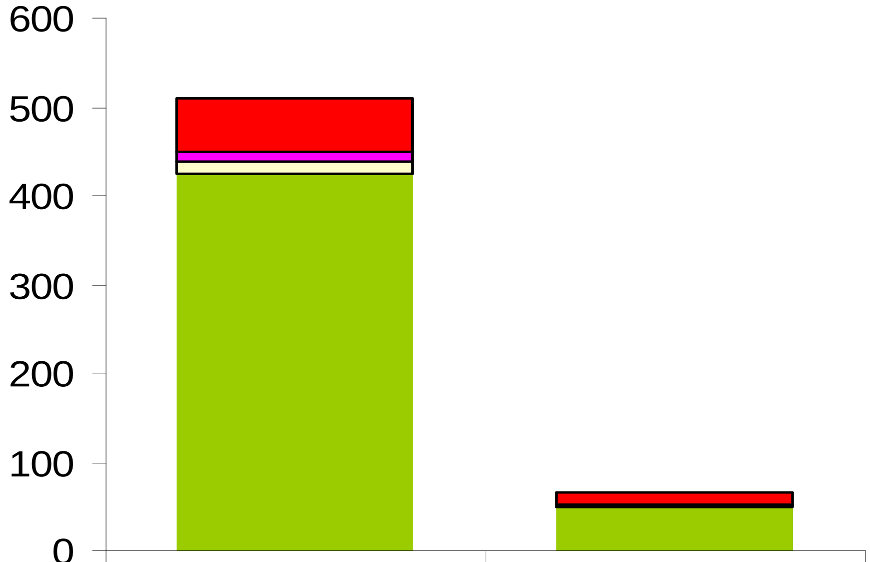
Division of electricity consumption into end-uses

Electricity (kwh/y)	Light	Radio/TV	Refrigerator	Grinder	Water pump	Total	Costs
Batteries	18	18				36	42000
Households with grid*	1168	332				1500	18000
Clinic etc.	500		400			900	10800
Agriculture (grinder)				400		400	4800
Total	1686	350	400	400	0	2836	75600

* Light for households with grid: Each household has in average 4 lamps 40 W each used 4 hours/day

Energy Balance Present situation	Fuel (kWh/year)				Electri-city	Total	Efficiency		End-use (kWh/year)
in kWh/year	Wood	Dung/ waste	Gas	Diesel/kero sene.		**All source**	Fuel	Electr icity	All uses
Stove, type 1 (wood)	324,000					**324,000**	12%		38,880
Stove, type 2 (dung/waste)		100,80 0				**100,800**	11%		11,088
Light				10800	1,686	**12,486**	0.3%	12%	235
Radio/TV					350	**350**		50%	175
Refrigerator					400	**400**		50%	175
Village grinder (agriculture)				10000	400	**10,400**	15%	60%	1740
Water pump						**0**			0
(other)			914			**914**	50%		457
(other)						**0**			
Tractor (agriculture)				60,000		**60,000**	20%		12,000
Total	324,000	100,80 0	914	80,800	2,836	**509,350**			64,750
Costs	7200	0	1440	202000	75600	**286,240**	Rs/year		
Cost/household excl. Agri.	144	0	29	540	1200	**1,913**	Rs/year in average		
Costs that stay in village	7200	0	0	0	8400	**15,600**	Rs/yr that stay in village**		
Work in village	100	30	0			**130**	Work in hours/day***		
CO2-emmissions							CO2 emissions kg/y		

Current Village Energy Use



	Energy Input	Net energy use
Tractor	60	12
Grinder	10	1.7
Refrigerator	0.4	0.2
Radio/TV	0.4	0.2
Light	12.5	0.2
Cooking	426	50

(Energy in 1000's of kWh= MWh/ year), total 187 MWh/year

The main energy input and uses from the energy balance are shown in Figure. The total energy consumption in the village is 509,000 kWh (509 MWh), as calculated previously The right column is end-use energy that gives an overview of how much the consumption needs to be without losses in consumption.

It is clear from the energy balance that current energy use is mainly for cooking and heating. It is also clear that the energy use is inefficient: most of the energy, coming from the wood, diesel, electricity, etc., is lost in the conversion to heat in food, movements of the tractor, light, etc.

From the energy balance can be calculated energy costs, workload and CO2 emissions for the fuel and electricity, based on prices for batteries, grid electricity, diesel, kerosene, and what (some) villagers pay for firewood. It is also calculated how much of this stays in the village as payment and profits to people.

The costs for the villagers and the employment effects of the current energy use are:

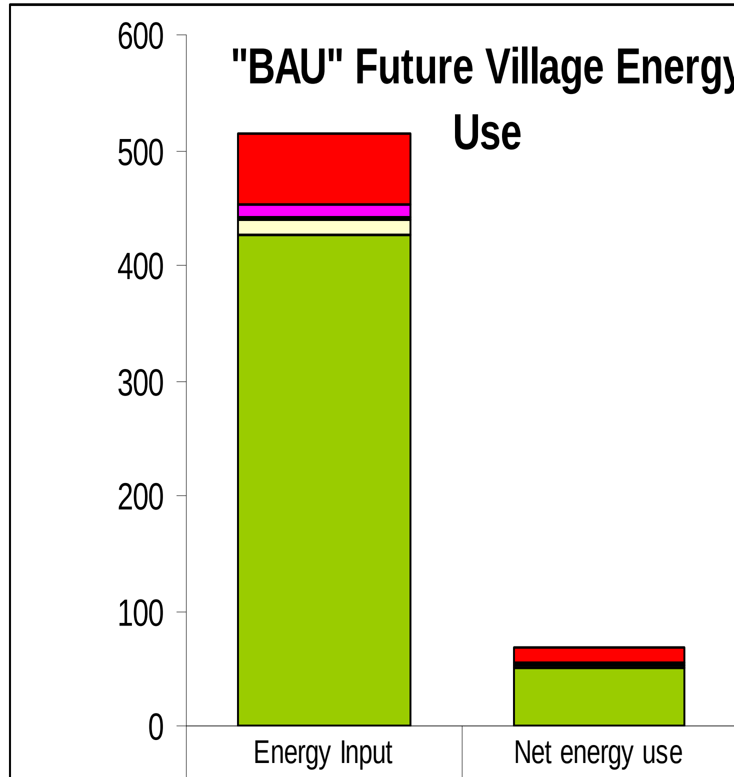
- **Total energy costs for village: Indian Rs. 286,000 (IRP) of which Rs. 16,000 stays in the village**
- **Total work in village: 130 hours/day, mainly to collect wood & dung**
- **(All figures from Annex A are rounded to 1000's of Rs. & to 1000's or 100's of kWh in this chapter)**

Another part of the basis for a local energy strategy is an estimation of available resources. Summary of resources could be:

- **1. Water stream available for Pico hydropower plant, 2 kW permanent power**
- **2. Dung from 60 cows and 60 buffaloes, partly used today as fuel**
- **Dry land that could be planted with energy crops, 2 hectare (20,000 m2)**
- **Straw, 20 tonnes/harvest.**
- **5. Solar energy, 1800 kWh/m2**

Elaboration of Future Energy Balance (Business as Usual- BAU)

The present situation in the village is not satisfactory. In the future all households would like to change to grid electricity and use the same energy that the three households with grid electricity use today. They find that they could afford the electricity instead of buying batteries and kerosene, but they cannot necessarily afford the connection fee. In addition the village will invest in a water pump for drinking water, a cold storage, and 4 street lamps. No investment in energy efficiency or local energy supply is expected in the BAU situation.



	Energy Input	Net energy use
Water pump	0.4	0.3
Tractor	60	12
Grinder	10	1.7
Refrigerator	0.8	0.4
Radio/TV	3.3	1.7
Light	13	1.6
Cooking	426	50

Energy in 1000s of kWh= MWh/year)

"Business as usual" future energy consumption	families	Use/ family	Use/day	Use/year	Energy content	Energy use/ year
		kg	kg/day	kg/year	kWh/kg	kWh/year
Wood	50	4	200	72000	4.5	324000
Dung	30	2	60	21600	3	64800
Agricultural-waste/Straw	25	1	25	9000	4	36000
Gas bottles (14,5 kg/bottle)	5	0.04	0.2	72	12.7	914
	families	no./month	Use/month	Use/year	kwh/battery	kwh/year
Batteries D-Size	50	1	50	600	0.025	15
Batteries AA-size	50	1	50	600	0.005	3
Grid electricity use	families	kWh/month	kWh/month	kWh/year		kWh/year
Household use	50	25	1250	15000		15000
		kWh/month		kWh/year		kWh/year
Clinic& office		75		900		900
Village grinder				400		400
Water pump		30		360		360
4 street lights, 50 W, 12h/d.		72		864		864
Small cold storage, 1 kWh/d		30		360		360
Oil/kerosene use	Number	ltr/family /month	ltr/month	ltr/year	kWh/ltr	kWh/year
Household kerosene	0	2	0	0	10	0
Village grinder				1000	10	10000
Tractor	1			6000	10	60000

Division of electricity consumption into end-uses							
Electricity (kwh/y)	Light	Radio/TV	Refrigerator	Grinder	Water pump	Total	Costs
Batteries	18	0	0			18	21000
Households with grid	11680	3320	0			15000	180000
Clinic etc.	500	0	400			900	10800
Agriculture				400		400	4800
Common facilities*	864		360		360	1584	19008
Total	13062	3320	760	400	360	17902	235608

* In this case street lights, cold storage, water pump

Future "Business as usual" energy balance	Fuel (kWh/year)				Electricity	Total	Efficiency*		End-use (kWh/year)
kWh/year	Wood	Dung/waste	Gas	Diesel/ker.		**All sources**	Fuel	Electricity	All energy
Stove, type 1 (wood)	324,000					**324,000**	12%		38,880
Stove, type 2 (dung/waste)		100,800				**100,800**	11%		11,088
Light				0	13,062	**13,062**	0.3%	12%	1,567
Radio/TV					3,320	**3,320**		50%	1,660
Refrigerator					760	**760**		50%	380
Village grinder (agriculture)				10000	400	**10,400**	15%	60%	1,740
Water pump					360	**360**		75%	270
(other)			914			**914**	50%		457
(other)						**0**			
Tractor (agriculture)				60,000		**60,000**	20%		12,000
Total, energy	324,000	100,800	914	70,000	17,902	**513,616**			68,043
Costs, total	7,200	0	1,440	175,000	235,608	**419,248**	Rs/year		
Cost/household, excl. Agr.	144	0	29	0	4,616	**4,760**	Rs/year per family in average		
Income in village	7,200	0		0	4,200	**11,400**	Rs/yr that stay in village**		
Work	100	30				**130**	Work in hours/day***		
							CO2 emissions kg/y		

*** Electric efficiencies are relative to best available technology.**
**** It is estimated that 20% of battery costs are going to local shop/seller in the village**
*****It is estimated that it takes 1/2 hour to collect one kg firewood and 1/2 hour to collect and dry one kg cow dung**

The future "BAU" energy use is calculated as shown. Since no changes were made to energy for cooking and heating that are the largest types of energy consumption, little change can be seen in the figure, total energy input increases to 514,000 kWh = 514 MWh.

From the detailed energy balance can be seen that electricity consumption increases from 1900 kWh/year to 17,500 kWh/year and consumption of kerosene goes down with 1080 ltr/year. The end-use energy (net energy use) for light and Radio/TV goes up from 410 kWh/year to 3300 kWh which shows that people would have much more light and radio/TV if the BAU situation is realized.

The results regarding costs and work for the BAU situation are:

Total energy costs for village (annual): Indian Rs. 419,000 which Rs. 11,000 stays in the village

Total work in village: 130 hours/day, mainly to collect wood and dung.

Contd…

With these changes the annual energy costs will go up with Indian Rs. 146,000 (almost Indian Rs. 3,000 per family) because of the increased use of electricity.

The expensive batteries and kerosene are exchanged with grid electricity; but the use of light, refrigeration and radio/TV goes up. The BAU has investments, mainly in electric grid/grid connection which also will increase the total cost for the village. The part of the cost that stays in the village is going down because the local shop sells fewer batteries. The business as usual (BAU) forecast does not include improvements, such as cleaner kitchens or more efficient energy use.

Important discussions are if the village can afford this scenario and what benefits and problems that it has (e.g. is it realistic and desired to rely on grid electricity with outages).

Calculations for Single Technology

A number of sustainable solutions are now suggested. For each of these solutions, the costs and benefits are calculated.

Examples:

Pico-hydro, 2 KW:
Investment: Rs. 200,000; Annual costs: Rs. 5000; Energy production: 16,000 kWh/year; Replaces grid electricity at Rs. 4 per KWh; Simple payback: 3.4 years; Additional effects: more reliable than grid, avoids power shortages, needs local electric grid costing additional Rs. 200,000.

Family biogas plants:
Investment: Rs. 35,000; Annual costs: Rs. 2000; Energy production: 12 KWh/day (2 m3 gas/day); Replaces firewood and dung, saves work of 3 hours/day; Additional effect: Cleans kitchen facility.

Solar street lamps:
Investment: Rs. 10,000; Annual costs (replacement battery every 3 yr): Rs. 400; Extra costs compared with normal street lamps: Rs. 3,000; Saves 350 KWh/yr at Rs. 4 per KWh; Simple payback: 3 years; Additional effects: Works during power cut.

Efficient light bulbs *for households:* [11 Watt replaces a 40 W normal light bulb] Investment: Rs. 250; Annual cost: 0 (during lifetime of 6 years); Saves 44 KWh/yr (4 hours use/day) and one normal bulb (Rs. 30); Simple payback: 1.2 years; Additional effects: none.

Solar home systems*:*
Investments: Rs. 45,000; Annual cost (replacement battery every 5 yr): Rs. 1400; Produces 100 KWh/year, can provide electricity for 4 efficient light bulbs 4 hours/day + Radio/TV; Simple payback compared with kerosene (2 ltr/month) and batteries (3 per month): 35 years, but only 11 years if two families share a system. Simple payback compared with grid electricity: 45 years, but only 30 years if savings in local grid is included. (This example of a large solar home system is not economic with these calculations, but it has other advantages: it gives better light and electricity than kerosene and more reliable electricity than grid in many places)

Jatropha plant field of 2 ha to replace oil; modification in truck to run on Jatropha oil; oil expeller/ press + conversion of truck

Investment: Rs. 150,000; Annual cost: picking 4 tons of nuts/year at 5 kg/hour = 800 hours/year of work at Rs. 15/hour = Rs. 12,000; Production 1400 ltr. Jatropha oil with local rainfall conditions, replaces 1300 ltr, diesel oil at Rs. 30/ltr = Rs. 39,000/year. Simple payback is 5.6 years + 3 years when the bushes grow up.

Calculations of Different Mixes of Technologies

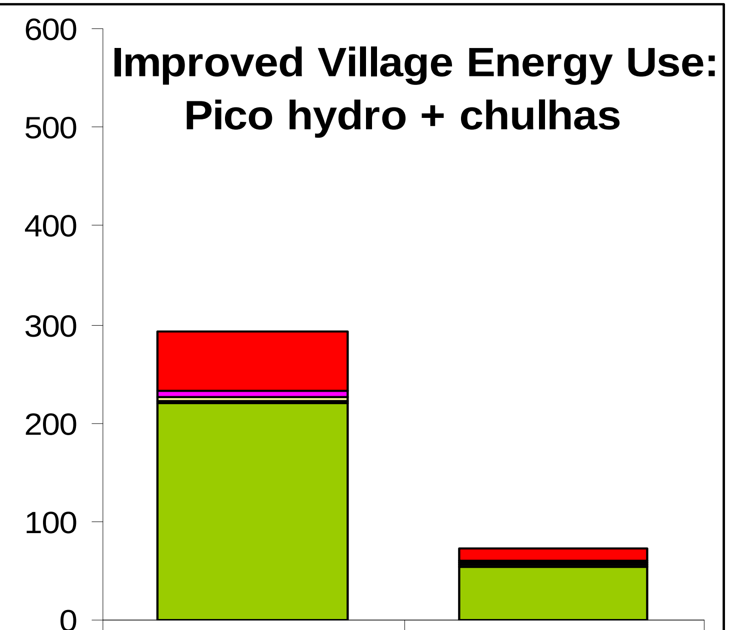
Based on the above descriptions of solutions, some combination of solutions is chosen for further discussions.

Examples could be:

Hydropower + efficient light bulbs:

The reason for this is the good economy of the micro-hydro; and that the limitation of the hydro capacity gives a need to save electricity compared with the business as usual scenario, where electricity demand is above the hydro production (16,000 kWh/yr). Investment (including 209 efficient light bulbs: 4 per family (9 Watt each) + street lamps, clinic etc.) Rs. 260,000 (rounded). To that figure must be added investment in wires between houses (the wires are also necessary in the business as usual-BAU scenario), e.g. Rs. 200,000) and capacity limiters, allowing e.g. 40 Watt per house as maximum use.

An extended solution is to combine the pico-hydro with improved chulhas for efficient cooking with wood and phase out use of dung and agricultural waste as fuels. With this, the demand for wood fuel is reduced by 1/3, and the demand for dung and agricultural waste etc., is reduced to zero. The energy use with this combination is shown in Figure-2.3. The detailed energy balance and investment calculations are shown in *Annex-A*. The total energy consumption (293,000 kWh= 293 MWh per year) is lower than the “BAU” example because of the efficient chulhas (cook stoves) and the efficient light bulbs. The net energy use (about 70 MWh/year) is about the same as in the “BAU” example- so the improvements with more lights etc., would be the same. In addition the proposal includes improved kitchen facilities and stopping the use of dung as fuel, so it can be used for improving agriculture.



	Energy Input	Net energy use
Water pump	0.4	0.3
Tractor	60	12
Grinder	5.6	2.5
Refrigerator	0.8	1.6
Radio/TV	3.3	1.6
Light	2.9	1.8
Cooking	220	53

Energy in 1000s of kWh =MWh/year

Future "pico-hydro - chulha" energy consumption	families	Use/ family	Use/day	Use/year	Energy content	Energy use/year
		kg	kg/day	kg/year	kWh/kg	kWh/year
Wood	50	2.7	135	48,600	5	218,700
Dung	0	2	0	0	3	0
Straw/Agri-waste	0	1	0	0	4	0
Gas bottles (14,5 kg/bottle)	5	0.04	0.2	72	13	914
	families	no./month	Use/month	Use/year	kwh/battery	kwh/year
Batteries D-Size	50	1	50	600	0	15
Batteries AA-size	50	1	50	600	0	3
Picohydro-electricity use	families	kWh/month	kWh/month	kWh/year		kWh/year
Household use	50	10	493	5,912		5,912
		kWh/month		kWh/year		kWh/year
Clinic & office		42		500		500
Village grinder				3,600		3,600
Water pump		30		360		360
4 street lights, 15W, 12h/d.		22		259		259
Small cold storage		30		360		360
Oil/kerosene use	Number	ltr/family/month	ltr/month	ltr/year	kWh/ltr	kWh/year
Household kerosene	0	4	0	0	10	0
Village grinder				200	10	2000
Tractor	1			6000	10	60000

Division of electricity consumption into end-uses

Electricity (kwh/y)	Light	Radio/TV	Refrigerator	Grinder	Water pump	Total	Costs
Batteries	18	0	0			18	21000
Households with grid	2628	3284	0			5912	
Clinic & office	25	0	475			500	
Agriculture				3600		3600	
Common facilities*	259		360		360	979	
Total	2930	3284	835	3600	360	11009	

*** In this case street lights, cold storage, water pump**

Investments "pico-hydro.."	Pieces	Costs	Loan	Subsidy	Cash	
Pico-hydro plant	1	200000	140000	50000	20000	I.Rs.
Chulhas, 50 families	50	12500	0	0	12500	I.Rs.
CFL's 4 per family*50	200	44000	0	0	44000	I.Rs.
CFLs, mayor office, clinique	5	1100	0	0	1100	I.Rs.
CFLs, 4 street lamps	4	880	0	0	880	I.Rs.
Total for energy solutions		258480	140000	50000	78480	I.Rs.
Additional costs:						
Minigrid	1	200000	150000	0	50000	I.Rs.
Street lamps	4	28000	0	0	28000	I.Rs.
Water pump	1	4000	0	0	4000	I.Rs.
Small cold storage	1	10000	0	0	10000	I.Rs.
Total additonal costs		242000	150000	0	92000	I.Rs.
Investment, total		500480	290000		170480	I.Rs.
Investment per family					5683	I.Rs.

"pico-hydro+chulha" Energy Balance	Fuel (kWh/year)				Electricity	Total	Efficiency*		End-use (kWh/yr)
	Wood	Dung/ waste	Gas	Diesel/ kerosene		All sources	Fuel	Electricity	All energy
Stove, improved chulha	218,700					218,700	24%		52,488
Stove, type 2 (dung)		0				0	11%		0
Light				0	2,930	2,930	0.3%	60%	1758
Radio/TV					3,284	3,284		50%	1642
Refrigerator					835	835		50%	1642
Village grinder (agriculture)				2000	3,600	5,600	15%	60%	2460
Water pump					360	360		75%	270
(other)			914			914	50%		457
Tractor (agriculture)				60,000		60,000	20%		12000
	218,700	0	914	62,000	11,009	292,624			72,717
Costs, total	4860	0	1440	155000	41200	202500	Rs/year****		
Cost/household, excl. Agr.	162	0	29	0	0	162	Rs/year per family in average		
Income in village	4860	0		0	9200	14060	Rs/yr that stay in village**		
Work	89	0		2		91	Work in hours/day***		
							CO_2 emissions kg/y		

* Electric efficiencies are relative to best available technology.

** It is estimated that 20% of battery costs are going to local shop/seller in the village

*** It is estimated that it takes 1/2 hour to collect 1 kg firewood and 1/2 hour to collect and dry 1 kg cow dung

****For electricity is estimated that the annual cost of Rs.10,000+ 31.200 to pay for investments in pico-hydro

Annual payments "pico-hydro+chulhas"		
Energy payment incl. Loan for micro-hydro incl. mini grid*	202500	I.Rs/yr
Payment, excl. Agriculture	34028	I.Rs/yr
Payment per family excl. Agriculture, average	1134	I.Rs/yr
Payment per family compared with present situation (- is savings), average	-779	I.Rs/yr
Payment per family compared with future "BAU"(- is savings), average**	-3626	I.Rs./yr

***Loan repayment is assumed to be annually 10% of the total value of the loan (low-cost loan)**

The results with this example regarding energy cost and work are given as under:

Investments: 500,000 Indian Rupees (IRP) of which cash 170,000 (IRP) cash, loans 290,000 (IRP) and subsidy 50,000 (IRP) subsidies (assumed that subsidy will be available).

Total annual energy costs for village: Indian Rs. 203,000 (IRP) of which Rs. 14,000 (IRP) stays back in the village (this includes repayment of loans of Indian Rs. 32,000).

Total work in village: 89 hours/day, to collect wood + two hours/day to manage Pico-hydro and the electric grid

In the above example the costs are only 71% of the present costs for energy. This includes estimated repayment of Pico-hydro, mini-grid and efficient light bulbs; but not investments chulhas and improvements (such as cold storage and street lights) that the villagers have to finance in other ways.

Biogas plant and solar:

Another example would be to combine biogas with solar energy. Biogas plants can solve cooking needs and light with gas lamps while and solar can give electricity for Radio/TV.

To supply the village, 40-50 family biogas plants are needed with a combined investment of Rs. 690,000.

<u>Other examples</u>:

Other systems can also be chosen for calculations such as solar home systems, solar street lamps, Jatropha oil, etc.

When a sufficient number of alternatives are made a decision should be taken with priorities of the different solutions. It is not yet time to make final decisions. They can only be made after an action plan is made. An important part of discussing priorities is that solutions should be presented for and discussed with the people in the village. Then priorities can be made with solutions from the different alternatives.

Priorities could be:

- **hydropower and development of local grid**
- **development of biogas plants**
- **introduction of efficient light bulbs**

For each of the suggested solutions should be made a more detailed feasibility study, looking at factors such as uncertainties, variations over the year of demand and supply, subsidies, etc.

Elaboration of an Action Plan

The action plan should describe how the solutions with the highest priorities can be introduced over a period, how they can be financed, and what the villagers should commit to. It should also propose organizational solutions, uncertainties, and a financing plan.
Then it is time to present the solutions for the people to be involved so they can make their decisions and start improving their situation

Basic data for the example in this chapter are mostly taken from surveys of 12 eco-villages in the Bharatpur district in Rajasthan state of India; but the example does not fully represent any of the existing villages. All use of the methods described in this chapter must be based on the information collected from the actual villages that are analyzed and on local information for costs of energy, equipments etc.

THANK YOU