FINAL DRAFT

Feasibility Study of Domestic Biogas in Pakistan

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Abbreviations:

ADB	Asian Development Bank
AEDB	Alternative Energy Development Board
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CNG	Compressed Natural Gas
CO	Community Organization
FIDA	Foundation for Integrated Development Action
GDP	Gross Domestic Product
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MFI	Micro Finance Institution
MINFAL	Ministry of Food, Agriculture, and Livestock
m^3	Cubic meter
NWFP	North West Frontier Province
PARC	Pakistan Agricultural Research Council
PCRET	Pakistan Council of Renewable Energy Technologies
PRSP	Punjab Rural Support Programme
Rs	Pakistani Rupees
RSPN	Rural Support Programme Network
SNV	Netherlands Development Organization
TOE	Tonnes of Oil Equivalent
UNDP	United Nations Development Programme
VER	Verified Emission Reduction
VMC	Village Milk Centre

Exchange rate US$= Rs 60.00

1.0 Introduction and background

Lying between latitude 23°N and 37°N and longitude 60°E and 76°E, Pakistan is a geographically diverse country with a long coast line and tropical mangrove swamps in the south and snow-covered peaks and glaciers in the north. The middle of the country is a mix of fertile irrigated farms as well as deserts. It has an estimated population of 160 million which continues to grow at a high rate of over 2.5%. The economy has been growing fast at 6-8% a year for the past decade. The high population growth and fast growing economy have put a lot of pressure on the country's energy resources as well as on agricultural production. The livestock sector plays a key role in the agricultural economy of Pakistan. Its share in the country's agricultural production is around 49%, while its contribution to the GDP is just over 11%. Some 57 million cattle and buffaloes and an estimated 100 million sheep and goats and 400 million poultry birds in the county can also provide sufficient raw material for substantial production of biogas. The country has among the highest unexploited potential for biogas production in the region.

The Government of Pakistan, particularly the Ministry of Environment, is keenly interested in promoting domestic biogas as an alternative energy for fuel and fertilizer and has sought expertise and support for setting up a national biogas programme to significantly scale up the number of well performing digesters in the country. Shortage of energy and the high prices of petroleum are considered to be road blocks to the country's rapid economic growth and poverty reduction. Although the household biogas technology is well known in Pakistan, the numbers of installations so far are limited to around six thousand – only a fraction of the potential believed to exist in the country. Rural people are currently cooking largely on unsustainably harvested fuel wood, agricultural residue and dried animal manure to the detriment of local forests and agricultural productivity. The country has to a great extent been deprived of the proven benefits of household biogas – particularly to women and children in terms of reduced burden of firewood collection and less indoor air pollution.

Previous experiences of biogas in Pakistan have been mixed with digesters constructed in the 1980s widely considered to be failures. Plants constructed in the late 1990s appear to be technically sound and are generally functioning well. However the numbers of plants have remained small with no more than a few hundred being constructed each year. Programs are dependent on government grants and no market mechanism is in place for interested users to routinely purchase systems.

Based on the successful experience of implementing biogas programmes in a number of other Asian countries, where tens of thousands of biogas plants are being installed annually, UNDP Pakistan, Winrock International and SNV (Netherlands Development Organisation) carried out a feasibility study for establishing a large-scale household biogas programme in Pakistan in early 2007. This report examines the potential for household scale biogas in Pakistan for cooking and lighting in rural areas. This is based on the availability of sufficient numbers of stall-fed livestock and other enabling conditions such as availability of water and warm temperature. After establishing that there is a sufficient market for biogas plants, the report then examines how a program might be set up in Pakistan to supply large numbers of high quality biogas digesters in the country.

An important factor in the case of Pakistan is that biogas is currently only feasible in areas where people are not being supplied by or anticipating piped natural gas. Natural gas is both a

convenient source of fuel and at the current prices also the least expensive (See Table 5). At present around 18% of households, mostly in urban centres, have access to natural gas. Although it is uneconomic and probably unfeasible for large numbers of rural households to have access to piped natural gas, the anticipation of extension of pipelines is a major deterrent to investment into alternatives such as biogas, particularly in areas close to urban locations that are served by the gas pipeline.

1.1 Objectives

The objective of the study is to assess the feasibility of launching a national level domestic biogas program in Pakistan. More specifically, the study will assess the following:

- Country background including agriculture and livestock sector, energy demand and supply, energy policy and plans;
- History of biogas in the country and lessons learned;
- Potential demand for domestic biogas and possible supply capacity;
- Stakeholder analysis
- Feasibility of a large-scale household biogas programme in Pakistan;
- Identification of institutional modality for carrying out the proposed biogas programme and funding options for launching such a program.

1.2 Methodology and limitations

The following methodology has been applied in carrying out the study:

- Collection and study of secondary information and preparation of checklist/ questionnaire for primary data collection;
- Field visits for interviews with farmers, knowledgeable persons/ organizations and observation of biogas plants constructed earlier;
- Discussions with concerned government officials, Rural Support Programmes, (I)NGOs, private companies, financial institutes and possible stakeholders;
- Analysis of the collected information and formulation of a draft report and submission for comments to Government of Pakistan, UNDP, and concerned individuals;
- Presentation of the draft final report findings among identified stakeholders and discussion before finalization;
- Finalization of the report and submission to Government of Pakistan and UNDP.

The major limitations of the study were constraints in time and resources to carry out a more extensive study. This resulted in inability to visit provinces other than Punjab. Within Punjab, visits were made to communities around the towns of Sialkot and Gujjaranwala. It is not clear how extensively the findings and observations made in the visited communities can be extended to the rest of the Punjab province. Although Punjab has the highest potential for household biogas, Sindh and NWFP also have substantial potential for biogas. Another limitation of the study was the inability to examine large numbers of functioning and dysfunctional biogas plants from earlier programs.

2.0 Country background

2.1 Agriculture sector

Agriculture is a very important sector of Pakistan's economy, contributing close to a quarter of the country's GDP. It employs half of the labour force of the country. Its growth rate over the last five decades has remained constant at around 4% per annum. Of Pakistan's total area of 79.61 million hectares, 27% is cultivated and 8% is covered by forests (MINFAL 1995). Most of the cultivated land is irrigated, with 70% of the water coming from canals and the rest from wells. This provides excellent opportunities to use bio-slurry from biogas plants directly in liquid form in the fields. The Indus Basin, the largest continuous irrigation system in the world, provides most of the canal irrigation. Summer monsoons in July and August and winter rains in January and February provide additional water for both irrigated and rain fed or *barani* land (PARC 1997).

Food grains are grown on 56% of the cropped area, cash crops on 17%, pulses on 7%, oilseeds on 3%, fruits on 2%, other crops, including fodder and vegetables, on 15% (MINFAL 1995). There are two main crop seasons: cotton, rice, sugarcane, maize, jawar and bajra are grown during kharif, which starts between April and June and ends between October and December, and wheat, gram, barley, tobacco, rapeseed and mustard during rabi, which starts between October and December and ends between April and May. Punjab Province alone produces about 65% of cereals, 85% of cotton, 50% of sugarcane and 68% of pulses (MINFAL 1995).

Fertilizer consumption has been increasing at a constant rate in the country growing three fold between 1980 and 2002 (FAO 2004). The main chemical fertilizers used are nitrogen (78%), phosphate (21%) and potash (1%). Requirements of commercial fertilizers are met both from domestic production and imports. Whereas the country imported well over 50 percent of its annual fertilizer requirements prior to 1980, the situation changed following the expansion of the local industry during the 1980s, particularly with respect to nitrogen fertilizers. Nitrogen production in the country has the advantage of domestic natural gas resources, with around 13% of the country's annual natural gas consumption being used for fertilizer feedstock. Imports as a percentage of deliveries for the five years (1998/99 to 2002/03) averaged about 11 percent for nitrogen and 72.5 for phosphate.

It has been estimated by FAO (2004) that about 50 percent of animal wastes in the country is collected. Of this recovered quantity, about 50 percent is used as fuel, resulting in scarcely a quarter of the animal wastes being available for use as organic fertilizers. The animal wastes together with an equal quantity of stable bedding material, left-over fodder and household wastes provide the total quantity of farm yard manure (FYM) available. About 50 percent of the farmers reported that they use FYM on one crop or another. Based on different assumptions, it is estimated that about 1.5 million tons of nutrients are available from FYM. Of this quantity, nitrogen accounts for 726 thousand tons, P_2O_5 for 191 thousand tons and K_2O for about 617 thousand tons (FAO 2004). Censuses and surveys show that farmers apply FYM when it is available and when there is adequate labor available to collect, store and spread it. A national biogas program in the country would assist in increasing the percentage of FYM being used in farming both by reducing the manure being burned and also by providing an incentive to collect and digest more of the manure.

The livestock sector plays a key role in the agricultural economy of Pakistan. Whereas agriculture contributes 24.5% to the country's GDP, employs 50% of the labour force, and about 60% of export earnings, the livestock sub-sector's share in agriculture is around 49%, amounting to

11.4% of overall GDP. Income from livestock and livestock products is the main source of cash income (43%) at the national level followed by remittance (34%) and crops (20%) (SEBCON 2006). Pakistan has a large livestock population, which is well adapted to local conditions, and includes some of the best tropical breeds. There are two breeds of dairy buffaloes, the Nili–Ravi and Kundi (Shah 1991), and 10 breeds of cattle: the Sahiwal and Red Sindhi dairy breeds, the dual-purpose Cholistani and Dhanni, and the draft breeds Thari, Dhajal, Bhaghnari, Lohani, Rojhan and Konkrej. There are also 2 million cross-bred cattle.[1]

Table 1 below gives the distribution of livestock in the country among provinces. Punjab dominates in the population of cattle and buffaloes, with 65% of the buffaloes in the country and 49% of the cattle of the country, and thus has the highest potential for household biogas plants.

Table 1: Livestock and Poultry Populations by Provinces of Pakistan (Livestock Census 2006)

Species	Pakistan (in millions)	Punjab (%)	Sindh (%)	NWFP (%)	Balochistan (%)
Cattle	29.56	49	23	20	8
Buffaloes	27.33	65	27	7	1
Sheep	26.49	24	15	13	48
Goats	53.79	37	23	18	22
Camels	0.92	22	30	7	41
Horses	0.34	47	13	22	18
Mules	0.16	41	12	43	4
Asses	4.27	52	24	13	11
Poultry	73.65	35	19	38	8

Source: Pakistan Livestock Census 2006
(http://www.statpak.gov.pk/depts/aco/publications/pakistan-livestock-cencus2006/report.pdf)

The Livestock Census which has been carried out every ten years since 1956 shows that the livestock population has been steadily growing in the country, with large growth in numbers of buffaloes, sheep and goats and phenomenal growth in poultry. In the fifty years between 1956 and 2006, the buffalo population increased by 369%, cattle by 153%, sheep by 324%, goats by 723%, and camels by 50%. The 2006 Census showed that there are an estimated 29.56 million cattle, and 27.33 million buffaloes in the country making a joint population of close to 57 million buffaloes and cattle. Buffaloes are kept mainly in the northern and southern irrigated plains, and cattle are raised throughout the country. More than 50% of sheep are reared in the western dry mountains, western dry plateau and northern dry mountains. Goats are raised in all Agro-ecological Zones (AEZs) of the country, but larger herds are common in areas with forage and grazing. Table 2 shows that the number of buffaloes has been growing particularly rapidly.

[1] Mohammad Afzal (Animal Health Institute, National Agriculture Research Centre). Paper presented at: *Consultation on Setting Livestock Research Priorities in West Asia and North Africa*, 12–16 November 1997, ICARDA Headquarters, Tel Hadya, Aleppo, Syria.

Table 2: Growth in livestock numbers in three decades (in millions)

Species	1976	1986	1996	2006	Average growth rate
Buffaloes	10.6	15.7	20.3	27.3	3.2%
Cattle	14.9	17.5	20.4	29.6	2.3%
Goats	21.7	29.9	41.2	53.8	3.1%
Sheep	18.9	23.3	23.5	26.5	1.1%
Camel	0.8	1.0	0.8	0.9	0.4%
Horses	0.4	0.4	0.3	0.3	-0.5%
Asses	2.2	3.0	3.6	4.3	2.3%
Mules	0.06	0.1	0.1	0.16	3.2%

Source: Adapted from:
www.statpak.gov.pk/depts/aco/statistics/**livestock**/**livestock**.html and (http://www.statpak.gov.pk/depts/aco/publications/pakistan-livestock-cencus2006/report.pdf)

Animal production is closely integrated with crop production. Exceptions are nomadic sheep, goats and camels, freely grazed cattle, peri-urban dairying and commercial poultry. Most farms are fully integrated mixed units with cattle, buffaloes and sometimes sheep and/or goats. Traditionally, cattle were kept as draft animals, with milk as a by-product, and buffaloes as milking animals. With the mechanization of agriculture, however, higher milk yielding cross-bred cattle are replacing the poorer breeds.

There are four main types of system (FAO 1987)[2] for the production of milk from cows or buffaloes in Pakistan:

- Rural subsistence smallholdings, producing milk for the family at minimal cost. The average subsistence unit consists of three buffaloes, including one or two adults. Grazing provides more than half of the feed requirement. Some green fodder and straw is provided and a small quantity of concentrate is given to milking cows. This traditional system makes heavy demands on family labour.

- Rural, market-oriented smallholdings, with satisfactory access to milk markets, producing milk in excess of family requirements for sale. These farmers usually keep better quality animals. A typical unit consists of fewer than six buffaloes and cattle, with two or three in milk. Milking animals are generally stall fed with seasonal green fodder, straw and concentrate, and dry cows and herd followers are grazed. There is usually no adult bull in the herd. Calves are retained during lactation, and then the males are disposed of and females are kept as replacements. This system is the main source of milk in Pakistan.

- Rural commercial farms, with more than 40 animals, 90% buffaloes and 10% cattle, on mixed crop–livestock farms or specialised farms for breeding and milk production. Fodder crops are grown and straw may be home grown or purchased. Concentrates are fed and dry females and heifers are, if possible, grazed. There is usually a bull for natural mating and the government

[2] Although this is an old reference the dairy practices still largely fall within these categories.

artificial insemination service is also used. These farms are well organised and keep good records, but their contribution to the total milk supply is small.

- Peri-urban commercial dairy farms, around all big cities, the largest being at the Landhi Cattle Colony, Karachi, where more than 150,000 milking animals are kept. Most herds in this sector have 15 to 50 animals and more than 90% are buffaloes, mostly adult lactating females. Turnover is very high. Animals close to calving or in calf are purchased; the calf is allowed to suckle for a few days and is then sold, generally for slaughter. Dry females are either sold for slaughter or returned to the rural areas for breeding. Most cows are not mated, as pregnancy reduces milk yield. Green fodder is purchased, but feed consists mainly of concentrate and straw. Since this is a high-cost system, only high-potential animals are kept.

A relatively new phenomenon is the establishment of milk collection centres in rural areas by commercial dairy companies such as Nestle and Haleeb. Nestle collects from over 120,000 farmers at some 2,400 Village Milk Centers. These VMCs are located in the Punjab and are limited to milk "pockets". In the cities, families sometimes keep one or two animals and sell the surplus milk, usually to neighbours.

The rural population engaged in livestock production has been estimated at 30 to 35 million, and these households derive 30 to 40% of their income from livestock (Economic Survey of Pakistan 2004-05). Statistics indicate that national milk production exceeds 28 million tons, having increased from around 12 million tons in 1990, a steady increase of > 5% each year.[3] Pakistan ranks as the 5th largest producer of milk in the world and dairy is by far the largest livestock sector, valued in 2002 at Rs 300 billion (US$ 5 billion) per year.

A recent baseline survey of the livestock sector carried out in 30 districts of Pakistan under the EU/Government of Pakistan project, "Strengthening of Livestock Services Project (SLSP)" (SEBCON 2006) shows the central important of income from livestock and livestock products to urban as well as rural households. The study notes that:

"On a national basis, the total annual income in the Urban/Peri Urban areas was Rs 178,466 (US$2,974) at the household level with the highest income from livestock products (41%) followed by remittances (37%), crops (9%), and livestock (8%). In the rural areas, the total income was reported to be lower with Rs 126,926 ($2,115). The highest source of income was crops (34%), followed by remittances (31%), livestock products (24%), and livestock 9%)."

Dairy farmers by and large practice stall grazing, which is favourable to the adoption of biogas technology as this makes collection of animal dung much easier. This is seen from Table 3 below which shows that buffaloes which are the primary source of milk in the country are mostly stall fed in the Punjab and mostly stall fed and grazed in the other provinces.

[3] Wynn et al 2006. "Report on Dairy Mission to Pakistan 8 to 20th May 2006" carried out under the auspices of the Australia-Pakistan Agriculture Sector Linkages Program.

Table 3: Feeding Practices of Buffaloes in Pakistan

Table 3.10. Feeding Practices of Buffaloes in Pakistan

LOCATION	GRAZING ONLY (% Population)	STALL FEEDING ONLY (% Population)	BOTH GRAZING AND STALL (% Population)
Punjab	6.5	64.5	29.0
Sindh	6.1	12.2	81.7
N.W.F.P	4.5	44.5	51.0
Baluchistan	10.2	16.2	73.6
Pakistan	7	34	59

Source: Ministry of Food, Agriculture and Livestock (Livestock Wing) 2003

2.2 Energy sector

Pakistan is a net importer of energy. In 2006, it spent $7 billion, equivalent to over 40% of total imports, to import petroleum to meet its energy needs. Oil importation is a heavy burden on the country's foreign exchange. Recent high oil prices and their continuous fluctuation have further increased this burden. Most of the imported oil is for electricity generation. Over 70% of Pakistan's electricity comes from thermal sources, a little less than 30% from hydro, and less than 1% from renewable and other sources. Even with all this imported energy, Pakistan currently faces a 20% power shortage. Only 59% of Pakistan's population has access to electricity from the national grid. In rural areas, the percentage with electricity access falls to 37%.

Indigenous natural gas dominates the commercial energy sector of the country accounting for 51% of primary commercial energy used in the country. This is followed by oil (29%), hydro (11%), coal (8%), and nuclear 1%. Roughly 30% of the country's total primary energy comes from traditional biomass fuels. The majority of the rural population uses firewood and other biomass fuels for cooking and heating and kerosene for lighting and some cooking.

Piped natural gas is available to 18% of the population for domestic use (Pakistan Economic Survey 2004-05) and is only available to users in urban and semi-urban areas. Towns that are not within the piped natural gas network have access to LPG (Liquefied Petroleum Gas) for cooking, although the high cost of this fuel limits its use to higher income families. Due to large costs involved in expanding the network, competing alternative uses such as fuel for power plants, input for fertilizer and other manufacturing sector factories, and vehicular transportation fuel, it is unlikely that the natural gas can be made available to a large number of the unconnected rural households any time soon. Furthermore, total availability of developed gas resources is not sufficient to meet the increasing demand for energy. This accounts for the increasing dependence on imported petroleum into the country. To meet the shortfall, the government has initiated discussions to import natural gas, both through pipelines and as LNG, from regional countries Iran and Turkmenistan.

The Government of Pakistan had set a goal of doing away with most natural gas tariff subsidies as well as subsidies on petroleum fuels by May 2005, but against the backdrop of rapidly rising world oil prices driven by lower production, the government had to reconsider and continue to subsidize natural gas as well as petroleum prices. To provide a buffer to people from the persistently high international oil prices, the government announced in the 2007-08 national

budget that it will provide a subsidy of Rs 15 billion ($250 million) to keep diesel, kerosene, and LPG prices at affordable levels. This is an increase of 50% over the subsidy of Rs 10 billion provided in the 2006-07 budget. An additional subsidy of Rs 72 billion (1.2 billion) is projected to be provided in 2007-08 to the power sector to keep electricity prices affordable[4]. It would thus be logical for the Government of Pakistan to strongly support and contribute to a future national biogas programme as investment in biogas will reduce the recurrent subsidies needed each year on fossil fuels.

Pakistan's renewable energy potential is substantial and the vast majority of it remains untapped. The Government of Pakistan has decided to put greater emphasis on renewable energy. In May 2003, it announced that it had set a target of 5% of the country's total power generation to be from renewable energy by 2030 (9,700 MW) and established the Alternative Energy Development Board (AEDB) as the apex organization to coordinate renewable energy promotion. AEDB has been tasked by the government under the Roshan Pakistan Programme to electrify the remaining unelectrified villages in the country within the next three years using distributed renewable energy technologies. In terms of off-grid renewable energy systems, 140 micro wind turbines of 500 Watt capacity have been installed to meet the needs of rural households and institutions and 400 villages are being electrified using solar home systems through micro-finance.

2.3 Domestic fuel use in Pakistan

Based on the Pakistan Household Survey (2004-05), Table 4 shows that average monthly expenditure at the household level disaggregated by rural and urban areas and expenditure by fuel types. Energy expenditure at the household level comes to Rs 713 in Pakistan. Of this the largest single expenditure item in both urban and rural areas is for electricity. The next largest expenditure is on natural gas in urban areas but is on firewood, as expected, in rural areas. However it is clear that after adding the different fuel sources rural areas spend most of their energy expenditure on cooking fuels: around 45% of their energy expenditure goes on solid biomass fuels:- firewood, agricultural residues, and dung cakes. An additional 12% goes to LPG, kerosene, natural gas and candles, which are used for cooking and for lighting.

Table 4: Average monthly expenditure on energy in Pakistani households (2004-05)

Energy	Pakistan	Urban	Rural
Average Monthly Expenditure	713	904	622
Firewood	22.1%	7.5%	32.1%
Kerosene	2.8%	0.8%	4.2%
Charcoal	0.1%	0.0%	0.1%
Coal	0.1%	0.0%	0.2%
Dung cakes	3.6%	0.8%	5.5%
Natural Gas	9.1%	20.3%	1.4%
LPG	3.8%	3.6%	3.9%
Electricity	50.4%	63.1%	41.7%
Candles	2.0%	1.7%	2.3%
Agriculture residues	4.5%	0.7%	7.1%
Accessories (bulbs etc)	1.5%	1.5%	1.6%

[4] http://www.dailytimes.com.pk/default.asp?page=2007\06\10\story_10-6-2007_pg7_9

Source: Household Integrated Economic Survey 2004-05,
http://www.statpak.gov.pk/depts/fbs/statistics/hies0405/hies0405.html

Figure 1 below provides a graphic of how energy expenditure is divided among fuels in the average rural household in Pakistan.

Figure 1: Domestic fuel use in rural Pakistan

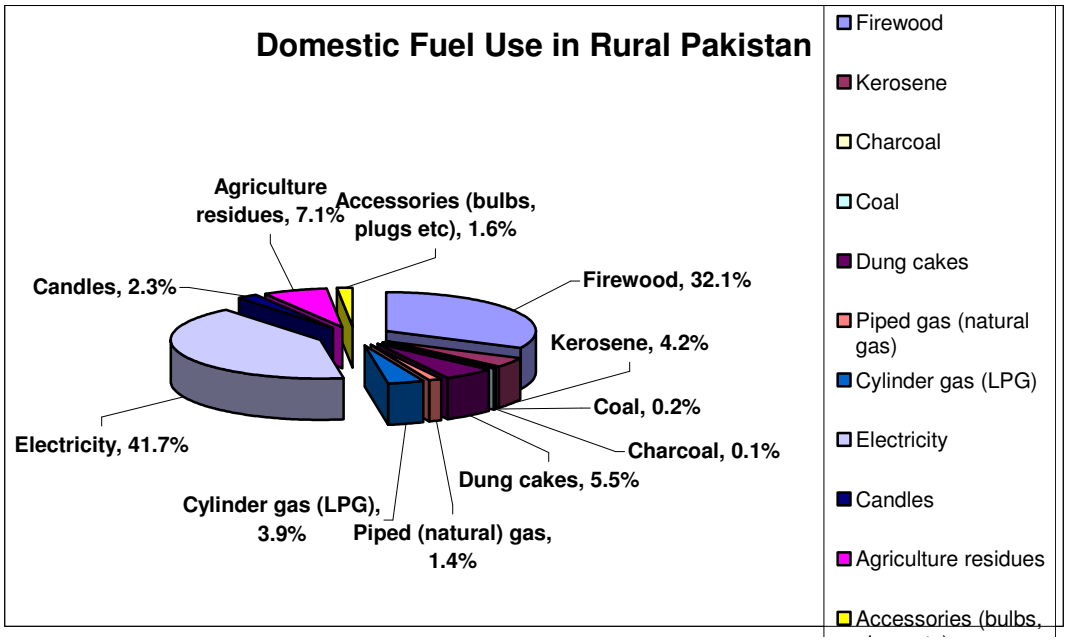


Table 5 below shows the relative prices among options for fuel in Pakistan available for meeting domestic cooking needs: including firewood, animal dung, biogas, kerosene, LPG, natural gas and electricity. The fifth column of the table lists the market prices of fuels while the eighth and ninth columns lists the costs to users in terms of Rs per MJ and kWh for each of the fuel options taking into account the relative efficiencies of typically available stoves. The Table shows that the least expensive fuel for the purposes of domestic heating and cooking, by far, is piped natural gas – for those areas lucky enough to be served by the piped network. When the relative efficiencies of different stoves are taken into account, column 10 of the Table shows that the effective energy cost to dung cake and firewood users, and users of LPG, and kerosene comes remarkably to between 3, 8, 12 and 14 times as high as to the lowest slab of natural gas users! Household biogas plants would provide cooking fuel at a rate 5 and 7 times as high as the lowest slab natural gas user with and without a government subsidy.

The low tariff on natural gas, particular to the lower slab lifeline user, added to its attractiveness as a clean fuel to use in the home, and its versatility and ease of use all combine to make it the fuel source of choice for most people in Pakistan.

Table 5: Relative costs of cooking fuels in Pakistan

Fuel and stove technology	Stove efficiency	Calorific Value (MJ/unit)	Unit	Market price of fuel (Rs per unit)	Unit	Effective price of fuel (Rs/unit) including burning efficiency	Effective Rs/MJ	Effective Rs/kWh	Relative costs of energy by fuel
Firewood - medium efficiency stove	15%	15	kg	2.50	kg	16.67	1.11	4.00	7.92
Animal dung	15%	15.5	kg	1.00	kg	6.67	0.43	1.55	3.07
Agricultural residue	15%	12.6	kg	1.00	kg	6.67	0.53	1.90	3.77
Biogas with government subsidy	53%	20	m3	7.64	m3	14.42	0.72	2.60	5.14
Biogas without subsidy	53%	20	m3	10.41	m3	19.65	0.98	3.54	7.00
Kerosene pressure stove	38%	45.6	kg	35.23	liter	92.23	2.02	7.28	14.42
LPG	53%	47.8	kg	43.00	kg	81.13	1.70	6.11	12.10
Sui Gas (<1.77 Mcft/mo)	53%	1.0339	Mcft	76.84	Mcft	144.99	0.14	0.50	1.00
Sui Gas (1.77 to 3.55 Mcft/mo)	53%	1.0339	Mcft	80.46	Mcft	151.81	0.15	0.53	1.05
Sui Gas (3.55 to 7.10 Mcft/mo)	53%	1.0339	Mcft	146.47	Mcft	276.36	0.27	0.96	1.91
Sui Gas (7.10 to 10.64 Mcft/mo)	53%	1.0339	Mcft	234.32	Mcft	442.12	0.43	1.54	3.05
Sui Gas (> 10.64 Mcft/mo)	53%	1.0339	Mcft	304.82	Mcft	575.14	0.56	2.00	3.97
LESCO electricity (<50 units/mo)	60%	3.6	kWh	1.60	kWh	2.67	0.74	2.67	5.28
LESCO electricity (low efficiency stove)	45%	3.6	kWh	1.60	kWh	3.56	0.99	3.56	7.04
LESCO electricity (<100 units/mo)	60%	3.6	kWh	2.70	kWh	4.50	1.25	4.50	8.91
LESCO electricity (low eff stove)	45%	3.6	kWh	2.70	kWh	6.00	1.67	6.00	11.88
LESCO electricity (100-300 units)	60%	3.6	kWh	3.70	kWh	6.17	1.71	6.17	12.22
LESCO electricity (low eff stove)	45%	3.6	kWh	3.70	kWh	8.22	2.28	8.22	16.29
LESCO electricity (301-1000 units)	60%	3.6	kWh	6.30	kWh	10.50	2.92	10.50	20.80
LESCO electricity (> 1000 units)	60%	3.6	kWh	7.60	kWh	12.67	3.52	12.67	25.09

Sources:

1. Pakistan Energy Yearbook 2005
2. Prices of natural gas (March 2007) and kerosene fuel (July 2007) from Oil and Gas Regulatory Authority (http://www.ogra.org.pk/cats_disp.php?cat=86)
3. Electricity tariff for Lahore Electricity Supply Company (LESCO) March 9th 2007, from National Electric Power Regulatory Authority "Determination of the Authority w.r.t Lahore Electric Supply Company (LESCO)" 2007 http://www.nepra.org.pk/
4. LPG prices from Daily Times July 4, 2007. "LPG prices surge to Rs 2,097 per tonne" http://www.dailytimes.com.pk/default.asp?page=2007%5C07%5C04%5Cstory_4-7-2007_pg5_9
5. Firewood, dung cakes, and agricultural residue prices from field survey

Notes:

1. Biogas plant is assumed to cost Rs 23,000 and subsidy Rs 6,000 (US$100) per plant

In addition to the 18 percent of the population, mostly in urban areas, that has access to piped natural gas, 2 million of the 23.9[5] million households in the country are thought to be using liquefied petroleum gas (LPG) as a cooking fuel – mainly in peri-urban areas that do not have piped natural gas supply. Kerosene is the other fossil fuel that is used for cooking in areas that are not served by natural gas. The vast majority of rural people, however, continue to use solid biomass, primarily firewood, dried animal manure, and agricultural residue, as their primary cooking fuel.

There is some evidence that households that had started to use cleaner liquid and gas based fuels for cooking have again slipped back to using dirtier solid biomass fuels, most probably as a result of increasing petroleum prices. Kerosene consumption in Pakistan dropped from 487,155 TOE / year in 1999-2000 to 232,447 TOE / year in 2004-05. LPG use has increased overall but appears to be increasingly used in urban areas in industry and transport rather than for domestic cooking.

[5] Source: CRPRID / Planning Commission, 2006.

LPG was once considered the fuel for the poor and its use in industrial, commercial and transport sectors was declared illegal to keep demand and prices low. However LPG has been deregulated and although the Government keeps a cap on the supply prices to the distribution and marketing companies, the marketing companies are free to sell at the market prices. Government has also recently allowed the use of LPG in motor vehicles. The use of LPG in motor vehicles along with its demand in the commercial sector due to electricity and gas load shedding has essentially priced LPG out of the reach for the poor. Distributors have little interest in expanding their supply chain to the rural areas, as they now have a ready market in the urban centres. This is despite the Government's policy directive to all LPG suppliers to devote 6–10 percent of their marketing operations in remote areas. The Government's policy of deregulating the sale price of kerosene and LPG appear to have resulted in the poor stepping down the energy ladder to biomass. (UNDP 2006).

LPG use has shifted from the rural household to urban commercial and transport sectors forcing Pakistani women down the energy ladder, exposing them to unclean fuel, hazards of indoor air pollution, and hours of extra work in searching and collecting biomass (UNDP 2006). Barriers to adoption of LPG for cooking by low-income households come from the combination of the start-up cost (Rs 1,000–2,000) and the cash outlay at each refill (Rs 700 per 11.8 kg cylinder). Furthermore according to the World Bank's 'Pakistan: Oil and Gas Sector Review', "the low population density in rural areas, low LPG uptake and low consumption among those who sign up for LPG make it difficult to establish commercially viable LPG distribution networks. The lack of economies of scale in catering to rural domestic consumers is the most important factor hindering ready access to LPG." (Lele 2007).

Rural households are largely dependent on biomass to meet their cooking needs. Some 29% of biomass users living in rural areas have reported that they purchase wood. This compares with 84% of biomass consumers buying firewood in urban areas and the remaining collecting it. Another major source of fuel in rural areas is dried animal manure. About 70% of the Pakistani population lives in rural areas. Collecting of firewood and shrubs is mainly done by women and children in rural areas as is the manual formation of dung cakes.

Energy consumes a major portion of disposable income especially of the poor. The expenditure on fuels (including biomass fuels) amounts to 10.7 % of the total annual household expenditure; the percentage is higher for the rural households (12.8%) than the urban households (7%). Likely reason for this is that urban households have access to low-priced natural gas, while rural areas do not. A major portion of the overall expenditure on the part of the average rural household is for non-commercial biomass fuels (8.2%), while the share of commercial fuels including electricity, natural gas, kerosene and LPG is much lower (2.5%). As is the case in most countries the share of energy related expenditure in total household spending falls as the income level rises. Consequently for the highest income group the share of energy expenditure is less than 4 % of the total spending; by contrast for the lowest income group this number is as high as 23 %. (UNDP 2006)

In the communities in the districts of Sialkot or Gujjaranwala in the Punjab visited by the study team, it was striking to see extensive use of dung cakes for cooking. Heaps of animal dung, flat dung cakes stuck to every external wall, and soccer-ball size balls of dung cake being dried on the top of wall and open ground spaces are ubiquitous and greet the visitor in every community. Women are generally seen making the dung patties and balls to dry plastered on walls or on top of walls. The dung cakes made in the winter are stored for use during the wet monsoon months. In some of the communities, there is also a market for dried dung cakes which sell by the basket or by

number patties coming out to around Rs 1.00 per kg. Equally striking was the absence of tree cover in these rural agricultural areas. Most of the firewood purchased by villagers was trucked in from outside the area or is the shavings from saw mills and was found to be quite expensive – ranging from Rs 100 per mund (40 kg) to up to four times this amount. Households were typically using the firewood to start the fire and get the dung patties burning.

Around 30% of Pakistan's total primary fuel comes from biomass, including firewood, bushes, agricultural residues, and animal waste. In spite of this fact, wood-fuel or biomass is largely neglected in the national energy policies. Trading in biomass is not considered a commercial activity and there is little data available on the sector. Lack of interest at the state level is encouraging the inefficient use of biomass, deforestation and loss of bio-diversity, and negative health impacts from indoor air pollution. Serious attention is needed to develop technologies to use biomass in more efficiently both for environmental and health benefits.

In the rural areas, cooking is the most important energy need in terms of women's time and effort, there seems to be a dichotomy between the prevalent energy needs for cooking and the focus of energy policies, which is heavily tilted towards village electrification. Biomass continues to be the main source of cooking energy, and in fact the use of kerosene in Pakistan has declined in favour of biomass – bringing the rural women down the energy ladder. Similarly the LPG use has shifted from the rural household to urban commercial and transport sectors forcing the Pakistani women again down the energy ladder, exposing them to unclean fuel, hazards of indoor air pollution, and hours of extra work in searching and collecting biomass. (UNDP, 2006).

3.0 History of biogas in Pakistan

Pakistan is typical of many countries around the world where the biogas technology has been tried with some success in the past but has yet to be widely adopted. Around six thousand digesters have reportedly been installed whereas the potential in the country is for around five million digesters based on its suitable climate and numbers of livestock.

The Government of Pakistan started a comprehensive biogas scheme in 1974 and commissioned 4,137 biogas units by 1987 throughout the country. These were large plants with capacity varying from 5-15 cubic meters gas production per day. This programme was developed in three phases. During the first phase, 100 demonstration units were installed under grant by the government. During the second phase, the cost of the biogas was shared between the beneficiaries and the government. In a subsequent third phase, the government withdrew financial support for the biogas plants, although technical support continued to be provided free of cost. Unfortunately, after the withdrawal of the government financial support, the project did not progress any further (World Energy Council)[6].

The Pakistan Centre for Renewable Energy Technologies (PCRET) is the leader in the country and has installed around 1600 biogas plants.[7] The Initiative for Rural and Sustainable Development (IRSD), an NGO, has installed around 150 biogas plants with support from the UNDP Small Grants Program. The benefits of biogas are well recorded. One report on IRSD states, "'Biogas plants have

[6] http://www.worldenergy.org/wecgeis/publications/reports/renewable/country_reports/chap_2_6_2.asp

[7] PCRET has so far also disseminated more than 60,000 improved cook stoves and has provided training in construction and use of such stoves to NGOs and users.

dramatically changed the lives of women and girls in an impoverished village in Pakistan. The introduction of a simple, gas-forming machine in the village of Maira Khurd, some 65 kilometres southwest of the capital city of Islamabad, has allowed hundreds of families to resolve the scarcity of fuel supply in the village."

A number of the Regional Support Programmes and NGOs also include biogas among the projects they support. The NGO 'Koshis' in Sialkot, Punjab has reportedly helped villagers to build over 200 biogas plants. Another NGO Green Circle Organization is building community based plants with funding from the Pakistan Poverty Alleviation Fund. Most NGOs receive technical assistance from PCRET in the design of their plants. With some exceptions most plants are still carried out on a pilot basis and have not been promoted commercially to any large scale. The large potential for biogas in the country is often quoted by promoters. The PCRET website states: "There is enough livestock for producing biogas up to 16 millions cubic meter a day and it can be very effectively used as fuel. The biogas activity was initiated in the country in the early seventies when more than 4,000 plants of capacity varying from 5 – 15 cubic meter per day were installed in the country. Recently 1,200 more biogas plants have been installed throughout Pakistan on subsidized basis, where the beneficiary pays only 50% of the cost of the plant. Quite a know-how and infrastructure of the biogas technology is now available does in the country. However there is a need to initiate a public awareness campaign for wide dissemination of the technology for the people living in rural areas."

Most of the biogas plants installed in recent years have been smaller household designs compared to the larger plants in the 1970s and '80s. In addition to the 1600 household biogas plants it has installed, PCRET has plans to install another 2,500 plants by 2008 for which Government of Pakistan has approved financial support. It is thought that the quality of biogas plants has improved over time and about 75% plants installed within 5 years are believed to be functioning well; although no comprehensive study has been carried out to confirm this.

The biogas technology most commonly used in Pakistan is the floating drum design. Another design, Chinese fixed-dome design, was installed on a pilot basis but was reportedly not successful. The Chinese design pilot biogas plants apparently showed persistent leakage and seepage problems and moreover the gas pressure was low. The floating drum design has little chance of leakage, at least in the first few years of operation, and were found to work adequately in most cases.

Twelve fixed-dome 'Nepal design' biogas plants Model GGC 2047 of 6m^3 were installed in *tehsil* [8]Pasrur of Sialkot District in partnership in partnership with the Punjab Rural Support Program (PRSP) and three plants of the same design were installed in sizes 8, 20 and 35 m^3 in Dera Ismail Khan in partnership with the Foundation for Integrated Development Action (FIDA) by the Rural Support Programme-Network (RSPN) in June of 2007. An evaluation of these plants will provide guidance on the applicability of this design in Pakistan.

During the field survey the main weaknesses found in the construction of the existing floating drum biogas digesters are as follows:

a. The external frame to hold the drum was found missing or inadequately built in most plants resulting in the steel drum tilting to one side. Some of the drums in plants of over 5 years had

[8] The tehsil is the second-lowest tier of local government in Pakistan and consists of a cluster of villages. Each tehsil is part of a larger District.

developed holes from corrosion and these were plastered over by a mixture of dung and clay to keep them from leaking gas.

b. The gas pipe from the drum to the kitchen was plastic in most cases and was left unsecured and hanging, leading to opportunities for water to collect at low points without any easy way to remove the water.
c. The biogas stoves used were adapted from natural gas or LPG stoves and did not have a mechanism for pre-mixing the gas with air. Flames were often seen to be long and graceful but without much heat.
d. Some of the NGOs constructing biogas plants were not clear about the ratio of animal dung to gas production and the amount of gas needed per day by families. In one instance an undersized digester using a 10 m^3 gas storage drum had been built for thirty families.

Reasons of non-functioning of biogas plants in Pakistan in general have been reported as follows:

- Lack of proper training to the users on plant operation and maintenance
- No regular feeding
- Construction faults and no standardized product
- No maintenance services and monitoring
- Natural calamities such as earthquakes

Different programmatic and organizational reasons have also been put forward for lack of success of biogas plants in the past. A review by Energia says: "The projects failed due to lack of community interest at the experimental stage. …. The progress has been slow due to non-involvement of communities and non – availability of equity participation. The demand is muted mainly due to lack of initiative by the government in publicizing the usefulness of the project."

This study observed that the slow pace of investment in household biogas in Pakistan results from a number of factors. Firstly, the floating drum design has been found to be expensive particularly with the increase in the price of steel in recent years, costing around Rs 35,000 each (USD 600) for a household size unit. The 50% subsidy offered for construction of plants covers only around one thousand plants a year and microfinance institutions do not currently provide loans for biogas plants. The market does not expand by itself beyond these subsidized digesters or those constructed by NGOs for rural communities. Furthermore the quality of construction is inconsistent with some plants being built with poor quality and no mechanism for consumers to get a warranteed product. This results in lack of consumer confidence in the product and unwillingness on the part of most prospective buyers to invest in a biogas plant on commercial terms. The supply side has also remained weak. Only a small number of NGOs and individual masons are actively building biogas plants. Till the present time, private companies which would have a natural interest in continuously expanding their market, have not entered the sector. In summary, it is lack of an organized approach to scale-up of high quality biogas plants, which would strengthen both the supply and demand aspects, that is standing in the way of development of a potentially very attractive market for household biogas plants in Pakistan.

4.0 Benefits of household biogas

Biogas is a reliable and easy to use source of household energy. It has several benefits to users, particularly to women and children, and can contribute in a number of ways to the Millennium Development Goals.

Gender benefits: Biogas provides direct benefits at the household level, especially to rural women. This comes about as a result of the reduction of the firewood collection workload when cooking with conventional biomass is substituted with biogas. Users find it much easier to cook on biogas and cooking times are much faster than cooking using solid biomass fuels. Moreover, biogas is smokeless and does not require constant attention while cooking, allowing women to tend to others activities simultaneously. Experience from the region shows that on average biogas save approximately 2 hours per day per family mainly due to the reduction in time used for collecting biomass and/or making dung cakes, cooking and cleaning of utensils. This saved time can be used more productively by women for childcare, income generating activities, education, recreation and other social activities.

Environmental benefits: The use of biogas significantly improves the indoor air quality in user' homes. In addition, construction of biogas plants results in proper management of farm-yard-manure. Biogas plants can contribute to improved sanitation through the connection of toilets to the digester, as is the case in Nepal. Biogas plants also reduce demand on firewood and hence lower pressure on forests. One biogas plant of 6 m^3 capacity enables the saving of about 2.0 tonnes of biomass per year. This mitigates considerable amount of green house gas emissions by reducing the amount of unsustainable biomass that is burned. Biogas plants can also be used to manage waste from larger dairy and poultry farms. The surroundings become clean, healthy and odour-free when a biogas plant is constructed to manage waste from commercial farms making them more acceptable to the neighbours.

Health benefits: A major problem for the rural people especially to the housewives and small children is indoor air pollution due to exposure to smoke inside the kitchen while cooking with solid biomass fuels. Poor indoor air quality is one of the major risks factors for acute respiratory infections, the leading killer of children under five in developing countries. Use of biogas reduces smoke and significantly improves air quality inside the kitchen reducing the incidences of respiratory diseases, coughing, dizziness and headaches, and eye infections.

Economic benefits: Biogas reduces the expenses on fuel for cooking, and over the long run. Savings of fuel expenses as a result of installing biogas plants makes it possible to recover the total plant investment cost within four to five years typically.

Bio-slurry obtained from the plant has proved to be excellent organic manure. This manure is more effective and is of higher quality than traditional manure such as farm-yard manure. The use of bio-slurry as manure helps in increasing farm production and the farmer's income. It also reduces the high cost of chemical fertilizers and the adverse effects arising from their use.

Table 6 provides a summary of how household biogas technology can contribute to the Millennium Development Goals.

Table 6: MDG benefits of biogas

MDG 1: Eradicate extreme poverty and hunger
• Reduce fuel expenses to the household and make money more available for food and other essentials • Improve agriculture production by using slurry as fertilizer • Enhance economic opportunity by creating jobs in the biogas sector
MDG 2: Achieve universal primary education
• Provide lighting for school children to read at home after dark in areas not served by grid power
MDG 3: Promote gender equality and empower women
• Reduce the drudgery on women of firewood collection and making dung cakes • Reduce women's workload (fuel collection, cooking and cleaning) and empower them through alternative economic and social activities
MDG 4: Reduce child mortality
• Reduce indoor air pollution and associated respiratory diseases such as ARI
MDG 7: Ensure environmental sustainability
• Reduce pressure on local forests and biodiversity including in protected areas and national parks • Restore nutrients to soil • Reduce GHG emission

5.0 Potential for household biogas in Pakistan

5.1 Technical factors

Biogas potential is determined through a number of parameters. These are: availability of sufficient feeding materials such as dung and water, warm temperature, availability of construction materials, enough land (space) for plant installation, freedom from floods, and availability of human resources for plant construction.

The recently carried out Livestock Census 2006 shows that there are a total of 57 million cattle/buffaloes in Pakistan. The majority of this livestock population is confined to Punjab, Sindh, and NWFP provinces. It is estimated that these animals are kept by some 10 million households in the country.[9] In the Punjab where field research was carried out in the course of the study, the available buffaloes and cattle were found to be large animals, mostly stall fed and estimated to produce an average of 15- 20 kg of dung every day. Water is accessible through irrigation canals and tube wells in the agricultural regions of Punjab and Sindh. These are also the areas with the highest population of buffaloes and cattle. However, water is not easily accessible in arid parts of these provinces and some of the other provinces like Baluchistan are considerably drier. The temperature in Punjab and Sindh is high in the summer months (over 40 degree Celsius). In the winter the temperature can drop down to 2.0 degree Celsius in the northern parts of Punjab.

Construction materials are easily available in most areas of the country and the transportation network is well developed including in rural areas. Most of the farming households have enough

[9] Table 8 below shows that six million households have buffaloes and another 6.2 million households have cattle. However the total number of households with at least one head of cattle will be less than the sum of these two numbers since some households will have both cows and buffaloes.

land to install biogas plant and are safe from floods. Skilled and unskilled human resources are relatively expensive in Pakistan, compared to other countries in the region, but are easily available everywhere. While calculating the potential number of household biogas plants, households with a minimum of 2 adult cattle/buffaloes are considered as potential households. However, among the households that do possess sufficient cattle, about 30% households are estimated to be non-potential because of lack of a suitable location for biogas plant construction, ready access of natural gas in the region acing as a deterrent, low temperature in the winter months and lack of water.

Taking into account the above parameters, the study estimates that at least 5 million biogas plants can be installed in Pakistan based on cattle/buffalo dung. However, this number can be increased if horses, mules and poultry waste is included. The methodology for calculating biogas potential is presented in Table 7.

Table 7: Calculation of potential of household biogas plants based on cattle and buffaloes

Particulars	**No. of household**
Total households with cattle/buffalo	10 million
Households with only one cattle/buffalo	(2 million)
Households unsuitable for biogas since they are served by natural gas supply or likely to be, low temperature, insufficient water or land	(3 million)
Total biogas potential households	**5 million**

The regular 10-year Livestock Census reports show that the livestock population is showing a consistently increasing trend in Pakistan with buffaloes taking the lead among the large household animals in this growth, increasing two and a half times in thirty years between 1976 and 2006. This indicates that biogas has good and growing scope in Pakistan. Table -2, earlier in the paper, presents the growth in animals over four Livestock Census periods: 1976, 1986, 1996, and 2006.

Table 8 below shows the distribution of households by the numbers of buffaloes and cattle in each of the four provinces. If the tables for buffaloes and cattle were combined, it would show that in 2006, around 12.2 million households had at least one buffalo or cow. However, it will not be accurate to simply add the tables since this will lead to double counting of those households which have both cows and buffaloes. So the real numbers of households with at least one head of buffalo or cattle are likely to be slightly less than what the sum of the tables would give us.

Table 8: Number of families owning different numbers of buffaloes and cattle by province

	Buffaloes				
No of Animals	Pakistan	Punjab	Sindh	NWFP	Balochistan
1 to 2	2,545,011	1,764,091	403,117	364,943	12,860
3 to 4	1,654,487	1,147,979	354,020	141,101	11,387
5 to 10	1,426,594	927,633	407,125	75,973	15,863
11 to 20	293,562	177,468	100,140	11,075	4,879
> 20	76,608	44,464	25,890	4,504	1,750
Total families	5,996,262	4,061,635	1,290,292	597,596	46,739

	Cattle				
	Pakistan	Punjab	Sindh	NWFP	Balochistan
1 to 2	2,667,710	1,695,492	387,892	525,900	58,426
3 to 4	1,699,983	1,005,454	272,908	367,651	53,970
5 to 10	1,455,295	724,776	336,944	301,517	92,058
11 to 20	276,817	93,991	95,636	51,637	35,553
> 20	88,469	30,316	25,621	16,842	15,690
Total families	6,188,274	3,550,029	1,119,001	1,263,547	255,697
Total families	**12,184,536**	7,611,664	2,409,293	1,861,143	302,436

Source: Livestock Census 2006, Agriculture Census Organization, Statistics Division, Government of Pakistan

Table 9 reproduced from the 2006 Census lists numbers of households reporting both milch cows and buffaloes. This table demonstrates that a lower bound on the number of households in the country with at least one cow or buffalo is 8.4 million.

Table 9: Households reporting Milch Cows/Buffaloes

Animals	Pakistan	Punjab	Sindh	NWFP	Balochistan
1 to 2	5,145,807	3,205,548	809,337	1,012,194	118,728
3 to 4	1,879,195	1,134,211	414,750	270,093	60,141
5 to 10	1,163,329	631,857	361,361	116,885	53,226
11 to 20	174,154	84,723	60,958	18,554	9,919
> 20	57,207	27,190	18,252	7,750	4,015
Total households	**8,419,692**	**5,083,529**	**1,664,658**	**1,425,476**	**246,029**

Source: Livestock Census 2006, Agriculture Census Organization, Statistics Division, Government of Pakistan

Based on interviews it was determined that rural families usually cook meals 3 times a day and require 4-5 hours cooking gas a day, assuming a stove burning flow rate of around 400 litres of biogas per hour. This would imply the need for 40-50 kg of dung per day as input for biogas plants requiring 2-3 buffaloes or cows. Many of the biogas potential areas in Pakistan have access to electricity for lighting; however, biogas light is also in demand because of expensive electricity and frequent power cuts.

In addition to the potential for household plants, Pakistan has a large potential for larger biogas plants that can be used to meet the energy needs of larger farms and also as a convenient way to manage and even market manure. Energy needs of larger dairy farms that biogas can supply

include pasteurizing, cooking and heating up feed for animals in the winter, heating up water for cleaning, and production of electricity from biogas to substitute for grid power or for diesel fuel in generators. It is estimated that this commercial market might be as large as 100,000 biogas plants in Pakistan in the 30 to 100 m^3 size range. Table 8 shows that more than 230,000 households have sufficient cattle for these large sized plants, i.e. with more than 10 heads of buffaloes or cows.

5.2 Social factors

Biogas is likely to be socially accepted in Pakistan. Since most rural families make dung cakes with their bare hands, handling cattle dung and slurry should not be a problem. Indeed households with biogas plants expressed no difficulty using them. However, most people interviewed during the course of the study expressed strong reservations to connecting the household toilet to the biogas digester and thus a toilet connection is not recommended as a mandatory component of the program at least in the beginning.

There are two types of families with a potential for biogas: a) families with cattle, land and house, and b) families with cattle and house but no land. The individual domestic size plant fits the needs of the first group of farmers. Community biogas plants may be tried for the second group. It must be kept in mind, however, that there is little experience world wide of successful community-based biogas plants. There are some community size biogas plants currently running in Pakistan at present, but with mixed results. Despite the fact that community-owned biogas plants have management and operation challenges the world over, some of the Rural Support Programs and NGOs believe that among the communities they are working with there are relatively homogeneous communities with sufficient social capital where a management system can be put in place to manage community size biogas plants in those situations where individual households may not have sufficient cattle or land for household level biogas plants for each member. One model that is being promoted by the NGO Green Circle Organization is that of a community biogas plant built on the property of a landed farmer for households who do not have sufficient land. The participating households feed the dung into the community digester from their animals, for which they receive free gas. The slurry is available to the owner of the farm where the biogas plant is located. One fixed-dome 35 m^3 'Nepal design' biogas plants Model GGC 2047 was installed as a community owned and managed plant to share benefits among participating families by the Rural Support Programme-Network (RSPN) in partnership with the Foundation for Integrated Development Action (FIDA), in Dera Ismail Khan in May 2007. Both of these models remain experimental. It would be useful to evaluate how well these models are working and to see if there is potential for their replication.

5.3 Economic factors

Most households surveyed during the course of the study expressed an interest in installing biogas plants. Many policy makers and development professionals, however, expressed concern that biogas may not be a suitable technology for Pakistan as it had failed in the past. The major concern of the potential households is the cost. The cost of the commonly used floating drum design plant presently ranges from Rupees 30,000 (US$500) to 40,000 (US$ 700) for a 3 to 5 cubic meter (gas volume) plant. Many households surveyed expressed the view that if the costs were to come down to Rs 20,000 for a household size plant and credit were to be easily available, dairy farmers in Punjab, Sindh, and NWFP can afford biogas plants. However, before they invest in the plant, they would have to be assured of sufficient gas production and continuous plant operation. The yearly average annual income of households is Rs. 178,466 in urban areas whereas in rural areas the annual household income is Rs. 126,926. (SEBCON Baseline Survey of Livestock Sector- 2006). Dairy farmers were seen to be owning buffaloes costing between Rs 30,000 and Rs 50,000 each. Farmers in the visited communities in Punjab typically had 2-10 of such buffaloes. In the post-pilot

phase, it is quite likely that an investment subsidy may not be needed for large numbers of farmers to purchase biogas plants, particularly in the more wealthy provinces like Punjab.

Biogas seems potentially beneficial to households given the high cost of fuelwood and the pervasive burning of dung cakes. Households expressed that they need to burn firewood to light the dung cakes – so both fuels are needed to be used. As Table 10 shows, the average rural household cash expenditure for energy in Pakistan is Rs 622 per month. Of this around 45% is spent each month on firewood, animal dung, and agricultural residue and another 5% is spent on LPG and natural gas. In total, the average rural household in Pakistan is spending 50% of its fuel expenses or Rs 311 per month on cooking fuels. This number does not take into account the labour that women put into collection of firewood or making of dung cakes. We can use Rs 311 a month as a reference number to calculate the financial rate of return of biogas plants on cooking fuel substitution to the average rural Pakistani household. Similarly the expenditure on non-electricity lighting fuel which can also be substituted by biogas comes to Rs 40 per month. If we assume that with the biogas plant, the household would no longer have to purchase lighting or cooking fuels and assuming that a 6 m^3 plant costing Rs 23,000 (Annex I) will be the average size of biogas plant, we can calculate the financial IRR of the biogas plant on this basis to be 15%. It is assumed that biogas would not reduce expenditure on electricity.

Table 10: Breakdown of average monthly energy expenditure in rural Pakistan

Average monthly energy expenditure in rural Pakistan	**100%**	**Rs 622**
Firewood	32.1%	
Agricultural residue	7.1%	
Dung cakes	5.5%	
LPG	3.9%	
Natural gas	1.4%	
Total cooking fuels	**50.0%**	**Rs 311**
Kerosene	4.2%	
Candles	2.3%	
Total non-electricity lighting fuels	**6.5%**	**Rs 40**
Electricity and other accessories	**43.3%**	**Rs 270**

The analysis above shows that a domestic biogas plant can be an attractive financial investment for the average rural household in Pakistan based solely on current cash expenditure on fuels. These numbers are supported by the field survey carried out in the course of the survey. Rural households in a small sample in two communities in Punjab are reportedly purchasing firewood at anywhere from Rs 2.50 to Rs 5.00 per kg and those with insufficient cattle also purchase dung cakes at around Rs 1.00 per kg. The actual amounts of firewood and dung cakes purchased vary by household.

We can thus expect that the economic internal rates of return (EIRR) of an investment into household biogas would be much higher than this, once other non-cash benefits are also included. These benefits will likely include the following:

- Time saved by women and children in the collection of firewood and the making of dung cakes as well as time saved through faster cooking and cleaning. (assume 1.5 hours of savings per day at Rs 10 per hour).
- Health benefits to family members from reduced indoor smoke (assume Rs 400 per year).
- Benefits from increased productivity of land and reduced use of chemical fertilizers (for a 6 m^3 plant comes to 39 kg of Nitrogen, 19 kg of Phosphorous, and 39 kg of Potash – which comes to a value of Rs 4,094 for a 6 m^3 plant in Pakistan).

- Benefits to the global environment as a result of reduced greenhouse gas emissions (2.2 tons of CO_2 equivalents per year at $10 per ton).

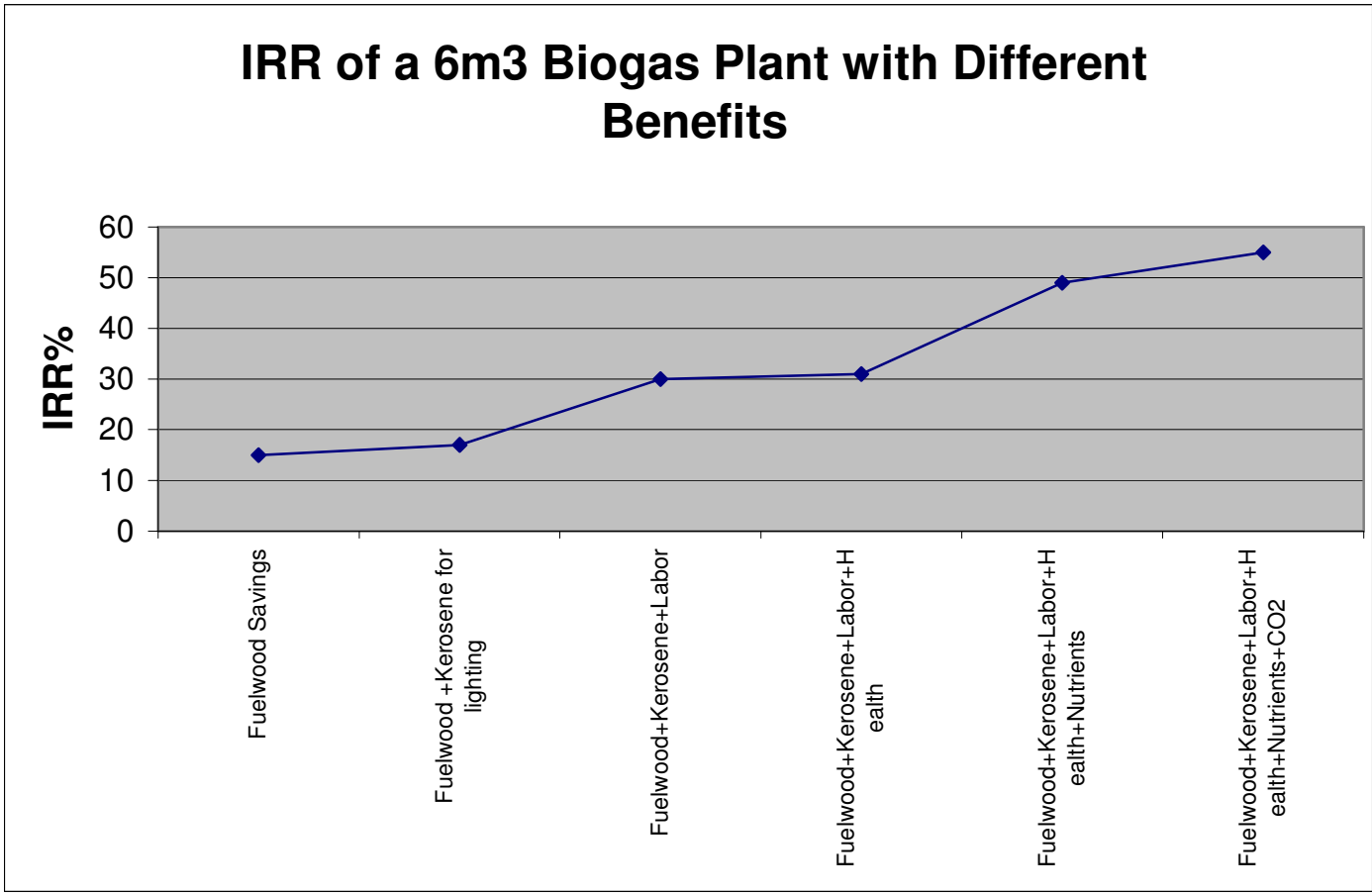
While these benefits may not be immediately available in the form of cash benefits to the household users of biogas, they can be captured by the individual biogas plant owner over time. These benefits can be transformed into financial benefits as income from alternative income generating activities using the saved time; health benefits translated from reduced expenditure on medicine and increased income from fewer sick days away from work; reduced expenditure on chemical fertilizer and increased productivity of agriculture; and finally from registering the project as a Clean Development Mechanism (CDM) project and by selling the accrued Certified Emission Reduction (CER) units or in the voluntary carbon market as a Verified Emission Reduction (VER).

Table 11 and Figure 2 below show how the IRR of a 6 m^3 biogas plant increases as the different benefits are added.

Table 11: Cumulative Internal Rates of Return from different benefits

Benefits	IRR (%)
Fuelwood Savings	15
Fuelwood +Kerosene for lighting	17
Fuelwood+Kerosene+Labor	30
Fuelwood+Kerosene+Labor+Health	31
Fuelwood+Kerosene+Labor+Health+Nutrients	49
Fuelwood+Kerosene+Labor+Health+Nutrients+CO2	55

Figure 2: IRR of a biogas plant



In addition to the benefits above, biogas plants provide additional benefits that are less easily quantified. On the social front, this includes reduced drudgery on the part of women and children in collecting firewood and making dung cakes. On the environmental front, we can include reduced pressure on forests and positive impact on maintaining them and preserving biodiversity.

Subsidy: The moderately attractive Financial IRR on a biogas plant investment even when only the avoided fuel costs are accounted for, and the much higher IRR once the other benefits are realized, would appear to argue that no subsidy is needed at the household level to promote biogas in Pakistan. It is clear that if the market were well developed and there were reliable suppliers of high quality biogas plants, there would be many households in rural areas of the country that could afford to have a biogas plant installed even without an investment subsidy. Nevertheless this study recommends that a modest subsidy of Rs 6,000 per plant be included in the programme, at least in the pilot phase. One important justification for the subsidy is that it is needed for the initial development of the market for biogas in Pakistan by making it attractive for private companies to participate in the programme. The subsidy program assures the companies that there will be demand for digesters. On the other hand, routing of the subsidy through the participating private companies allows the Project a lever to ensure quality control. Installation of high quality plants in turn ensure confidence in the product and result in the growth of the market.

Another justification for the subsidy is the fact that the Economic IRR from investment into a biogas plant is much higher than the FIRR that accrues immediately to the participating household. It is thus justifiable for the government or society at large to provide a subsidy to the purchaser of the biogas plant in lieu of the benefits that society receives from its construction. Finally, the subsidy can also be justified on account of the CERs/VERs that the biogas plant is likely to generate over its life. The carbon revenue from each plant can not be captured by each individual owner as the transaction costs would be too high. However, a national program can claim these credits in lieu of the subsidy provided to each user household for the construction of the biogas plant. We have assumed conservatively that each biogas plant might reduce 2.2 tons of CO_2 emissions each year. At a market rate of $10 per ton, this comes to $22 a year. The proposed $100 subsidy per plant would be the equivalent of 4.5 years of carbon revenue.

6.0 Proposed national biogas programme for Pakistan

Despite the very high potential and previous experience with the household biogas technology in Pakistan the number of biogas plants in the country is limited to around six thousand. The main barriers that have hindered development of larger scale adoption of biogas are the following:

a) lack of an organized approach to scale up;
b) poor performance of previous biogas initiatives in the country for a variety of reasons;
c) expectations of imminent access to piped natural gas which provides an extremely versatile and convenient source of energy at a very low price;
d) high upfront investment cost for biogas plants and limited availability of affordable credit;
e) lack of appreciation of full fertilizer value of bio-slurry.

It is proposed that these barriers can be overcome under a public-private partnership through a market-based approach. The proposed approach includes the following:

i) Involving public investments to reduce the cost of construction of plants, standardize the technology, provide a grant subsidy per built plant, and enforce quality control.
ii) Ensuring that private companies market a high quality, guaranteed product to consumers on competitive market principles.
iii) Availing micro-credit in order to increase affordability to users.
iv) Organizing households to increase access of the technology to poorer households.

This general approach has been found to work in a number of other countries in Asia (Nepal, Bangladesh, Vietnam and Cambodia). The feasibility study concludes this approach can be successfully adapted for use in Pakistan.

6.1 Overview of potential stakeholders

This section will list the currently identified stakeholders in a future national biogas program in Pakistan. However, this subject will be studied in significantly more detail while carrying out the formulation of the Implementation Plan. Such a study will also determine what the likely role will be of each of the key stakeholders. A future national biogas initiative in Pakistan can be expected to have two major components: a) on the supply side and b) on the demand side.

The supply side will mostly be concerned about the construction of tens and eventually hundreds of thousands of consistently high quality biogas plants. The major stakeholders in implementing such a program will be the following:

1. Government agencies involved in promotion of the biogas sector: The Alternative Energy Development Board (AEDB) was established by the Government of Pakistan in 2003 as an autonomous body with the aim of promoting and facilitating investments into renewable

energy technologies. AEDB can be expected to have a role in developing the Government of Pakistan policy on biogas and also in securing government support for a national program. The Pakistan Council of Renewable Energy Technologies (PCRET) has been assigned the responsibility of Research and Development, dissemination, training to promote renewable energy technologies in the country. The Council, which has offices in Islamabad as well as the four provincial capitals of the country, is actively promoting household biogas plants. PCRET can be expected to make valuable contributions on biogas technology development, training, and awareness creation in any future national program.

2. Private sector companies: Private national companies will carry out the actual construction of biogas for clients. These will be rural-based companies that specialize in the construction of biogas plants. The companies will also be expected to provide a warranty on their product as well as maintenance services. For a company to be financially viable, it is estimated that it would have to construct a minimum of 100 biogas plants per year and have a turnover of around US$30,000 per year. Larger companies might be 10 to 20 times this size. It is expected that there would initially be between ten and twenty biogas companies per province depending on the size of the local market. Some of these companies can also be NGOs, such as Koshis and Green Circle Organization, which are already building biogas plants on a commercial or semi-commercial basis.

3. Micro Finance Institutions. A number of MFIs will be identified to provide credit to households that wish to acquire biogas plants but can not pay for them in a single instalment. Funds can be made available to them at low interest rates to on-lend for household biogas.

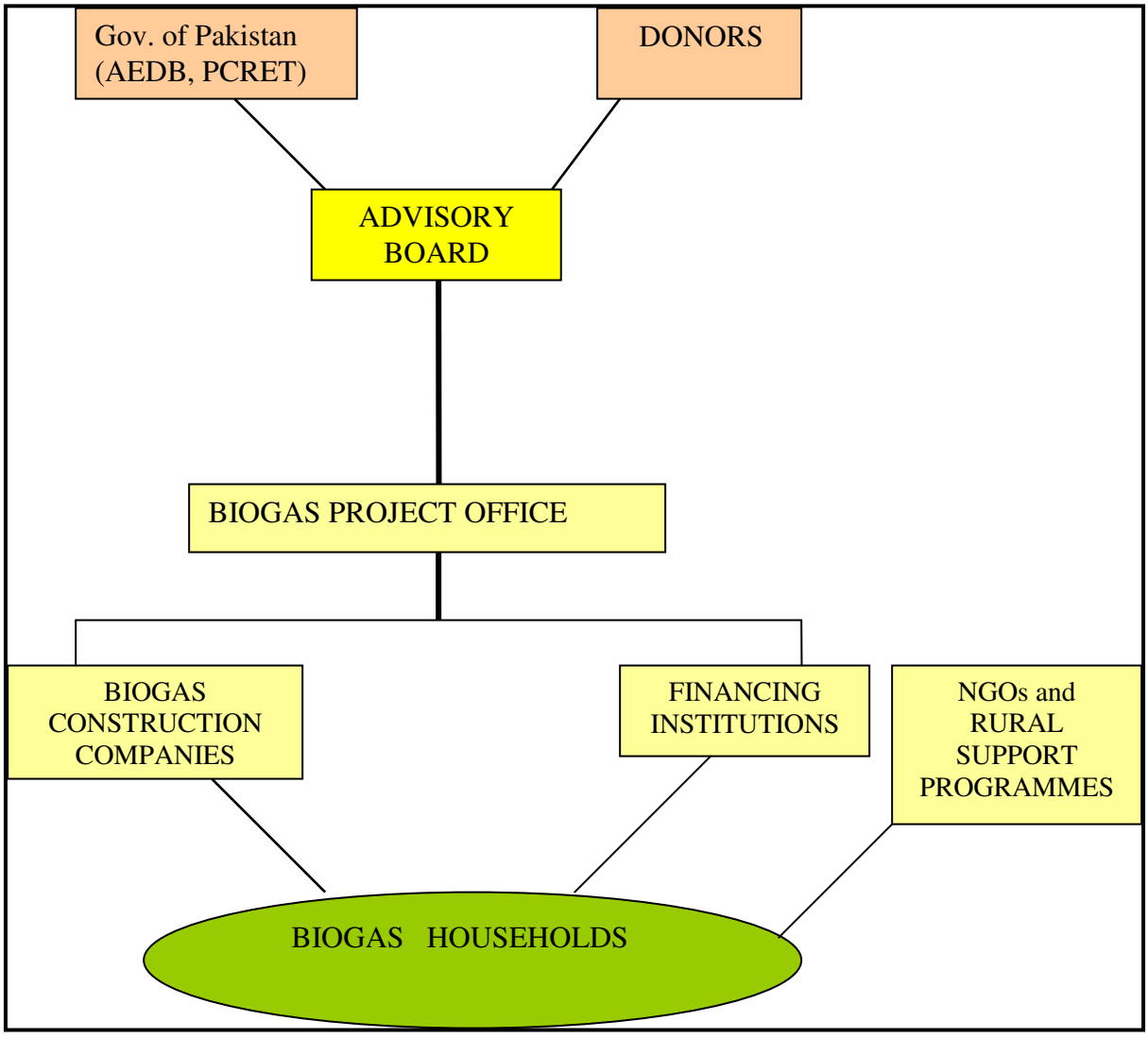
In addition to the stakeholders on the supply side, it is anticipated that there will be a number of partners in this initiative working on the demand side. These partners, primarily Rural Support Programmes and NGOs, will organize demand from prospective users. Such an aggregation of demand will serve the important function of making the biogas technology available and affordable to poorer households. A purely market-based mechanism without investment on the demand side will result in supply companies selling only to the more affluent rural households that can afford biogas plants. Demand side organizations will provide social mobilization and micro-finance either directly or through an MFI to support the purchase of biogas plants by households that would not be reached by market mechanisms alone. The biogas plants that get built with social mobilization inputs can be community biogas plants where a number of households will invest in one large biogas plant. They will share the tasks of feeding manure into the biogas plant and benefit jointly from the gas and bio-slurry that comes out. Given the challenges of management of community-owned and managed biogas plants, demand side organizations can also organize communities and encourage individual household biogas plants in the homes of all members through revolving funds and other mechanisms.

Key stakeholders on the demand side are likely to include:

1. Rural Support Programme Network and its member Rural Support Programs
2. Pakistan Poverty Alleviation Fund
3. Initiative for Rural and Sustainable Development (IRSD), Foundation for Integrated Development Action (FIDA), Green Circle Organization, Koshis, and other NGOs.

Figure 3 presents a proposed institutional setup to carry out the national biogas program. This is an initial and tentative proposal and will need confirmation in the next phase of the study – during the preparation of an Implementation Plan.

Fig 3: Proposed institutional setup



6.2 Outline of proposed pilot biogas programme

Programme name: National (Pilot) Biogas Programme
Duration: 4 years
Plant construction target: 30,000 household digesters
Locations: Initially in most suitable markets of Punjab; to be expanded to Sindh, NWFP, Balochistan, Northen areas and AJK as appropriate
Plant installers: Private companies, NGOs
Demand side Partners: Rural Support Programme Network, Rural Support Programmes, NGOs
Subsidy: 6,000 rupees (flat for all sizes)
Credit: through MFIs
Plant design: To be decided after assessment.

a. Household plants for households with sufficient cattle and land
b. Community plants for households who have sufficient cattle but can not invest in an individual plant.

Budget outline:

Particulars	No. of plants	Rs. per plant	Total in Rs	Total in US $
Subsidy	30,000	6,000	180,000,000	3,000,000
Programme cost	30,000	4,000	120,000,000	2,000,000
Farmers' contribution (20%)	25,000	4,600	115,000,000	1,916,667
Construction through cash (without loan)	5,000	23,000	115,000,000	1,916,667
Credit fund	25,000	12,400	310,000,000	5,166,667
Total	**30,000**		**825,000,000**	**14,000,000**

Financial mechanism:
Three alternative financial models are presented below for family owned plants and community managed plants.

a) **Individual household plant:** The subsidy will be provided to the user household through the construction company, which will deduct the subsidy amount and charge the remaining to the household. Credit will be made available to user households through micro finance institutions. The individual household is responsible to repay the loan.

b) **Community managed plant:** Credit and subsidy will be provided to the community organization for the installation of larger plants that share biogas between up to 15 households. In this case the subsidy level can be higher because it serves the smaller and poor farmers. Community (Village organization) is responsible to pay back the loan amount. Community plants would be considered under a research and development framework since a robust management model for them is yet to be demonstrated.

c) **Grant seed money as a revolving fund to the community**: This model is designed to support each household of a Community Organization to own her/his own biogas plant. NGOs or RSPs working with the CO will make available a conditional grant to the Community Organization with the condition that each household within the community must have a biogas plant within a certain period of time. The community will select the first lot of households for the first year and give loans to them out of the seed money to be repaid by the households within a year. The money will again revolve to the second batch of households the following year. In this way, once all households have

biogas plants, the seed money will be converted into a grant to the community which the community can use for plant maintenance or other activities. The community will be free to decide on the interest rate and can even make a partial grant to the poorest households in order to ensure that all households adopt the biogas technology. Twelve fixed-dome 'Nepal design' biogas plants Model GGC 2047 of 6m^3 were installed in *tehsil* Pasrur of by the Rural Support Programme-Network (RSPN) in partnership with the Punjab Rural Support Program (PRSP) using such a revolving fund. An evaluation of this mechanism will provide guidance on how it can be replicated on a larger scale.

6.3 Biogas technology

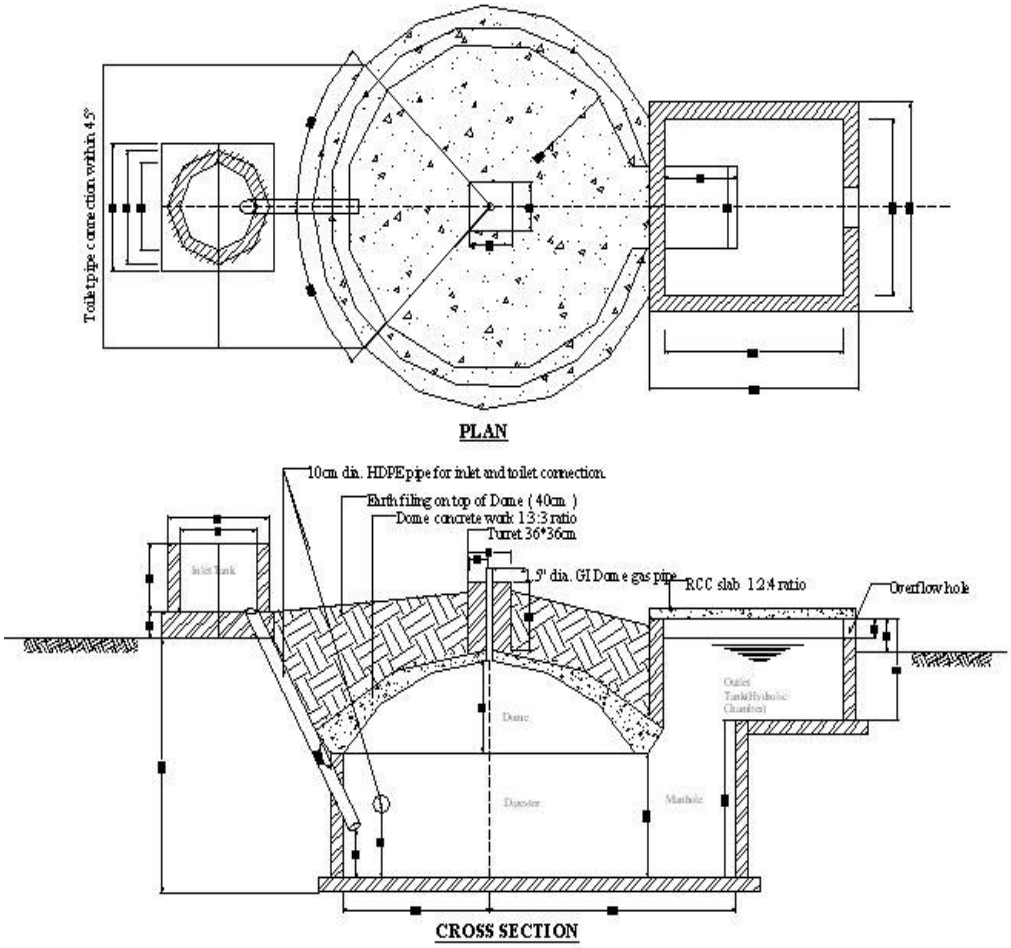
The biogas technology that is being used almost exclusively in Pakistan at present is the floating drum design. The biggest advantage of this design is that it is a very intuitive design and it is very easy to see when the digester is producing gas and working well. Its major disadvantage is that it needs a large steel drum to hold the gas and with the high international price of steel, this has become the single most expensive component of the biogas plant. Furthermore, since the drum corrodes and has to be replaced every 5-8 years, this adds a large running cost to the operation of biogas, typically equivalent of Rs 3,000 to Rs 5,000 per year.

The biogas technology that is popular outside Pakistan including in Nepal, India, and Bangladesh is the fixed dome design. The fixed dome design has no moving parts and no drum to replace. The biggest benefit of the fixed dome design - Fig 4 below shows the Nepal design of which over 160,000 units have been built – is its low cost and robustness. Our calculations show that a 6 m3 fixed dome plant would cost around Rs 23,000 in Pakistan[10] compared to around Rs 35,000 for a floating drum. Perhaps the largest advantage of a fixed dome design biogas plant is that it has no large running cost per year and can thus provide the user 'free' energy once the digester has been paid for. The challenge of the fixed dome design is that the dome has to be built to a high quality standard if gas is not to leak from it.

It is recommended that a technology assessment be carried out of both the currently used floating drum design and the fixed dome design biogas digesters before deciding on which technology will be recommended for adoption in the proposed pilot phase.

[10] This cost is based on the experience of constructing twelve 6 m3 fixed dome GGC 2047 plants in Tehsil Pasrur of Sialkot District, Punjab in May-June 2007.

Fig 4 – Fixed dome digester GGC 2047 'Nepal design'



7.0 Conclusions

- Pakistan has one of the largest unexploited biogas resources in the region. Based on the availability of livestock and suitable climatic conditions, this study concludes that there is a potential of over 5 million household biogas digesters in Pakistan.

- The main barriers to large-scale adoption of biogas have been: a) lack of an organized approach to scale up; b) poor performance of previous biogas initiatives in the country for a variety of reasons; c) expectations of imminent government extension of piped natural gas to different urban and rural areas; d) high upfront investment cost for biogas plants and limited availability of affordable credit; e) lack of appreciation of full fertilizer value of bio-slurry.

- Biogas technology can be attractive to Pakistani households just on the basis of financial returns resulting from avoided currently incurred costs for cooking and lighting fuels. The

IRR is substantially higher when other benefits of saved labour, improved health, increased agricultural productivity, and reduced greenhouse gases are included.

- Biogas is likely to be socially acceptable in Pakistan as making dung cakes to use as cooking fuel is a common practice among rural women. The added benefits of a toilet attachment to a biogas plant may be limited in Pakistan, at least initially, because of social reluctance.

- Credit mechanism is not well established in the country for biogas and other renewable energy technologies. A careful assessment is needed to identify suitable MFIs to participate in the programme.

- Private sector companies are not currently active in the biogas sector. A small number of NGOs are active in the construction of biogas plants but on a very small scale. Private companies need to be attracted to the sector and their capacity enhanced to build high quality biogas plants.

- In view of the large market, the energy needs, and availability of resources, it is feasible to implement a pilot phase to build around 30,000 household biogas digesters in Pakistan in four years. Further analysis is required to confirm the exact time period and size of this pilot project. Once this pilot phase can demonstrate that large numbers of high quality biogas plants can be built in Pakistan, a future phase can be launched on the same principles to build many more plants.

- This pilot phase may need to include a subsidy of Rs 6,000 per digester primarily as a marketing tool to motivate private installation companies to enter this market and to use as leverage to enforce quality control. Further studies and analysis are required to determine the need of this subsidy and the actual amount.

8.0 Recommendations

This study recommends that concrete steps be taken towards development of a national scale program to promote household biogas digesters through a market mechanism, keeping in view the excellent potential for this technology in Pakistan.

The next step will be to build upon this feasibility study to prepare a detailed Implementation Plan for executing such a program. The Implementation Plan will carry out detailed assessments and examine steps to be taken for executing a pilot phase to build 30,000 household biogas digesters in four years in Pakistan.

In the course of developing this Implementation Plan, the program team will carry out the following:

- technology assessment, including cost and performance, of both the floating drum design used currently in Pakistan and the fixed dome design biogas digester which is popular in China, Nepal and other Asian countries before deciding on the technology(ies) recommended for the pilot phase;
- survey of existing biogas plants based on representative sample, including functional and dysfunctional units;
- assessment of interest among private sector companies to participate in the construction of biogas digesters by involving them in the first two activities;

- organization and institutional assessment to understand and agree on the most effective institutional setup for the initiative;
- discussions with the Government of Pakistan and potential donors to solicit support for the pilot program.

It is proposed that the Implementation Plan be prepared by a program team consisting of representatives of Winrock International and SNV working closely with the Ministry of Environment, UNDP Pakistan, Rural Support Programme Network (RSPN), AEDB, and PCRET.

Time schedule

The Implementation Plan will be completed over a ten month period, tentatively from September 1st, 2007 to June 30th, 2008. The overall timeline for key activities is outlined in the table below.

Months	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Finalize study team, work plan & schedule	x																			
Survey of existing biogas plants		x	x	x	x															
Technology assessment of biogas plants				x	x	x	x													
Organizational and Institutional Assessment					x	x	x	x	x	x										
Draft / final reports										x	x	x								
Discussions with government of Pakistan and donors for support							x	x	x	x	x	x	x	x	x	x				
Signing of agreements to commence project														x	x	x	x	x	x	
Setting up pilot project																			x	x

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Annex- 1

Estimated cost of 6m^3 fixed dome biogas plant in Pakistan*

Items	Unit	Quantity	Unit Price	Total price
Bricks	piece	1000	3	3,000
Sand	bags	10	60	600
Aggregate	bags	15	35	525
Cement (50 kg)	Bag	13	250	3,250
Rod for slabs (10mm)	kg	16	40	640
Emulsion paint	litre	1	200	200
GI wire # 8	kg	0.5	50	25
Skilled labor	days	7	350	2,450
Unskilled labour	days	20	200	4,000
Vertical mixer device	piece	1	400	400
Inlet pipe (PVC 4")	m	4	90	360
Centre gas pipe(1.5")	m	1	350	350
1/2" GI pipe	m	12	90	1,080
Main gas valve	piece	1	200	200
Water drain	piece	1	150	150
Gas tap	piece	1	200	200
Gas stove	m	1	400	400
Fittting goods		LS	1,000	1,000
Company service and warranty charge	Rs	LS	4,000	4,000
Total cost of plant	**Rs**			**22,830**

* Plant size in m^3 refers to the volume of plant not the gas production.

Annex-2

List of persons contacted and participants in consultative meeting

1. Ms. Zehra Abbas, Manager Policy and Devolution, RSPN
2. Mrs. Helga Ahmed, IRSD
3. Dr. Parvez Akhter, Director General, PCRET
4. Mr. Hafiz Ali, Dungree Haria Madarsha, Sialkot
5. Mr. Arif Alauddin, ARR and Chief Energy & Environment Unit, UNDP
6. Mr. Arshad Baryar, Director, Koshis, Sialkot
7. Dr. Basharat Hasan Bashir, Member Board of Directors, Alternative Energy Development Board
8. Dr.Pervaiz Naeem, KfW, Islamabad
9. Mr Akhter, Manager PRSP Gujjaranwala
10. Mr. Cheema, Chairman, Village Organization, Gujarnwala
11. Mr. Allaha Dita, Salkot
12. Mr. Mahboob Elahi, Director General, Ministry of Environment
13. Mr. Majid ul Hassan, Director, PCRET
14. Mr. Syed Farrukh Hussain, SARI/E, USAID
15. Mr. Talib Kayani, DG National Hydropower, Alternative Energy Development Board
16. Mr. Sami-ul-Haq Khilji, Additional Secretary, Ministry of Environment
17. Mr. M. Abrar Malik, Technical Advisor, GTZ
18. Mr. Marc Mazairac, Head of the Department of Economic affairs, The Netherlands embassy, Islamabad
19. Mr. Rana Shafiq-ur-Rehman, Secretary General, Green Circle Organization
20. Ms. Shamsa, Green Circle Organization
21. Mr. Zaffar Pervez Sabri, General Manager, Pakistan Poverty Alleviation Fund
22. Mr. Zahid Shakeel, Sr. Management Executive, Pakistan Poverty Alleviation Fund
23. Mr. Tayyab, Shahzad, Sub Program Manager, NEAP-Support Programme, UNDP/Ministry of Environment

Annex 3

Tables from Pakistan Livestock Census 2006

TABLE 9. HOUSEHOLDS REPORTING AND NUMBER OF CATTLE BY SEX, AGE AND SIZE OF HERD

SIZE OF HERD	TOTAL CATTLE		CATTLE THREE YEARS & ABOVE			CALVES BELOW THREE YEARS				
							MALE		FEMALE	
	HOUSE-HOLDS REPORT-ING	NUMBER OF ANIMALS	TOTAL	MALE	FEMALE	TOTAL	BELOW ONE YEAR	1 YEAR TO BELOW 3	BELOW ONE YEAR	1 YEAR TO BELOW 3
1	2	3	4	5	6	7	8	9	10	11
PAKISTAN										
TOTAL	**6188265**	**29558812**	**19303444**	**4146859**	**15156583**	**10255367**	**3910700**	**1463317**	**3426117**	**1455238**
01 TO 02 ANIMALS	2667710	4405000	2824074	652791	2171288	1580920	644219	202208	524229	210259
03 TO 04 ANIMALS	1699983	5938722	3646050	666959	2978383	2292675	934211	282771	768228	307466
05 TO 06 ANIMALS	836347	4555829	2856094	577287	2278807	1699742	683046	201932	597741	217051
07 TO 10 ANIMALS	618948	5063011	3252010	671244	2580764	1811007	712019	219954	646170	232864
11 TO 15 ANIMALS	207073	2597817	1685685	317803	1367879	912126	344431	113149	325387	129202
16 TO 20 ANIMALS	69744	1234484	803088	143167	659916	431398	158557	55134	152004	65695
21 TO 30 ANIMALS	46100	1132365	755221	147833	607394	377128	134746	58297	123264	60814
31 TO 50 ANIMALS	23838	923390	648446	115530	532918	274943	95036	39741	88898	51263
51 ANIMALS AND ABOVE	18531	3708204	2832771	854255	1978510	875434	204440	290168	200203	180622
N.W.F.PROVINCE										
TOTAL	**1263547**	**5967886**	**3997984**	**959925**	**3038059**	**1969900**	**892224**	**200912**	**672957**	**203813**
01 TO 02 ANIMALS	525900	921123	566126	92335	473795	354996	184743	23987	122146	24123
03 TO 04 ANIMALS	367651	1291682	807730	153022	654700	483954	232440	39850	168006	43656
05 TO 06 ANIMALS	177532	968189	622987	141223	481763	345199	160083	31430	121268	32421
07 TO 10 ANIMALS	123985	1007946	661083	156620	504464	346864	148574	35312	122400	40579
11 TO 15 ANIMALS	39685	496289	328368	71903	256461	167927	68479	17879	58995	22570
16 TO 20 ANIMALS	11952	210450	140553	25831	114722	69902	27614	8614	23028	10647
21 TO 30 ANIMALS	7516	185385	127457	24982	102475	57924	21199	9464	17588	9668
31 TO 50 ANIMALS	6300	255058	193844	21501	172345	61210	24641	5718	21003	9852
51 ANIMALS AND ABOVE	3026	631766	549841	272511	277328	81927	24452	28651	18526	10296
PUNJAB PROVINCE										
TOTAL	**3550020**	**14412323**	**9036491**	**1660110**	**7376380**	**5375834**	**1905919**	**807974**	**1746460**	**915485**
01 TO 02 ANIMALS	1695492	2733198	1719852	366926	1352926	1013340	366622	149641	330069	167005
03 TO 04 ANIMALS	1005454	3477822	2068838	342229	1726609	1408983	524146	203299	454079	227459
05 TO 06 ANIMALS	446042	2419996	1456730	257894	1198839	963268	353356	135585	325427	148898
07 TO 10 ANIMALS	278734	2253712	1379105	236755	1142348	874611	311609	129021	295952	138028
11 TO 15 ANIMALS	73423	916016	565318	83720	481600	350695	122339	52213	115775	60362
16 TO 20 ANIMALS	20568	363317	231223	34647	196571	132095	43397	18634	44384	25675
21 TO 30 ANIMALS	14570	359700	231104	37908	193200	128590	45227	22021	39208	22132
31 TO 50 ANIMALS	7580	287657	192263	32666	159600	95394	31354	13097	29494	21452
51 ANIMALS AND ABOVE	8166	1600913	1192051	267367	924683	408859	107866	84453	112077	104461
SINDH PROVINCE										
TOTAL	**1119006**	**6925022**	**4668094**	**1012227**	**3655866**	**2256927**	**834577**	**382633**	**775777**	**263939**
01 TO 02 ANIMALS	387892	647500	465587	173650	291940	181915	76144	26839	61176	17751
03 TO 04 ANIMALS	272908	976211	635939	135783	500154	340275	146502	36045	125002	32729
05 TO 06 ANIMALS	168801	925450	610331	127934	482397	315121	131139	31362	122786	29836
07 TO 10 ANIMALS	168143	1401234	937139	196002	741138	464093	191907	45680	181491	45015
11 TO 15 ANIMALS	68102	856703	567154	98247	468908	289545	109311	32895	112175	35165
16 TO 20 ANIMALS	27534	488904	316233	50718	265513	172668	66163	19059	66025	21419
21 TO 30 ANIMALS	15711	381672	253172	39138	214037	128496	46266	16791	45913	19529
31 TO 50 ANIMALS	5680	216866	146944	20906	126037	69921	22488	11185	24358	11890
51 ANIMALS AND ABOVE	4230	1030482	735592	169850	565741	294890	44660	162775	36850	50609
BALOCHISTAN PROVINCE										
TOTAL	**255692**	**2253581**	**1600875**	**514597**	**1086278**	**652706**	**277980**	**71798**	**230923**	**72001**
01 TO 02 ANIMALS	58426	103179	72509	19880	52627	30669	16710	1741	10838	1380
03 TO 04 ANIMALS	53970	193007	133543	35925	96920	59463	31123	3577	21141	3622
05 TO 06 ANIMALS	43972	242194	166046	50236	115808	76154	38468	3555	28260	5896
07 TO 10 ANIMALS	48086	400119	274683	81867	192814	125439	59929	9941	46327	9242
11 TO 15 ANIMALS	25863	328809	224845	63933	160910	103959	44302	10162	38442	11105
16 TO 20 ANIMALS	9690	171813	115079	31971	83110	56733	21383	8827	18567	7954
21 TO 30 ANIMALS	8303	205608	143488	45805	97682	62118	22054	10021	20555	9485
31 TO 50 ANIMALS	4278	163809	115395	40457	74936	48418	16553	9741	14043	8059
51 ANIMALS AND ABOVE	3109	445043	355287	144527	210758	89758	27462	14289	32750	15256

TABLE 10. HOUSEHOLDS REPORTING AND NUMBER OF BUFFALOES BY SEX, AGE AND SIZE OF HERD

SIZE OF HERD	TOTAL BUFFALOES		BUFFALOES THREE YEARS & ABOVE			CALVES BELOW THREE YEARS				
							MALE		FEMALE	
	HOUSE-HOLDS REPORT-ING	NUMBER OF ANIMALS	TOTAL	MALE	FEMALE	TOTAL	BELOW ONE YEAR	1 YEAR TO BELOW 3	BELOW ONE YEAR	1 YEAR TO BELOW 3
1	2	3	4	5	6	7	8	9	10	11
PAKISTAN										
TOTAL	**5936480**	**27334985**	**16172503**	**609956**	**15562548**	**11162483**	**3747902**	**957815**	**4276456**	**2180310**
01 TO 02 ANIMALS	2545011	4292597	2510412	44623	2465785	1782189	601143	117792	711108	352150
03 TO 04 ANIMALS	1654487	5769943	3271711	73204	3198504	2498232	835778	199112	966518	496767
05 TO 06 ANIMALS	801119	4364262	2516910	81258	2435651	1847354	611598	152865	719384	363503
07 TO 10 ANIMALS	625475	5095767	2998087	129064	2869026	2097676	715767	183180	788220	410506
11 TO 15 ANIMALS	218159	2734046	1652708	90108	1562599	1081343	363266	100089	406204	211788
16 TO 20 ANIMALS	75403	1330594	822385	48961	773421	508212	173339	48392	189120	97363
21 TO 30 ANIMALS	44467	1081066	683097	42351	640749	397967	128511	38762	145521	85179
31 TO 50 ANIMALS	20144	764379	495415	25424	469991	268968	86150	27128	106533	49153
51 ANIMALS AND ABOVE	11997	1902321	1221782	74961	1146826	680539	232297	90497	243855	113886
N.W.F.PROVINCE										
TOTAL	**597604**	**1927495**	**1187226**	**97265**	**1089957**	**740267**	**312407**	**55928**	**293851**	**78083**
01 TO 02 ANIMALS	364943	622241	371936	16737	355196	250309	110180	16844	102237	21046
03 TO 04 ANIMALS	141101	489009	288655	23569	265084	200355	83487	14592	80740	21534
05 TO 06 ANIMALS	49905	270056	167222	20521	146700	102833	41783	8105	41298	11647
07 TO 10 ANIMALS	26068	209666	129686	15755	113933	79979	31236	6342	31663	10737
11 TO 15 ANIMALS	7488	93691	59412	7013	52402	34282	13433	3467	12584	4776
16 TO 20 ANIMALS	3587	65747	43232	4373	38858	22516	10185	1290	8807	2238
21 TO 30 ANIMALS	2495	62247	40699	3521	37379	21347	8152	2886	7322	2989
31 TO 50 ANIMALS	1234	48921	37586	1809	35778	11337	3848	945	4683	1858
51 ANIMALS AND ABOVE	775	65911	48602	3971	44632	17308	10106	1437	4516	1249
PUNJAB PROVINCE										
TOTAL	**4061637**	**17747474**	**10141653**	**245476**	**9896181**	**7605822**	**2429278**	**670042**	**2807359**	**1699136**
01 TO 02 ANIMALS	1764091	2960357	1689738	17648	1672086	1270620	413643	83385	485135	288459
03 TO 04 ANIMALS	1147979	3981132	2191455	31125	2160331	1789682	589578	144746	651677	403676
05 TO 06 ANIMALS	529413	2876960	1604000	33147	1570854	1272958	410808	107375	468738	286032
07 TO 10 ANIMALS	398220	3227782	1847577	54358	1793221	1380203	459201	120555	494106	306340
11 TO 15 ANIMALS	133462	1671967	984287	39149	945138	687678	226179	62798	245318	153387
16 TO 20 ANIMALS	44006	772594	468594	20585	448010	304003	97342	29520	107710	69428
21 TO 30 ANIMALS	27004	657225	408117	21126	386995	249105	75672	24934	86874	61627
31 TO 50 ANIMALS	11640	436829	262163	10759	251405	174667	56609	18070	64531	35453
51 ANIMALS AND ABOVE	5820	1162618	685718	17582	668137	476900	100241	78657	203269	94731
SINDH PROVINCE										
TOTAL	**1290299**	**7340162**	**4639628**	**246916**	**4392712**	**2700535**	**959252**	**224574**	**1126382**	**390331**
01 TO 02 ANIMALS	403117	687675	434942	9329	425612	252733	72956	17154	120484	42144
03 TO 04 ANIMALS	354020	1257578	765864	16842	749023	491713	155065	39021	226865	70760
05 TO 06 ANIMALS	213641	1172914	717830	24258	693571	455086	151507	36771	201863	64947
07 TO 10 ANIMALS	193484	1594901	981105	53737	927368	613793	216057	54675	252485	90577
11 TO 15 ANIMALS	73599	922649	581123	41137	539983	341526	117095	32920	140697	50817
16 TO 20 ANIMALS	26541	469981	297212	22325	274884	172768	62539	17212	69084	23933
21 TO 30 ANIMALS	14206	343156	222239	16743	205494	120918	42270	10398	48960	19292
31 TO 50 ANIMALS	6764	259608	182892	9765	173125	76716	24112	7276	34384	10947
51 ANIMALS AND ABOVE	4920	631706	456427	52775	403655	175281	117651	9149	31568	16911
BALOCHISTAN PROVINCE										
TOTAL	**46940**	**319854**	**203996**	**20299**	**183698**	**115859**	**46965**	**7271**	**48864**	**12760**
01 TO 02 ANIMALS	12860	22324	13796	909	12891	8527	4364	409	3252	501
03 TO 04 ANIMALS	11387	42224	25737	1668	24066	16482	7648	753	7236	797
05 TO 06 ANIMALS	8160	44332	27656	3332	24526	16477	7500	614	7485	877
07 TO 10 ANIMALS	7703	63418	39719	5214	34504	23701	9273	1608	9966	2852
11 TO 15 ANIMALS	3610	45739	27686	2809	25076	17855	6559	884	7605	2808
16 TO 20 ANIMALS	1269	22272	13347	1678	11669	8925	3273	370	3519	1764
21 TO 30 ANIMALS	762	18438	11842	961	10881	6597	2417	544	2365	1271
31 TO 50 ANIMALS	506	19021	12774	3091	9683	6248	1581	837	2935	895
51 ANIMALS AND ABOVE	482	42086	31035	633	30402	11050	4299	1254	4502	995