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WHITEPAPER

The Pakistan Private Energy Sector Project

BIOGAS:

An Overlooked Piece in the Renewables Puzzle in Pakistan

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ACKNOWLEDGEMENTS

To ensure that salient features from the biogas sector are reflected and that all research elements are robust and verified, external experts were brought on as consultants for this whitepaper. This whitepaper builds on their industry expertise and aligns with insights from multiple stakeholders from the biogas sector in Pakistan that took part in the, USAID funded and UNIDO implemented, Pakistan Private Sector Energy Project roundtable discussion, exploring barriers and opportunities for biogas proliferation in the country (the signatories can be found on page no 39).

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ACRONYMS

ARE	Alternative and Renewable Energy
AEDB	Alternative and Renewable Energy Development, Pakistan
BCCs	Biogas Construction Companies
BOT	Build, Operate and Transfer
CNG	Compressed Natural Gas
CAGR	Compound Annual Growth Rate
CBG	Compressed Biogas
CTBCM	Competitive Trading Bilateral Contract Market
DFIs	Development Finance Institutions
EJ	Energy equal to 10 18 joules
GoP	Government of Pakistan
GWh	Giga-Watt hour
KWh	Kilo-Watt hour
m3	Cubic Meters
MNRE	Ministry of New and Renewable Energy, India
MSW	Municipal Solid Waste
MW	Mega-watts
NARC	National Agriculture and Research Council
NUST	National University of Science and Technology
RSPN	Rural Support Programmes Network
PCRET	Pakistan Council of Renewable Energy Technologies
PARC	Pakistan Agricultural Research Council
PPIB	Private Power and Infrastructure Board, Pakistan
PPP	Public Private Partnership
PPSE	Pakistan Private Sector Energy Project
SBP	State Bank of Pakistan
SNGPL	Sui Northern Gas Pipelines Limited
SSGC	Sui Southern Gas Pipelines Limited
TOE	Tones of oil equivalent
TA	Technical Assistance
UAF	University of Agriculture, Faisalabad
WBA	World Bioenergy Association

EXECUTIVE SUMMARY

Pakistan's economy is suffering due to a severe energy crisis with heavy reliance on imported fossil fuels coupled with inadequate transmission and distribution infrastructure. It has become pertinent to explore indigenous forms of energy resources e.g. Solar, Wind, Biomass that can provide clean, affordable and reliable energy to meet the country's energy demands. The transition towards cleaner forms of fuels for electricity and thermal energy generation could lead the country towards sustainable economic growth while meeting its SDGs and NDC targets. Among various abundant alternative and renewable energy resources available in the country, waste to energy (biogas) is the missing link in the renewable energy landscape of Pakistan. However, the tremendous potential of the biogas sector in meeting the energy needs of the country is yet to be fully realized.

In this context, USAID funded Pakistan Private Sector Energy Project and implemented by UNIDO, conducted a multi-stakeholder discussion on biogas's untapped potential in Pakistan. The objective was to develop an in-depth understanding of the market potential/prospects in the biogas sector and underline the key barriers/challenges which needs to be addressed through various interventions that could in turn support the uptake of commercial scale biogas plants in Pakistan. The purpose of this whitepaper is to gather insights from the discussion and further research barriers and opportunities for key players in a concise and consolidated manner. Market intelligence is part of PPSE's mandate and this whitepaper on biogas encapsulates key takeaways from the discussion to be shared and utilized by a wider audience, particularly, for policy makers and private sector companies looking to leverage biogas technology for cleaner energy generation.

Moreover, based on the key findings from the stakeholder's discussion, the paper provides recommendations in the form of interventions supported by case studies that could promote investment in commercial scale biogas technologies in Pakistan and support overall development of the biogas sector in the country. Pakistan is an agro-based country with considerable untapped biogas potential through various forms of available raw material including agri waste, manure from livestock, poultry waste, kitchen waste and municipal solid and liquid waste. All these could be utilized optimally as feedstock to produce around 12–16 million m3/day of biogas that could be used for electricity and heat generation and other forms of bio-fuels and bio-fertilizers. Despite the potential, the biogas industry in Pakistan is facing various challenges such as; lack of regulatory and institutional support, limited access to finance, lack of technical skills and required infrastructure, underdeveloped market and value chains, capacity gaps and socio cultural and environmental issues.

The paper highlights the potential opportunities that exist in Pakistan's biogas sector as well. For instance, the SMEs associated with diary, poultry and farming products possess readily available feedstock to be utilized for captive generation of biogas that could substitute expensive and "dirty" diesel and would help meet inhouse electricity and gas needs. Similarly, at farm levels, biomass residues and cow manure could be used as raw material for biomass based decentralized electricity generation to power the off-grid communities, storage facilities and tube wells. In order to tap these lucrative opportunities following interventions are required at Macro, Meso and Micro Level:

MACRO LEVEL

- Create an enabling environment for the private sector through developing and implementing an integrated
- Action Plan for uptake of Biogas Sector;
  Provide fiscal incentives i.e. tax rebates/subsidies for development of commercial scale biogas plants
- Determine biogas potential through carrying out sectoral analysis such as for Diary,Poultry, Sugarcane and hospitality sectors;
- Develop/Specify technical specifications and standardized procedures for setting up commercial scale biogas plants;
- Develop/Specify tariff setting mechanism for commercial scale biogas Plants for both electricity and gas generation;
- Develop biogas feedstock management and pricing mechanism;
- Develop quality and performance standards for Low carbon waste to energy conversion technologies;
  Harmonization of institutional process for RE (biogas) based distributed generation projects;
- Develop sustainable financing and business models for commercial scale biogasprojects; develop instruments to de-risk the investments in biogas projects;
- Ensure gender mainstreaming in biogas sector and associated value chains.

MESO LEVEL

- Promote localization of waste to energy technologies (including anerobic digestion,pyrolysis, gasification);
- Strengthening local capacities of key stakeholders on feasibility, design, installation,operations and maintenance of large-scale biogas plants;
- R&D collaboration of Local and International universities on Biogas research
  projects;
- Capacity enhancement of engineers and technicians with support of academia and vocational/technical training Institutions on biogas related technologies.

MICRO LEVEL

- Demonstrating technical and financial viability of commercial scale biogas projects by piloting of medium to large scale bio-methanation plants for electricity and gas generation to be implemented in PPP or BOT mode;
- Biogas Supply chain Management through establishing biogas feedstock collection centers;
- Establish data collection and monitoring mechanisms to support the R&D activities;
- Establish Biogas lab testing facilities in different cities;
- Promotion and awareness raising of local masses and dissemination of success stories

PROBLEM STATEMENT & OBJECTIVE

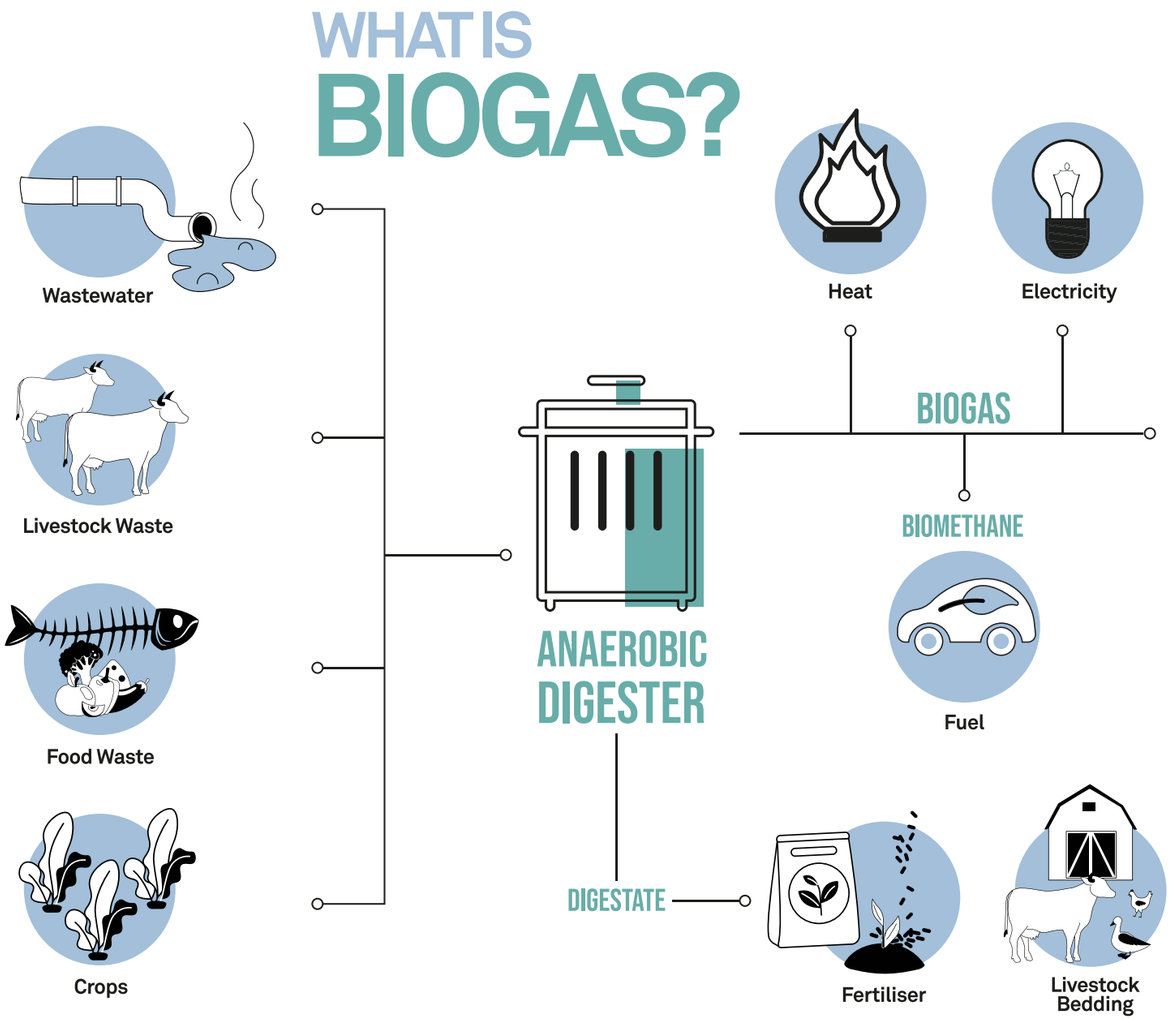
To help address the critical issue of energy supply and work towards a greater level of energy independence, the Alternative Energy Development Board (AEDB) of Pakistan has been charged with the promotion and development of renewable energy. The focus of the Government of Pakistan's long termclimate actions are informed by current climate-induced vulnerabilities: Pakistan ranks 5th most vulnerable on the global index. Thus, the Government is setting ambitious targets to enhance Pakistan's resilience and decarbonize the economy, such as the cumulative conditional target of overall 50% reduction of its projected emissions by 2030, partly by shifting to 30% renewable energy and completely ban imported coal.

While solar, wind and hydro power have been heavily promoted to help reach these targets, bioenergy –including biogas, despite Pakistan's abundant supply of feedstock, has to date been largely left to the sidelines. Yet, out of all renewable resources, bioenergy is considered one of the most easily accessible with its unique environmentally friendly nature, constant supply, wide availability, and ease of integration into existing infrastructure. Despite the presence of an abundance of biogas energy resources, there is still a need for work on the use of these sources to produce energy at scale. *This whitepaper delves deeper in to why biogas's proliferation in Pakistan has been hampered and explores potential and solutions via recommendations from stakeholders and market case studies from home and abroad.*

In particular, we explore the potential within the private sector comprised of a diverse ecosystem ofSMEs and large corporations that have a unique opportunity to leverage biogas as both, a form of renewable energy to sustainably power operations but also produce biogas as an end product to other companies and households across the country. The objective of this whitepaper is to serve as market intelligence and a knowledge product for various private and public sector players in the biogas sector who can leverage insights, case studies and recommendations.

There is a dearth of research on biogas in the country which is one of the barriers to the sector'sunderstanding and scaling.This served as an impetus to consolidate key takeaways from PPSE's multi-stakeholder discussion on biogas, desk research and case studies. PPSE is not publishing this whitepaper as an exhaustive paper but from the private sector market insights lens and scope we have adopted. While this whitepaper is intended for individuals somewhat familiar with biogas, one of the objectives is to entice more interest in to the sector from novices or laypeople. This is why it is first imperative to understand what biogas is.

In simple terms, and as illustrated by the graphic, biogas is a renewable energy source comprised of a mixture of gases, primarily consisting of methane, carbon dioxide and hydrogen sulphide, produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste and food waste. Biogas is methane-rich fuel potentially produced by manure, agricultural waste or aquatic weeds. The production process is carried out by fermentation of biodegradable material in absence of oxygen (anaerobic process). The gas thus produced accumulates in an airtight chamber (a biogas plant or biogas digester) specifically designed to serve as biogas reservoir. Biogas burns with an odorless, soot less and intense flame with appreciable thermal efficiency. This gas can be scrubbed (upgraded) to biomethane and compressed for injection into gas supply networks, for use as transport fuel or for driving turbines to produce electricity; at the household level biogas can also be used as a cooking fuel. Production is possible from a wide range of organic substrates including livestock waste, waste water, food waste, crop residue, waste vegetation etc. The bio-digestion process leads additionally to the production of organic fertilizer (digestate – both liquid and solid forms) as well as thermal energy which can often be used for industrial processing.



Biogas is therefore seen as a circular zero waste to energy technology (W2E) which produces multiple revenue streams while mitigating CO2 emissions and addressing the critical issues of waste treatment and sustainable energy production.

GLOBAL SCENARIO AND MARKET TRENDS IN BIOGAS SECTOR

In recent years, the demand for bio-methane as cleaner fuel has increased drastically predominantly, due to rising concerns over the GHG emissions from fossil fuel-based energy generation. As per WBA, in 2018 around 59.3 billion m3 of biogas was produced globally, equivalent to 1.3 EJ. During the period 2000-2018 the biogas sector experienced an annual growth rate of 9%. Currently, global biogas market size stands around USD 25 billion (2021) in monetary terms and is expected to grow further to USD 37 billion by 2028 at a CAGR of 5.4%.

Growing focus to achieve diversity in the energy portfolio, rapid transition towards clean energy resources, effective waste management practices, circular economy approaches and rising energy demand are the key drivers for growth of the global biogas industry. As per WBA's statistics, Europe is a market leader in production of biogas. In 2018, it produced around 30.9 billion m3 of biogas which accounted for more than half of the total world's biogas production, with Asia coming second with a share of 32%. Europe, Germany, Spain, Italy, and Sweden are key countries for bio-based energy. Germany is the major producer across the globe with around 10,000 commercial scale biogas plants operating. In Asia, India installed around 50.28 lakh family size/small scale biogas plants under various programs supported by the government. Moreover, under MNRE's National Policy on Biofuels, India aims to reduce the amount of crude oil imported by India by 10% in 2022 through increased use of ethanol, biodiesel, and Compressed Biogas (CBG). To promote CBG, the Sustainable Alternative Towards Affordable Transportation Program supports development of 5,000 CBG plants with an expected production capacity of 15 million tons of CBG annually by 2023.

BIOGAS POTENTIAL AND OVERVIEW OF THE BIOGAS MARKET IN PAKISTAN

Oil and Gas are the predominant energy sources used in meeting Pakistan's commercial energy needs. About 85% of oil needs are through imports as well as Liquefied Petroleum Gas (LPG) and imported coal. The total primary energy commercial supplies of Pakistan are around 80.62 million tons of oil equivalent (TOE) while final energy consumption was recorded as 52.17 million TOE as of 2020. A per the economic survey, the country spent around USD 17.03 billion on the import of fossil fuels in FY 2021- 22. Contrary to this, the country has set an aggressive target to diversify its total electricity generation mix with increasing the share of renewables up to 30% by 2030. In order to diversify its energy mix and to enable the clean energy transition, the country has to fully tap potential of various indigenous renewable resources for energy such as Biogas.

Being the 4th largest milk producing country in world, Pakistan is the home to around 196 million livestock comprising of buffalos, cow, sheep, goats and camels that generate around 417.3 million tons (2018) of manure every year. The optimal utilization of manure as raw material for biogas could produce around 26,871.35 million m3/year of biogas-with a production potential of 492.6 petajoules (PJ) of heat energy and 5521.5 MW of electricity.
Another sub-sector with great potential of biogas production is from Municipal Solid Waste (MSW); MSW in Pakistan is rich in organic components (up to 64%) and has a biogas yield of 97 – 114 m3 / ton. Major cities (like Karachi, Lahore, Islamabad, Peshawar, Faisalabad, Multan, Quetta, Gujranwala, Rawalpindi) produce a total quantity of 24,131 tones day of MSW, out of which 5,631 tones/day is the organic component; this means that MSW has a potential of biogas about 0.56 million m3/day (205 million m3/year) and 449 MW of electricity. It is estimated that currently waste management companies in Pakistan dump 27,861 tonnes/day of MSW in landfills but produce only 1.234 million m3/year of biogas.
Beside this, rural areas of Pakistan are replete with a variety of biogas resources (animal dung waste, MSW, Agri-industrial, and agricultural waste), which can be used to produce about 12 million m3 of biogas per day, which is enough to fulfil energy requirements of 28 million rural people.

The utility of Biodigester technology has been considered over recent decades in Pakistan and most parts of Pakistan have favorable conditions for it. The country's livestock population are found mostly in Punjab, Sindh, and KP and it's estimated that 10 million households are involved in raising livestock. In most parts of Punjab and Sindh, the temperature is favorable for the production of biogas and construction materials for biogas digestor are easily available. Moreover, the land for installing biogas plants is not a problem for most farmers in Pakistan. Only 30% farmers do not have favorable conditions for installing biodigesters due to the non-availability of land or harsh temperature conditions. Pakistan has the capacity of 5 million biodigesters that can be installed in different farming areas.

Currently, Pakistan possesses approximately 5,357 operational biogas units, with a varying production capacity of 3–15 m3/day. However, the targeted total biogas potential is 12–16 million m3/day. In Pakistan, the installment of biogas plants started in 1974 when the government focused on the development of biodigester technology and the then Pakistan Council for Appropriate Technology (PCAT) constructed 31 fixed dome digesters in different areas of Pakistan. Since then, 4,137 plants were installed until 1987 with government support. After which growth rate of this biodigestor technology dropped drastically and only 6,000 biogas plants were installed till the end of 2006. Later in 2009, RSPN launched Pakistan Domestic Biogas Programme (PDBP) with financial assistance from SNV Netherland. The program envisaged installation of 300,000 biogas small scale biogas plants across Pakistan. However, out of which only 5,360 biogas plants small scale (up to 25m3) have been constructed till 2014 in 12 districts across Punjab. Moreover, under the research development component of the project, 6 biogas plants of 50 m3 and 10 plants of 100 m3 were installed for electricity generation. Due to lack of reporting and monitoring, it is difficult to gauge whether these projects were sustainable or are functional today.

Under the PDBP, 450 masons were also trained and 50 Biogas Construction Companies (BCCs) were registered, out of which 28 BCCs are working efficiently after the phase-out of PDBP. Similarly, PCRET initiated a project for the installation of 1,200 family-size biogas plants on public -private cost–sharing basis. In view of prompt and positive response of the people the project ended by installing 35% additional biogas plants than the target originally set forth in PC-1. (Actual 1,604 units installed against target of 1,200 units) up till June 2006.Encouraged by positive public response, PCRET launched another project for installation of 2,500 biogas plants in 2007 with a subsidy component of PKR 17000/- per plant.

Despite various financial constraints, about 2,500 biogas units were installed successfully. PCRET is also exploring ways and means of using biogas for lighting as well as irrigation purposes. Keeping this aspect in view, PCRET came forward to make possible the usage of biogas in generating power for lighting, refrigeration, electric fans, mobile charging, running washing machine and iron for pressing clothes etc. For this purpose, relatively a bigger size biogas plants (10, 15, 20, 50, 100, 200, 500M3) gas production capacity per day have been designed and installed by PCRET in Sialkot, Narowal, Jhang and other places. As per field reports, the success rate of such plants is very high. Nevertheless, the overall biogas used to produce electricity in Pakistan on a small to medium scale is still low and to our knowledge and scope, only 92 biogas plants are operational generating around 790 KW of electricity. Significant potential is unexplored to install biogas plants for electricity production in Pakistan.

KEY CHALLENGES: COMMERCIAL SCALEUP OF BIOGAS IN PAKISTAN

Though various local and international case studies are testament to biogas's value and potential for Pakistan, the Small and Medium Enterprises (SMEs) in Pakistan is still facing several insurmountable challenges for widescale adoption of waste to energy (biogas) technologies in Pakistan. These critical challenges in the biogas sector are related to lack of regulatory and Institutional support, weak supply chain, price volatility, lacking logistical support and infrastructure, technological barriers, access to finance and capacity gaps. These challenges are acutely faced by biogas SMEs as they tend to have lesser resources than their large corporate and multinational counterparts. However, biogas, as both an energy source for production and as an end-product, is uniquely suited for SMEs linked with the dairy, poultry and agriculture sectors. Following the discussion with biogas stakeholders, the paper highlights major challenges in detail below:

LACK OF REGULATORY AND INSTITUTIONAL SUPPORT

Successful development and adoption of Alternative & Renewable Energy sources all over the world is dependent on promotional policies, enabling regulatory framework and access to commercial finance. The GoP had taken various initiatives but a holistic and integrated approach was not followed to promote the uptake of commercial scale deployment of biogas technologies. The new ARE Policy 2019 provides provisions to support the uptake of Alternative Renewable Energy technologies such as waste to energy and biogas in Pakistan. Although the policy provides clear targets for achieving the 20% and 30% share of renewable in total generation by 2025 and 2030. However, an integrated action plan to achieve these targets through various renewable energy sources such as waste to energy, biogas still lacking. For instance, the base case scenario of Integrated Generation Capacity Expansion Plan (IGCEP) 2021 does not include any commercial scale biogas plants to be included in the generation mix by 2030.

Due to limited institutional capacities and lack of nodal agencies, there does not exist any codes or standardized procedures for design, installation, operations and maintenance of commercial scale biogas facilities. The local minimum performance and quality control standards for the biogas plants are virtually non-existent. In addition to this, the tariff setting mechanisms for waste to energy projects in particular, biogas plants for electricity and gas generation are not developed as yet. Furthermore, no efforts have been made at the national level to determine the overall potential of biogas generation from various resources such as dairy, poultry, agriculture and municipal solid and liquid waste. The biogas feedstock pricing and management mechanism for developing a sustainable and regulated supply chain for biogas is not in place, which is one of the major impediments in widescale development of commercial scale biogas plants.

Currently there is not any policy for utilization of biogas/bio-CNG as alternative fuel for transport and the industrial sector. While on the contrary, our neighbouring country India has gradually developed policies and taken concrete measures to promote the commercial scale development of biogas plants and the biogas market. The relative flourishing of biogas in India compared to Pakistan, given as a similar cultural context, indicates that India has developed its own biogas regulatory framework taking into consideration local requirements and global insights. The following highlights illustrate some of the common and differentiated features adopted by the neighboring country and that have relevance for Pakistan. However, it should be noted that currently, the total biogas production in India is 2.07 billion m3/year. This is quite low compared to its potential, which is estimated to be in the range of 29–48 billion m3/year, but its relative production is still higher than Pakistan owing in large part to government schemes and initiatives.

The Indian Government has also launched several biogas schemes that have helped biogas entrepreneurs emerge in the sector, such as the National Biogas and Manure Management Programme (NBMMP), under which about 10 million family sized plants have been installed. The BPGTP Scheme is being implemented by the Agriculture and Rural Development Departments of the States and Dairy Cooperatives. The programme provides subsidies linked to the power generation capacity of biogas plants.

The New National Biogas and Organic Manure Programme (NNBOMP), for Biogas Plants size ranging from 1 m3 cu.m. to 25 m3 cu.m. per day. This is another subsidy led programme initiated by the e Indian gGovernment, which provides initiated a provision of a 50% subsidy for household level biogas plants plus an additional incentive of USD 20 if the plants are based on cattle manure and linked to a sanitary toilet in the household.
Eight Biogas Development and Training Centres (BDTCs) have also been established across India that are providing technical expertise, and trainings, field inspection capability and information & publicity assistance to the State Rural Development Departments / State Nodal Agencies for biogas development and awareness.

This whitepaper has drawn from regulatory framework from India facilitating the uptake of biogas through desk research and from PFAN Global experts based in India. Even a cursory look at India's proactive biogas regulations and provision of incentives shows the efficacy of government-led initiatives in can support helping an underserved renewables industry such as biogas, helping it become more technically specialized and better positioned for scale up.

The following table is a policy and incentives comparison between India and Pakistan:

TYPE OF INCENTIVE

TYPE OF INCENTIVE	INDIA	PAKISTAN
INSTITUTIONAL PROCESS	CLEAR	NOT CLEAR
RESOURCE AVAILABILITY-MONITORING PROCESS	YES	MACRO ASSESSMENT JUST COMPLETED
TECHNOLOGY DEVELOPMENT	YES	NO
CLEAR TARGET FOR DIFFERENT TECHNOLOGIES	YES	ONLY FOR BAGASSE COGEN
MONITORING SYSTEM	YES	NO
REGULATORY POLICIES		
REGULATORY INSTITUTION	STRONG	YES
REGULATORY PROCESS	STRONG	WEAK
POWER PURCHASE AGREEMENT	YES	YES
FEED-IN-TARIFF/ PREMIUM PAYMENT	REGULATORY PROCESS	ONLY FOR SOLAR
ELECTRIC UTILITY QUOTA OBLIGATION/RPS	YES	NO
NET METERING	YES	YES
TRADABLE REC/GREEN CERTIFICATE	YES	NO
MONETARY & FISCAL		
ACCELERATED DEPRECIATION TAX BENEFIT	YES	YES
FISCAL INCENTIVES AND PUBLIC FINANCING	YES	YES
CAPITAL SUBSIDY OR REBATE	LOW	NO
INVESTMENT OR PRODUCTION TAX CREDITS	YES	

LIMITED ACCESS TO FINANCE

Lack of bankable projects coupled with limited financing for SMEs is one of the major obstacles for the scaling up of biogas production. SMEs consider installing biogas technology as an added cost, not realizing the immense environmental, economic and social potential of biogas. In addition to this, biogas projects are considered to require higher upfront costs and often longer paybacks, compared with similar Renewable Energy (RE) projects on Solar PV and Wind. Due to lack of any information repository in Pakistan to justify higher investment via independently verified and bankable case studies of commercial scale biogas plants, SMEs don't usually see the value incorporating biogas in their business model. This is why this whitepaper will be delving in to case studies in the upcoming section.

Although concessional financing from the State Bank of Pakistan is available for RE projects but in absence of due diligence mechanisms and the lack of expertise of financial institutions to perform financial appraisals for waste to energy projects, the banking sector is unable to develop specific financial/credit products for biogas projects. Moreover, local biogas solution providers do not provide any performance guarantees that could boost investor confidence on biogas technology and minimize project risk. On the contrary, project based financing is usually limited to organizations with long credit history and most of the industrial enterprises in Pakistan are SMEs with low credit worthiness. In the absence of risk coverage for SMEs, their financing hardly has significant presence on financial institutions balance sheet. As a result, financial Institutions front load their products with risk premium for SME finance, resulting in frequent reluctance of SMEs to take on loans for biogas projects.

In order to improve access to finance for women entrepreneurs in underserved areas of the country, 'Refinance and Credit Guarantee Scheme for Women Entrepreneurs in Underserved Areas' has been offered by SBP under which financing at a subsidized rate (up to 5 percent) along with risk coverage is available for setting up of new businesses or expansion of existing ones. Smaller developers, such as women, suffer from lack of collateral and adequate financing skill sets in building and developing financial models and communicating with banks. Women need support for development of the project proposal, business plan and implementation strategy to the financial support for having a biogas plant.

LACK OF TECHNICAL SKILLS AND INFRASTRUCTURE

One of the crucial technical barrier is weak infrastructure and an unreliable supply of the required feedstock due to lack of appropriate waste collection, segregation, allocation and storage mechanism for biogas..

These are major hinderances in the realization of the commercial scale biogas projects. Moreover, there is no biogas testing and analysis infrastructure available to perform feedstock analysis and various stability tests of digester substrate that could address major challenges related to scientific waste management, through bio-methanation route in Pakistan. Besides these, limited infrastructure is available for CH4 delivery and distribution and third-party access to local gas distribution network is not allowed under the current regime. Optimized operations and maintenance are critical to get constant yields from biogas plants especially at commercial scale. However, due to lack of technical know-how most the operators and farmers are not always aware of the fragility of handling biomass and waste

Another technical barrier is the limited availability of localized commercial scale biogas solutions and technologies in market. To our knowledge, there are very few companies in the local market providing biogas solutions. Most of them are at a nascent stage and lack technical expertise and resources for development of large-scale biogas projects. SMEs are key actors to play their role for technology indigenization, adoption and upscaling to meet their energy needs through optimal utilization of biogas. Unfortunately, SMEs in Pakistan have overlooked application of biogas technologies, an essential segment of RE generation and circular economy.

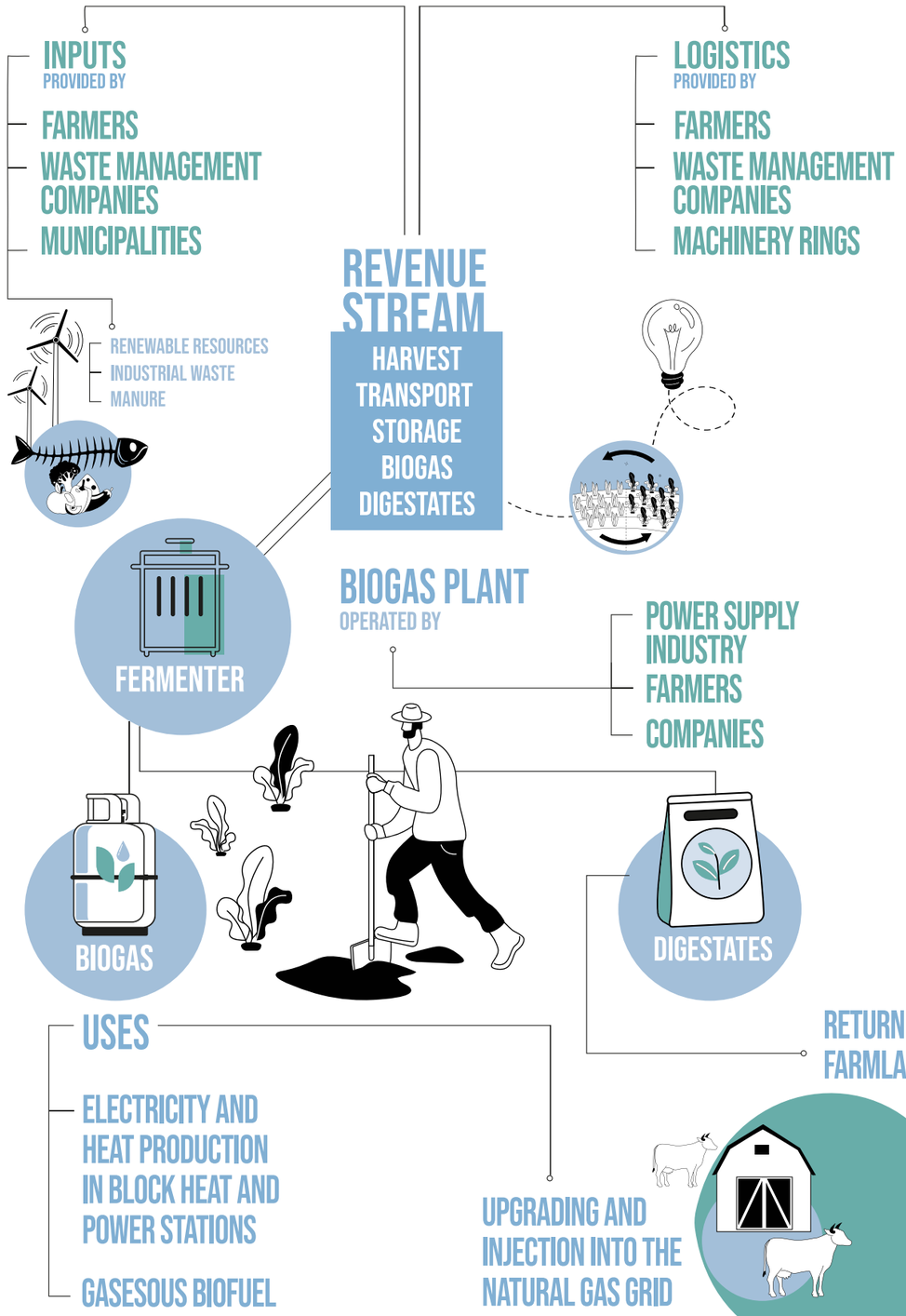
UNDEVELOPED MARKET AND REVENUE STREAMS

Biogas production is a sensitive process as commercial production is inextricably linked to constant supply of feedstock to yield, to produce the same amount of thermal and electrical energy over time. While Pakistan has a high volume of animal manure, cow dung and agri-waste for biogas production, ensuring consistency of biogas feedstock for reliable and sustainable biogas production per ton is woefully lacking. The absence of sustainable feedstock supply, deregulated prices and lack of adequate infrastructure, holds investors back. Investors are reluctant to invest in biogas projects because they see various parts of the supply chain as volatile and difficult to manage.

Moreover, there exists a huge unexplored revenue potential in different segments of the biogas sector. From waste collection to segregation, production of electricity and gas to producing fertilizer as by-product. All these streams could generate lucrative revenues and create ample jobs. Unfortunately, value added streams in biogas sector has never been explored and realized at large scale in Pakistan, mainly due to lack of know-how of business models, technical expertise and practical demonstration. Therefore, there's a need for demonstration of various biogas technologies showcasing their techno-economic viability and replication potential at commercial scale.

This infographic suggests revenue streams within the biogas production and supply chain that could monetize various processes and economically incentivize different players within the industry.

Revenue Streams



CAPACITY AND AWARENESS GAPS

The biogas sector itself is very vast and different technological applications require trained professionals and skilled staff. In Pakistan, there aren't any specialized and consistent training program to capacitate local engineers and technicians on design, installation, operation and maintenance of large-scale biogas plant, Although, some research institutions like UAF, NARC, PARC and NUST do have required expertise and talent to conduct research on biogas technologies, they lack foreign collaboration and funding to undertake high level research projects/programs. Furthermore, data collection and monitoring mechanisms with support of industrial partners and academia needs to be established, this could pave way for applied research and technology localization. At the industrial level, awareness gaps exist at the high management level on the techno-economic viability and key success factors of biogas projects. Similarly, at rural community level, women who uses raw biomass as source of fuel need awareness on efficient utilization of biomass through technological interventions that could provide them heat and electricity whilst reducing the indoor air pollution.

SOCIO-CULTURAL & ENVIRONMENTAL ISSUES

Usually SMEs in Pakistan are resistant to change and the adaptation of new technologies such as waste to energy requires change of mindset in existing SMEs culture. A solution driven approach to implement out of the box solutions remains a missing link in diffusion of biogas technologies at the commercial level. This requires dissemination of success stories and lessons learned from installed biogas projects to create a domino effect.

At rural level, people who have the raw materials readily available do not have any knowledge of biogas technology. It is therefore important to educate by first explaining and then demonstrating this technology to rural communities. This would help to deal with some misconceptions that smallholders and farmers might have about biogas, increase their understanding of the technology, and consequently enable them to realize the benefits offered. Their acceptance of its usefulness is essential to their willingness to adopt biogas as a source of energy.

In addition, despite of significant environmental benefits of biogas, there are few potential negative environment aspects such as noise pollution, odor complaints and the need for abundant water resources for biogas digestors. Moreover, sometimes due to inadequate maintenance, the broken digestor caps and gas valves that are not airtight can cause significant environmental problems such as escaping the gas in the atmosphere and increasing GHG emissions. These issues are raising concerns of environmental suitability of biogas projects.

Women's role in uplifting the biogas sector remains limited with only a handful of women trained so far on small scale biogas plants use. Increased participation of women energy professionals on deployment of biogas technologies could potentially be a true value addition in the various streams of biogas sector. For all the commercial biogas projects, gender mainstreaming should be ensured at all levels. Furthermore, women-led initiatives for development of pilot scale success stories to attract more female in bioenergy sector are important to record and disseminate.

There is no woman BCC supervisor working currently, though in the past three years, women were trained and they also identified 2-3 plants but due to their mobility problems they could not continue their work. Despite available expertise and knowledge, systematic and structural barriers prevail.

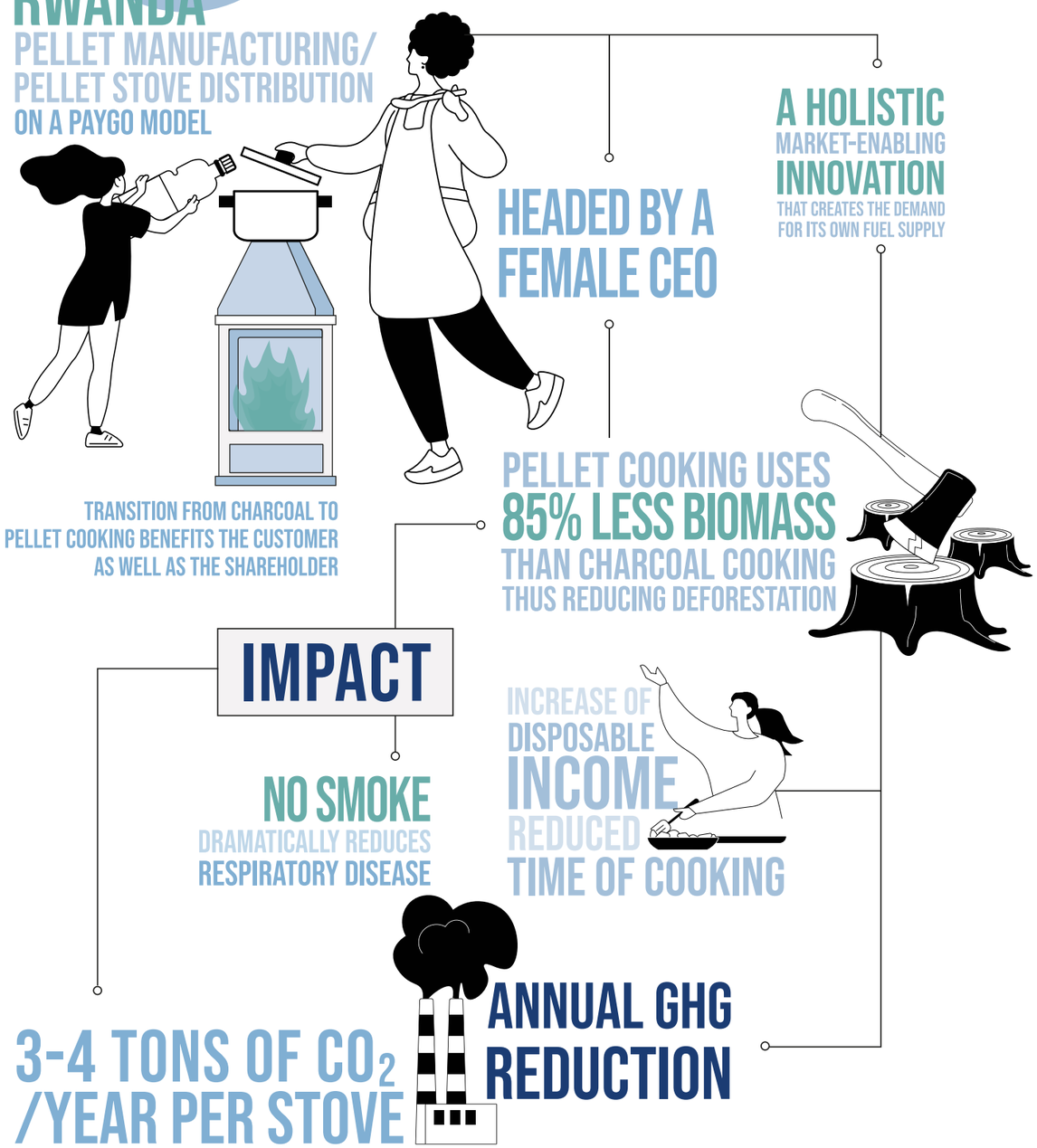
Thus, efforts are needed to win the trust of the local communities to engage women equally in the demand and supply side of the project. To increase the ownership of household level biogas plants, ; the credit facilities opportunity should be pro-actively exclusively offered to women so their unique value proposition can be unlocked cemented in what is effectively still a male dominated sector.

Women's role can be through identification of opportunities to involve women as promoter, trainers, community organizers, income generation facilitators, microfinance lenders, and as an integrators of biogas into their social and economic activities. Successful frameworks can produce multiple revenue streams that will equip women financially and serve to strengthen business models.

PFAN Global has developed and implemented a four-dimensional gender lens when it comes to projects, including for biogas, such as evaluating projects on the basis of women in the supply chain, as workers and management in leadership roles and as end users. Below is a success story from PFAN Global's biogas project pipeline for a biomass SME that has ramification for biogas projects as well, as biomass and biogas are inextricable linked. Women-led BioMassters, is a scalable and culturally transferrable model for biogas in Pakistan as well, that positions keeps women as not only the producers of energy but also as the end-customers:

BioMassters

The clean cooking solution



POTENTIAL OPPORTUNITIES FOR SMES IN THE COMMERCIAL SCALE UP OF BIOGAS

SMEs have great potential for waste to energy (biogas) especially in diary, poultry and agro industry. Most medium to large scale industries have already taken some initiatives on installing biogas plants at commercial scale for meeting their thermal and electricity requirements as is shown in the example below:

Biogas Production and Electricity Generation
THREE LARGEST DAIRY FARMS

	DAILY MANURE (TONNES)	BIOGAS PRODUCTION (M3/YEAR)	GROSS ELECTRICITY OUTPUT (GWH/YEAR)	ANNUAL ELECTRICITY EXPORT TO THE GRID (GWH)
SARSABZ DAIRY FARM NESTLE	8	71,191	0.28	0.27
JK DAIRIES PVT. LTD	29	351,510	0.95	1.9
ENGRO DAIRY FARM NARA	63	758,637	2.8	2.8
TOTAL	100	11,81,338	4.03	4.97

This infographic represents the three largest dairy farms with the highest rate of biogas production, reflecting the untapped biogas potential by other multinational and large corporations in Pakistan.

The deployment of commercial scale biogas plants shall not only improve their efficiency but reduce the overall operational costs and environmental footprint. Moreover, the cattle colony of Landhi in Karachi is the most feasible site in Pakistan for a large-scale or multi-opertional commercial scale biogas plant project.
This cattle colony covers about 3 km2 area and has a population of about 400,000 animals, making it one of the world's largest cattle associations. The animals produce about 4,200 tons of manure each day and have an electricity generating capacity of around 20 MW to 22 MW. Various feasibilities have been conducted to establish a biogas plant including for, power generation and Bio-CNG in the cattle colony but none of these projects have actually materialized as yet, mainly due to lack of funding/financing, regulatory, technical and administrative hurdles.

Biogas plants are also a reliable source of decentralized RE for heating, cooking as well as generating electricity and thermal energy application alternatives at rural community/SMEs level. This could be a potential investment opportunity in Decentralized Renewable Energy Source (DRES) of power generation, specifically in the small capacity range (3 kW to 250 kW) and thermal energy for heating/cooling from the biogas produced from Biogas plants of 30 M3 to 2500 M3 capacity. The readily available quantity of biodegradable organic waste(s) such as cattle dung/animal wastes, food & kitchen waste, poultry dropping waste, agro-industry waste etc could be used as feed stock for these Biogas plants. Such decentralised plants are especially beneficial for meeting off-grid power requirements for individual dairy and poultry plants, dairy co-operatives for operation of dairy equipment. The installations of these biogas systems could replace expensive diesel gensets used for milk chilling applications and other general applications such as pumping, lighting, irrigation as well as cooking. In addition, farmers can also sell surplus biogas/electricity to their neighbours in off-grid mode, thereby helping increase the income of farmers/end users. The nutrient enriched organic bio-fertilizer is another stream of income generation from biogas projects and at the same time saving in the expenditure of chemical fertilizers by reduction of use of chemical fertilizers and other profitable ventures like organic farming.

The advent of gas crises in country in the wake of sky rocketing prices of Liquefied Natural Gas (LNG) and Liquified Petroleum Gas (LPG), Bio-methane and Bio-CNG could be used as alternative fuel for meeting the gas demand of industrial, household and transport sector. Both SNGPL and SSGC can handle Bio-methane as it is a pipeline quality gas which can be transmitted and distributed through existing network. Moreover, localized biogas networks can be developed in Karachi starting from the available buffalo waste there. Nevertheless, a lot of homework needs to be done to exploit the biogas resource potential and related value chain in the country.

CASE STUDIES ON COMMERCIAL SCALE BIOGAS PLANTS

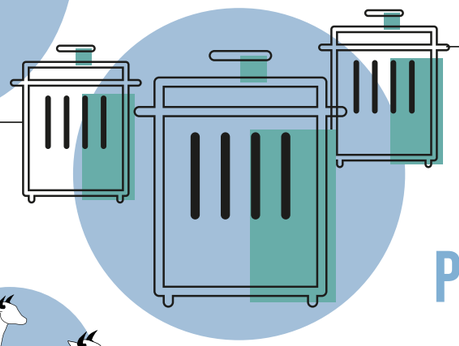
Success stories and case studies of demonstrated biogas scale up are essential in understanding business models and feasibility plans in order to impart insights for biogas proliferation. Case studies from Pakistan and other countries with similar cultural contexts help build knowledge and expertise, as well as allow for localizing technology and business cases. Following are a mix of several biogas case studies from Pakistan and other countries, predominantly from the private but with some insights from public sector feasibility studies for uptake of biogas as a RE source to improve Pakistan's sustainability.

1. NESTLE BIOGAS FARMS

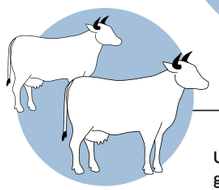
Dairy farms mostly use diesel for electricity generation which puts immense pressure on the already strained fossil fuel powered electricity sector in Pakistan and skyrocketing fuel prices negatively impact profit margins. To off-set dependency on diesel in companies, Winrock International, with a grant from U.S. EPA, implemented a project to build the capacity of private biogas companies by installing medium-sized biogas plants. Under this project, biogas plant construction companies and dairy farmers mobilized a project using cow manure for biogas production and to meet on-farm electricity requirements. It was a market based and private sector led model which targeted 25 – 35% reduction of diesel usage: 15 pre-feasibility and feasibility studies were performed towards 5 biogas plants being established at 4 dairy farms in Okara, Sukheki, Multan, and Sargodha.

The feedstock was cattle manure and the system included a fixed dome biodigester, water separator, H2S scrubber, power generator as well as cooking stoves. The produced biogas was used for milk chilling, water pumping and fodder cutting. The financing model was based on the savings in cost of diesel through the replaced chilling system and the system reduced GH emissions by using animal manure management and replacing diesel leading to annual emission reductions. A partnership was further developed with milk processing companies Nestle and Engro for scaling up through co-financing. Nestle's Sukheki Dairy Farm was one of the companies that Winrock helped build the biogas plant for. This is another success story with a viable business model comes from the commercial scale biogas plant installed.

NESTLE TRAINING FARMS
Commercial scale biogas plant at
SUKHEKI



175 COWS

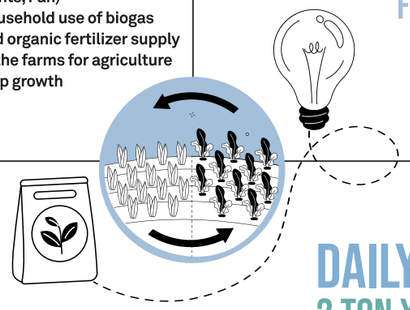


20KG MANURE /DAY PER COW

3500KG AVERAGE DAILY MANURE

2800KG AVERAGE COLLECTABLE DAILY MANURE

Used for electric power generation (Milk Chiller, Lights, Fan)
Household use of biogas and organic fertilizer supply to the farms for agriculture crop growth

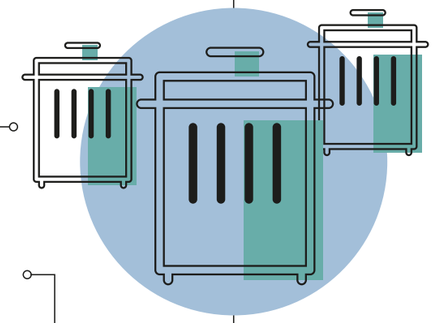


TOTAL COST
200M³ PLANT
PKR 2.56 MILLION

COMPRESSOR CAPACITY OF
15 PSI INSTALLED
FOR GAS STORAGE

DAILY DUNG FEEDING
2 TON X1 GENERATOR100 KVA
RUN ON BIOGAS MIXED WITH DIESEL

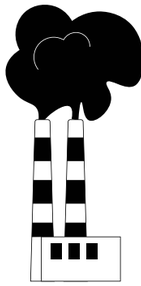
NESTLE TRAINING FARMS
Commercial scale biogas plant at
SARSABZ



CAPACITY
400M³ PLANT

4 COW TONS MANURE PRODUCES 158M³GAS FROM 4 DIGESTERS

GAS USED FOR ELECTRICITY GENERATION SAVES 60 L OF DIESEL PER DAY

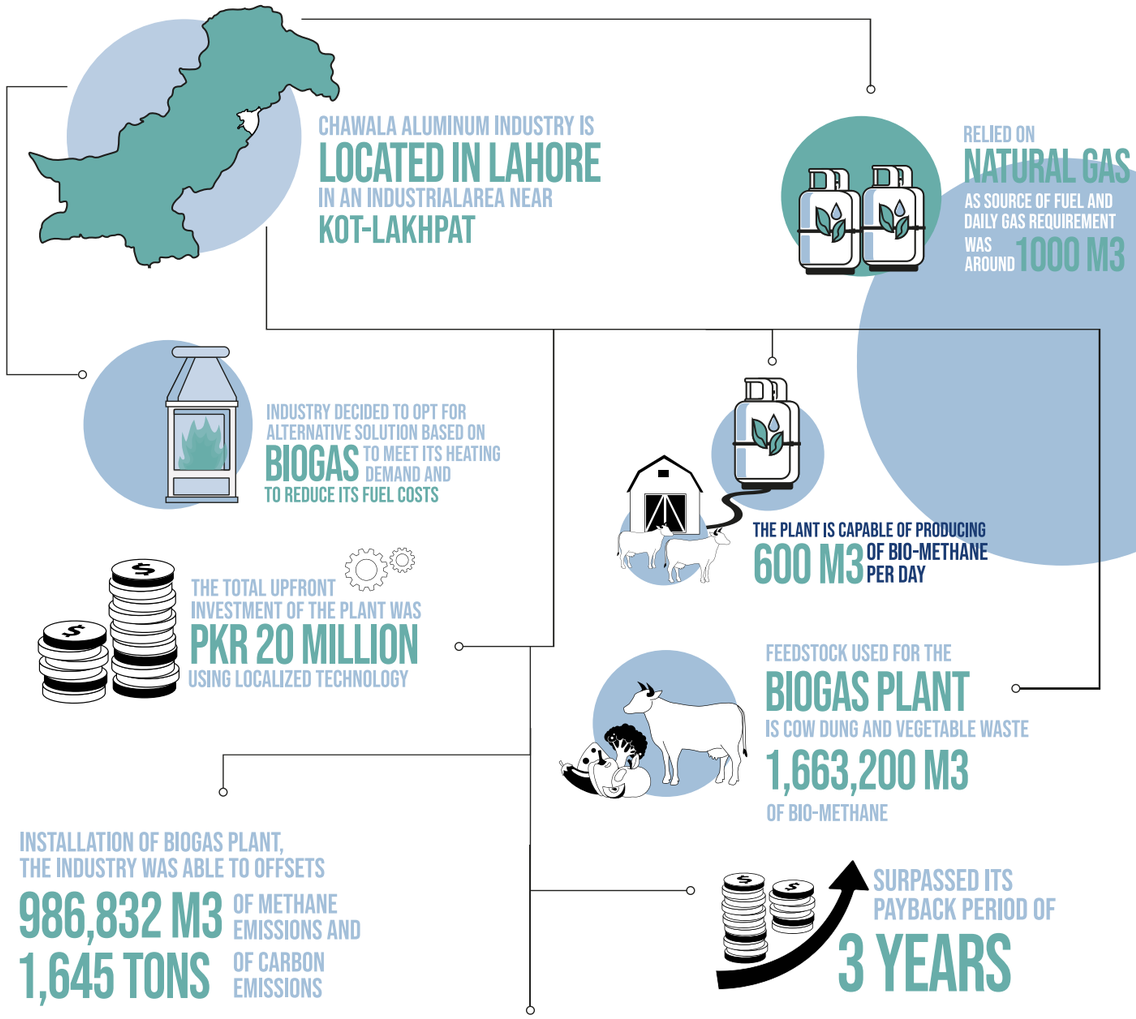


ACHIEVED EMISSION REDUCTION
58,000 KG CO_2

Nestle Pakistan installed another biogas plant of 400m3 capacity at Sarsabz farm 2014, this time, without the assistance of Winrock International, proving that such multi-stakeholder biogas projects have the power to achieve sustainable uptake and scaleup of biogas plants.

2. BIOGAS PLANT INSTALLED IN CHAWALA ALUMINUM INDUSTRY, LAHORE, PAKISTAN

CASE STUDY OF BIOGAS PLANT
Installed in Chawala Aluminum Industry
LAHORE, PAKISTAN



Chawala Aluminum Industry is located in Lahore in an industrial area near kot-lakhpat. The industry heavily relied on natural gas as source of fuel and daily gas requirement was around 1000 m3. Natural gas was used for the heating purposes in aluminum manufacturing processes. Back in 2015, the industrial processes were badly affected resulting in continuous loss of materials due to gas load shedding. Expensive Liquified Petroleum Gas (LPG) was then used as an alternative fuel which substantially increased the cost of production of goods. The industry was facing difficulties to keep up with the production orders whilst minimizing the production costs. To reduce the cost of Natural gas and LPG, the industry decided to opt for alternative solution based on biogas installed by Revgreen to meet its heating demand and to reduce its fuel costs.

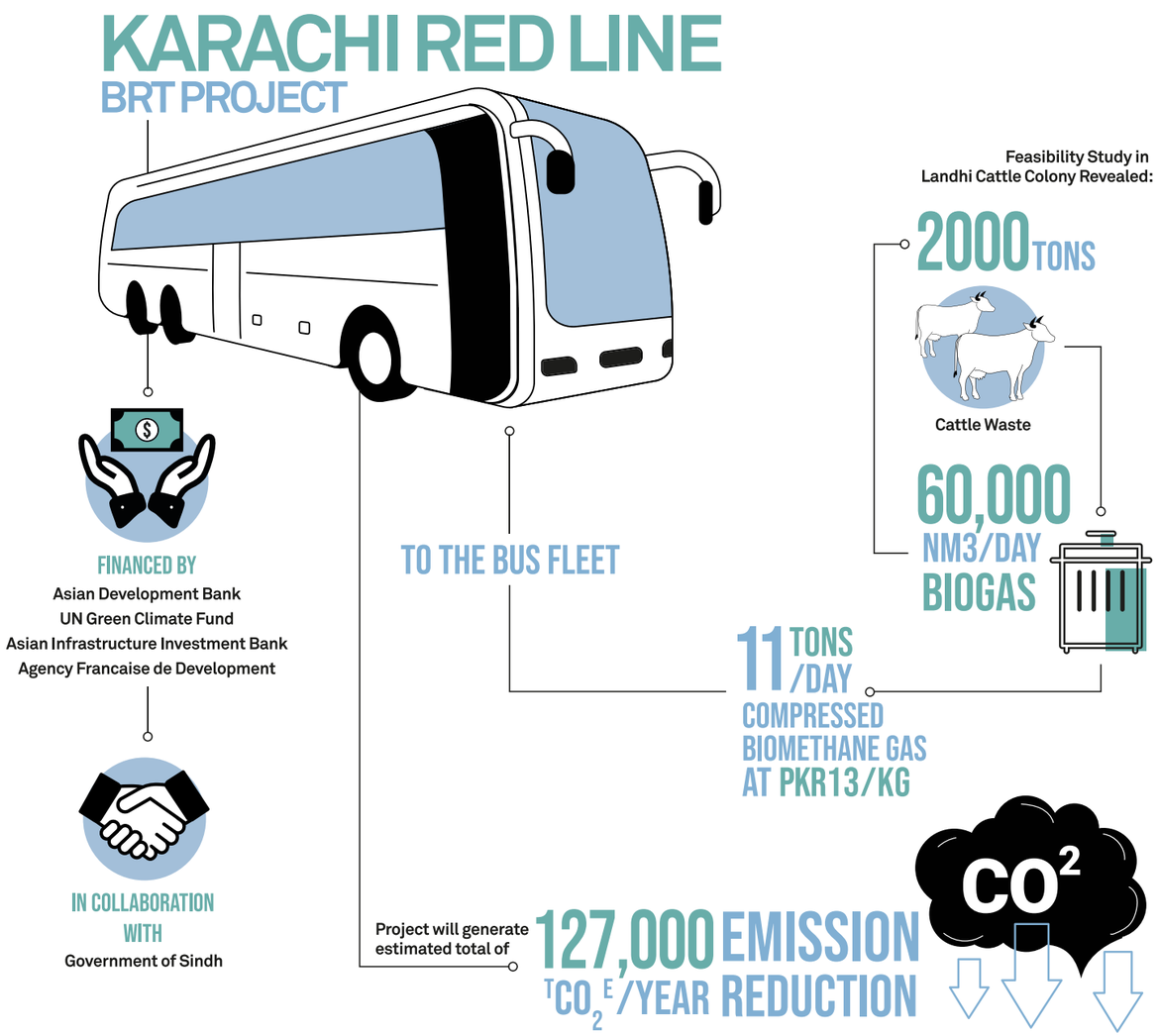
The feedstock used for the biogas plant is cow dung and vegetable waste which is being procured through a outsourced contractor. Since the commissioning of the plant, it has produced around 1,663,200 m3 of Bio-methane; otherwise being procured from the utility or LPG. The plant has already surpassed its payback period of 3 years and is successfully running meeting the overall energy demand of the production facility. Revgreen Pakistan is a key player in biogas plant construction and operations and since 2009 the company is been working in this sector. Following are some examples of operational plants set up by Revgreen:

REVGREEN PAKISTAN
Summary of different biogas projects

LOCATION	CAPACITY	NUMBER OF DIGESTERS	FEEDSTOCK	BIOGAS M3/DAY	UTILIZATION
ISLAMABAD	1 X 200 M^3	1	COW DUNG FARM WASTE	100	HEAT AND POWER GENERATION
KASUR	2 X 100 M^3	2	POULTRY	200	70 KVA GAS GENERATOR
MANGA MANDI	1 X 300 M^3	1	COW DUNG	150	50 KVA GAS GENERATOR
SHEIKHUPURA	1 X 700 M^3	1	COW DUNG VEGETABLE WASTE	100	75 KVA GAS GENERATOR
LAHORE	1 X 1200 M^3	1	COW DUNG VEGETABLE WASTE	800	150 KVA GAS GENERATOR
LAHORE	5 X 500 M^3	5	COW DUNG VEGETABLE WASTE	2000	METHANE PRODUCTION FOR FACTORIES
LAHORE	3 X 1000 M^3	3	COW DUNG VEGETABLE WASTE	1000	GAS

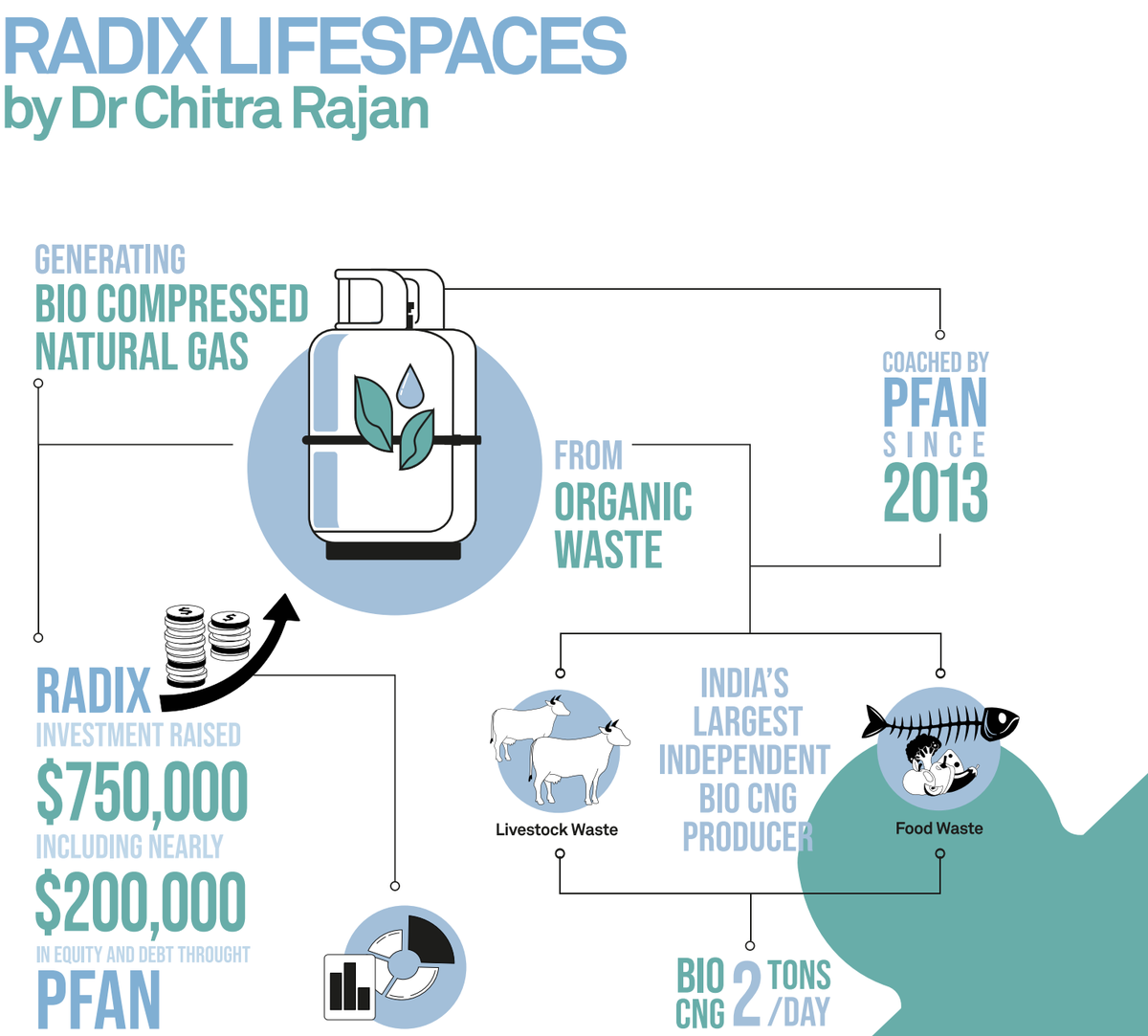
3. KARACHI RED LINE BRT PROJECT

The Karachi Red Line BRT project was launched and financed by the Asian Development Bank (ADB), UN Green Climate Fund (GCF), Asian Infrastructure Investment Bank, and the Agence Francaise de Development (AFD) in collaboration with the government of Sindh. A feasibility study on Landhi Cattle colony projected that 2,000 tons of cattle waste would be used to produce 60,000 Nm3 per day of biogas. While, the biogas plant would deliver 11 tons per day of compressed biomethane gas (CBG) to the bus fleet and this would be an innovative solution to solve Karachi's urban mobility issue in a sustainable way, thus far, the project is only at the feasibility stage.



4. RADIX LIFESCAPES, INDIA

In addition to local case studies and business models, it is imperative to look to other successes of biogas proliferation in similar emerging economy contexts. During the PPSE Biogas Roundtable, Dr. Chitra Rajan, CEO Radix Lifespaces, was the key speaker and she shared many useful insights regarding the nuanced challenges facing India and Pakistan's biogas sector and entrepreneurs. Radix Lifespaces is a company in the PFAN project pipeline and is generating Bio Compressed Natural Gas (Bio- CNG) from organic waste. It has grown from four small proof-of-concept plants to become the largest independent Bio- CNG producer in India, with a capacity to process 40 tons of organic waste and produce 2 tonnes of Bio-CNG every day and has confirmed orders for the supply of 10 tonnes of Bio CNG per day.

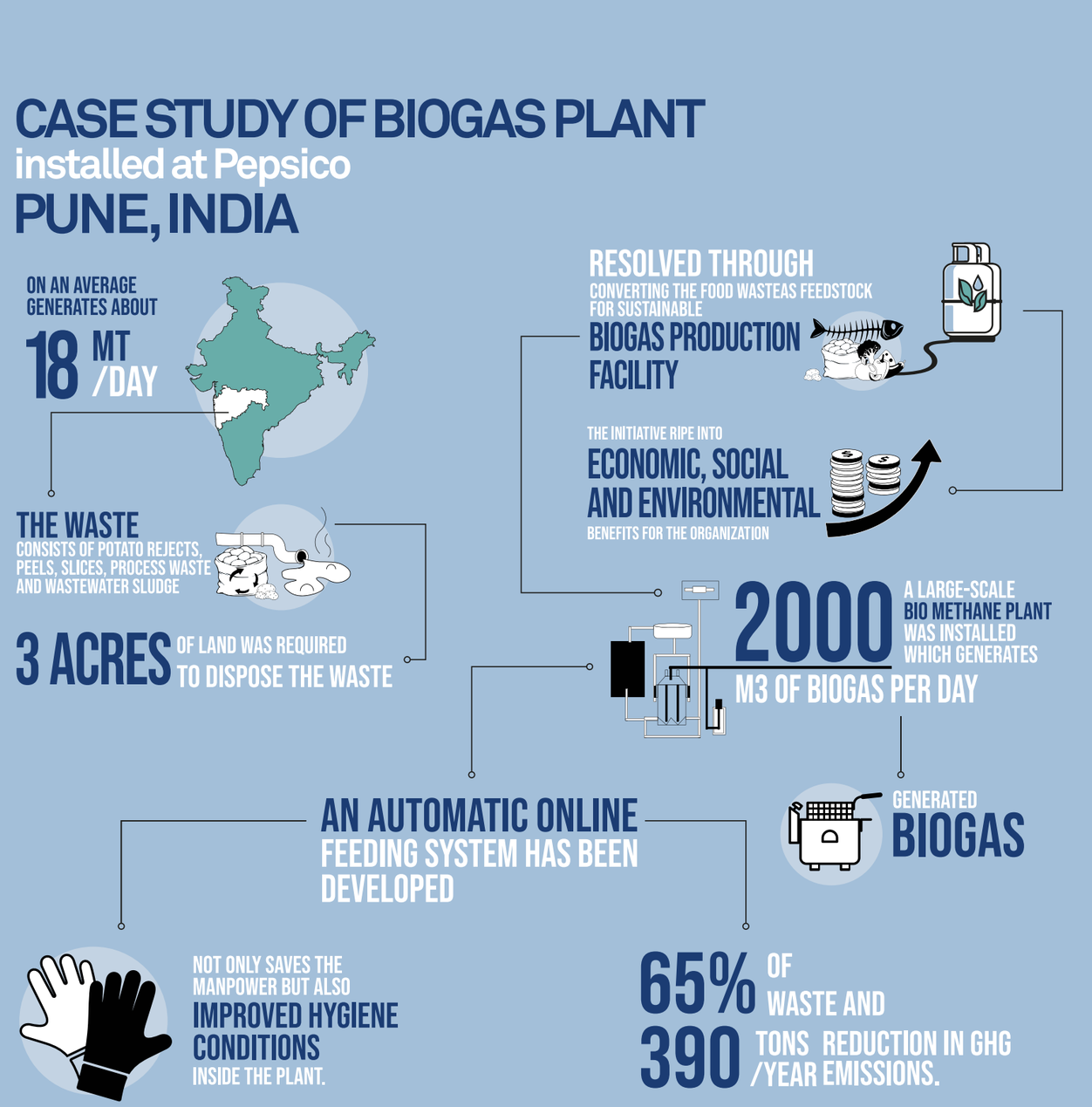


Dr. Rajan attributes some of the success of her business to changes in India's government regulatory framework in support of biogas incentives and support in business scale-up. Such as when Radix started operations in 2016, the emphasis was on generating electricity from biogas. At that time, the Government of India had a scheme of giving capital subsidies to project developers to the tune of INR 20,000 for every KW of installed electricity generation capacity.

“I approached PFAN to raise funds for my project. My mentor Mr. Nagraja Rao suggested that since it is a viable project with good prospects instead of selling equity I should take the debt route. I decided to approach Banks in India for the same. With extensive help from my mentor, I was able to complete the documentation needed for the banks and successfully availed the loan. I have been associated with PFAN since 2013. Though the mentoring contract got over long back I still keep in touch with my mentor. Today he has become my go-to person for all business & finance-related matters. I make it a point to touch base with him every six months or so and keep him appraised about my business. I have learned a lot about risk assessment, financial planning, and market analysis from my mentor.” - Dr. Chitra Rajan (Designed as floating quote)

5. BIOGAS PLANT INSTALLED AT PEPSI CO, PUNE, INDIA

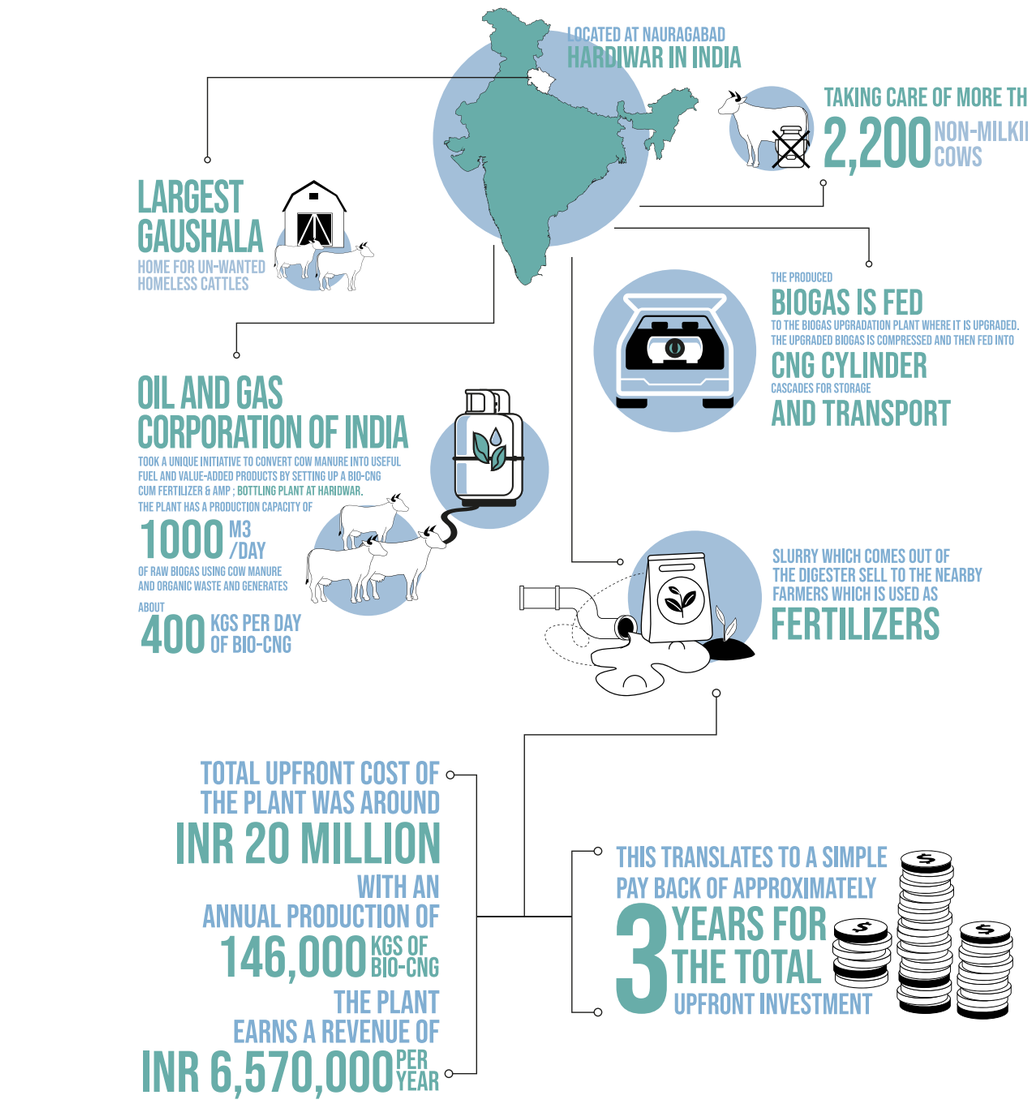
The Pepsi Co plant in Pune, India on an average generates about 18 million tons of waste per day. The waste consists of potato rejects, peels, slices, process waste and wastewater sludge. The waste used to be disposed off through vermi-composting method and to handle waste to the volume of 18 million ton per day, approximately three acres of land was required. The issue of waste disposal was resolved through converting the food waste as feedstock for sustainable biogas production facility. The initiative ripe into economic, social and environmental benefits for the organization.



In the initial stage, a pilot biogas plant was installed to understand the process, its controls and variations and also to identify the potential of biogas production. Upon successful demonstration of the pilot project a large-scale Biomethane plant was installed which generates 2000 m3 of biogas per day. Generated Biogas is used in Kurkure fryer through modifying the burners and after undergoing a purification process. Moreover, an automatic online feeding system has been developed. The first of its kind initiative by Pepsi Co, where the slicer fines are conveyed through screw conveyor crushed and then transferred through the pump to the biogas digestor. This not only saves manpower but also improved hygiene conditions inside the plant. The biogas plant has resulted in saving of 140 million tons of Liquified Petroleum Gas (LPG), approximately cost of USD 140 million per annum. Furthermore, 65% of waste and 390 tons/year reduction in GHG emissions.

6. BIO-CNG PLANT AT KRISHNAYAN GAUSHALA, HARIDWAR, INDIA

This is the largest gaushala (home for un-wanted homeless Cattles) in Uttarakhand mainly taking care of more than 2,200 non-milking cows. Oil and Gas Corporation (ONGC) of India took a unique initiative to convert cow manure into useful fuel and value-added products by setting up a Bio-CNG cum Fertilizer & Bottling Plant at Haridwar.



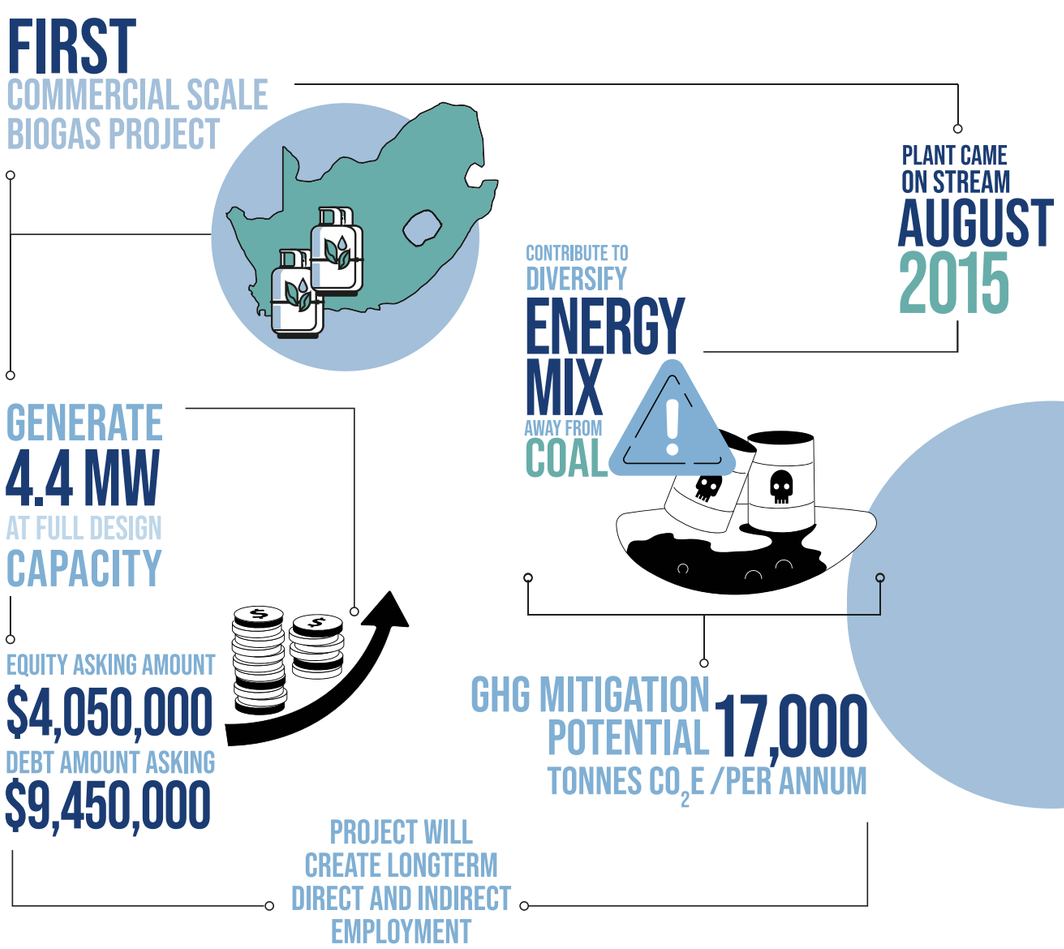
The manure is collected and brought to the plant and kept on the feeding area. Then it is fed into the biogas plant where under anaerobic conditions, the biogas is produced. Stirring is done using agitators inside the digester. The produced biogas is fed to the biogas upgradation plant where it is upgraded. The upgraded biogas is compressed and then fed into CNG cylinder cascades for storage and transport. The produced Bio-CNG or compressed biogas is sold to nearby factories whereas the slurry which comes out of the digester, goes to the solid-liquid separator. The gaushala is able to sell the dried part of the slurry and the liquid slurry to the nearby farmers which is used as fertilizers. The total upfront cost of the plant was around INR 20 million (USD 250,000), with an annual production of 146,000 kgs of Bio-CNG the plant earns a revenue of INR 6,570,000 (USD 83,000)/year. This translates to a simple pay back of approximately 3 years for the total upfront investment.

The plant is helping in carrying out waste management in a clean and hygienic manner in the gaushala premises. Moreover, the initiative is also helping in protecting the fauna (i.e. 2,200 non-milking cows) by making the gaushala self-sustaining from the revenue generated from the project.

7. BIO2WATT, SOUTH AFRICA

A biogas project in PFAN Global's project pipeline, Bio2Watt had a successful 4 megawatt biogas plant in Johannesburg, South Africa and the team tried to replicate a similar plant in Cape Town, 3 megawatts. However, as Cape Town had different feedstock, grass and water, different technology was needed than the Johannesburg plant. So, even in the same country, along different regions and contexts, technology and structure are heavily influenced by the kind of feedstock. Thus, each plant becomes a stand-alone plant that is very difficult to scale because the technology has to be designed to individual requirements of feedstock. The heterogenous quality of technology coupled with the expertise needed from feedstock operators are two big challenges facing the scale up of biogas in countries such as Pakistan. However, case studies such as Bio2Watt can help SMEs premeditate and plan for such challenges while establishing new biogas plants or scaling up existing business models.

Bio2Watt (Pty) Ltd
South Africa



SPECIFIC RECOMMENDATIONS FOR UPTAKE OF COMMERCIAL SCALE BIOGAS MARKET AND PROJECTS IN PAKISTAN

Based on the inputs from the stakeholders, following are the specific recommendations and interventions required at Macro, Meso and Micro level that could help overcoming the challenges being faced by biogas sector in Pakistan and could support the uptake of commercial scale biogas projects in Pakistan:

KEY RECOMMENDATIONS:

MACRO LEVEL-POLICY AND REGULATORY SUPPORT

Intervention(s)	Proposed Activities	Expected Outcomes	Potential role of PPSE Project
CREATE AN ENABLING ENVIRONMENT FOR THE PRIVATE SECTOR	Develop an Integrated Action Plan (IAP) to support the uptake of biogas sector clearly setting targets for biogas production. The plan may include provisions such as: Prioritization of distributed & decentralized biogas-based power generation projects, gender mainstreaming in biogas sector of Pakistan, establishing sustainable biogas supply/value chains, assessing and aligning roles of key stakeholders	IAP developed and implemented by the competent authorities	Advisory support to Public Sector for developing a holistic action plan for promotion and uptake of biogas sector in Pakistan
DETERMINATION OF BIOGAS POTENTIAL IN PAKISTAN	Determine biogas generation potential in Pakistan through different resources such as agriculture waste, cow dung, poultry & kitchen waste, municipal solid waste	Study to determine the biogas generation potential published and disseminated among key stakeholders	
DEVELOP/SPECIFY TECHNICAL LIMITS, CODES, STANDARDIZED PROCEDURES FOR SETTING UP COMMERCIAL SCALE BIOGAS PLANTS	Development of technical specifications and standardized procedures for setting up of commercial scale biogas plants i.e. design, installation and commissioning	Codes and procedures for setting up of biogas plants adopted by the public/private sector	Provide TA to public sector for developing codes and procedures for setting up of commercial scale biogas plants
DEVELOP/SPECIFY TARIFF SETTING MECHANISM FOR COMMERCIAL SCALE BIOGAS PLANTS	Develop tariff structures for commercial scale biogas plants for thermal, gas and electricity generation	Tariffs setting mechanism approved and adopted by the regulator	Provide TA for development of tariff structures through engaging foreign/local experts, identifying best practices, organizing stakeholder consultations/ facilitation workshops

DEVELOP BIOGAS FEEDSTOCK MANAGEMENT AND PRICING MECHANISM	Develop biogas feedstock (manure,cattle dung, MSW, Kitchen waste,energy crops etc.) supply chain management and pricing mechanism	Determination of the biogas feedstock prices and supply chain regulation by the public authorities	
DEVELOP QUALITY AND PERFORMANCE STANDARDS FOR LOW CARBON WASTE TO ENERGY CONVERSION TECHNOLOGIES	Formulation of minimum quality and performance standards for waste to energy conversion technologies including for anerobic digestion	Adoption of the standards by PSQCA as voluntarily standards	
HARMONIZATION OF INSTITUTIONAL PROCESS FOR RE (BIOGAS) BASED DISTRIBUTED GENERATION PROJECTS	• Constitute a steering committee to develop methodologies and procedure for approval and financial appraisal of distributed generation-based biogas projects • Organize quarterly meetings of the committee	Procedures for the approval and financial appraisal of commercial scale biogas projects adopted by decision makers / relevant public sector entities i.e., PPIB, AEDB, PCRET	Capacity building of institutions and identification of nominees for steering committee
ACCESS TO FINANCE	• Assessment of the investment potential in the different waste to energy segments • Develop an investment portfolio for bankable commercial scale biogas projects • Capacity building of banks/FIs on financial appraisal and due diligence of commercial scale biogas projects • Development of sustainable financing instruments to de-risk investments in waste to energy technologies/projects including biogas i.e. partial credit guarantees schemes • Establish a crowd fund through the support of DFIs for providing grants such as viability gap funding for the waste to energy projects • Promote viable business model for commercial scale biogas projects	Building investors' confidence and de-risking investments in waste to energy (biogas) projects	• Market scoping of biogas sector of Pakistan specially focusing on SMEs (i.e. medium size dairy industries, poultry farms etc.) • Support in developing a pipeline of bankable WtE Projects • Investor facilitation for investment ready commercial scale biogas projects • Promotion of viable business models implemented in other countries with similar socio-economic conditions like Pakistan

KEY RECOMMENDATIONS:

Meso Level-Capacity Building and Technology Localization

Intervention(s)	Proposed Activities	Expected Outcomes	Potential role of PPSE Project
PROMOTE LOCALIZATION OF WASTE TO ENERGY TECHNOLOGIES (INCLUDING ANEROBIC DIGESTION)	• Initiate sustainable cleantech innovation program to promote and support the localized waste to energy (biogas) solutions in Pakistan • Launch performance- based grants program with support of development sector organizations for biogas related R&D projects	Promotion of innovative and localized biogas-based solutions in Pakistan	
STRENGTHENING CAPACITIES OF KEY STAKEHOLDERS	• Carry out capacity needs assessment of the key market player in biogas market • Design and implement capacity building programs on techno-economic viability of small to medium and large-scale biogas projects for key stakeholders • Develop tools for economic and life cycle assessment of commercial scale biogas plants	Enhanced capacities of key market players on biogas technologies to provide market-driven services	Support awareness raising programs on techno-economic viability of commercial scale biogas plants through sharing the success stories and feasibilities of biogas projects implemented in other countries with the key decision makers in public and private sector
R&D COLLABORATION OF LOCAL AND INTERNATIONAL UNIVERSITIES ON BIOGAS RELATED THEMATIC AREAS	Facilitate matchmaking and cooperation agreements between local and foreign universities/research institutions on Bio fuels, Bio-CNG and other waste to energy streams	Creating enabling environment to support local R&D/ applied research on waste to energy(biogas) Solutions	
CAPACITY ENHANCEMENT OF ACADEMIA AND VOCATIONAL/TECHNICAL TRAINING INSTITUTIONS	Introduce short courses and certification programs on design,installation, operation and maintenance of commercial scale biogas plants in universities and vocational/technical institutes	Enhanced capacities of academia /training institutions and key market players to support the technology implementation	

KEY RECOMMENDATIONS:

Micro Level-Demonstration and Replication

Intervention(s)	Proposed Activities	Expected Outcomes	Potential role of PPSE Project
DEMONSTRATING TECHNICAL AND FINANCIAL VIABILITY OF COMMERCIAL SCALE BIOGAS PROJECTS	Piloting of the medium to large scale (i.e.500 m3 – 1000 m3) Bio-Methanation plants for electricity and gas generation in PPP mode on Build-Operate-Transfer bases	Techno-economic viability of commercial scale biogas projects demonstrated with high replication potential	PPSE project could support in due diligence and financial appraisal of commercial scale biogas projects through leveraging pool of global and local technical experts in PFAN
BIOGAS SUPPLY CHAIN MANAGEMENT	Establish biogas feedstock collection and distribution centers to be owned and operated by public and/ or licensed private entities	Biogas supply chain strengthened and regulated	
ESTABLISH DATA COLLECTION AND MONITORING MECHANISMS	Biogas data collection and monitoring mechanism to be established in collaboration with the academia institutions. This shall include the collection of data on feedstock, installed plants and their performance, GHG emissions reduction that could be used for research and development purposes	Boosting R&D and market development	Support data collection and case study exercises as undertaken by this whitepaper
ESTABLISH BIOGAS LAB TESTING FACILITIES	Biogas lab testing facility shall be established in collaboration with academia, capable to perform feedstock analysis and various stability tests of digester substrate like Dry matter, Organic Dry Matter, Biogas Production Potential (BPP) and so on	Testing and analysis infrastructure of waste to energy (biogas) streams established	
PROMOTION AND AWARENESS RAISING	• Launch promotion and awareness raising campaign on the application of biogas technologies in various sectors of economy • Dissemination of success stories & lessons learned of biogas projects	Increased recognition of the technical feasibility and commercial viability of the waste to energy (biogas) projects (for process heat and electricity generation)	

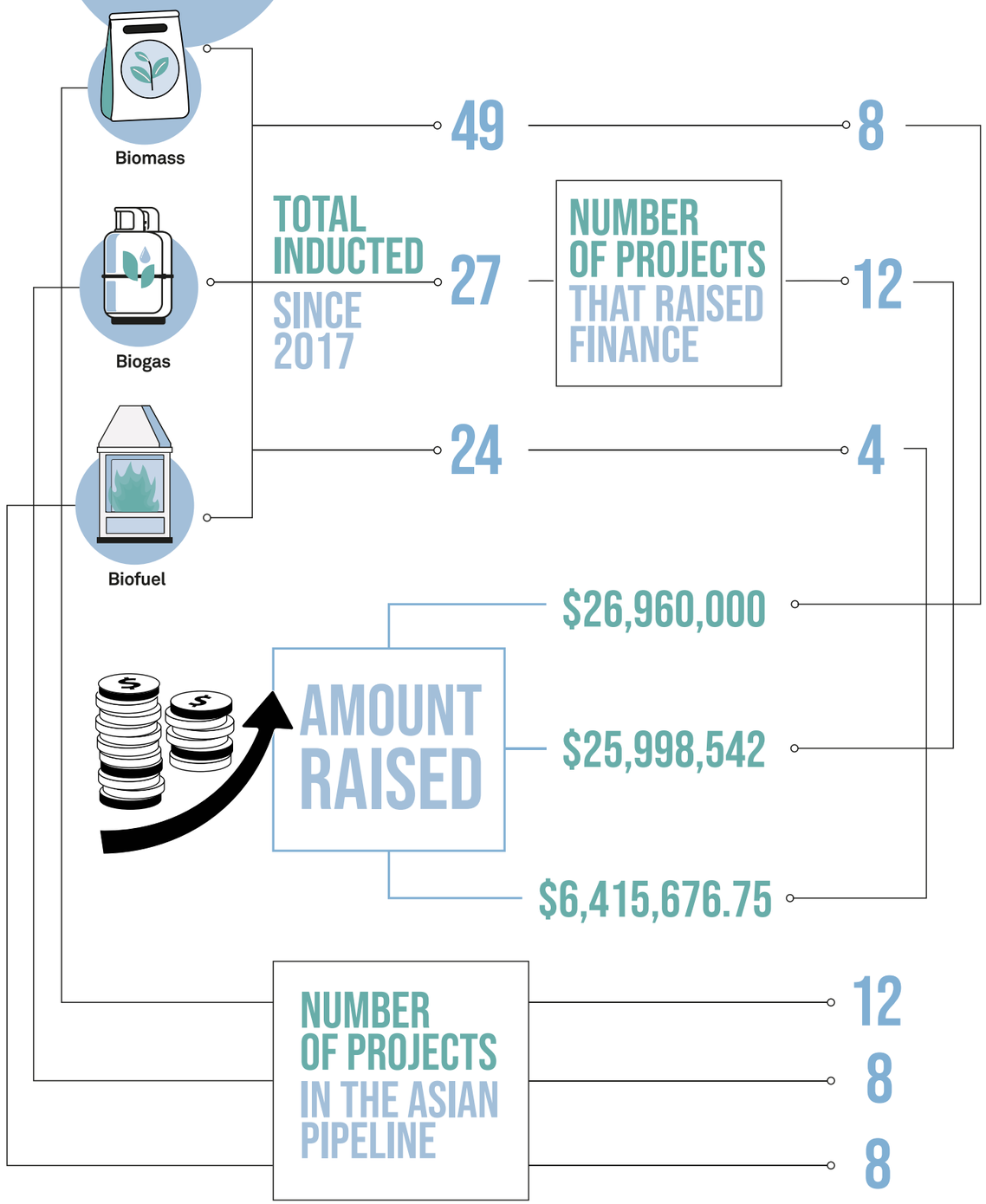
CONCLUSION

The market for biogas, as potential source of renewable energy needs to be developed at a wider scale in Pakistan. This requires political will and coordinated efforts from all the stakeholders (including policy makers, technology suppliers and solution providers, financial institutions, development partners, academia and end-beneficiaries). Nevertheless, the role of women cannot be neglected and must be enhanced in development of the biogas value chain. The interventions as recommended above will be required at all hierarchical levels to fast track the uptake of biogas technologies at commercial scale. Large scale deployment of the biogas plants for electricity and heat generation, bio-fuels and bio-fertilizers will be a true value addition in the developing economy of Pakistan. Establishing an overall eco-system for biogas production could yield multiple benefits such as reducing the GHG emissions, income generation, employment creation and adaptation of circular economy practices in Pakistan.

Pakistan has seen some interventions to introduce biogas as alternative fuel to thermal energy needs of the rural domestic sector. These interventions were primarily grant based and did not employ market-based mechanism to scale. Previous national experience shows that support/assistance is imperative for promoting the technology. Regional experiences show that, with targeted fiscal incentives, private sector investment can be mobilized for adoption of biogas for commercial sector as well as residential sector. PFAN's global experience shows that biogas based commercial solutions can play a significant role for not only meeting the electrical and thermal energy requirements but also creation provision of increased employment opportunities, particularly for women.

While, PFAN Global has a sizeable number of biogas projects in its pipeline as shown below, there is currently no biogas project in its PPSE pipeline which shows the urgency needed for government intervention and private sector innovation to inculcate biogas in Pakistan's clean energy transition.

PFAN PROJECTS



Government can play an integral role in de-risking investment in biogas and the private sector, particularly SMEs, can help make biogas more profitable through consistent feedstock supply, supply chain strengthening, capacity building of plant operators and household uptake.

This paper delved in to a number of case studies with demonstrated business models for biogas development on household, government and commercial scales.

Each case study, from the Karachi Red Line project to biogas uptake at some Nestle Dairy Farms to cross-country businesses in neighbouring India, show that with astute entrepreneurial vigor and thinking, government incentives and subsidies, technical expertise and community involvement, biogas has a much more comprehensive future in the renewables puzzle than currently exists. Unlike renewables such as solar and wind power, biogas that drives its most consumers and producers within agricultural and rural settings, has massive untapped potential to bring women on board as both consumers and producers of biogas at the household level for a more sustainable and healthy future. Recommendations have been derived from the PPSE-led multistakeholder discussion with biogas experts from Pakistan and India, leveraging PFAN Global's network on private financing and scaling up of clean energy companies. These recommendations aim to be holistic, addressing lacunas on government and market levels and proposing innovative and grassroots solutions to problems that on-ground biogas developers face.

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Thank you to everyone who attended our discussion on biogas and gave your insights that shaped this whitepaper

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