INDEPENDENT EVALUATION DIVISION
OFFICE OF EVALUATION AND INTERNAL OVERSIGHT

Independent Terminal Evaluation

PAKISTAN

PROMOTING SUSTAINABLE ENERGY PRODUCTION AND USE FROM BIOMASS IN PAKISTAN

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ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
AEDB	Alternative Energy Development Board
ARE	Alternative and renewable energy
APL	All Power Labs (a USA BGT Manufacturer)
Bar	1 atmosphere of Pressure = 100,000 Pascals (Newtons/m^2)
bbl	Barrel (of crude oil = 42 US gallons = 159 liters)
BCT	Biomass Combustion Technology
BCT	Biomass Combustion Technology
BGT	Biomass Gasification Technology
CERDoc	CEO Endorsement Request Document (for GEF grant funding approval)
CEST	Condensing Extraction Steam Turbine
CHP	Combined Heat and Power
DESL	Development Environergy Services Ltd (Delhi, India)
EUR	Euro (currency)
FiT	Feed in Tariff
FY	Financial Year
GEF	Global Environment Facility
GFC	Great Financial Crisis (of 2008 – 2009)
GHG	Greenhouse Gas
GOP	Government of Pakistan
HQ	Headquarter
IGCC	Integrated Gasification Combined Cycle (for powerplants)
IPP	Independent Power Plant
kW	Kilowatt
LNG	Liquified Natural Gas
LoA	Letter of Agreement
M&E	Monitoring and Evaluation
MoCC	Ministry of Climate Change
MoIP	Ministry of Industry and Planning
MTR	Mid Term Review
MW	Megawatt
NEPRA	National Electric Power Regulatory Authority
NGO	Non-governmental organization
NOx	Nitrous Oxide

Abbreviation	Meaning
NPC	National Project Coordinator
NPD	National Project Director
NUST	National University of Sciences and Technology
OEM	Original Equipment Manufacturer
PIR	Project Implementation Review
PKR	Pakistan Rupee
PMU	Project Management Unit
PPAF	Pakistan Poverty Alleviation Fund
PPG	Project Preparatory Grant (for GEF projects)
ProDoc	Project Document (for GEF Agency use)
PIR	Project Implementation Reports
RE	Renewable Energy
RMG	Ready Made Garments
RO	Reverse Osmosis
SAFWCO	Sindh Agricultural Forestry Workers and Coordination Organization
SME	Small and Medium Enterprises
SMEDA	Small and Medium Enterprise Development Authority
STAP	Scientific and Technical Panel (of GEF)
TE	Terminal Evaluation
ToC	Theory of Change
TOR	Terms of Reference
UMT Lahore	University of Management and Technology Lahore
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USD	US Dollar
USPCASE	US Pakistan Centre for Advanced Studies in Energy (at NUST)
WTI	West Texas Intermediate (a US based crude oil reference price)
ZWD	Zero Water Demand

GLOSSARY OF EVALUATION-RELATED TERMS [1]

Term	Definition
Assumptions	Hypotheses about factors or risks, which could affect the progress or success of a development intervention. Necessary conditions for the achievement of results at different levels; conditions that must exist if the project is to succeed but which are outside the direct control of the project management (also called the external logic of the project because these conditions lie outside the project's accountability and can be related to laws, political commitments, political situation, financing, etc.).
Baseline	The situation prior to a development intervention against which progress can be assessed or comparisons made.
Conclusions	The factors of success and failure of the evaluated intervention, with special attention paid to the intended and unintended results and impact, and more generally to any other strength or weakness. A conclusion draws on data collection and analyses undertaken, through a transparent chain of arguments.
Effectiveness	The extent to which the development intervention's objectives were achieved, or are expected to be achieved, taking into account their relative importance.
Efficiency	Measuring how economically resources/inputs (funds, expertise, time, etc.) are converted to results.
External evaluation/review	The evaluation/review of a development intervention conducted by entities and/or individuals outside the donor and implementing organizations.
Gender mainstreaming	Strategy for making women's as well as men's concerns and experiences an integral dimension of the design, implementation, monitoring and evaluation of policies and programmes in all political, economic and societal spheres so that women and men benefit equally and inequality is not perpetuated (the ultimate goal being to achieve gender equality).
Indicator	Quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect the changes connected to an intervention.
Impact	Positive and negative, primary and secondary long-term effects produced by a development intervention, directly or

[1] Definition of main evaluation concepts based on OECD DAC Guidelines

Term	Definition
	indirectly, intended or unintended.
Lessons learned	Generalizations based on evaluation that abstract from the specific circumstances to broader situations. Frequently, lessons highlight strengths or weaknesses in preparation, design, and implementation that affect performance, outcome, and impact.
Logical framework	Management tool used to improve the design of interventions, most often at the project level. It involves identifying strategic elements (inputs, outputs, outcomes, impact) and their causal relationships, indicators, and the assumptions or risks that may influence success and failure (thus aimed at facilitating planning, execution, monitoring and evaluation of a development intervention).
Milestones	Interim targets; points in the lifetime of a project by which certain progress should have been made, providing an early warning system and basis for monitoring the trajectory of change during the lifetime of the project.
Monitoring	A continuing function that uses systematic collection of data on specified indicators to provide management and the main stakeholders of an ongoing development intervention with indications of the extent of progress and achievement of objectives and progress in the use of allocated funds.
Outcome	The likely or achieved short-term and medium-term effects of an intervention's output(s).
Outputs	The products, capital goods and services, which result from a development intervention; changes resulting from the intervention which are relevant to the achievement of outcomes.
Recommendations	Proposals aimed at enhancing the effectiveness, quality, or efficiency of a development intervention; at redesigning the objectives; and/or at the reallocation of resources. Recommendations should be linked to conclusions.
Relevance	The extent to which the objectives of a development intervention are consistent with beneficiaries' requirements, country needs, global priorities, partners' and donors' policies. Note: Retrospectively, the question of relevance often becomes a question as to whether the objectives of an intervention or its design are still appropriate given changed circumstances.
Results	The output, outcome or impact (intended/unintended, positive/negative; direct/indirect) of a development intervention.

Term	Definition
Review	An assessment of the performance of an intervention, periodically or on an ad hoc basis. Note: Frequently "evaluation" is used for a more comprehensive and/or more in-depth assessment than "review". Reviews tend to emphasize operational aspects.
Risks	Factors that may affect the successful achievement of an intervention's objectives (often outside the scope of the project).
Sustainability	The continuation of benefits from a development intervention after major development assistance has been completed. The probability of continued long-term benefits. The resilience to risk of the net benefit flows over time.
Target	Definite ends to be achieved; specifies a particular value that an indicator should reach by a specific date in the future.
Target group	Specific individuals/organizations for whose benefit an intervention is undertaken.
Theory of Change	Assumed overarching intervention logic from outputs to impact; schematic conceptual basis of the interventions including assumptions.

EXECUTIVE SUMMARY

Key findings

The project Promoting sustainable energy production and use from biomass in Pakistan (Pakistan Biomass) aimed to promote market-based adoption of modern biomass energy conversion technologies for process heat and electricity generation in Small and Medium Enterprises (SMEs) and in rural areas in Pakistan. The project worked towards this goal through four project components, namely: (1) supporting biomass demonstrations; (2) information dissemination and confidence building; (3) establishing suitable policy and regulatory frameworks; and (4) capacity building and technology support. The project was funded by the Global Environmental Facility (GEF) and implemented by the United Nations Industrial Development Organization (UNIDO) in collaboration with Pakistan's Small and Medium Enterprise Authority (SMEDA) with support from the Alternative Energy Development Board (AEDB).

This independent terminal evaluation assessed the entire intervention and all its activities, from the project's design preparation starting in March 2009, its approval in March 2012, to its closure in March 2019. The project's overall performance was reviewed against the standard evaluation criteria of relevance, efficiency, effectiveness, progress to impact and sustainability. A combination of evaluation tools were applied including interviews, documentation review, a technical assessment of Pakistan's broader energy environment and the global experience with biomass energy systems and in particular biomass gasification technologies (BGTs). In addition to assessing overall results, the evaluation also aimed to identify lessons learned and to develop recommendations to inform and strengthen UNIDO's future interventions.

In terms of the project's design relevance, at the project's formulation in 2009-2012, world crude oil prices were at historically high levels and were still increasing. Rural SMEs in Pakistan faced widespread power cuts due to unaffordable oil-fired grid power generation. SMEs found that using their own captive diesel generator sets was often unaffordable. However, the relevance of the project was undermined by its exclusive focus on the use of Biomass Gasification Technologies (BGT) on the basis that BGTs were stated as being "modern" while Biomass Combustion Technologies were stated (incorrectly) as being (intrinsically) energy inefficient for power, process heat or cogeneration uses. Pre-feasibility studies had been undertaken as part of the project design, and a number of critical issues regarding BGTs were flagged in the prefeasibility study report but were ignored in the project's design, and these issues were also ignored in the project's implementation.

In terms of effectiveness, the project provided significant support to a 5.5 MWe BCT CHP (Combined Heat and Power) plant, a 25 kW rural water pumping BGT plant was commissioned after the project's end, and a 40 kWe BGT CHP plant was supported by the project and might still be built. All three project supported biomass plants will be for SMEs. The support of a suitable and soundly engineered 5.5 MWe BCT CHP demonstration is a good example of adaptive management by the project. The project also was effective in increasing recognition of the potential role of biomass technologies in Pakistan albeit with an exclusive emphasis on BGT technologies and not with a balanced BGT and BCT focus. The project usefully supported efforts by AEDB to promote the application of Biomass Technologies in Pakistan by creating a suitably enabling policy environment for grid connected biomass power. It also achieved significant capacity building results.

In terms of efficiency, the project significantly overran its implementation timeframe by three years, however in energy and GHG mitigation terms a well-engineered 5.5MWe baseload electricity output CHP biomass system was completed at Sapphire Finishing Mills with significant project input, and, the project met its overall envisaged level of co-financing.

In terms of sustainability, the reduction in international oil prices from 2014 considerably hampered the financial and economic viability and comparative advantage of biomass energy technologies. The project supported 5.5 MWe Sapphire Finishing Mills BCT CHP system is highly likely to operate sustainably for decades. Significant biomass energy capacity has been developed at the National University of Sciences and Technology (NUST9 and other academic institutions, which is likely to continue after the project's end.

Conclusions

In the ten years from the start of project development to the project completion, and in the seven years from the project's approval to its end, none of the three demonstrations totaling 2.3 MWe of Biomass Gasification Technology (BGT) installations in the project's design had been achieved.

The project instead supported the first biomass combustion technology (BCT) CHP plant (of 5.5 MWe) which is now successfully in operation with an overall CHP energy efficiency of 85% in the textile sector, a major economic sector in Pakistan.

With project support, by November 2019 a 25kW mechanical power BGT for rural water pumping has been commissioned, and a 40kWe CHP BGT was in the process of securing commercial bank funding and in finalizing its bidding documents.

It is important to note that at no stage in the project design or implementation was it acknowledged that there were any issues involved in scaling up BGTs to 300 kWe or 1 MWe as per the project design. The project's stated rationale for switching mid-implementation to a BCT for the textile demonstration plant was that BCTs were a lower capital cost option, however this is a highly questionable rationale. In fact, the cost of USD15.5 million for the 5.5MWe textile BCT plant is not a particularly low cost. There were very good reasons why the Sapphire Finishing Mills CHP plant uses BCT, but a low capital cost is not one of these reasons.

There was also no known project identification in its design or implementation that a biomass energy project in cogeneration mode would provide twice as much heat as electricity, or that BCTs could provide process heat at a higher temperature than BGTs could. These were fundamental project demonstration success factors that were not picked up in the project's design, nor were these issues acknowledged or addressed in the project's implementation. This raises serious questions regarding the project's design and its subsequent management-for-results implementation orientation.

The project overran its timeframe by three years. There was little tangible project implementation in the 19-month period between the project design approval in March 2012 and the first Project Steering Committee meeting in September 2013. The project's implementation was delayed for around another year by the 2014 reduction in global oil prices. Other reasons for the time overrun include high UNIDO staff turnover and delays in getting visas and permission to travel within Pakistan for specialist Indian biomass energy consultants.

The project has built useful capacity in Pakistani academic institutions which has resulted in biomass energy related courses being offered at bachelors and masters levels, helped develop a biomass energy Feed in Tariff (FiT) and net metering for grid connected biomass up to 1 MWe, and helped develop standardisation and minimum performance standards for biomass gasification technologies.

The project supported 5.5 MWe BCT CHP system was provided by a European vendor with 100 years of relevant boiler experience. The system provides process steam at 10 bar/185C which will all be used in the textile plant. In contrast, the BGT technologies that were the sole focus of the project would not be able to provide process steam at 10 bar/185C. The textile CHP plant will run at a 95% availability factor. The plant will be a key real-world demonstration application going forward for 1 MWe and larger biomass CHP energy systems in Pakistan.

The project supported 25kWe BGT powered water pumping demo unit that has been commissioned and/or the 40 kWe CHP BGT unit (if it proceeds) could be the first step towards Pakistan produced standard BGT units with suitable producer gas clean up and automatic gasifier controls in the smaller 25 – 50 kWe sizes that are most appropriate for BGTs in SMEs. However, the development of standardised smaller capacity BGT units, although absolutely critical for post project replication, was not included in the projects design or implementation.

LESSSONS LEARNT

Avoiding Excessive Single Technology Focus

The Pakistan Biomass project made a number of critical design assumptions that were widely known at the time to be questionable, as was readily found by the evaluation team with some quick internet searching and by talking to biomass gasifier experts. The critical design assumption issues were also explicitly flagged in the project funded pre-feasibility studies that were completed 15 months before the project's design approval.

But once BGTs were chosen as the one and only technology to be used in the project, the exclusive use of BGTs was never questioned again. There was extensive literature available regarding how few of the gasifiers that have been deployed since the 1973 first oil crisis continued working for very long, how nearly all successful biomass gasifiers are of small capacity using a single biomass fuel type, and how few large BGTs were working worldwide. The project never addressed how the large amounts of low temperature waste heat from a BGTs reciprocating engine was supposed to be fully used in SMEs with small process heat loads and with heat loads at higher temperatures. The project never articulated that BGTs and BCTs were complementary technologies, depending on the scale, intermittent or continuous operation, and the temperature of waste heat to be used in CHP mode.

Explicitly Acknowledging Changes in Focus

The Pakistan Biomass project shifted its focus under successful adaptive implementation management from the proposed BGT applications to the Sapphire (Textile) Finishing Mills BCT – but never explicitly acknowledged this change. The project's documentation and focus remained exclusively on BGTs, which are intrinsically best suited to smaller outputs, intermittent operation, single biomass fuels, and low temperature waste heat provision. Without the change in focus being acknowledged, the project could not learn from its own operational experience, nor could the project communicate this experience to its stakeholders for maximizing post-project effectiveness and sustainability.

RECOMMENDATIONS

Avoiding Excessive Single Technology Focus

It is recommended that, in future projects, UNIDO undertakes a thorough and formal due diligence on the proposed technology to ensure it actually is a proven mainstream technology elsewhere, that the scale of the proposed technology is appropriate, and that the output of the proposed technology is what is actually needed in the proposed specific technology applications.

Explicitly Acknowledging Changes in Focus

It is recommended that when a UNIDO project's focus changes, then the change should be publicly acknowledged and documented by UNIDO along with the rationale for the change. The project documentation and project language should also explicitly be changed to align with the new reality.

PROJECT RATINGS

#	Evaluation criteria	Rating
A	**Impact**	**Moderately Satisfactory**
B	**Project design**	Unsatisfactory
1	• Overall design	Unsatisfactory
2	• Logframe	Unsatisfactory
C	**Project performance**	Satisfactory
1	• Relevance	Satisfactory
2	• Effectiveness	Moderately Satisfactory
3	• Efficiency	Moderately Satisfactory
4	• Sustainability of benefits	Highly Likely
D	**Cross-cutting performance criteria**	Moderately Unsatisfactory
1	• Gender mainstreaming	Unsatisfactory
2	• M&E: ✓ M&E design ✓ M&E implementation	Moderately Unsatisfactory
3	• Results-based Management (RBM)	Moderately Unsatisfactory
E	**Performance of partners**	Moderately Satisfactory
1	• UNIDO	Moderately Satisfactory
2	• National counterparts	Moderately Satisfactory
3	• Donor	Satisfactory
F	**Overall assessment**	Moderately Satisfactory

1. INTRODUCTION

1.1 EVALUATION OBJECTIVES AND SCOPE

The purpose of the evaluation is to independently assess the project to help UNIDO improve performance and results of ongoing and future programmes and projects. The terminal evaluation (TE) will cover the whole duration of the project from its 27 March 2012 project approval to its 31 March 2019 completion date.

The evaluation had two specific objectives:

(i) Assess the project performance in terms of relevance, effectiveness, efficiency, sustainability and progress to impact; and

(ii) Develop a series of findings, lessons and recommendations for enhancing the design of new projects and in the implementation of ongoing projects by UNIDO.

1.2 OVERVIEW OF THE PROJECT CONTEXT

At the time of the project's formulation in 2009 – 2012, Small and Medium Enterprises (SMEs) were (and they still were at the project' end) a very important part of Pakistan's economy. Many SMEs were located in rural areas, often in clusters in and around villages and towns.

At the same time, world crude oil prices were at historically high levels and were still increasing. Pakistan's rural SMEs were greatly hindered in their operations by the resulting widespread power cuts due to unaffordable high oil costs for the around one third of Pakistan's grid power generation that came from oil fired power plants. These grid power cuts greatly affected Pakistan's SMEs, and the alternative of using their own captive diesel generator sets was often unaffordable due to the then high diesel prices.

34% of Pakistan's energy supply is from natural gas and Pakistan has 120,000km of natural gas pipelines[2], so many industrial plants and SMEs in urban areas have access to pipeline natural gas. Indigenous natural gas production was under pressure from declining reserves and growing demand, so imports of LNG (Liquified Natural Gas) started in 2015[3] to serve power generation, CNG use in vehicles, industrial uses, and fertiliser manufacturing. Pakistan now imports around 75% of its natural gas as LNG. This means that at the project design period of 2009-2012 that Pakistan's internal oil product prices were set by world crude oil prices but that natural gas was under-priced but of increasingly limited supply. From 2015 Pakistan's natural gas availability increased but natural gas prices were increasingly related to world crude oil prices, as world LNG prices track world crude oil prices.

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[2] https://www.linkedin.com/company/pakistan-lng-limited

[3] https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/070519-pakistans-third-lng-terminal-gets-approval-but-delays-expected

At the 2009-2012 project design period, and until 2014 in the project's implementation period, standby or captive diesel generator sets were often too expensive to run. For process heat, SMEs often relied on increasingly unaffordable furnace oil and hard to get natural gas (where this was reticulated) to 2015 when natural gas availability increased but prices increased. There were also many rural areas that had not yet then been connected to the electricity grid.

At the time of project formulation in 2009-2012, Pakistan's agricultural and livestock sector produced large amounts of biomass in the form of multiple types of crop residues, such as sugar cane bagasse and rice husks, and animal manure wastes. Most of this biomass and animal waste was then being collected and used in a very inefficient manner. A considerable amount of biomass waste would also have been simply burned in the fields[4] to dispose of it and to return the waste's nutrients to the soil (but this burning of waste in the fields was not mentioned in the project design documentation).

It therefore seemed logical (at that time) to explore and develop options for using biomass to generate power and/or to provide process heat for SMEs, and also to electrify remote villages.

With the steady increase in global crude oil prices from the year 2000, the electricity supply shortfall in Pakistan in 2009 – 2012 was as much a matter of world oil (and related gas price) economics as it was a result of physical power generation, transmission and distribution constraints in Pakistan.

In 2009 – 2012, around 67% of Pakistan's electricity was generated from oil and gas generation plants, total generation capacity was insufficient, tariffs were set at below full cost recovery levels, and circular debts between electricity distributors, generators and fuel suppliers limited the operation of the available thermal capacity and the deployment of additional thermal capacity.

Standby or captive diesel generators could have supplied reliable power for SMEs and remote villages, but at higher prices than grid electricity, hence at a price that would have been unaffordable for many SMEs and remote villages.

In the project's formulation period of 2009 - 2012, it was widely expected that oil prices would stay high for the foreseeable future. This was then a common perception, as per the then "peak oil" argument where global low cost conventional light sweet crude supplies were thought to be at a permanent maximum supply plateau, with new global

[4] Some biomass already had a commercial value in some locations and applications, but in many cases its value would have been low. If the project had been successful in using biomass for power generation and/or process heat use, then the price of the applicable biomass would have then risen through normal supply and demand interaction effects.

oil supplies having to come from more expensive heavy sour crudes, expensive deep-water oil developments, and from expensive tar sands and other "unconventional" oil supply sources.

At the time of the project's formulation in 2009 – 2012, it was not known, nor could it have been predicted, that the US developments in oil shale and natural gas fracking would lead to the US moving from being a major oil and gas importer to its current status as a current net overall oil and gas exporter by its oil and gas production doubling as a result in the growth of fracking. Along with increased oil supply from other countries, and from Saudi Arabia keeping its output high to defend its market share, the US shale oil and gas fracking revolution led to the international price of crude oil sharply reducing from 2014. With the drop in international crude oil prices[5], and some electricity sector and other economic reforms in Pakistan, the electricity supply situation then greatly improved, and grid electricity prices dropped. The supply situation for reticulated gas to industries and some SMEs has also significantly improved from 2015 when importing of LNG to Pakistan started.

These improved electricity and reticulated gas supply factors from 2014 reduced one of the Pakistan Biomass project's key drivers for the use of biomass for power and/or heat production for SMEs, and for power generation for un-electrified villages. This occurred just after the project was moving into its active implementation mode, which effectively started in September 2013.

1.3 OVERVIEW OF THE PROJECT

The Pakistan Biomass project was a GEF-4 cycle climate change mitigation project under *CC-SP4, Promoting sustainable energy from biomass*. The project was conceived, and was implemented by, the United Nations Industrial Development Organisation (UNIDO). The project was scheduled to have AEDB, in cooperation with SMEDA, as its key implementing partners.

The stated objective of the Pakistan Biomass project was to *Promote market based adoption of modern biomass energy conversion technologies for process heat and electricity generation in Small and Medium Scale Enterprises and rural areas in Pakistan.*

The Pakistan Biomass project's formal development started in March 2009 with the submission of a request for a Project Preparation Grant (PPG) from GEF of USD70,000 (with a matching UNIDO contribution of USD90,000). The project's work program development started in June 2009. The then target timeframe was that the project preparation phase would be completed in May 2010.

[5] Although Pakistan still had considerable oil and gas reserves in 2009 - 2012, Pakistan's oil prices were necessarily driven by global trends, and from 2015 Pakistan's natural gas prices were linked to imported LNG prices, which were more closely related to global oil prices, as globally oil and gas are substitutes for each other for power generation and process heat generation.

No specific type of biomass energy conversion technology was specified at the initial PPG stage of the project's development. However, this was soon changed to assert that "modern" biomass technologies were biomass gasification technologies (BGT), with biomass combustion technologies (BCTs) being ignored. A key stated rationale for the choice of BGT being the sole "modern" biomass technology was that BGTs were stated (incorrectly) as being (intrinsically) more energy inefficient[6] for power, process heat or cogeneration uses.

A GEF STAP (Scientific and Technical Advisory Panel) screening of the then Project Information Form (PIF) was undertaken in February 2010. The STAP review endorsed the project's development to the GEF Secretariat and the relevant GEF Agency (UNIDO). However, the STAP review stated that, although in the then project proposal it was stated that gasification technology was scheduled to be used, but that the (GEF) CEO endorsed document (CERDoc) should specify what other biomass technologies should also be used in the envisaged demonstration projects. In addition, the STAP review asked for clarification whether the pilot (demonstration) projects would be aimed at generating process heat, or power generation or both. The STAP review also asked for clarification on how important a national policy framework for having promoting bioenergy was, and if this was then currently a barrier.

The STAP review stated that the then PIF recognised all the technical, economic policy and price risks, but that many of the risks were rated as low but that the actual risks were high indeed. Hence, the STAP review in February 2010 highlighted that: (1) biomass technology options other than BGT should be considered; (2) that there should be clarification whether power and/or heat should be the focus; (3) the importance of national policies should be considered; (4) and that the project's technical, economic, and policy risks were being understated.

By the revised PIF stage of August 2010 it was stated that (all) "modern" biomass energy technologies to generate heat and power would be biomass *gasification* technologies (BGTs).

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[6] The most common biomass combustion technology in use in 2009-2012 would have been sugar cane bagasse cogeneration. Historically, sugar cane processing plants globally were not allowed to export to the nearby electricity grid as the relevant electricity utilities generated all their own power and did not buy power from anyone else. From the global development of open energy markets from the early 1980's this changed. From the 1990's sugar cane bagasse electricity exports to the grid began in most major sugar cane growing countries [Pakistan is the eighth largest sugar producing country in the world]. Previously sugar cane plants essentially incinerated the waste bagasse in deliberately energy inefficient and low-cost boilers and low-pressure steam plants. With new markets for exported electricity, most sugar cane bagasse plants were progressively retrofitted with modern high temperature/high pressure steam boilers/turbines which produce more electricity from the same amount of bagasse. So although many biomass combustion plants were energy inefficient at the time of project formulation, this energy inefficiency was a deliberate and logical choice, not an intrinsic attribute of the biomass combustion technologies used.

By July 2010 a consulting firm had been engaged and was working on the PPG to prepare the UNIDO Project Document (ProDoc) and the GEF CEO Endorsement Request (CERDoc). By October 2010 the project's documentation referred solely to gasification, on the basis that biomass gasification technologies were "modern" and that they allegedly gave higher efficiencies.

By December 2010, (pre)feasibility studies had been undertaken for the selected pilot projects, co-financing had apparently been arranged, and draft ProDoc and CERDoc documents had apparently been developed. In the 15 months from January 2011 to March 2012 the project's development appeared to have lost momentum with no identified project activities or outputs.

Project Profile at Approval:

Project title	Promoting sustainable energy production and use from biomass in Pakistan
UNIDO ID	100333
GEF Project ID	3921
Region	South Asia
Country	Pakistan
Project donor(s)	GEF
Project implementation start date	March 2012
Expected implementation end date	April 2016
GEF Focal Areas and Operational Project	GEF 4 - Climate Change, CC-SP4, Promoting sustainable energy from biomass
Implementing agency(ies)	UNIDO
Executing Partners	Alternate Energy Development Board (AEDB) in cooperation with the Small and Medium Enterprise Development Authority (SMEDA)
GEF project grant (excluding PPG, in USD)	USD 1,820,000
Project GEF CEO endorsement / approval date	March 2012
UNIDO input (cash, USD)	60,000
Co-financing at CEO Endorsement, as applicable	USD 5,340,000
Total project cost (USD), excluding support costs and PPG	USD 7,160,000
Mid-term review date	May 2014

The actual project implementation started in September 2013, 17 months after the project's approval.

By June 2014, 1st draft feasibility studies had been completed under component 1 for a 3 MWe rice husk-based gasification plant in a rice mill and a 1 MWe wood residue based CHP plant for a plywood mill, and data collection for a 300 kWe rural electrification demo was underway (in practice none of these proposed specific demonstration plants were built). Work under components 2 - 4 was then also underway. A mid-term evaluation was completed in February 2018. The final project closure date was 31 March 2019.

During the Pakistan Biomass project's implementation, the National University of Science and Technology (NUST) assumed a significant role in providing ongoing capacity building.

Financing plan summary - Outcome breakdown:

Project outcomes	**Donor (GEF/other) (USD)**	**Co-Financing (USD)**	**Total (USD)**
1. Demonstrating technical feasibility and commercial viability of modern biomass energy conversion technologies in SMEs in clusters and for power generation in rural areas	838,200	3,840,000	**4,678,200**
2. Information dissemination and confidence building	215,050	512,000	**727,050**
3. Establishment of policy and associated regulatory framework promoting the adoption of BGTs	170,250	155,000	325,250
4. Capacity building and strengthening of technology support system	405,500	420,000	**825,500**
5. M&E	44,000	60,000	**104,000**
6. Project Management	147,000	353,000	**500,000**
Total (USD)	**1,820,000**	**5,340,000**	**7,160,000**

Source : CEO endorsement document

The Pakistan Biomass project undertook significant information dissemination (Component 2), policy and regulatory framework (component 3) and capacity building (component 4) activities, solely focussed on biomass gasification. This included a major 1st International Conference and Expo on Biomass Gasification Technologies held in Islamabad in July 2016 at NUST that had 1000 participants from 15 countries.

In terms of biomass demonstrations (Component 1), which accounted to 46% of GEF grant funding and 82% of envisaged co-funding in the Project Document (ProDoc), the Pakistan Biomass project's achievements appear to be mixed. The Pakistan Biomass project's ProDoc target was three installed demonstration projects with an installed capacity of 2.3 MWe using biomass gasification technologies (BGT). In practice none of the proposed three BGT demonstration plants were built during the project implementation period from March 2012 to March 2019.

A 25 kW BGT demonstration plant for rural water pumping has been completed and commissioned by a Pakistan BGT development and manufacturing firm (Tawanai Solutions) post project end with full Pakistan Biomass project funding.

A 40kWe BGT for CHP use at KDC Boards (a plywood manufacturer) is still (in November 2019) seeking commercial bank funding and is still finalising its bidding documents. This demo is significantly downsized from its original 1 MWe concept.

The envisaged 3 MW BGT at Amir Rice Mills was reduced to a 1.05MW capacity at the feasibility study stage, but did not go ahead.

A USD15 million 5.5 MWe biomass combustion-based CHP plant was completed and is operational at Sapphire Finishing Mills (a major textiles export manufacturer and exporter). The project supported biomass supply chain study significantly assisted Sapphire's decision to go ahead with the CHP plant. The Pakistan Biomass project also supported the Sapphire demonstration plant with a USD100,000 monitoring, evaluation and publicity support for follow-on replication support.

The reasons for the major challenges and changes in the Pakistan Biomass projects demonstration component 1 are given in project documentation as primarily due to the significant drop in global oil prices that occurred in mid 2014.

Other major factors in the delays and eventual changes in the demonstration component were that: (1) the project initially targeted oversized (compared to their then own electricity and heat loads) BGT projects in SMEs with a need to large amounts of purchased biomass feedstocks to then export power to the grid; (2) the SMEs' power and heat loads were poorly known and could be undoubtedly have been more cost effectively supplied with smaller sized BGTs; (3) an underlying assumption that biomass combustion technology (BCT) based projects had intrinsically low combustion efficiency compared to biomass gasification technology (BGT) projects – this was never explicitly corrected in project literature even when it became apparent in the Sapphire demonstration plant that MW scale BCT CHP plants could be of equally high efficiency to BGT plants; (4) an underappreciation of the general low willingness to pay by target SMEs for higher cost baseload self-generated biomass power and heat rather than using a combination of lower cost grid electricity (albeit with regular and significant power cuts) and low capital cost and higher operating cost diesel generators; (5) a lack of appreciation in the project design that lower oil prices would lead to lower grid electricity tariffs and that lower oil prices would also lead to more reliable grid electricity supply - given the high proportion (around 50%) of Pakistan's power generation that is oil based.

1.4 RECONSTRUCTED PROJECT THEORY OF CHANGE

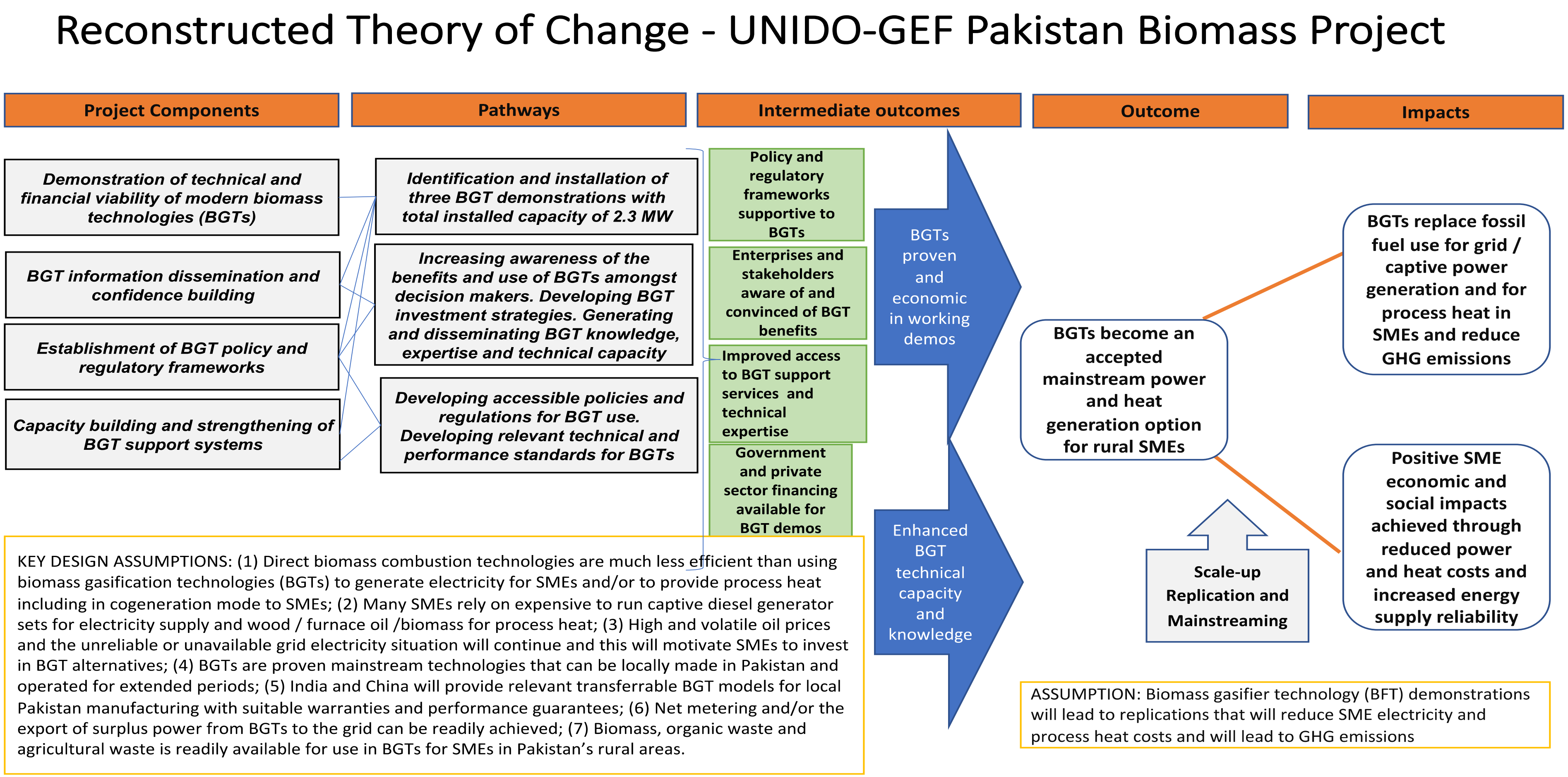

Figure 1: Reconstructed Theory of Change (ToC) of the project

A more realistic Theory of Change (ToC) would have been technology neutral between BGTs and BGT's and would have better reflected what was known both at the design stage of 2009 – 2012, and at the implementation stage of 2013 – 2019 when the ToC remained essentially unchanged.

1.5 EVALUATION METHODOLOGY

The Pakistan Biomass project evaluation started with a desk review of key relevant documents. The evaluation mission work physically started on 19 and 21 March 2019 in Vienna with meetings with relevant UNIDO project management staff and managers, and then with meetings with key project stakeholders and appropriate site visits in Pakistan from 25 - 29 March. There was then a debriefing of initial findings on 03 April at UNIDO in Vienna. The Pakistan Biomass TE Team Leader then drafted the terminal evaluation. This was followed by updating the draft report to reflect comments provided by UNIDO and the stakeholders to conclude a final draft report, including the required annexes and audit trail.

The evaluation methodology was to review all relevant documents and obtain face-to-face feedback of the project's progress and results from key stakeholders (a stakeholders list was provided by the UNIDO project implementation team and then refined as appropriate by the evaluation team). Individual meetings were held with project beneficiaries and key stakeholders as detailed in Annex D. Key evaluation issues and conclusions were checked with independent evidence and consolidated into a terminal evaluation report organized under the headings provided in the TOR.

1.6 LIMITATIONS OF THE EVALUATION

The five key limitations to this terminal evaluation were: (1) the limited evaluation mission time length; (2) limitations on the information and data provided to the evaluation team; (3) challenges in linking higher-level outcomes with immediate outputs; (4) a lack of gender disaggregated training and capacity building data; and (5) potential response bias on the part of respondents.

The evaluation team was able to visit two collaborating academic institutions, meet AEDB and SMEDA, visit one demo site with a working combustion based biomass co-gen system (Sapphire Finishing Mills), visit one of the original demo sites where a biomass gasifier technology system was still under active consideration (KDC Boards), meet one gasifier technology supplier (Tawanai) who built the 25kW rural water pumping system that is now commissioned post project end, and meet relevant UNIDO project staff in Pakistan during the one-week field mission. There were also pre and post fieldwork project staff meetings at UNIDO HQ in Vienna. There was unfortunately no time available to meet with or to interview other stakeholder groups, demo sites that did not proceed, or wider project beneficiaries during the field mission. There was also insufficient time available in the field mission to identify relevant extra stakeholders and to interview the recipients of project training and support activities. Hence project sources of information were used to assess these training and support aspects of the project. Every effort was made to assess every component and activity of the project to the fullest extent possible.

Response bias is a challenge inherent in all evaluations. To mitigate this challenge, the evaluation team compared answers from respondents with other respondents' responses and other sources of information, including those that could be found in internet searches.

In terms of gender perspectives, there was no gender disaggregated data available on participation in training and capacity building activities undertaken by the Pakistan Biomass project. Although the gathering of data by gender was not explicitly called for in the project's design documentation, this should have been added in the implementation phase as gender disaggregated data has become a standard element of project reporting.

2. PROJECT'S CONTRIBUTION TO DEVELOPMENT RESULTS - EFFECTIVENESS AND IMPACT

2.1 PROJECT'S ACHIEVED RESULTS AND OVERALL EFFECTIVENESS

The Pakistan Biomass Project contributed a pivotal biomass supply chain study that was a critical element in the realisation of the USD15 million 5.5 MWe CHP (Combined Heat and Power) power plant at Sapphire Finishing Mills that has been built by a Belgian company with 100 years of relevant power engineering experience (see Figures 2 - 5). The Sapphire project is the first large non-bagasse biomass CHP application in Pakistan and is almost certain to be able to sustainably operate for 20 - 30 years. With the project supported M&E and publicising of results contribution, the Sapphire plant is likely to be replicated by other SMEs that want to be able to generate their own power and heat in a sustainable way and without using fossil fuels. The Sapphire combined power and heat CHP efficiency is around 86%. With a project contribution to the Sapphire CHP of around 40% of its realisation assumed, then the Sapphire plant essentially meets the GHG emission reduction target of the project of 2.3 MWe and associated around 4 MWth of CHP heat utilisation.

However, it must be stressed that the Sapphire plant is a biomass combustion technology (BCT) plant, not one of the biomass gasification technology (BGT) plants that the project was predicated on. It should also be noted that the project support components of awareness raising, policy and regulatory framework adoption, and enhanced capacity of market players were successfully implemented, but that they were designed to solely support BGT applications right to the end of the project, The project support components documentation remained exclusively focussed on BGTs to the end of the project.

There are also two small 25 kWe and 40 kWe BGT plants that the project supported that have a reasonable prospect of sustainable operations. However, it is too soon to tell if the 40 kWe project-supported BGT demonstration will work as planned or if they are likely to be sustainable, and hence that BGTs might become an accepted mainstream power and heat generation option for rural SMEs in Pakistan.

In direct GHG mitigation terms the project was successful, albeit with BCT rather than BGT applications.

In indirect GHG mitigation terms, there is a lack of evidence one way or the other on what the project indirect impact is or might be.

2.2 PROGRESS TOWARDS IMPACT

In terms of progress towards the expected impact (see Figure 1 as above), the project made a modest and belated contribution to the stated design impacts as the expected project impacts were exclusively about BGTs. The 25 kWe BGT project was completed and commissioned post project end. The 40 kWe BGT CHP project had not yet been able to secure commercial bank funding by the end of the terminal evaluation process.

If the project had been designed to focus on biomass use for heat and/or power without an exclusive focus on BGTs, and with what was known at the time (see Figure 4), then the project would clearly have made significantly more progress towards its expected impact.

2.3 BEHAVIORAL CHANGE

In terms of behaviour change, the project has contributed towards the possibility of using waste agricultural biomass to generate electricity and/or heat in SMEs and rural villages to hundreds of engineering students at NUST and other academic institutions, and to government agencies and civil society stakeholders as well. However, the behaviour change is just a potential from the knowledge imparted, there is no evidence that the behaviour change had led to any tangible new biomass technology applications.

However, a negative feature is that the project promoted the idea that only BGTs (gasifiers) were "modern" and that BCTs (combustion systems) were intrinsically inefficient. This is a confusing and unhelpful message to be conveying, as it is not true.

Other messages that the project did not convey were that BGTs with reciprocating engines are best suited to smaller 20 – 50 kWe power outputs, and/or applications where large amounts of lower temperature (hot water) heat could be used, and where intermittent operation was all that is needed. In contrast BCTs were more promising for applications where 1 MWe or more power output is required, where large amounts of higher temperature (steam or thermal oil) process heat are useful, and where longer term (decades) continuous operation is required.

The project usefully contributed towards behaviour change in the use of biomass for energy. However, the project generated confusing messages that BGTs were the "modern" biomass technology of choice. The project failed to communicate that BGTs are best for smaller applications, with intermittent use and low temperature CHP application – and that BCTs are best for larger, continuous use, and higher temperature process heat CHP applications.

2.4 ADVANCING ECONOMIC COMPETITIVENESS

The large 5.5 MWe and 180 C / 10 bar process steam Sapphire project provides a well-engineered, long term viable, and economic 24/7 operational CHP plant for a modern textile factory in Pakistan's economically important textile sector. The use of a modern European (Vinke from Belgium) specifically designed biomass multi-fuel step/reciprocating grate boiler ensures that Sapphire has a power and heat CHP plant that should give decades of reliable energy supply while using a wide range of local biomass wastes.

The Pakistan Biomass Project supported the critical biomass supply chain study that enabled Sapphire to find a stable biomass energy plant alternative to the 7.5 MW of tri-fuel (HFO (heavy fuel oil), diesel and natural gas) Wartsila large reciprocating engines that were being considered that would have exposed Sapphire to the unpredictability of international oil prices, as natural gas in Pakistan is now 75% provided by imported LNG (Liquified Natural Gas) and LNG prices track crude oil prices. The new biomass CHP plant (see Figure 2 - 5) gives Sapphire the stable energy supply that they need for their major textile plant that produces cotton and cotton-blend fabrics as well as a high proportion of ready-made garment (RMG) production. Plants such as Sapphire have a large demand for medium temperature process heat so are a good fit for biomass cogeneration plants with their approximately 2:1 heat to power ratio and in particular the ability of BCT CHP systems to economically produce process steam as a by-product of power production. With the textile sector being a major source of economic competitiveness in Pakistan, the Sapphire plant is an excellent demonstration of a state-of-the-art biomass CHP plant - and can be expected to lead to wider replications in the future and advance the economic competitiveness of the textile sector and similar larger SMEs.

The two smaller BGT projects supported by the Pakistan Biomass project are of the most suitable 25 – 50 kWe size range for BGT technologies and have a reasonable chance of being successfully operated. The 40 kWe BGT KDC Boards plant will make use of KDC's existing wood wastes (see Figures 6 and 7 as below) and will provide process heat that KDC needs in its operations. KDC's intermittent operation is a good mix for a BGT which intrinsically needs daily ash removal, cleaning, and fuel hopper refilling.

The 25 kWe BGT power plant for rural water pumping that the Pakistan Biomass project is supporting with a USD40,000 grant has a specified 10 -15-year life and is targeted at advancing economic competitiveness. The recipient of this grant support is Tawanai, which is an experienced BGT designer and fabricator with around 1000 small BGT units for heat and power built to date, including for use in rural tractors, and with 70 return customers. Tawanai have a strong emphasis on using advanced control systems and claim to see their niche as being similar to that of All Power Labs in the USA. All Power Labs are the only known manufacturer producing significant numbers of standard packaged CHP and grid-paralleling capability BGTs with a well-engineered gas clean up system for the producer gas to be used in a low-cost standard internal combustion engine. These projects supported 25 and 40 kWe BGT plants are highly relevant for the large numbers of SMEs in Pakistan that need reliable power to be economically competitive (the grid supply in Pakistan still has regular power cuts) and also for SME plants that are not near to an existing grid electricity supply.

2.5 SAFEGUARDING THE ENVIRONMENT

The Pakistan Biomass project has made strong steps in the utilisation of renewable energy in the form of waste biomass for providing both electricity and thermal (heat) supply in SMEs.

The main project-assisted biomass energy tangible output is the USD15 million 5.5 MWe Sapphire Finishing Mills cogeneration plant, which is built to state of the art European biomass energy standards. The Sapphire CHP plant uses a biomass combustion technology (BCT) modern high temperature/pressure boiler and steam turbine, gives high temperature waste heat as 185C steam), and has a guaranteed CHP efficiency of 86%. The plant uses a wet scrubber, a multi-stage cyclone, and a EUR 780,000 electrostatic precipitator from Austria to ensure that stack emissions meet European Standards. A contract has already been signed for a water treatment plant so that by 2021 Sapphire will have full water recycling. Sapphire is aiming for ZWD (Zero Water Demand) which will be achieved by ultra-filtration and RO (Reverse Osmosis) of waste-water, so all fresh water will come from the plant's own treated waste-water. The Sapphire CHP plant will replace high-GHG marginal gas/oil/coal power plants' generation and use waste biomass that would be burnt in the fields or used for lower value and/or less energy efficient uses.

The Sapphire plant is already operating and should work reliably as the main baseload energy system for a 20 - 30 year life. The main fuel is rice husks and corn cobs. A 2nd phase will be a USD1.8 million grinding and materials handling facility that will enable Sapphire to also use wheat and other straw waste as its biomass fuels.

The Sapphire plant is an excellent demonstration project for other SMEs to replicate of large biomass fuelled CHP plants built to full European Standards that do the maximum possible to safeguard the environment.

2.6 REPLICATION AND SCALING-UP

The Pakistan Biomass project has supported the Sapphire CHP plant that has good prospects for replication amongst other larger SMEs that want their own reliable multi-MW CHP power and heat generation plant capable of decades of reliable continuous operation. However, the project has not undertaken an specific replication efforts of the Sapphire Biomass Combustion Technology (BCT) plant, instead focussing exclusively on general BGT (Biomass Gasification Technology promotion, support, and capacity building activities.

The packaged Tawanai 25 kWe biomass power plant that the project has fully funded has prospects to eventually lead to a more affordable Pakistan manufactured package similar to[7] the US All Power Systems PP30 CHP and grid paralleling biomass gasification technology (BGT) plant that is the only known standard unit in series production with a strong and credible money0back guarantee and warranty. However, there have not been any project supported specific moves to develop such standardised packaged BGTs in Pakistan

The Pakistan Biomass project has engaged NUST (the National University of Science and Technology) to undertake a cluster development project that includes a strong focus on replication and on scaling up aspects for biomass for energy development in Pakistan. This involves identification of potential local biomass energy systems manufacturers in Pakistan, the availability of biomass feedstocks by crop type and location, and financial models for various capacity biomass fuelled energy plants.

The project supported the development of an Upfront Biomass Generation Tariff, and provided inputs to the potential development of Minimum Quality Standards on Biomass Gasification Plants.

[7] The one-off Tawanai unit is specified to be able to run on multiple biomass fuels, while the proven series production APL PP30 unit only runs on 1-4cm wood chips and similar fuels.

3. PROJECT QUALITY AND PERFORMANCE

3.1 PROJECT DESIGN

3.1.1 Components and Activities

The Pakistan biomass project was organised around four (4) components and eight activities:

(1) *Demonstrating technical feasibility and commercial viability of modern biomass energy conversion technologies in SMEs in clusters and for power generation in rural areas*, with expected outputs of:

- three (3) demonstration projects installed with an installed capacity of 2.3 MW, to demonstrate the technical feasibility and commercial viability of biomass gasification technologies (BGTs) systems;

(2) *Information dissemination and confidence building*, with expected outputs of:

- Awareness on benefits and use of biomass gasification technologies (BGTs) created amongst decision-makers in SMEs, financial institutions and other stakeholders; and
- Investment and replication strategy for the use of BGTs in SMEs and in rural areas is developed. Knowledge and information on gasification applications disseminated;

(3) *Establishment of policy and associated regulatory framework promoting the adoption of BGTs* with expected outputs of:

- Concrete regulations and policy instruments and provisions promoting the use of BGTs developed as part of the RE Law; and
- Standardization and minimum performance standards of gasification technology developed and adopted; and

(4) *Capacity building and strengthening of technology support system with expected outputs of:*

- Staff in technical services and product providers for projects involving modern BGTs are trained in providing technical products and expertise to such projects;
- Capacity of training and research institutions that support markets for BGTs enhanced through organizing training and conducting applied research; and
- Technical capacity of beneficiaries to acquire, install, operate and maintain BGTs strengthened.

The Pakistan Biomass project's design was predicated on "modern" biomass energy technologies being exclusively biomass gasification technologies (BGTs), and the focus being on (a) SMEs in clusters[8] and (b) power generation in rural areas[9].

3.1.2 The 3 Proposed BGT Demonstrations

The two proposed SME BGT demonstrations were to be grid connected and hence were assumed to be able to sell their surplus electricity to the grid. The proposed village electrification project was also assumed to be able to sell its electricity to the grid when the village eventually became grid connected. A new Medium Term Renewable Energy (RE) Policy was expected to be in place in 2011 to facilitate this assumed grid connection option. The new RE policy was expected to include:

- Mandatory grid purchase of electricity from qualifying RE generation projects;
- Wheeling (with transmission charges) of RE from one location to another location;
- Allowing net metering and billing of surplus electricity to another time with the grid;
- De-licensing and deregulating small scale power production through RE up to 1 MWe for net metered projects;
- Simplified and transparent principles of tariff determination.
- Facilitating projects to obtain carbon credits for avoided GHG emissions.

One demo was be a village electrification project, apparently of 300 kWe electrical output providing power to the village of Malook Lakhi, district of Thatta, in Sindh Province, which was then apparently not connected to the power grid. In future, it was assumed that such off-grid village power systems could become grid-connected applications where the proximity to the power grid allowed for the feeding of excess power into the grid and for augmenting grid power in case of power outages. The village electrification project was also expected to lead to the introduction of productive uses from the energy provided to ensure that the villagers would have improved incomes to increase their ability to pay for the electricity. This project did not go ahead.

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[8] No rationale or examples were given in the project design what SMEs in clusters meant, and why SMEs in clusters were chosen, except that with SMEs in a cluster that it was expected to be easier to get other nearby SMEs to also adopt BGTs.

[9] A proposed location, Malook Lakhi, district of Thatta, in Sindh Province, was given for the off-grid power generation in rural areas demonstration. However, there was no information given as to why this particular village was proposed as a demo site. There was also no information given as to if any substantive analysis had been done on the villagers willingness and ability to pay, the availability and price or opportunity cost of suitable biomass near the village, the mix and seasonality of any biomass available centered on the village, how far the village was from the nearest grid connection point, any plans to extend the grid to the village, and the proposed BGT plant's biomass gathering, distribution system, ownership and management.

The two SME BGT demos were to be Amir Rice Mills in Gujranwala (of 1 MWe electrical output) and KDC Plywood Factory in Jehlum (also of 1 MWe electrical output).

The fuel to be used at Amir Rice Mills was to be their own and purchased rice husks, to meet the then operational electrical load of 800 kW, and a (undefined quantity in the pre-feasibility study of November 2011, but assumed to be around a very large 2 MW in the project's GHG mitigation calculations) demand for steam at 150C for parboiling rice. This project did not go ahead following its feasibility study of January 2015.

The KDC Plywood Factory had an electricity requirement of 250 kW and a (undefined quantity but assumed to be around a very large 2 MW of process heat in the project's GHG mitigation calculations in the pre-feasibility study of November 2011) demand for thermal oil used in the plywood manufacturing press at 150C and water heating at 50C, with the biomass fuel to be used being firewood. KDC was very interested in their own electricity supply at the biomass project's design phase, as in 2010-2011 they were then facing 11 hours a day of load shedding. However, KDC Boards closed their chipboard and adhesive plants in 2015-16 due to their need for major plant investment, and also particularly due to the unreliability of the grid power supply and the high cost of running diesel generators. KDC had a plentiful supply of waste timber. KDC advised the terminal evaluation team that they would have gone ahead with a BGT power plant and would have been able to keep the chipboard plant operating if the UNIDO team had been able to move faster, but that the UNIDO team had too many changes in staff in the critical (for KDC) 2014 - 2016 period. In early 2019 KDC was only facing 2-3 hours per day of load shedding, but KDC was still interested in a 40 kWe BGT plant in early 2019. The KDC BGT CHP plant was still working on obtaining commercial bank funding in November 2019. KDC were clearly a very motivated biomass energy user, but it was reported that the Pakistan Biomass project was not able to provide KDC with a suitable design in the timeframes that KDC needed.

Riaz Textile Mills, one of the proposed demonstration projects early on in the project's development cycle, was identified in the Pre-Feasibility Study (PFS) report of November 2011 (15 months before the CERDoc and ProDoc were finalised) as having a total operational load of 6 MWe and that the applicable biomass available within a radius of 30km would have been a mixture of rice husks, rice and wheat straw, corn cobs, plant stalks, wood waste etc. Riaz Textiles would have been a strong candidate for BCT use, as was later chosen and implemented for the Pakistan Biomass project supported Sapphire Finishing Mills 5.5 MWe power output demonstration. However, the Riaz Textiles biomass power plant consideration was totally focused on BGT use in the project development cycle without a suitable comparative analysis with BCT use, although BCT technologies and their attributes were extensively described in the body of the Riaz Textiles Pre-Feasibility Study (PFS). The Riaz Textiles BGT plant did not go ahead. It is not known if the Pakistan Biomass project ever presented a more appropriate BCT option to Riaz Textiles - as was successfully later implemented at Sapphire Finishing Mills.

Figure 2: Sapphire Finishing Mills' Boiler for 5.5 MWe
Biomass Plant Showing Boiler Scale

Figure 3: Sapphire Mills' 5.5 MWe CHP CEST Steam Turbine

Figure 4: Sapphire Finishing Mills' Rice Husk Stockpile with Standby Power Plant Behind

Figure 5: Sapphire Finishing Mills' CHP Plant Schematic and Summary

A further very negative issue in the project design was that the two proposed SME demo projects were not based on comprehensive energy end use reviews (energy audits and energy balances), they lacked daily and seasonal electricity and heat load profiles, and process heat load temperatures were also poorly defined or were lacking.

The proposed demonstration project BGT sizing was apparently based on limited if any energy audits or realistic energy balances. For example, Amir Rice Mills had an observed maximum load of 800 kW and an unknown but almost certainly small steam demand at 150C used for some rice parboiling (the steam demand was not specified). However, a 1 MWe power output BGT was specified in the CERDoc/ProDoc with an implicit assumption that its 2 MW of waste heat at say 90-115 C could somehow be fully utilised and could substitute for the limited amount of 150C steam used for rice parboiling. A 3 MWe BGT was specified in the TOR for the final feasibility study based on ambitious compound rice milling growth assumptions, which was reduced to a more realistic 1.05 MWe power output BGT size, but still without addressing what the vast amounts of low temperature waste heat would be usefully used for.

Figure 6: KDC Boards sawmilling plant showing old and energy inefficient plant being used

Similar oversized estimates of gasifier power outputs occurred for the KDC Boards proposed demonstration where the project design stage stated that the actual electrical load was 250kW and the thermal load was not defined, yet where it was implicitly assumed that 2 MW of process heat in CHP mode at 90C (with a maximum of 90 - 115 C) could somehow be used for process heating for the plywood (and the then chipboard) plants that were then supplied with 150C thermal oil from a steam boiler. A terminal evaluation (TE) field mission site visit to KDC Boards in March 2019 showed the continued use of extremely old equipment (see Figures 6 and 7), which was almost certainly highly energy inefficient. New electric motors and optimised thermal energy systems would almost certainly have been a more cost-effective investment alongside a smaller BGT unit than simply deploying a larger BGT unit to meet existing loads as was envisaged at KDC in the Pakistan biomass project's pre-feasibility and feasibility studies.

Figure 7: KDC Boards very old plywood cutting machine

Many of the problematic issues that would arise from the exclusive project design focus on BGT were detailed in the prefeasibility studies that were completed in November 2011, which was 4 months before the ProDoc and CER were finalised. For example, the prefeasibility study stated:

- *"A well-designed biomass steam system has a reasonable expectation of operating in the 92 to 98 percent availability range";*
- *"Boiler Efficiency on HHV Basis of 71.26% for a Biomass Stoker Boiler [for a small facility] on an as received (moisture) biomass basis……and… Stoker boilers have long been a standard technology for biomass as well as coal";*
- *"Compared with direct-fired biomass systems, gasification is not yet an established commercial technology";*
- *"For use in reciprocating engines…… a very clean gas is required….. the primary contaminants in syngas are tars, particles, alkali compounds, and ammonia";*
- *"Due to the fact that commercialization of biomass gasification plants is in its early stages, no facility survey information was found on their availability or reliability";*
- *"The actual number of biomass gasification systems in operation worldwide is unknown, but is estimated to be below 50 based on literature review and discussions with industry sources";*
- *"Gasifier efficiency (moisture adjusted) is 65%";*

- *"The most suitable scale for off-grid biomass electrification projects is below 100 kW";*
- *"The [BGT] technology providers and many of the hardware suppliers are happy to sell plants and walk away";*
- *"The recent track record for successful commercial power gasifiers is very limited and the reliability of those systems operating in the field is low";*
- *"Manufacturers promote their gasifiers with performance figures. However, these [performance figures] rarely seem to be based on practical operation";*
- *"A comprehensive World Bank study in 1998 examined gasification plants installed in the 1980s and came to the following disillusioning results: Most gasifier plants had been taken out of operation".*

However, the trade-offs between BGT and BCT, and the fact that BGTs were not yet a mainstream technology were not included in the components and activities in the project design's CERDoc and ProDoc that was finalised 4 months after the prefeasibility study was completed where the above cautionary issues were stated. The Pakistan Biomass project initially therefore proceeded with an almost exclusive, but known to be questionable, focus on BGTs. This was its main and its key design weakness.

3.1.3 Low Temperature CHP Heat and Heat to Power Ratio

In the project design (CERDoc and ProDoc), the 2.3 MWe of the three BGT plants were assumed to produce 15,330 MWh-e of electricity and 28,255 MWh-th of heat (in combined heat and power – CHP mode), with direct GHG cumulative emission reductions of 83,828 tCO_2 (due to the replacement of electricity from the grid, the replacement of the use of diesel generators and the replacement of furnace oil for process heat supply). This gave an overall assumed electricity capacity factor of 76%, presumably made up of a higher capacity factor for the two SME demos and a lower capacity factor for the village electrification demo. Given that the village project would presumably not have included a CHP element, this presumably then meant that the two SME demos were assumed to have a heat to power ratio of close to 2:1 It is also implicitly assumed that all this waste heat provided by the BGTs would have been at a usable temperature for the two SMEs' process loads, that all the usable heat would have been able to be utilised by the SMEs[10], and that all of the heat load would have been otherwise provided by furnace/fuel oil.

[10] With no energy balance available at the time of project design, it is highly unlikely that the two SME demos proposed could actually each use 2 MWth of hot water, given that it is highly unlikely that gasifiers feeding reciprocating engines can produce 150C steam in a 2:1 ratio to the electrical power generated.

3.1.4 Biomass Energy Technologies, Biomass Fuels, and Scaling Up

In smaller power capacities (under 1 MWe), BGTs providing producer gas to reciprocating engine generators[11] in principle have some advantages over biomass combustion technologies (BCTs) which are based on steam boilers and steam turbines. BGTs also have some advantages for intermittent use, when using a single biomass feedstock, and where low temperature process heat or no process heat is required. But this was not the situation at all for the two SME BGT applications proposed in the project's design.

Modern combustion technologies are applicable down to under 1 MWe of power output, can simultaneously provide high temperature process heat, can provide power and/or process efficiencies as high or higher than gasification-based systems, can more readily run on multiple biomass fuels, can run continuously for 20 - 30 years, and are a well proven technology worldwide. "Modern" sugar cane bagasse cogeneration based on combustion technologies with steam pressures of up to 130 bar and 525 C steam temperatures and using suitable condensing extraction steam turbines (CEST) can give 40% electrical generation and overall cogeneration efficiencies of up to 90%[12]. Modern sugar cane bagasse cogeneration technologies were already widely deployed in India[13] at the time of the Pakistan Biomass project's implementation.

In contrast, biomass gasification technology (BGT) power and/or cogeneration systems are better suited to lower capacities (around 20 -50 kWe) and with intermittent use - than are combustion power and/or cogeneration technologies. At the around 1 MWe power output capacities where the technologies overlap, the best BGT and the best biomass combustion technologies (BCT) would give similar power and/or heat efficiencies.

Combustion technologies in cogeneration mode can produce higher temperature process heat than can be obtained from gasification technologies using reciprocating engines for power production. Hence the power and/or heat requirements, and the process heat temperature requirements are critical determinants of whether BGT or biomass combustion technology (BCT) systems are the best technical answer in any particular application.

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[11] The reciprocating engines can be compression ignition (diesel) engines using about 15 - 35% diesel for stable combustion, or spark ignition (petrol) engines or diesel engines converted to spark ignition.

[12] Power generation from sugarcane biomass.... - Khatiwada et al | Energy 48 (2012) 241 - 254 (Elsevier) and Energy performance comparisons and enhancements in the sugar cane industry - in Biomass Conversion and Biorefinery (2019) 9:267 – 282 | SpringerLink - Birru, Erlich and Martin

[13] Bagasse Cogeneration in India - Status, Barriers - Mishra et al - IOSR-JMCE. By the end of August 2013, a total of 213 sugar mills in India had installed *bagasse optimum cogeneration* plants with a total installed capacity of 2,332 MW, according to the Press Information Bureau**,** Ministry of New and Renewable Energy (MNRE).

To say that BGTs are "modern" and combustion systems are "not modern" is therefore not a useful way to compare the two different biomass power and/or heat technologies. Combustion technologies are complementary technology options to BGT, along with anaerobic digestion which is generally best for wet biomass and manure bioenergy applications.

While it is true that gasification technologies can be deployed at lower power generation kW and/or heat capacities than combustion technologies: (1) the gasifier gas clean up issue is complex and non-trivial for stable and low wear long term use in reciprocating engines used for power generation; (2) gasifiers are generally optimised for just one (biomass) fuel[14]; (3) any heat recovered from the reciprocating engine is intrinsically of low temperature (under about 90C and at most 115C); (4) overall gasifier based system efficiencies in power generation, heat supply, and/or cogeneration are generally no higher and are often lower than that for modern combustion based biomass energy systems; (4) there is a limited (if any) international track record of gasifier biomass power generation energy systems successfully running for decades - in contrast to the case for combustion based biomass system; and (5) historical gasifier use (in particular in WW2) was an emergency measure driven by a lack of availability of suitable liquid fossil fuels - high engine and gasifier maintenance requirements and highly polluting operation was accepted as the stark alternatives were then walking or using horse drawn transport.

For successful ongoing BGT operations, very significant attention to (and considerable investment in) gasifier design and producer gas[15] clean-up is required to remove the complex mix of tars and ash in the producer gas for long term reciprocating engine life. In addition, standard well-proven commercially available BGT designs with credible guarantees and warranties, and highly skilled operators and/or sophisticated controls are needed for successful gasifier operation (let alone if using different biomass feedstocks) and to ensure stable and viable long term BGT operations[16]. An added complexity is that gasifiers need to have different designs for different biomass fuels.

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[14] Waste biomass fuel availability is seasonal and locally determined. So either the process uses its own waste fuels (e.g. rice mills using rice husks in their power gasifiers) for only part of the year, or year round availability purchased fuels such as wood, or multiple waste biomass fuels have to be gathered, transported to the biomass facility site, processed, and then used in a multi-fuel format.

[15] Producer gas from gasifiers comes from the reaction of Biomass + Limited Air = Carbon Monoxide + Hydrogen + Methane + Carbon Dioxide + Water Vapor + Nitrogen + tars + ash

[16] One of the few (and perhaps only) OEM commercially available packaged standard small BGT co-gen units currently available is produced by APL (USA), and is the result of 7 years of development and multi-million USD external funding support. The APL PP30 packaged BGT has a 22-24kW power output with fully automatic controls, standard grid paralleling capability, a money back guarantee, a 2 years or 4000 hours warranty, and a CHP heat output of up to 50kW at 75 – 90C. But APL's PP30 standard BGT unit is only approved to run on 1- 4cm sized feedstock of wood chips, coconut shells, tree nut shells (except for almond husks and cashew husks), and corn cobs (with increased

The only references that can be found for standard design gasifier systems with credible warranties (22 - 24 kWe units are from All Power Labs (USA), 46/50/56 kWe units from Froling (Austria) and 32 kWe units from Husk Power Systems (India)). These examples are all smaller output systems of up to about 50 kWe and optimised for a single biomass fuel or type of fuels. These systems appear to use unpressurised downdraft gasifiers and to be able to use a simple packaged producer gas clean up system to produce clean enough producer gas to be used in a reciprocating engine.

In cogeneration (Combined Heat and Power - CHP) mode such gasification systems will produce around a 2:1 heat to electricity output ratio. The heat will be recovered from the engine radiator (90 C), oil cooler (75 C) and possibly from the exhaust stack and gasifier (115 C). In CHP mode there is then a need to match the system to an enterprise that needs large amounts of low-grade heat, such as the ready-made garments (RMG) industry. But an RMG enterprise that would be interested in its own biomass power plant almost certainly needs more than 100 kW of low-grade heat.

It was also assumed that suitable BGTs could be designed by local Pakistan companies that had no suitable prior experience in BGT technology at all, let alone at the 1 MWe scale proposed. This was, and still is, a completely unrealistic assumption.

Even an established firm such as Tawanai Solutions, with its significant small gasifier engineering experience and solid engineering capabilities, and with apparently 1000 gasifiers sold to date (including micro gasifiers for cooking purposes, small BGTs for around 25-40 kW for use in agricultural tractors, and 70 customers being repeat orders) would take many years of development and major external R&D funding to produce a reliable base load 1 MWe BGT - even if say 4*1MWth gasifiers each providing producer gas to a 250 kWe reciprocating engine were used to give a total 1 MWe BGT system.

maintenance). The PP30 units are designed for 3500 hours/year operation. The expected engine life is only 10,000 – 17,000 hours and the expected alternator life is only 20,000 – 40,000 hours. The 2019 complete PP30 co-gen and grid paralleling unit price ready to ship from the factory in California is USD51,413. Ref: PP30 (Power Pellet 30) Packaged OEM 22-24 kW CHP Ready Genset Data Sheet, Sales Terms and Conditions, and Data Sheet - All Power Labs, CA-USA, and personal correspondence with APL – Aug - Sept 2019.

Figure 8: USPCASE-NUST Demonstration Gasifier

Gasifiers, and their gas clean up systems look simple, and it is relatively easy to design and build a small bench scale gasifier that works for a few hours (see Figures 8 and 9). However, it is a completely different task to design and build a 1 MWe gasifier and high temperature heat recovery system that will run for 100,000 - 200,000 hours, i.e. 11.5 – 23 years, on 24/7 operation) in the real world and with clean enough producer gas for the reciprocating engine to last say 15,000 - 50,000 hours (which is the expected time between major overhauls of mainstream international brand diesel generators[17]). However, unfortunately, this sort of wild extrapolation from small proof-of-concept biomass gasifiers running for a few hours (as per Figures 8 and 9) to MWe scale BGT units that are supposed to run for decades is unfortunately very common in the design and implementation of BGT projects worldwide.

[17] Diesel Engine Generators Life Expectancy - How Long Do They Last? - Worldwide Power Products (USA)

Figure 9: Faisalabad Agricultural University Student Designed Demonstration Gasifier

Figure 10: The project funded Tawanai Solutions 25kW gasifier and diesel motor for rural water pumping

Figure 11: Commercially Available All Power Labs' USD51,413 Power Pallet 22-24 kWe PP30 CHP Unit - Developed over 7 Years with Multi Million USD External Funding Support

The reference in the project design to BGTs having been deployed in large numbers for power generation in the past (in particular the 1 million BGTs in use by the end of WW2 (using charcoal and wood as the biomass feedstock)) was because suitable liquid fuels were then just not available at all where and when the BGTs were then being used. These gasifiers worked but needed constant adjustment and they led to very high engine maintenance demands, which were tolerated at the time as the stark alternative was to walk or ride a bicycle or use a horse.

The literature is clear that nearly all biomass gasifier demonstrations in the multiple phases of gasifier deployment since the 1970s did not operate for long before being abandoned. There have been some examples of limited series production of standardised gasifier designs being successful with BGTs of generally 10 – 30 kWe outputs[18]. When BGTs are used for powering agricultural tractors (e.g. Tawanai in Pakistan), for remote water pumping or for transport uses (e.g. in DPRK – North Korea) it is generally because conventional petrol and diesel is either not available or is not affordable. The project design did not state that such examples of biogas use for vehicles/tractors generally comes with much higher engine maintenance requirements and greatly reduced engine performance and reduced engine life for the vehicle or

[18] http://nznano.blogspot.com/2019/07/doug-williams-pillar-of-gasification.html

tractor being used compared with their use with the conventional diesel or petrol fuels that they were designed to use.

In India, only 5% of biomass power production comes from BGTs, and most BGTs are for systems of less than 250 kWe power output. India has some useful experience in medium scale BGTs sustainably using rice husks (of up to 300 kWe), but the idea of producing such proven Indian rice husk BGT designs under licence in Pakistan was not detailed in the project design documentation.

There are apparently fewer than 10 installations in India of over 1 MWe power output[19]. There are reported to be fewer than 50 BGTs operating worldwide generating biogas for power in excess of 1 MW (thermal) input rating[20] (about 250 kWe of power generation).

In China, gasifiers are apparently primarily focussed on using coal, and BGTs are apparently more a research focussed than a widely deployed technology[21].

There has been a large historical investment in very large gasifiers for generating liquid fuels for transport use by the Fischer-Tropsch process, for generating industrial chemicals, and for large scale power generation using integrated gasification combined cycle (IGCC), power plant technologies based on coal. This interest was driven by a critical lack of conventional liquid fuels (in Germany in WW2 and in South Africa under apartheid era sanctions), and an interest in generating industrial chemicals in countries such as China with massive coal reserves and limited oil and natural gas reserves. But this very large gasifier experience is based on high (20-30 bar) gasifier pressures, a huge scale, coal at nearly zero cost and no thought of GHG emissions, so it is not relevant to the 1 MWe and smaller scale biomass gasifiers that were envisaged in the Pakistan biomass project.

Hence, contrary to what was claimed in the project design, BGTs were not (and still are not) a widely deployed mainstream biomass energy technology in India and China that could be directly replicated in Pakistan at the 300 kWe - 1 MWe scale as envisaged in the project design.

Biomass Combustion Technologies (BCTs), with steam turbines, are the most common technologies used in applications for above 2 MWe of power generation capacity, where

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[19] Current Status of Biomass Gasification in India – EAI

[20] Biomass Gasification and Pyrolysis - Roddy & Manson-Whitton - in Comprehensive Renewable Energy, ScienceDirect, 2012

[21] Biomass Gasification – An Overview of Technological Barriers and Socio-Environmental Impact – Intech – Wu et al – 2018.

multiple biomass fuels are used, and where long term (decades) of continuous operation are required. Where higher temperature process heat is required in cogeneration (CHP) mode, then condensing extraction steam turbines (CEST) would be used.

Above about 1 MWe of power generation, the power generation and co-generation efficiency of BGTs and BCTs is broadly similar. A critical factor is that BGTs intrinsically give low temperature waste heat in CHP mode, while BCTs can give higher temperature waste heat in CHP mode.

Anaerobic biodigesters are the more appropriate biomass energy technology where very wet organic waste (vegetable or fruit wastes) or manure are the bioenergy feedstocks.

However, these intrinsic BGT/BCT/anaerobic digestor factors were never presented in the key project design documents (CERDoc and ProDoc). It was just stated that modern biomass technologies were (all) BGTs.

3.1.5 Replication

A final issue was that an explicit replication element was missing in the project's design. It was therefore implicitly assumed in the project's design that the three project demonstrations would somehow lead to replications without any specific project provided interventions. However, in practice, for demonstration projects to lead to replications, there must be an explicit replication set of activities. The replication activities must be done on a regional basis, as just like most news is locally focused, demonstrations-replications must also be based on locally based information and publicity. To make a significant impact, a demo-based project focus should not be on just demonstrating a single biomass-energy application in one location, but rather in developing a set of biomass energy application packages that would be demonstrated in one or more location, and then these demonstrations would be monitored, evaluated, documented, publicised and supported in different SME clusters and in different provinces.

To be widely replicated, the biomass gasifier (BGT) packages would need to be of small power output (say 20 – 50 kWe), to be operated say 3500hrs/year (i.e. 40% capacity factor), and optimised for a single biomass fuel type, e.g. wood chips and equivalents, or rice husks, or biomass pellets, etc. The 25 kWe Tawanai water pumping BGT demo and the KDC 40 kWe BGT for CHP use demo could usefully be further monitored, evaluated and publicised as part of the ongoing post-project end Pakistan biomass project's replication efforts. The ultimate goal for widespread replication would need to be standard units with defined performance with credible warranties, hence a local version of the APL PP30 in Figure 11 as above.

For 1 MWe scale gasification systems, application and biomass fuel specific designs would be needed, it is not possible to simply scale up a generic 20 - 50 kWe BGT design with a 40% capacity factor to a I MWe BGT design operating at a 95% capacity factor For 1 MWe applications, combustion (BCT) technologies such as the project supported demo project at Sapphire Finishing Mills are likely a more promising approach.

During the concluding phase of the project, the Pakistan Biomass project funded work by NUST in the development of a Biomass Cluster. One of the elements of the project funded biomass cluster work by NUST was the development of a replication strategy for energy from biomass in Pakistan. However, the NUST work is solely focussed on the use of BGT applications in the 25 – 500 kWe range and only focusses on the power aspects. The NUST work does not explicitly address the process heat aspects in CHP mode, nor the 2:1 heat to power ratio from any biomass energy plant, or that BGTs provide lower temperature process heat compared to BCT technologies. The fact that smaller BCT applications are best suited to intermittent use, while BCT applications are suited to continuous operation, is also not mentioned in the NUST Biomass Cluster work.

3.1.6 Summary re Biomass Gasification Technologies (BGTs)

Biomass Gasification Technologies (BGT) are a reasonably well proven technology for producing a clean fuel gas for use in a reciprocating engine generator at a small scale of up to 50 kWe. This technology typically operates at atmospheric pressure and gasifies biomass using air and the inherent moisture from the biomass.

Scaling up the BGT technology 20 times from 50 kWe to 1000 kWe (1 MWe) or more is seriously non-trivial. Thermal efficiency of gasification and compactness of the plant would be enhanced by pressurization of the gasification process. However, pressurisation introduces significant issues with the feeding of biomass materials and a pressurized fuel gas is not required for a small naturally aspirated internal combustion engine. Therefore, small scale, unpressurised biomass gasification is the preferred and proven BGT technology.

The history of BGT includes many examples of failed attempts to scale up small biomass gasifier designs which have successfully produced a tar-free gas at a small scale. The key to producing a tar-free fuel gas is for all the volatiles driven off from the biomass feedstock to pass through a coherent bed of hot biomass char, where the tar components are broken down. When the char bed size is increased, pathways occur in the hot char bed for unreacted tars to pass through the char bed unreacted; producing a fuel gas containing tars. A tarry gas requires expensive clean-up operations to avoid problems with coking in the internal combustion engine using the gas. This is the principal reason why the scale-up of biomass gasification technology is a seriously non-trivial technical issue.

3.1.7 Non-Technology Components

The Information (Component 2), Policy and Regulatory Framework (component 3), Capacity Building (Component 4), and Monitoring and Evaluation (Component 5) and

Project Management (Component 6) and their related activities were fairly standard and generally appropriate for such a technology demonstration-led project.

3.1.8 Risks

The project risks were generally well identified, but the risk ratings were uniformly too low - this understating of risks had been explicitly identified and articulated in the STAP review that was provided to the project design team two years before the project design was finalised.

3.1.9 Project Logframe/Results Framework

The project Logframe/Results Framework was logically laid out and well organised. The Logframe/Results Framework constraints were, like the other aspects of the project, the exclusive emphasis on BGT technologies, the assumptions that all the waste heat produced could be utilised (and at the lower intrinsic BGT waste heat temperatures), the lack of an explicit replication focus, the assumptions that BGTs could be simply and successfully scaled up by a factor of ten to a hundred times in one step, and other issues as discussed above.

3.1.10 Overall Design Rating

The overall rating for the project's design is "unsatisfactory".

3.2 RELEVANCE

The project objective of *Promote market-based adoption of modern biomass energy conversion technologies for process heat and electricity generation in Small and Medium Scale Enterprises and rural areas in Pakistan* was, and still is, highly directly relevant for overall and regional/rural economic development, employment, economic competitiveness, security of energy supply, reduction in air pollution and national and international GHG mitigation reasons in Pakistan.

The project is still very relevant even although the original impetus was the then severe constraints in grid electricity supply, indirectly related limited availability of piped natural gas for SMEs that utilise this fuel, and the high price of fossil fuels (diesel and furnace oil).

The grid electricity supply situation is now significantly improved for SMEs in Pakistan, but there are still regular power cuts. The electricity industry still suffers from fundamental issues of large circular debts, high technical and non-technical losses, and below cost tariffs for many consumers.

The price of oil is lower than it was in 2009-2010 when the project was formulated, but oil prices are by their very nature cyclical on a roughly 10-year cycle and are essentially volatile and hence unpredictable at any given time. Therefore, the use by SMEs of locally available low value biomass to substitute for unreliable grid electricity and unpredictable cost furnace oil or natural gas (where available) for thermal loads is still very relevant in Pakistan.

Although the project did not realise a demonstration off-grid power supply for villages in rural areas, this is still a relevant area where biomass could be used in the right circumstances for electricity supply, including for productive uses (although productive uses do not generally spontaneously arise, they need multiple specific interventions before they become significant loads).

Although the project had an original exclusive focus on biomass gasification technologies (BGTs) in its design and early implementation, the project focus then was usefully widened to also include biomass combustion technologies with its support for the Sapphire Finishing Mills Biomass Supply Chain Study in January 2015, which was a critical input for the decision in December 2015 of Sapphire to go ahead with a biomass combustion technology (BCT) boiler and condensing extraction steam turbine (CEST) to supply the 180C 10-bar steam for Sapphire's process heat requirements.

Hence, since the project was adjusted to also include continuous operation BCT systems alongside smaller capacity and intermittent operation BGT systems (at KDC mills and for a rural water pumping application), the project had been refocused to be relevant in its final operations.

The Information (Component 2), Policy and Regulatory Framework (component 3), Capacity Building (Component 4), and Monitoring and Evaluation (Component 5) and Project Management (Component 6) and their related activities were very relevant.

The reason that the project has not been evaluated as highly satisfactory in relevance terms was:

(1) its initial focus on BGT to the exclusion of BCT in applications where BCT was a more suitable biomass energy technology;
(2) its ongoing failure to identify that BCT systems intrinsically give higher waste heat temperatures than a BGT does in cogeneration or CHP mode;
(3) the ongoing failure to recognise that 1 MWe and larger BCT systems can run for decades in baseload continuous operations, while BGT systems in the tens or hundreds of kW electricity generation size are really only suitable for limited life and/or part time operation systems due to the limited life of smaller reciprocating engines (even if proper gas clean-up is achieved);
(4) and the ongoing failure to recognise that there is little intrinsic difference in the power generation efficiency of BGT and BCT systems in the 1-3 MWe size ranges.

The rating for overall relevance is "satisfactory".

3.3 EFFICIENCY

The project's efficiency was assessed by the degree to which its overall objective was achieved within its budget and timeframe, and if it overran its timeframe were there sound reasons for this time overrun.

The project significantly overran its timeframe by three years, from its original ProDoc end date of April 2016 to its final end date of March 2019. The project start-up was delayed for over a year, due to partnership issues with AEDB and the time consumed by project organization and mobilization. In 2015-16 the project implementation was delayed again by the reduction in global oil prices resulting in the cancellation of two of the originally proposed BGT pilots, and delays in the proposed KDC Board demonstration due to the closing of the chipboard plant in 2015-2016 and a downsizing of the BGT capacity to its project-end 40 kWe from its original 1 MWe size. Other key reasons for the time overrun include high UNIDO staff turnover that was out of the control of the project, major and unforeseen delays in getting Visas and permission to travel within Pakistan for specialist Indian biomass energy system consultants, and the unforeseen dramatic drop in the price of oil (partly driven by the dramatic impact of US oil shale fracking) and the subsequent improvement in grid electricity supply availability and a drop in the price of natural gas for industries.

In terms of the project's energy and GHG mitigation results, an extremely well-engineered 5.5 MWe baseload electricity output biomass system has been completed at Sapphire Finishing Mills with significant project input to determine a suitable biomass supply chain and with project support for the monitoring, evaluation and publicising of results. A project funded 25 kW rural water pumping BGT has been constructed by Tawanai Solutions and has been commissioned.

A project supported 40 kWe BGT CHP unit at KDC was still (in November 2019) awaiting commercial bank funding any may yet still go ahead. In GHG mitigation terms, the project was moderately successful, as the project contribution to the Sapphire plant was very useful but not a fully determining factor in it going ahead.

The Information (Component 2), Policy and Regulatory Framework (Component 3), Capacity Building (Component 4), and Monitoring and Evaluation (Component 5) and Project Management (Component 6) and their related activities were efficiently implemented in achieving their desired results within the GEF budget deployed.

The project's original overall budget was USD7.16 Million, including a co-financing share of USD5.43 Million of which USD3.84 million was for Component 1 for the three proposed demonstrations. In practice, the Sapphire Finishing Mills 5.5 MWe BCT plant cost USD15 million which was funded by Sapphire. Although the Sapphire plant going ahead as a demonstration was not 100% due to the Pakistan Biomass Project's interventions, a USD5 million cash contribution can reasonably be attributed to the project. With in-kind contributions from NUST, SMEDA, AEDB and other project partners, it can be concluded that the project met its overall envisaged level of co-financing.

The rating for overall efficiency is "moderately satisfactory".

3.4 SUSTAINABILITY

In terms of the post project end sustainability of the project's achievements and capacity, the need to plan for, and set in place strategies for, the project's official closure on 31 March 2019 was raised and addressed by the PMU and addressed through a number of strategies and actions. A key project sustainability element was the project funded work by NUST on the development of a biomass cluster, and a replication and localization strategy. During the concluding phase the project focused strongly in establishing a biomass cluster in Pakistan which would provide an enabling platform to all the stakeholders to work together and to promote the use of low carbon biomass technologies in Pakistan including biomass gasification technologies (BGT).

The reduction in international oil prices considerably hampered the financial and economic viability and comparative advantage of biomass energy technologies. However, biomass energy technologies can still usefully proceed in the right project and with the right technology and the right size.

A 25kWe BGT for rural water pumping using a diesel engine was fully funded by USD40,000 from the project in February 2019. This plant has been commissioned and has reasonable prospects of medium-term sustainable operations.

A project supported 40 kWe BGT CHP unit at KDC Boards was still awaiting commercial bank funding at November 2019. It is not possible to definitely say if this project will go ahead, let alone if its operation is likely to be sustainable.

Sapphire Finishing Mills has invested USD15 million in a state of the art BCT co-generation plant, with its commissioning and plant hand-over to its operators occurring in May 2019. Sapphire is a particularly progressive company in energy and environmental matters - with further investment planned of USD1.8 million in a grinding and materials handling facility so that a wider mix of biomass feedstocks can be used in future. A future zero water demand (ZWD) development at Sapphire is also envisaged. The project supported Sapphire biomass CHP plant's operations are highly likely to be sustainable.

For evaluating the sustainability of project interventions, GEF guidelines include four key risk areas for consideration, each of which are to be evaluated separately and then rated as to the likelihood and extent that they are likely to impede sustainability of the project outcomes post project end. These risks include: 1) financial risks; 2) socio-political risks, 3) institutional framework and governance risks; and 4) environmental risks.

3.4.1 Financial Risks

The project in its design and implementation aimed to introduce and promote modern biomass energy conversion technologies as a cost-effective option for SMEs to obtain the reliable electricity and/or process heat needed for their financially viable business operations. In the project design and operation there was a very specific and sole emphasis on the adoption of biomass gasification technologies (BGTs) in Pakistan. The cornerstone of the project was to be the development and successful implementation of two SME BGT pilot demonstration cogeneration/CHP projects of 1 MWe electrical output and the generation and use of associated process heat generation of 2 MWth for each of the SME demonstrations, along with one 300 kWe electrical output only BGT demonstration project with a rural community - for a total electricity generation capacity of 2.3 MWe and around 4 MWth process heat use.

The key financial risk to project success that was rated of low probability was a major reduction in international oil prices. However, international oil prices started to fall in a sudden and dramatic fashion in 2014, for reasons detailed in the Project Context section as above. The reduction in oil prices led to a significant improvement in grid electricity supply and reliability to SMEs, along with a reduction in electricity tariffs. There was also an associated improved availability of natural gas for process heat use, which was very relevant for those SMEs with access to natural gas. This greatly reduced the financial imperative for SMEs to invest in biomass systems to provide themselves with lower cost and more reliable electricity and process heat supplies.

However, this financial factor was important, but it was not the only reason why the proposed demonstration projects did not go ahead. Equally important was that the BGTs that were being promoted by the project were a new technology for Pakistan. In fact, if the proposed demonstration sites had done their own due diligence via the internet, they would have found that 1 MWe electricity output BGTs were rare in neighboring counties, with only 10 in place at this scale in India (see section 3.1 above). There would also would have been issues around the lack of proper electricity and heat load analysis at the proposed demonstration project sites, along with a mismatch between the temperature and quantity of heat being produced in cogeneration/CHP mode of the proposed 1 MWe BGT plants and the actual SME process heat demand and the process heat temperatures required.

There is also a financial risk that many biomass “waste” streams have competing uses for process heat or materials uses, so that biomass prices are not likely to be fixed over a biomass energy project’s lifetime. In many countries this is addressed through adjustments in the applicable electricity export tariff. However, such special biomass energy export tariffs can end up being higher than the price that consumers pay for their electricity. In a financially precarious power system such as Pakistan, such subsidies to support biomass export power could become difficult to sustain over time and the ability to keep accessing advantageous electricity export tariffs over decades may be financially questionable.

The reduction in oil prices that led to the improvement of grid electricity supply, and the reduced cost of operating diesel generator sets, would also have contributed to the proposed 300 kWe off grid village power supply project not going ahead.

Given the non-viability of two of the proposed BGT demonstrations, the project shifted its attention and resources towards potential demonstration projects with other strong drivers, such as the reliability of power and heat supply, the desire to utilise well proven biomass technologies from very experienced international biomass equipment suppliers with a long and successful track record in the technology chosen, and the need to have a sustainable or "green" profile to meet the requirements of the demanding foreign customers of the SME's products.

Hence the project supported a biomass supply chain study and funded the monitoring, evaluation and publicising of results for Sapphire Finishing Mills installation of a state-of-the-art biomass combustion technology (BCT) plant (with 86.5% cogeneration/CHP efficiency for 5.5 MW of electricity supply and for the supply of 185C steam) for the generation of electricity and steam for Sapphire Finishing Mills' own plant.

Regarding financial risks to project capacity building and awareness related interventions, the project has fostered strong relations with relevant leading academic institutions, especially with NUST. This has led to the incorporation of courses related to biomass gasification technologies in regular bachelor's and master level courses at NUST and UMT Lahore. These courses should therefore continue to provide training in the basics of biomass use for energy purposes once financial support for the project ends, and regardless of fluctuations in global oil and gas prices and changes in the tariff and reliability of grid electricity in Pakistan.

The rating for financial risks is "likely".

3.4.2 Socio-Political Risks

Reliability, affordability, and low environmental impact remain a key driver of energy policies and actions in Pakistan.

The use of agricultural waste biomass has strong and ongoing socio-political support due to the (1) very large biomass resources available, often at low cost, and denominated in local currency; (2) the ongoing burning of biomass in the fields with resulting high smoke pollution; (3) the high cost and political sensitivity of charging market prices for grid electricity and its strong link with uncontrollable international crude oil prices; (4) furnace oil and reticulated gas (which is now 75% derived from imported LNG) costs being directly related to uncontrollable international crude oil prices.

There are no major socio-political risks foreseen in the promotion of biomass energy technologies and their applications or in the continuity of project benefits post project end. There is a reasonable degree of national ownership, and the necessary supportive RE biomass related policies and enabling environment has been developed and further polices and supportive measures are under consideration.

The rating for socio-political risks is "highly likely"

3.4.3 Institutional Framework and Government Risks

The project design included developing concrete regulations and policy instruments, and that provisions promoting the use of modern biomass (in particular BGTs) would be developed as part of the RE Law. The rationale for this was that there was a lack of suitable regulatory frameworks for grid connected biomass power projects and that this was a constraint to the development of biomass projects, many of which would be grid connected and would either sell excess power to the grid through an appropriate Feed in Tariff (FiT) or would connect to the grid via net metering arrangements. With input from the Pakistan Biomass project through AEDB, the Pakistan National Electric Power Regulatory Authority (NEPRA) published an Upfront Generation Tariff for Biomass Projects (effectively a biomass FiT) in December 2017. The Upfront Generation Tariff for Biomass Projects was for 2 years to a maximum cap of 100 MWe. It is understood that net metering for individual biomass plants was allowed up to a limit of 1 MWe.

The project design also included the development and adoption of suitable standardisation and minimum performance standards for gasification technologies. A comprehensive draft minimum quality standard for biomass gasification plants (based on Indian biomass technology practices and experience) was finalised by consultants in May 2017 for the Pakistan Biomass Project, following widespread consultation in Pakistan. A Pakistan Standards and Quality Control Authority technical committee meeting was held in September 2018 to consider the draft BGT quality standards developed by the Pakistan Biomass Project.

With regard to biomass combustion technologies (BCTs), the Pakistan government has a number of mechanisms in place to support the power export from sugar cane bagasse power plants, and a growing number of sugar industries are involved in the export of power to the grid. According to AEDB, at the time of the project's Mid Term Review (MTR) of February 2018, a peak output of around 160 MW of electricity was produced from sugar cane bagasse and there were Letters of Agreement (LoA) then in place with AEDB for another 1200 MW of peak power supply from private sector sugar cane bagasse plants.

In terms of the sustainability of biomass supply for energy support post project end, there are two enduring particularly relevant Government of Pakistan institutions namely SMEDA and AEDB that are maintaining an interest in the areas of intervention that the Pakistan Biomass project covered. There is also significant biomass energy capacity that has been developed in NUST and other academic institutions, which is likely to continue after the Pakistan Biomass Project's end.

Pakistan still has a large waste agricultural biomass resource that is not being fully utilised and that is still frequently just burned in the fields to dispose of it and to return trace nutrients to the soil in time for the next crop, and therefore deriving little value from this biomass resource and causing major air pollution. With the ongoing electricity supply challenges in Pakistan, and the ongoing drain on currency reserves from the need to import oil and LNG, more fully utilising waste biomass must be a part of any sensible Pakistan energy strategy going forward.

The rating for institutional framework and government risks is "likely"

3.4.4 Environmental Risks

The overall project goal was to reduce GHG emissions from energy use in SMEs and rural areas in Pakistan. The project focus to enhance the use of biomass wastes was directly relevant to the project goal. The project initially focused on the adoption of BGTs as BGTs were considered a more efficient and hence more environmentally friendly biomass energy technology option as compared to energy generation from biomass combustion technologies (BCTs). Any use of waste biomass has lower GHG emissions than using any fossil fuel power generation options. However, any use of biomass energy technologies will still lead to some environmental impacts, either smokestack emissions, or disposing of resulting tar, ash etc. This means that any biomass technology needs to have appropriate exhaust gas clean up and tar, ash etc waste disposal environmental standards and practices in place.

For BGTs, this means that the starting point should be developing and then using standardised proven packaged BGT units such as the US All Power Labs AP30 22-24 kWe wood chip fired CHP unit or the 32 kW rice husk fried units of Husk Power in Bihar, India. The Pakistan Biomass Project funded 25kWe BGT for use in rural water pumping, from Tawanai Solutions, with its similar design philosophy to APL, and having a producer gas clean up system and automatic gasifier controls, is the best way forward to get BGT's with low smokestack and solid waste environmental emission levels to be available in Pakistan.

Instead, after 7 years of promoting unrealistically large sizes and non-standard BGTs in Pakistan there were still no BGT units operating with SMEs at November 2019. And if the project had built such large power output one-off BGT units, it is almost certain that there would have been significant adverse environmental impacts. A clear vision of developing BGTs of 20 - 50 kWe of generation capacity could by now after 7 years of the

Pakistan Biomass project's operations have had such small ambient pressure units being commercially available to run on defined packages of biomass fuels to proven low levels of environment impacts.

For BCT units, the use of international environmental standards will ensure that they operate with the minimum possible environmental impacts. The project supported 5.5 MWe Sapphire Finishing Mills BCT CHP system is being provided by a European vendor with 100 years of relevant boiler experience to European standards, and which will give the lowest possible environmental impacts. Discussion with Sapphire management showed that they are very well aware of the strong environmental concerns of their European customers, and they are hence adopting European quality and environmental standards to reduce their carbon emissions, dust and now NOx emissions.

The overall rating for sustainability is "highly likely"

3.5 GENDER MAINSTREAMING

The project had no specific gender aspects mentioned in the project documentation. In its implementation the project did not provide any specific emphasis on gender mainstreaming, no specific gender related interventions were designed or implemented, and gender disaggregated attendance lists were not produced for project supported training activities or meetings. However, UNIDO should have been aware from its wider involvement in GEF and other donor funded projects that gender was an issue that was increasing in importance across all donor funded activities and that gender disaggregated data should therefore be gathered by the project in all its activities. The project design implicitly assumed that the overall project would automatically benefits both genders. The project training activities were attended by female students and faculty members from respective universities. Female members from various governmental and other organizations also participated in the project's conferences, workshops, seminars and meetings. However, due to the lack of data gathered on a gender basis in the project, it is very difficult to assess if women benefited equally to men in project activities and capacity building.

The rating for gender mainstreaming is "unsatisfactory"

3.6 PERFORMANCE OF PARTNERS

3.6.1 UNIDO

UNIDO had the primary Pakistan Project's design and implementation responsibility, covering:

- undertaking the Pakistan biomass and energy situation and baseline analyses;

- developing the project's logical framework[22];
- identifying the biomass energy technology or technologies (BGT, BCT, anaerobic digestion) to demonstrate and then to actively support replications (or not);
- choosing the target sectors for the application of the biomass energy technologies;
- the mobilisation and organisation of Pakistan partners and counterparts;
- developing TOR, recruiting, and managing project staff and consultants;
- the management of project outputs within component and within overall GEF budgets;
- the mobilisation of co-funding;
- the monitoring of project outputs through suitable M&E systems;
- making necessary project adjustments and advising GEF of significant changes; and
- the realisation of GHG emission reductions.

The project design stage has been analysed in depth elsewhere in this report, in summary suffice to say that the fundamental shortcomings of the design were that it was assumed that:

- "modern" biomass technologies were solely biomass gasification technologies (BGT;
- biomass combustion technologies (BCTs) were energy inefficient[23], including in cogeneration (CHP) mode;
- relevant mature Indian BGT designs (implicitly providing 1 MWe of power and 2 MWth of relevant temperature process heat) multi-biomass fuelled gasification units (driving continuous operation reciprocating engines) existed and could be successfully manufactured and deployed in Pakistan;
- oil prices would stay high;
- the two 1 MWe SME demonstration projects would have a use for 2 MW of process heat at the 75 -115 C that the gasification technology systems could supply, and that the 2 MW of heat per SME demonstration would otherwise be fully supplied by furnace oil;
- that the necessary Feed in Tariffs (FiT) and/or net metering for surplus electricity generated from BGT plants would be established in time for the two grid connected SME demos' establishment to go ahead in the project's operational period;

[22] The reconstructed project design and operational stages Theory of Change (ToC) is shown in Figure 1.

[23] See "Burning biomass is not efficient from an energy conversion point of view." P53, ProDoc

- that suitable quantities and prices of multiple relevant types of waste biomass would be available at economic transport cost distances to the three demos;
- that the Amir Rice Mills demo could run on their own and purchased rice husks as a fuel, and that KDC Boards could use their waste wood as a fuel (supplemented by purchased firewood)
- that the rural village power BGT would be able to be successfully operated on a wide range of biomass fuels;
- that there would be a suitable willingness and ability for consumers to pay for the rural village power BGT demonstration's electricity produced; and that
- suitable productive uses would appear without Pakistan Biomass Project interventions in the rural village power demo once a BGT mini-grid power supply was established.

As detailed elsewhere in this report, most of the above project assumptions were too simplistic, or in the case of the BGT technical assumptions, wrong.

The assumptions that were reasonable (at the time of project design) were that oil prices would stay high (as this was what was generally thought at the time) and that the Amir Rice Mills gasifier could run on their own supply rice husks and the KDC Boards gasifier could run on their own supply of wood waste and wood chips – although these rice husk and wood waste supplies were at a much lower level that needed with the very expansive and ambitious BGT sizing assumed for these two proposed demo sites.

UNIDO had a high turnover of project staff (at least four project managers in the UNIDO Pakistan office and two project managers at UNIDO HQ), which contributed to the significant project implementation delays.

The PMU was established at UNIDO's premises in Islamabad and was headed by a National Project Coordinator (NPC) along with technical and support staff. The PMU was responsible for day to day management, implementation, and the monitoring of project interventions. The PMU was mostly effective in the project's implementation. However, the PMU also had a high turnover of NPCs, with the NPC position remaining vacant since June 2017. The project secured strong partnerships, especially with NUST's biomass supply chain work, SMEDA, and with the demonstration SMEs of Sapphire Finishing Mills and KDC Boards. The project was managed and overseen by a UNIDO-HQ based Project Manager and other staff from Vienna and at the field level project interventions were coordinated by a National Expert from June 2017.

Overall, the UNIDO-led PMU appears to have communicated reasonably effectively with key stakeholders for implementation purposes. However, there were no specific project communication mechanisms put in place to share project progress, results and knowledge products with wider stakeholders, although some knowledge products were apparently available in project stakeholders' websites. The project document envisaged creation of a project website for the sharing of project related information, and this project website[24] appears to have been put in place, although it is not clear how widely accessed it was. It appears that the website has not been updated since August 2017 and the links to any documents, meetings etc on the website no longer work. The project has generated many valuable knowledge products, but they are in a scattered form and not easily accessible.

The project design had some specific end of project indicators in its results framework, but many activities had no quantified end of project indictors of success, including any gender disaggregated indicators of success. The project planning in annual work plans, and the reporting in annual PIRs (Project Implementation Reports) generally did not specify the number of attendees at project supported training events, even when numerical targets were included in the project design's Results Framework.

It did not appear that there was any formal M&E system in place within UNIDO to track project progress (including gender disaggregated results) against project indicators, and hence there are significant questions as to how the project was managed by UNIDO without suitable formal M&E monitoring tools.

The overall rating for UNIDO's performance is "moderately satisfactory".

3.6.2 National counterparts

The original project design envisaged the involvement of a number of stakeholders including AEDB, SMEDA, State Bank, PPAF, Academic institutions, the private sector and communities. An indispensable part of the project design was to be the establishment of a Project Steering Committee (PSC) that would meet quarterly. The PSC was to be chaired by the CEO of AEDB. The PSC was to be the national project ownership governance body that would involve all key stakeholders. The PSC's role was to oversee, monitor and guide the project's implementation.

The project design had a critical role envisaged for AEDB, as the main project partner. AEDB had the relevant mandate to promote biomass energy as the lead government organization for the development of renewable energy in Pakistan.

However, at the start of the project, differences arose between UNIDO and AEDB on the project's implementation modalities. The AEDB management was of the view that the project should be directly implemented and managed by AEDB. However, according to the project design (as seen by AEDB and as approved and as funded by GEF) the project was to be executed directly by UNIDO. These differences on the implementation modalities, management arrangements and control of funds finally led to a lack of

[24] See http://psepb.unidogefpakistan.org.pk/

interest and a lack of active cooperation of AEDB in project implementation. This resulted in AEDB abstaining from participation and from leading the PSC and PMU and for that matter not accepting any major role in project implementation. Though later on AEDB was involved in the project's policy and regulatory framework their expected lead role in project implementation was never realized. With AEDB's withdrawal, the Project Steering Committee (PSC) was established and headed by the Secretary / Additional Secretary, Industries of the Ministry of Industries and Production (MoIP). The PSC met four times since the project's inception on 15 - 17-month intervals (not at the quarterly intervals as specified in the project design) and provided high-level formal overall guidance and oversight to the project's implementation.

A Project Management Unit (PMU) was also to be established to ensure efficient management and implementation of the project. To ensure national ownership, AEDB was to designate a senior official as the National Project Director (NPD), who would lead the PMU. Other members of the PMU were to include a National Project Coordinator, technical experts, and administrative/support staff. SMEDA was also supposed to make available a staff member as a Technical Representative in the PMU.

In practice, the project start-up and establishment of management structures faced considerable delays and changes. The tangible project start was delayed for over a year and the organization of the PSC and PMU took considerable time as well.

A wide range of public and private sector organizations and academia were involved in the project's capacity building and awareness related events and programmes. More than 500 participants participated in and benefited from project events and capacity building workshops.

The rating for the national counterparts' performance is "moderately satisfactory".

3.6.3 Donors

The key relevant project donor was GEF with a grant contribution of USD1.82 million.

AEDB was supposed to contribute USD300,000 in cash, USD700,000 in kind, and USD2.5 million via loans to the project. However, these AEDB contributions did not eventuate.

There was supposed to be a total of USD490,000 contributed to the project from the State Bank of Pakistan, SAFWCO, ASFWCO-PPAF, and PPAF for village electrification. It does not appear that such funds were contributed to project purposes by these proposed stakeholders.

USPCASE-NUST was a recipient of Pakistan Biomass Project funding support, but it also brought an in-kind contribution of laboratories, offices and staff and student inputs. There was also a USD90,000 in-kind project contribution from USAID towards USPCASE-NUST's gasifier monitoring and data acquisition work.

The private sector and beneficiaries were supposed to contribute USD1.29 million. In practice USD15.5 million was invested in their own 5.5 MWe biomass plant by Sapphire Finishing Mills. The project cannot realistically claim that all of the Sapphire funding was due to the project interventions. However, the Sapphire project may not have gone ahead without the prior (to the Sapphire decision to proceed with its biomass plant) project supported biomass supply change study done for Sapphire. In addition, the project supported M&E will make credible Sapphire demonstration results widely available for subsequent replication projects to utilise. A realistic estimate would be that USD5 Million of Sapphire's USD15.5 Million biomass CHP unit investment value was due to the Pakistan Biomass Project's interventions with Sapphire.

The rating for the donors is "satisfactory"

3.7 RESULTS-BASED MANAGEMENT AND MONITORING & EVALUATION

The project was executed and managed by UNIDO in collaboration with partners including Government, Academia, and the Private Sector. The project was overseen and guided by a PSC, led by MoIP and consisting of members from key stakeholders. A PMU was established to manage the implementation of the project. The project faced early and major initial partnership issues with AEDB regarding project implementation modalities which resulted in the withdrawal of AEDB from its role in project implementation, participation in the PSC and providing the envisaged major project co-financing component. On the other hand, the project fostered very strong collaboration with other stakeholders, in particular SMEDA, NUST and the private sector.

The PMU role was critical in driving the project's implementation and in its coordination with stakeholders. However, the frequent turnover of the NPC, and the NPC position remaining vacant since June 2017, was a negative factor for effective project implementation. Overall, the project management provided by UNIDO was effectively adjusted to the changing circumstances and was suitably focussed on delivering the expected project results. However, the final actual project end date was March 2019 - instead of the original project closing date of April 2016.

Project progress was mainly monitored through annual progress reviews in the PSC, preparation of annual PIRs, field visits and meeting with stakeholders. The absence of dedicated resources and specific M&E expertise within the PMU hampered the development and implementation of effective M&E mechanisms, especially collection, analysis and reporting of data related to project progress and progress related to outcome and impact indicators.

The project prepared two detailed annual work plans covering the period from January 2015 to December 2017. Two other annual work plans were produced for FY 2017 (1 July 2016 to 30 June 2017) and 2018 to the end of 2018. However, the latter two work plans did not contain any detailed sub-activities information by timeframe.

The project start was delayed and the 1st PSC meeting was held in September 2013, when a first work plan was presented. There was little tangible project implementation in the 19-month period between the project design approval in March 2012 and the first PSC meeting.

The project had four PSC meetings, in September 2013, January 2015, July 2016 and September 2018. This contrasts with project design documents where there were supposed to be quarterly PSC meetings. This meant that the project's implementation lacked the regular high-level oversight and review envisaged in the project's design.

The project documents envisaged three main tools to effectively monitor and evaluate the project interventions and results, namely: (1) quarterly and annual reviews; (2) preparation of annual project implementation reports (PIRs); (3) a Mid-term Review (MTR) and a Terminal Evaluation (TE). At the highest level, the project's progress was overseen and reviewed by the PSC and corrective measures were suggested to the project interventions as appropriate. The PMU monitored the progress of project interventions and results and the Annual Project Implementation Reports (PIRs), of which five (5) annual PIRs were completed. The PIRs were prepared in line with the GEF online project progress reporting system and were apparently submitted to GEF on an annual basis. Though the PIRs addressed GEF reporting requirements, the PIRs lacked elaborations and were only shared with GEF. Key stakeholders, including AEDB, NUST, USPCASE, and the private sector were apparently provided with details of the project's progress in meetings outside the PIR process. Stakeholders were also provided with progress highlights in the PSC meetings held at approximately 18-month intervals. UNIDO HQ team was also regularly engaged in provided a project oversight role through regular field visits, stakeholder consultations and progress reviews and reporting. It is important to mention the absence of dedicated resources for M&E purposes.

The project document also stipulated an external Mid-Term Review, and an end of project Terminal Evaluation as well. The MTR of the project was commissioned by UNIDO and was undertaken to take stock of the project to date and assess progress towards the achievement of the project objectives and outcomes. The MTR also included lessons learned and recommendations to adjust and to achieve the intended results over the remaining period (13 months) of the project's 7 years implementation period.

It is important to note that at no stage in the project's implementation or MTR was it acknowledged that there were any issues involved in scaling up BGTs to 1 MWe for Amir Rice Mills and KDC Boards, or even 3 MWe for Riaz Textiles (see the project design section of this terminal evaluation report for an explanation why such proposed biomass gasification technologies (BGTs) would have been unlikely to have worked at the 1-3 MWe and continuous operation scale envisaged).

During the MTR review it was recommended that " Though project has left with very limited time, however it is recommended that a final effort should be made to identify and engage a suitable partner for implementation of a small scale BGT demonstration with a SME." Based on the recommendations of the MTE, the feasibility studies for small scale BGT plants for KDC was conducted.

The stated project rationale for switching to biomass combustion technologies (BCTs) was that BCTs were a lower capital cost option (which is a questionable reason in any case). Apparently, the project also shifted its focus to BCT because BCT was proven at a large multi-MW scale and BCT could more readily utilize multiple biomass feed stocks, although these reasons to switch to BCT were not explicitly documented in any project reports or literature. There was also no known project identification that a biomass energy project in cogeneration mode would provide twice as much heat as electricity, or that BCTs would provide process heat at a higher temperature. These were fundamental project demonstration success factors that were not highlighted in the project's implementation or MTR, this calling into question the project's management for results real orientation.

The overall rating for results based management and M&E performance is "moderately unsatisfactory"

3.8 OVERARCHING ASSESSMENT

The overall rating for project performance is "moderately satisfactory"

4. CONCLUSIONS

4.1 PROJECT DESIGN

The Pakistan biomass project's objective was *to promote market-based adoption of modern biomass energy conversion technologies for process heat and electricity generation in SMEs and rural areas in Pakistan* - where modern biomass energy conversion technologies were stated as being exclusively biomass gasification technologies (BGTs).

The project logic was based on four components with outputs/outcomes of: (1) three BGT demonstrations of a total of 2.3 MWe; (2) BGT information dissemination and confidence building; (3) establishment of BGT policies and regulatory frameworks; and (4) BGT capacity building.

By the project's end, ten years after the Pakistan biomass project's development started, and seven years after the project's funding was approved by GEF, none of the three demonstrations totaling 2.3 MWe of BGT installations had been achieved by the project. However, the project instead provided useful support for the first biomass combustion technology (BCT) plant (of 5.5 MWe) in the textile sector, a major economic sector in Pakistan. A small project funded BGT plant of 25kw for rural water pumping was built and commissioned after the project's end. A project supported 40 kWe CHP plant was still awaiting commercial bank financing at November 2019 and may yet still go ahead.

The project's design in its ProDoc and CERDoc was predicated on: (1) BGTs being the "modern" way to utilise biomass for energy projects as BGTs were stated to be more energy efficient[25] (than BCTs); (2) that BGTs were a proven technology (at the project's 300 kWe off grid village power to 1 MWe SME CHP scales) in neighboring India and China[26]; (3) that 1 MWe BGT plants could readily be designed and built in Pakistan; (4) that the two proposed BGT 1 MWe demonstrations at Amir Rice Mills and KDC could fully use the 2 MWth of their reciprocating engine's intrinsically low temperature (75C - 115C)[27] process heat to replace furnace oil provided process heat; and (5) that the 1

[25] In the 2009-2012 project design period sugar cane bagasse cogeneration was the main biomass for energy use application in Pakistan. Originally, the sugar cane plants incinerated their waste bagasse in energy inefficient, low-cost and low-pressure steam plants as there was no policy environment in place for them to export any surplus power. From the 1990's hundreds of sugar cane bagasse plants were retrofitted worldwide (and in Pakistan) with modern high temperature/pressure steam boilers/turbines with combined medium temperature process steam (150 - 200C) and power 75% - 90% CHP efficiencies - with surplus electricity being exported to the grid.

[26] The project PPG funded prefeasibility study (completed 15 months before the GEF approval of the project design) stated (1) that the majority of gasifiers in use (in 2009) in India and China were small scale rice husk gasifiers; (2) gasifier systems producing electricity were unreliable in the field; and (3) gasification technology is principally well suited for small power plants ranging from 10 kW to over 100 kW.

[27] The pre-feasibility study stated that both proposed demo SMEs needed 150C process heat.

MWe BGT plants could reliably run at high availability factors[28]. None of these assumptions were realistic at the time of project design (nor were the assumptions relevant at the end of the project). The project design's main shortcoming was due to its nearly total focus on BGTs.

The project design was unrealistic, and hence the project design was unsatisfactory.

4.2 RELEVANCE

The Pakistan biomass project directly addressed a major problem at its inception period in 2009-2012 of an unreliable grid electricity supply adversely affecting SME operations, many remote villages having no grid electricity supply, and diesel generators being an expensive and often unaffordable electricity supply option for SMEs. Although the price of oil became lower from 2014, and hence electricity and natural gas supply became more reliable, Pakistan had and still has large quantities of unused or inefficiently used waste biomass, and there were and still are relevant biomass energy technologies that could produce reliable and affordable electricity and/or heat from this waste/low value biomass.

The Pakistan biomass project played a strongly supportive role in the now fully operational Sapphire Finishing Mills 5.5 MWe BCT CHP plant which is the first modern biomass plant in the large and economically and employment-wise significant textiles sector in Pakistan. The Sapphire CHP plant is operating at an impressive 86% combined power and process heat efficiency (while delivering medium pressure/temperature 10 bar/185C process steam), is built to European environmental standards and is highly likely to be able to operate at 95% capacity factors for decades. BCT is a more relevant biomass technology than BGT in capacities from 1 MWe and where medium temperature process heat is needed. The Sapphire plant is a highly relevant demonstration for post-project replication in the textile and other SME sectors in Pakistan.

The Pakistan biomass project fully funded a 25 kW BGT for rural water pumping plant built by Tawanai Solutions that has been commissioned. The project has also supported a 40 kWe BGT CHP plant for KDC Boards own power and process heat use that was still awaiting commercial bank funding in November 2019. These BGT 25 and 40 kWe sizes and applications are very relevant as demonstrations for later replication in Pakistan.

One significant negative relevance factor is that the project continued to promote BGTs as the "modern" energy efficient prime choice for biomass energy technologies, even when the Sapphire BCT project showed the advantages of BCT technologies in larger

[28] Scaling up 10 – 100kWe intermittent-operation gasifiers to 1MWe base-load CHP gasifier systems is not simply making everything 10 or 100 times larger, it involves using completely different technologies. Even in 2019 there were fewer than 10 installations in India of over 1 MWe power output.

sizes, in producing higher temperature process heat, and in being suitable for high availability long term operations – which are applications where BGTs are not suitable.

The rating for overall relevance is "satisfactory".

4.3 EFFECTIVENESS

Outcome 1: Three BGT demonstrations. The project did not achieve any of the three proposed BGT demonstrations during the project's seven years implementation period. However, the project did provide significant support to a 5.5 MWe BCT CHP plant, a 25 kW rural water pumping BGT plant that was commissioned after the project's end, and a 40 kWe BGT CHP plant was supported by the project that may yet be built. All three project supported biomass plants will be for SMEs. The village electrification plant did not go ahead. Given the slump in world oil prices from 2014 (that could not realistically have been foreseen), the three biomass demonstrations supported by the project are an effective outcome. The support of a suitable and soundly engineered 5.5 MWe BCT CHP demonstration is a good example of adaptive management by the project.

Outcome 2: Increased recognition. The project provided suitable conferences, seminars, workshops and provided publicity materials to enhance awareness and recognition of biomass technologies, albeit with an exclusive emphasis on BGT technologies and not with a balanced BGT and BCT focus.

Outcome 3: Policy and regulatory frameworks. The project usefully supported efforts by AEDB to promote the application of Biomass Technologies in Pakistan by creating a suitably enabling policy environment for grid connected biomass power to either: (1) export power to the grid under a suitable Feed in Tariff (FiT); or (2) to use the grid as a "battery" under net metering for capacities of up to 1 MWe. The project also provided technical data sheets for both biomass combustion technologies (CBT) and biomass gasification technologies (BGT), along with typical values for various biomass and equipment operation factors and parameters, and relevant manufacturing technical standards.

Outcome 4: Capacity building. The project conducted, through NUST, a capacity needs assessment and provided a series of trainings/workshops on technical and operational aspects of BGTs for engineers, non-engineers and rural communities. More than 300 participants attended these workshops. The project also fostered linkages and collaborations among local and international universities and service providers. At the end of the project biomass energy related courses had been designed and incorporated in the curriculum of Bachelor and Master level courses in NUST and UMT. However, in these courses there was a strong emphasis on gasification over combustion for biomass use for energy and no explicit focus on the relative strengths of gasification and combustion technologies for biomass use in: (1) BGTs for smaller capacities with intermittent operation and lower temperature process heat loads; and (2) BCTs for larger capacities, continuous operation, and higher temperature process heat loads.

The rating for overall relevance is "moderately satisfactory".

4.4 EFFICIENCY

The project significantly overran its implementation timeframe by three years. The project start was delayed for over a year, due to partnership issues with AEDB and the time consumed by project organization and mobilization. In 2015-16 the project implementation was delayed again by the reduction in global oil prices. Other key reasons for the time overrun include high UNIDO staff turnover and delays in getting Visas and permission to travel within Pakistan for specialist Indian consultants.

In energy and GHG mitigation terms a well-engineered 5.5MWe baseload electricity output CHP biomass system has been completed at Sapphire Finishing Mills with significant project input. The GHG reduction mitigation impacts of the project would be similar to that envisaged at the project design stage if a 40% attribution factor was given to the project assistance to the Sapphire Finishing BCT CHP plant.

The Information (Component 2), Policy and Regulatory Framework (Component 3), Capacity Building (Component 4), and Monitoring and Evaluation (Component 5) and Project Management (Component 6) and their related activities were efficiently implemented.

The project's original overall budget was USD7.16 Million, including a co-financing share of USD5.43 Million of which USD3.84 million was for component 1 for the three proposed demonstrations. In practice, the Sapphire Finishing Mills 5.5 MWe BCT plant cost USD15 million which was funded by Sapphire. With in-kind contributions from NUST, SMEDA, AEDB and other project partners, the project met its overall envisaged level of co-financing.

The rating for overall efficiency is "moderately satisfactory".

4.5 SUSTAINABILITY

The reduction in international oil prices from 2014 considerably hampered the financial and economic viability and comparative advantage of biomass energy technologies. However, biomass energy technologies can still usefully proceed in the right project, with the right technology and in the right size.

The key (low probability) financial risk to project success was the major reduction in international oil prices that occurred in 2014 that led to significant improvements in grid electricity and natural gas supply. This greatly reduced the financial imperative for

SMEs to invest in biomass systems to provide lower cost and more reliable electricity and process heat supplies.

Equally important to the originally proposed demonstration projects not going ahead was that 1 MWe electricity output BGTs were rare in neighboring counties, and a lack of proper electricity and heat load analysis at the proposed demonstration project sites, along with a mismatch between the temperature and quantity of heat from BGT plants and the actual SME process heat demand and the process heat temperatures required.

The project worked with relevant leading academic institutions which resulted in courses being developed and delivered in regular bachelor's and master level courses at NUST and UMT Lahore that were related to biomass gasification technologies. These courses should continue to provide training in the basics of biomass use for energy purposes once financial support for the project ends, and regardless of fluctuations in global oil and gas prices and changes in the tariff and reliability of grid electricity in Pakistan.

With input from the Pakistan Biomass project through AEDB, the Pakistan National Electric Power Regulatory Authority (NEPRA) published an Upfront Generation Tariff for Biomass Projects (effectively a biomass FiT - Feed in Tariff). This biomass FiT will be of particular value to future grid connected biomass projects in Pakistan.

The project design also included the development and adoption of suitable standardisation and minimum performance standards for biomass gasification technologies.

SMEDA and AEDB are two enduring relevant Government of Pakistan institutions that are maintaining an interest in the areas of intervention that the Pakistan Biomass project covered. Significant biomass energy capacity has been developed in NUST and other academic institutions, which is likely to continue after the Pakistan Biomass Project's end.

The project supported 5.5 MWe Sapphire Finishing Mills BCT CHP system was provided by a European vendor with 100 years of relevant boiler experience and which will give the lowest possible environmental impacts. The Sapphire BCT system will be the main demonstration model going forward for 1 MWe and larger biomass energy systems in Pakistan.

The Pakistan Biomass Project funded 25kWe CHP unit from Tawanai Solutions (see Figure 10) could be the first step towards Pakistan produced standard BGT units with suitable producer gas clean up and automatic gasifier controls in the smaller 25 – 50 kWe sizes most appropriate for the development of standard design BGTs (see Figure 11).

It is important to note that at no stage in the project's implementation was it acknowledged that there were any issues involved in scaling up BGTs to 300 kWe or 1 MWe as per the project design. The project rationale for switching to biomass combustion technologies (BCTs) was that BCTs were a lower capital cost option, which is a highly questionable rationale. There was also no known project identification that a biomass energy project in cogeneration mode would provide twice as much heat as electricity, or that BCTs could provide process heat at a higher temperature than BGTs could. These were fundamental project demonstration success factors that were not picked up in the project's implementation, thus calling into question the project's management for results orientation.

The overall rating for sustainability is "highly likely"

5. LESSONS LEARNED

To promote organisational learning, the following key lessons have been distilled from the project's design and implementation experience. These lessons learned are relevant for future project formulation and implementation by UNIDO and other project partners.

Avoiding Excessive Single Technology Focus

The Pakistan Biomass project made a number of critical design assumptions, in particular that: biomass gasification technologies (BGTs) were a universally applicable biomass energy technology that was more "modern" and that gave higher efficiencies than biomass combustion technologies (BCTs); and that BGTs were a mainstream biomass technology in neighboring India and China that could be simply and directly applied in Pakistan. These critical design assumptions were well known at the time to be questionable, as was readily found by the terminal evaluation (TE) team with some internet searching and by talking to biomass gasifier experts. In fact, these and other important issues were also explicitly flagged in the project funded pre-feasibility studies that were completed 15 months before the project design was approved, but these issues were then ignored in the project's design.

But once BGTs were chosen as the one and only technology to be used in the project, then the exclusive use of BGTs was never questioned again. There was extensive literature available regarding how few gasifiers have been deployed since the 1973 first oil crisis, how few gasifiers continued working for very long, how nearly all successful biomass gasifiers are of small capacity using a single biomass fuel type, and how few 1 MWe gasifier plants there were worldwide that were supposed to be simply deployed by the project in Pakistan SMEs. No one apparently ever asked how a super clean producer gas for use in 1MWe reciprocating engines was going to be produced by a local BGT equipment supplier who had never built a BGT before or had never run a gasifier with multiple different biomass feedstocks, how the low temperature waste heat from a reciprocating engine was going to be used in SMEs that had process heat loads at higher temperatures, or how the vast quantities of waste heat were going to be fully used in SMEs with low process heat demands. The project never articulated that BGTs and BCTs were complementary technologies, depending on scale, intermittent or continuous operation, and temperature of waste heat to be used in CHP mode.

Explicitly Acknowledging Changes in Focus

The Pakistan Biomass project shifted its focus under successful adaptive management from BGTs to BCTs – but on the stated basis that this was done because BCTs are less expensive, which is not the case. The project documentation never explicitly acknowledged that the project had shifted from a BGT to BCT demonstration focus, and that the only plant built with project assistance during the project's implementation period was a large continuous operation higher process temperature BCT CHP plant that used multiple biomass fuels. However, the project literature and focus remained on BGTs which are intrinsically best suited to smaller outputs, intermittent operation, single biomass fuels, and low temperature waste heat provision. So, the project focus changed, but the project language used did not reflect the key project change that had been made from a solely BGT to a BCT plus BGT focus. Without the change in focus being acknowledged, the project did not learn from its own operational experience, nor did the project communicate this experience to its stakeholders for maximising post-project effectiveness and sustainability

6. RECOMMENDATIONS

Avoiding Excessive Single Technology Focus

It is recommended that in future projects that UNIDO undertakes a thorough and formal due diligence on the proposed technology to ensure it actually is a proven mainstream technology elsewhere, that the scale of the proposed technology is appropriate, and that the output of the proposed technology is what is actually needed in the proposed specific technology applications.

Explicitly Acknowledging Changes in Focus

It is recommended that when a UNIDO project's focus changes, then the change should be publicly acknowledged and documented by UNIDO along with the rationale for the change. The project documentation and project language should also explicitly change to align with the new reality.

ANNEXES

ANNEX A. EVALUATION TERMS OF REFERENCE

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

TERMS OF REFERENCE

Independent terminal evaluation of project:

Promoting sustainable energy production and use from biomass in Pakistan

UNIDO ID: 100333
GEF Project ID: 3921

Contents

Project Background and Context

Project factsheet[29]

Project title	Promoting sustainable energy production and use from biomass in Pakistan
UNIDO ID	100333
GEF Project ID	3921
Region	South Asia
Country	Pakistan
Project donor(s)	GEF
Project implementation start date	1 May 2012
Expected implementation end date	31 December 2018
GEF Focal Areas and Operational Project	GEF 4 - Climate Change, CC-SP4, Promoting sustainable energy from biomass
Implementing agency(ies)	UNIDO
Executing Partners	Alternate Energy Development Board (AEDB) in cooperation with the Small and Medium Enterprise Development Authority (SMEDA)
GEF project grant (excluding PPG, in USD)	USD 1,820,000
Project GEF CEO endorsement / approval date	February 2012
UNIDO input (cash, USD)	60,000
Co-financing at CEO Endorsement, as applicable	USD 5,340,000
Total project cost (USD), excluding support costs and PPG	USD 7,160,000
Mid-term review date	February 2018
Planned terminal evaluation date	December 2018

(Source: Project document)

Project context

Pakistan is a lower-middle-income developing country featuring a very large population (>201 million inhabitants), a strong percentage of small and medium enterprises (SMEs) and a highly energy intensive industrial sector. Pakistani economy relies strongly on SMEs, which account for 90% of all enterprises, employing around 80% of the non-

[29] Data to be validated by the Consultant

agricultural labor force and contributing to 40% of the total GDP. SMEs are particularly important in rural areas, as they have the potential to support the industrial development of rural Pakistan, thereby contributing significantly to poverty reduction and employment creation. Main industries include chemicals manufacturers, large brick kilns, steel re-rollers, foundries, lime kilns, rubber driers, and ceramics manufacturers. Although data on the overall energy consumption in SMEs in rural areas is not readily available, targeted surveys covering specific regions have shown that most SMEs depend on fossil fuel or wood-based based heat and electricity.

In recent years, these SMEs faced a substantial gap between demand and supply, leading to energy shortages and reduced operations. These enterprises have difficulties in accessing modern energy services due to the frequent electricity supply interruption in the country, and have to resort to the use expensive diesel generators sets. The energy shortage results in lowering of their production, profit and capacities and opportunities to grow. At the same time, the high and volatile oil prices exacerbated the already difficult energy supply situation, pushing most SMEs to consider alternative solutions, specifically in renewable and low-cost energy technologies.

Among other, the sufficient and ready availability of biomass, organic and agriculture waste in the country provided significant opportunity and potential for adoption and promotion of sustainable energy production and use from biomass to meet the electricity and heat needs of these SMEs. Furthermore, encouraging the use of renewable energy in SMEs would usher a double dividend of reducing GHG emissions and increased productivity.

Project objective and expected outcomes

This project seeks to address the main barriers to wide-scale use of biomass gasification technologies in an integrated and holistic approach combining demonstration projects that have high replication potential with interventions that seek to establish a market environment conducive to investments in biomass gasification technology-based projects in SMEs and rural areas.

Among the main barriers faced by Pakistani SMEs:

<u>Information, awareness and financial:</u>

Technical information on product specifications;

Lack of demonstration of successful gasification and of systematic performance monitoring methods;

Information and awareness on biomass-based conversion technologies among intermediary stakeholders (NGOs, industry groups, micro-finance institutions);

High transition costs for financing gasifier projects.

<u>Cost, policy and regulatory barriers:</u>

High costs in renewable energy and wide fluctuations in supply;

Power supply from decentralized sources (IPPs) need further development;

Low awareness level among policy makers;

The procedures to develop a project and process for subsequent government approvals are lengthy;

There is no tariff benchmark or feed in tariff defined for biomass energy projects.

Technology and operation:
Information with respect to feedstock specifications and characteristics is often not available to the user from the technology supplier;
Lack of technical knowledge and information on the technology;
Manufacturing capabilities in gasification remain very limited;
Concerns for use in engines remains the quality of the gas (tar content);
No institutional mechanisms for interactions and networking among different stakeholders; no linkage between R&D and potential gasifier suppliers.

To achieve the overall goals and objectives, the project envisages a strategy consisting of four main components with related outcomes:
PC 1: Demonstrating technical feasibility and commercial viability of the use of biomass gasification technologies in SMEs in clusters and for power generation in rural areas
Outcome 1: Capacity of installed modern biomass energy technologies (BGTs) increased.

PC2: Information dissemination and confidence building
Outcome 2: Increased recognition of the technical feasibility and commercial viability of the use of BGTs and enhanced confidence of the financial institutions and other market players to invest in BGTs.

PC 3: Establishment of policy and associated regulatory framework promoting the adoption of modern biomass energy conversion technologies
Outcome 3: policy and associated regulatory framework for the promotion of BGTs in SME clusters and in rural areas is adopted.

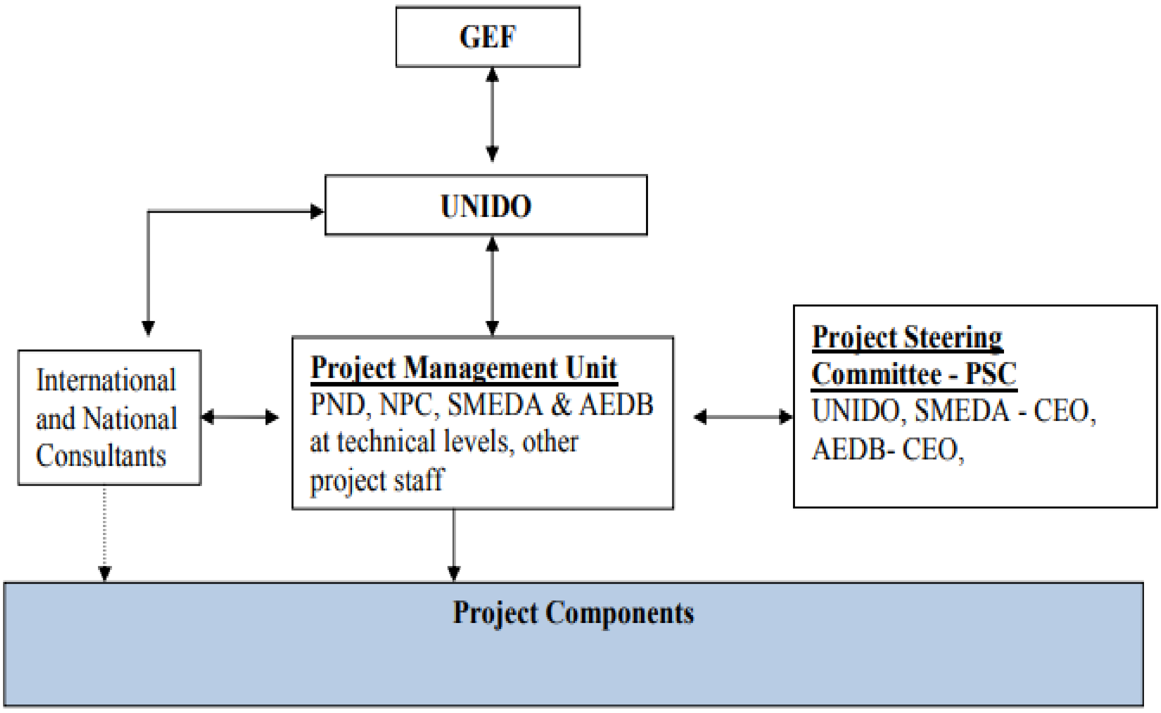
PC 4: Capacity building and strengthening of technology support system
Outcome 4: Enhanced capacity of key market players in the local supply chain to provide market-driven services to BGTs.
Project implementation arrangements

A **National Project Coordinator**, contracted by UNIDO, is responsible for the overall guidance and management of the project, including a) coordinating the project's activities with the stakeholders and industry; b) certifying that the expenditures are in line with approved budgets and work-plans; c) facilitating, monitoring, and reporting on the procurement of inputs and delivery of outputs; and d) reporting to UNIDO on project delivery and impact.

A **Project Management Unit (PMU)** was set up by project partners to ensure adequate organizational structure and systems for facilitating implementation. To ensure national ownership, AEDB was also responsible for designating a senior official as the **National Project Director (NPD)** heading the PMU. Adequate numbers of technical experts in different disciplines and project management experts/consultants with expertise in project, finance, energy, legal matters, etc. have been associated on a longer-term or short-term basis. SMEDA also made available a staff member as Technical Representative in the PMU.

A **Project Steering Committee (PSC**) was established at the inception of the project to monitor the project progress, to guide its implementation and to support the project otherwise in achieving its listed outputs and outcomes. The PSC is composed by representatives of all the agencies involved in implementation directly or which have a legal or regulatory stake in project outcomes or implementation. The PSC is chaired by the CEO of AEDB and meets quarterly. These agencies include: Alternative Energy Development Board (AEDB); Small and Medium Enterprise Development Authority (SMEDA); Ministry of Environment, Local Government and Rural Development; and UNIDO.

The project management structure as designed is provided in **¡Error! No se encuentra el origen de la referencia.**.



Main findings of the Mid-term review (MTR)

Project design: the overall project design and results framework were well formulated, which exhibited clear linkages among outputs, outcomes, objectives and goals. The results framework also provided indicators, baselines, targets, source of verification and assumptions.

Relevance: in view of the energy crisis and wide availability of biomass in the country, the overall project objectives and interventions were found relevant and consistent with needs of the target groups, Government policies, UNIDO and GEF priorities.

Effectiveness:

Outcome 1: the changes in choice of technology from gasification to combustion can be considered as a positive example of adaptive management in the wake of the developments in the fuel prices, which were far beyond the control of the project.

Outcome 2: interventions within this outcome were found very helpful in disseminating relevant information and know-how for the adoption and the promotion of BGTs within the country.

Outcome 3: inputs related to this outcome were found very useful.
Outcome 4: the project has made considerable efforts to create awareness and build the capacities of various stakeholders in BGTs.

Efficiency: despite several challenges, project management succeeded in adjusting itself to the dynamic circumstances. The role of UNIDO was found very leading and instrumental in guiding, planning, overseeing, coordinating and dealing with issues.

Budget information

Table 1. Financing plan summary

USD	***Project Preparation***	***Project***	***Total (USD)***
Financing (GEF / others)	70,000	1,820,000	1,890,000
Co-financing (Cash and In-kind)	90,000	5,340,000	5,430,000
Total (USD)	**160,000**	**7,160,000**	**7,320,000**

Source: CEO endorsement document

Table 2. Financing plan summary - Outcome breakdown[30]

Project outcomes	**Donor (GEF/ other) (USD)**	**Co-Financing (USD)**	**Total (USD)**
1.Demonstrating technical feasibility and commercial viability of modern biomass energy conversion technologies in SMEs in clusters and for power generation in rural areas	838,200	3,840,000	**4,678,200**
2. Information dissemination and confidence building	215,050	512,000	**727,050**
3. Establishment of policy and associated regulatory framework promoting the adoption of BGTs	170,250	155,000	325,250
4. Capacity building and strengthening of technology support system	405,500	420,000	**825,500**
5.M&E	44,000	60,000	**104,000**
6.Project Management	147,000	353,000	**500,000**
Total (USD)	**1,820,000**	**5,340,000**	**7,160,000**

Source: Project document / progress report

[30] Source: Project document.

Table 3. Co-Financing source breakdown

Name of Co-financier (source)	**In-kind**	**Cash**	**Total Amount (USD)**	**% / total**
Alternative Energy Development Board (AEDB) *(Government)*	3,200,000	300,000	3,500,000	*65,6%*
Private sector and beneficiaries *(Private sector)*		1,290,000	1,290,000	*24,2%*
State Bank of Pakistan *(Government)*	200,000		200,000	*3,7%*
Sindh Agricultural Forestry Workers & Coordinating Organization (SAFWCO) *(NGO)*	50,000		50,000	*0,9%*
SAFWCO-PPAF *(NGO)*		50,000	50,000	*0,9%*
PPAF – Village Electrification *(NGO)*		190,000	190,000	*3,6%*
UNIDO *(UN Agency)*		60,000	60,000	*1,1%*
Total Co-financing (USD)	**3,450,000**	**1,890,000**	**5,340,000**	***100%***

Source : CEO endorsement document

Table 4. UNIDO budget execution (Grant 4000210, 200000284)

Items of expenditure	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Total expend.**	***%/tot***
Equipment	4,452.3	18,109.3	41,308		358	5,9	5,479.6	69,713.2	***4,6%***
Contractual Services			479,378.4	144,144.1	5,228.8	100,713.5		729,464.8	***49%***
International Meetings		8,426.1		227.1	692.8			9,346	***0,6%***
Local travel	10,000	14,123.9	874.1	25,830.8	2,299.9	6,927.7	5,971.4	66,027.8	***4,4%***
Nat. Consult./Staff	3,614.6	45,246.8	38,426.8	67,856.3	51,617.8	61,588.6	65,923	334,273.9	***22,6%***
Other Direct Costs	3,654.9	5,044.5	2,096.4	2,720.9	9,917.8	13,865.2	5,835.3	43,135	***2,9%***
Staff & Intern Consultants		38,490.3	52,511.5	9,483.2		115.5		100,600.5	***6,8%***
Staff travel	5,086.5	4,227	2,840.9	7,222.7	5,624.2	4,449.1	1,112	30,562.4	***2,1%***
Train/Fellowship/ Study		8,578.4		-182.8				8,395.6	***0,5%***
Premises		9,408	21,900	11,946.5	22,181	22,727.9	8,092.6	96,256	***6,5%***
Grand Total	**26,808.3**	**151,653.3**	**639,336.1**	**269,248.8**	**97,920.3**	**210,393.4**	**92,413.9**	**1,487,775.2**	***100%***

Source: UNIDO Project Management database as of 25th October 2018

Scope and purpose of the evaluation

The purpose of the evaluation is to independently assess the project to help UNIDO improve performance and results of ongoing and future programmes and projects. The terminal evaluation (TE) will cover the whole duration of the project from its starting date to the estimated completion date in 31/12/2018.

The evaluation has two specific objectives:

- Assess the project performance in terms of relevance, effectiveness, efficiency, sustainability and progress to impact; and
- Develop a series of findings, lessons and recommendations for enhancing the design of new and implementation of ongoing projects by UNIDO.

Evaluation approach and methodology

The TE will be conducted in accordance with the UNIDO Evaluation Policy[31] and the UNIDO Guidelines for the Technical Cooperation Project and Project Cycle[32]. In addition, the GEF Guidelines for GEF Agencies in Conducting Terminal Evaluations, the GEF Monitoring and Evaluation Policy and the GEF Minimum Fiduciary Standards for GEF Implementing and Executing Agencies will be applied.

The evaluation will be carried out as an independent in-depth evaluation using a participatory approach whereby all key parties associated with the project will be informed and consulted throughout the evaluation. The evaluation team leader will liaise with the UNIDO Independent Evaluation Division (ODG/EIO/IED) on the conduct of the evaluation and methodological issues.

The evaluation will use a theory of change approach and mixed methods to collect data and information from a range of sources and informants. It will pay attention to triangulating the data and information collected before forming its assessment. This is essential to ensure an evidence-based and credible evaluation, with robust analytical underpinning. The theory of change will identify causal and transformational pathways from the project outputs to outcomes and longer-term impacts, and drivers as well as barriers to achieve them. The learning from this analysis will be useful to feed into the design of the future projects so that the management team can effectively manage them based on results.

Data collection methods

Following are the main instruments for data collection:

Desk and literature review of documents related to the project, including but not limited to:

The original project document, monitoring reports (such as progress and financial reports, mid-term review report, output reports, back-to-office mission report(s), end-of-contract report(s) and relevant correspondence.

Notes from the meetings of committees involved in the project.

[31] UNIDO. (2015). Director General's Bulletin: Evaluation Policy (UNIDO/DGB/(M).98/Rev.1)

[32] UNIDO. (2006). Director-General's Administrative Instruction No. 17/Rev.1: Guidelines for the Technical Cooperation Programme and Project Cycle (DGAI.17/Rev.1, 24 August 2006)

Stakeholder consultations will be conducted through structured and semi-structured interviews and focus group discussion. Key stakeholders to be interviewed include:
UNIDO Management and staff involved in the project; and Representatives of donors, counterparts and stakeholders.

Field visit to project sites in Pakistan.
Evaluation key questions and criteria
The key evaluation questions are the following:
What are the key drivers and barriers to achieve the long-term objectives? To what extent has the project helped put in place the conditions likely to address the drivers, overcome barriers and contribute to the long-term objectives?
How well has the project performed? Has the project done the right things? Has the project done things right, with good value for money?
What have been the project's key results (outputs, outcome and impact)? To what extent have the expected results been achieved or are likely to be achieved? To what extent the achieved results will sustain after the completion of the project?
What lessons can be drawn from the successful and unsuccessful practices in designing, implementing and managing the project?

The evaluation will assess the likelihood of sustainability of the project results after the project completion. The assessment will identify key risks (e.g. in terms of financial, socio-political, institutional and environmental risks) and explain how these risks may affect the continuation of results after the project ends. Table 5 below provides the key evaluation criteria to be assessed by the evaluation. The details questions to assess each evaluation criterion are in annex 2.

Table 5. Project evaluation criteria

#	Evaluation criteria	Mandatory rating
A	**Impact**	**Yes**
B	**Project design**	**Yes**
1	Overall design	Yes
2	Logframe	Yes
C	**Project performance**	**Yes**
1	Relevance	Yes
2	Effectiveness	Yes
3	Efficiency	Yes
4	Sustainability of benefits	Yes
D	**Cross-cutting performance criteria**	
1	Gender mainstreaming	Yes
2	M&E: M&E design M&E implementation	Yes
3	Results-based Management (RBM)	Yes
E	**Performance of partners**	
1	UNIDO	Yes
2	National counterparts	Yes
3	Donor	Yes
F	**Overall assessment**	Yes

Performance of partners

The assessment of performance of partners will ***include*** the quality of implementation and execution of the GEF Agencies and project executing entities (EAs) in discharging their expected roles and responsibilities. The assessment will take into account the following:

Quality of Implementation, e.g. the extent to which the agency delivered effectively, with focus on elements that were controllable from the given GEF Agency's perspective and how well risks were identified and managed.

Quality of Execution, e.g. the appropriate use of funds, procurement and contracting of goods and services.

Other Assessments required by the GEF for GEF-funded projects:

The terminal evaluation will assess the following topics, for which ***ratings are not required***:

Need for follow-up: e.g. in instances financial mismanagement, unintended negative impacts or risks.

Materialization of co-financing: e.g. the extent to which the expected co-financing materialized, whether co-financing was administered by the project management or by some other organization; whether and how shortfall or excess in co-financing affected project results.

Environmental and Social Safeguards[33]: appropriate environmental and social safeguards were addressed in the project's design and implementation, e.g. preventive or mitigation measures for any foreseeable adverse effects and/or harm to environment or to any stakeholder.

Rating system

In line with the practice adopted by many development agencies, the UNIDO Independent Evaluation Division uses a six-point rating system, where 6 is the highest score (highly satisfactory) and 1 is the lowest (highly unsatisfactory) as per **¡Error! No se encuentra el origen de la referencia.**.

Table 6. Project rating criteria

Score		Definition	Category
6	Highly satisfactory	Level of achievement clearly exceeds expectations and there is no shortcoming.	SATISFACTORY
5	Satisfactory	Level of achievement meets expectations (indicatively, over 80-95 per cent) and there is no or minor shortcoming.	
4	Moderately satisfactory	Level of achievement more or less meets expectations (indicatively, 60 to 80 per cent) and there are some shortcomings.	
3	Moderately unsatisfactory	Level of achievement is somewhat lower than expected (indicatively, less than 60 per cent) and there are significant shortcomings.	UNSATISFACTORY
2	Unsatisfactory	Level of achievement is substantially lower than	

[33] Refer to GEF/C.41/10/Rev.1 available at: http://www.thegef.org/sites/default/files/council-meetingdocuments/

C.41.10.Rev_1.Policy_on_Environmental_and_Social_Safeguards.Final%20of%20Nov%2018.pdf

Score		Definition	Category
		expected and there are major shortcomings.	
1	Highly unsatisfactory	Level of achievement is negligible and there are severe shortcomings.	

Evaluation process

The evaluation will be conducted from November 2018 to January 2019. The evaluation will be implemented in five phases which are not strictly sequential, but in many cases iterative, conducted in parallel and partly overlapping:

Inception phase: The evaluation team will prepare the inception report providing details on the methodology for the evaluation and include an evaluation matrix with specific issues for the evaluation; the specific site visits will be determined during the inception phase, taking into consideration the findings and recommendations of the mid-term review.

Desk review and data analysis;

Interviews, survey and literature review;

Country visits;

Data analysis and report writing.

Time schedule and deliverables

The evaluation is scheduled to take place from November 2018 to January 2019. The evaluation field mission is tentatively planned for December 2018. At the end of the field mission, there will be a presentation of the preliminary findings for all stakeholders involved in this project. The tentative timelines are provided in **¡Error! No se encuentra el origen de la referencia.**.

After the evaluation field mission, the evaluation team leader will visit UNIDO HQ for debriefing and presentation of the preliminary findings of the terminal evaluation. The draft TE report will be submitted 4 to 6 weeks after the end of the mission. The draft TE report is to be shared with the UNIDO PM, UNIDO Independent Evaluation Division, the UNIDO GEF Coordinator and GEF OFP and other stakeholders for receipt of comments. The ET leader is expected to revise the draft TE report based on the comments received, edit the language and form and submit the final version of the TE report in accordance with UNIDO ODG/EIO/EID standards.

Table 7. Tentative timelines

Timelines	Tasks
November 2018	Desk review and writing of inception report
End of November 2018	Briefing with UNIDO project manager and the project team based in Vienna through Skype
December 2018	Field visit to Pakistan
End of December 2018	Debriefing in Vienna Preparation of first draft evaluation report
January 2019	Internal peer review of the report by UNIDO's Independent Evaluation Division and other stakeholder comments to draft evaluation report
End of January 2019	Final evaluation report

Evaluation team composition

The evaluation team will be composed of one international evaluation consultant acting as the team leader and one national evaluation consultant. The evaluation team members will possess relevant strong experience and skills on evaluation management and conduct together with expertise and experience in innovative clean energy technologies. Both consultants will be contracted by UNIDO. The tasks of each team member are specified in the job descriptions annexed to these terms of reference. The ET is required to provide information relevant for follow-up studies, including terminal evaluation verification on request to the GEF partnership up to three years after completion of the terminal evaluation. According to UNIDO Evaluation Policy, members of the evaluation team must not have been directly involved in the design and/or implementation of the project under evaluation.

The UNIDO Project Manager and the project team in Pakistan will support the evaluation team. The UNIDO GEF Coordinator and GEF OFP(s) will be briefed on the evaluation and provide support to its conduct. GEF OFP(s) will, where applicable and feasible, also be briefed and debriefed at the start and end of the evaluation mission. An evaluation manager from UNIDO Independent Evaluation Division will provide technical backstopping to the evaluation team and ensure the quality of the evaluation. The UNIDO Project Manager and national project teams will act as resourced persons and provide support to the evaluation team and the evaluation manager.

Reporting

Inception report

This Terms of Reference (ToR) provides some information on the evaluation methodology, but this should not be regarded as exhaustive. After reviewing the project documentation and initial interviews with the project manager, the Team Leader will prepare, in collaboration with the national consultant, a short inception report that will operationalize the ToR relating to the evaluation questions and provide information on what type of and how the evidence will be collected (methodology). It will be discussed with and approved by the responsible UNIDO Evaluation Manager. The Inception Report will focus on the following elements: preliminary project theory model(s); elaboration of evaluation methodology including quantitative and qualitative approaches through an evaluation framework ("evaluation matrix"); division of work between the International Evaluation Consultant and national consultant; mission plan, including places to be visited, people to be interviewed and possible surveys to be conducted and a debriefing and reporting timetable[34].

Evaluation report format and review procedures

The draft report will be delivered to UNIDO's Independent Evaluation Division (the suggested report outline is in Annex 4) and circulated to UNIDO staff and national stakeholders associated with the project for factual validation and comments. Any comments or responses, or feedback on any errors of fact to the draft report provided by the stakeholders will be sent to UNIDO's Independent Evaluation Division for collation and onward transmission to the project evaluation team who will be advised of any necessary revisions. On the basis of this feedback, and taking into consideration the comments received, the evaluation team will prepare the final version of the terminal evaluation report.

[34] The evaluator will be provided with a Guide on how to prepare an evaluation inception report prepared by the UNIDO ODG/EVQ/IEV.

The ET will present its preliminary findings to the local stakeholders at the end of the field visit and take into account their feed-back in preparing the evaluation report. A presentation of preliminary findings will take place at UNIDO HQ after the field mission. The TE report should be brief, to the point and easy to understand. It must explain the purpose of the evaluation, exactly what was evaluated, and the methods used. The report must highlight any methodological limitations, identify key concerns and present evidence-based findings, consequent conclusions, recommendations and lessons. The report should provide information on when the evaluation took place, the places visited, who was involved and be presented in a way that makes the information accessible and comprehensible. The report should include an executive summary that encapsulates the essence of the information contained in the report to facilitate dissemination and distillation of lessons.

Findings, conclusions and recommendations should be presented in a complete, logical and balanced manner. The evaluation report shall be written in English and follow the outline given in annex 4.

Quality assurance

All UNIDO evaluations are subject to quality assessments by UNIDO Independent Evaluation Division. Quality assurance and control is exercised in different ways throughout the evaluation process (briefing of consultants on methodology and process of UNIDO Independent Evaluation Division, providing inputs regarding findings, lessons learned and recommendations from other UNIDO evaluations, review of inception report and evaluation report by UNIDO's Independent Evaluation Division).

The quality of the evaluation report will be assessed and rated against the criteria set forth in the Checklist on evaluation report quality, attached as Annex 5. The applied evaluation quality assessment criteria are used as a tool to provide structured feedback. UNIDO Independent Evaluation Division should ensure that the evaluation report is useful for UNIDO in terms of organizational learning (recommendations and lessons learned) and is compliant with UNIDO's evaluation policy and these terms of reference. The draft and final evaluation report are reviewed by UNIDO Independent Evaluation Division, which will submit the final report to the GEF Evaluation Office and circulate it within UNIDO together with a management response sheet.

Annex 1: Project Logical Framework

Project Strategy	Indicator	Baseline	Targets End of Project	Source of verification	Risks and Assumptions
Goal To reduce energy use related greenhouse gases produced by the energy use in SMEs in Pakistan	Incremental avoided CO2eq. (tonnes of CO2eq.) Energy generated from renewable energy (in MWh)	No direct CO2eq. emissions reductions. No indirect CO2eq. emissions reductions No installed gasification technologies.	Cumulative reduction of GHG by about 91.7 ktCO2 over the lifetime of the projects. Generation of electricity: 16,206 MWh-e annually and heat: 28,255 MWh-th annually from renewable energy.	Overall project reports. Validation reports for the pilot projects Project website	The Government remains committed to the development of renewable energy in the medium to long-term. Life cycle energy costs reduction becomes a priority for SMEs and consumers alike
Project Objective To promote market based adoption of modern biomass energy conversion technologies (by gasification) for process heat generation in SMEs in clusters and power generation in rural areas in Pakistan.	Installed capacity of renewable energy. Energy generated from renewable energy. Adoption of policy framework supporting the deployment of biomass gasification technologies	No application of gasification technologies in SMEs No energy generated from biomass gasification technologies. Broad RE law in place	2.3 MW installed biomass gasification capacity. Electricity: 16,206 MWh-e annually and heat: 28,255 MWh-th annually generated from biomass gasification technologies. Policy framework specific to promoting gasification technologies is developed adopted.	Project progress report Demonstration projects validation reports End-of-project impact report	The Government of Pakistan remains committed to the development of renewable energy in the medium to long-term. Life cycle energy costs reduction becomes a priority for SMEs and consumers
Component 1 : Demonstrating technical feasibility					
Outcome 1a Capacity of installed modern biomass energy technologies (BGTs) increased	Number and installed capacity of biomass gasification project implemented Energy generation by biomass gasification projects (MW)		3 BGT pilots implemented with a total capacity of 2.3 MW. Electricity: 16,206 MWh-e and heat: 28,255 MWh-th annually generated from BGTs pilot projects.		Companies and villages are interested to invest in BGTs project. Pilots operate successfully.
Output 1.1. 3 biomass gasification pilot projects installed	Number of pilot BGT projects implemented	No application of biomass gasification technology.	Three pilot projects have been implemented, with total installed capacity of 2.3 MW (electric power)	Evaluation reports Project reports	Feasibility of biomass gasification vis-à-vis alternatives.

Project Strategy	Indicator	Baseline	Targets End of Project	Source of verification	Risks and Assumptions
				on each pilot	
Outcome 1b Increased recognition of technical feasibility and commercial viability of biomass gasification technologies (BGTs) and enhanced confidence of the financial institutions and other market players to invest in BGTs	Number of training sessions organized and number of participants trained Investment and replication strategy for the use of BGTs established	Awareness of BGTs limited No strategy to promote investment and replication of BGTs.	Awareness of BGTs is created amongst key market enablers and players. Investment and replication strategy for the use of BGTs is adopted	Evaluation reports. Official and project reports. Project website	
Output 1.2 Awareness on benefits and use of biomass gasification technologies (BGTs) created amongst key decision-makers	Number of training and awareness raising sessions and events organized and number of participants trained Promotional material produced	Awareness of BGTs limited Information on BGTs is not readily available	About 10-20 workshops or events with at least 200 participants in total 10days of informative workshops, seminars that will be attended by over 200 participants 3 information packages are prepared and distributed	Training session reports. Website Information packages	Interest by stakeholders to apply BGTs (in SMEs) exists and can be maintained. Financial institution are interested to finance BGTs projects
Output 1.3 Investment and replication strategy for BGTs is developed	Investment and replication strategy document drafted and disseminated	No strategy to promote investment and replication of BGTs.	Detailed study on demand for and feasibility of gasification in various types of SMEs. Investors' guide elaborated. Portfolio of bankable gasification proposals identified.	Project technical report Progress reports	Willingness of Government agencies and commercial banks to support biomass gasification.
Component 2 : Establishment of policy and associated regulatory framework					
Outcome 2 Policy and associated regulatory framework for promoting BGTs is adopted	Concrete regulations and policy instruments are developed as part of the RE law Market environment for promoting BGTs established	No policy and regulatory frameworks promoting BGTs. Standards and minimum performance standards of BGTs not in place	Regulations and policy instruments promoting BGTs are developed and adopted. Standards and minimum performance standards of BGTs are developed and adopted	BGTs policy and regulatory framework document. Standards documents for BGTs	Government is willing to adopt the law. Government is prepared to adopt the performance standards for BGTs

Project Strategy	Indicator	Baseline	Targets End of Project	Source of verification	Risks and Assumptions
Output 2.1 Concrete regulations and policy instruments and provisions promoting the use of BGTs are developed as part of the RE Law	Policy instrument that promote biomass gasification	RE Law with no special focus on BGTs	Regulations established within the framework of current RE and power sector legislation that specifically focus on biomass-based technologies (gasification) through various measures like feed-in-tariffs, soft loans or guarantee schemes	Official publications. BGTs policy documents Progress reports Presentations and training materials	Willingness of Government to promulgate such regulations
Output 2.2. Standardization and minimum performance standards of gasification technologies developed and established	Biomass gasification equipment standard established and enforced.	No standards and minimum performance standards are in place	Recommendations for standardized packages, depending on application Recommendations for (voluntary) technology performance and quality standards	Progress reports Reports containing standardization packages and performance norms	Willingness of importers/suppliers to adhere to standardization and performance norms and government to enforce standards.
Component 3 : Capacity building and strengthening of technology support system					
Outcome 3 Enhanced capacity of key market players in the local supply chain	Staff of technical service and product providers involving BGTs is trained and able to provide technology and services. Training of research and training institutions and beneficiaries.	No technical service and product providers offer BGT and few users have technical staff to implement and operate Limited knowledge in research institutes	Trained staff at service providers (consultants, etc.) and knowledge institutes that provide adequate technology and satisfactory services	Progress reports AEDB website Technical reports	Availability and willingness of experts to receive training Willingness of importing/manufacturing companies to receive expert training
Output 3.1. Staff of technical service and product providers for projects involving BGTs is trained in providing technical products and expertise	Number of trained service and product providers and number of training and matchmaking and technology transfer agreements organized	Service and technology support providers have limited capacity to support BGTs based projects. No technology transfer agreement with other countries	Trained product providers and list of equipment providers (at least 20 days of training sessions in total) and at least 20 technology or service providers trained. At least 2 technology transfer agreements At least 2 technology transfer agreements are signed.	Progress reports. Copies of technology transfer agreements	Availability and willingness of experts to receive training Willingness of institutions to enter into agreements with international counterparts

Project Strategy	Indicator	Baseline	Targets End of Project	Source of verification	Risks and Assumptions
Output 3.2 Capacity of training and research institutions that support markets for BGTs enhanced through training and applied research.	Number of cooperation agreements signed and number of seminars and number of participants. Research publications	no capacity and cooperation agreements no applied research	Research institute informed and at least 1 cooperation agreement with foreign institute (at least 10 days of workshops, seminars, etc.) At least 3 applied research publications	Presentations and training materials Progress reports Publications	Willingness of experts to benefit from the training and supporting materials
Output 3.3 Technical capacity of beneficiaries to acquire, install, operate and maintain BGTs strengthened	Number of information packages and number of training sessions and trainees.	No readily available information and training packages	Information and training packages for groups of SMEs are developed Training imparted on selected SMEs	Presentations and training materials Project progress report	Willingness of the targeted public to benefit from the training and supporting materials

Annex 2: Detailed questions to assess evaluation criteria: *See Annex 2 of the UNIDO Evaluation Manual*

Annex 3: Job descriptions

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
TERMS OF REFERENCE FOR PERSONNEL UNDER INDIVIDUAL SERVICE AGREEMENT (ISA)

Title:	International evaluation consultant, team leader
Main Duty Station and Location:	Home-based
Missions:	Missions to Vienna, Austria and Islamabad and Lahore, Pakistan
Start of Contract (EOD):	1st January 2018
End of Contract (COB):	31st March 2019
Number of Working Days:	42 working days spread over the above-mentioned period

ORGANIZATIONAL CONTEXT

The UNIDO Independent Evaluation Division (ODG/EIO/IED) is responsible for the independent evaluation function of UNIDO. It supports learning, continuous improvement and accountability, and provides factual information about result and practices that feed into the programmatic and strategic decision-making processes. Independent evaluations provide evidence-based information that is credible, reliable and useful, enabling the timely incorporation of findings, recommendations and lessons learned into the decision-making processes at organization-wide, programme and project level. ODG/EIO/IED is guided by the UNIDO Evaluation Policy, which is aligned to the norms and standards for evaluation in the UN system.

PROJECT CONTEXT

Detailed background information of the project can be found the terms of reference (TOR) for the terminal evaluation.

MAIN DUTIES	Concrete/ Measurable Outputs to be achieved	Working Days	Location
1. Review project documentation and relevant country background information (national policies and strategies, UN strategies and general economic data). Define technical issues and questions to be addressed by the national technical evaluator prior to the field visit. Determine key data to collect in the field and adjust the key data collection instrument if needed. In coordination with the project manager, the project management team and the national technical	Adjusted table of evaluation questions, depending on country specific context; Draft list of stakeholders to interview during the field missions. Identify issues and questions to be addressed by the local technical expert	6 days	Home-based

MAIN DUTIES	Concrete/ Measurable Outputs to be achieved	Working Days	Location
evaluator, determine the suitable sites to be visited and stakeholders to be interviewed.			
2. Prepare an inception report which streamlines the specific questions to address the key issues in the TOR, specific methods that will be used and data to collect in the field visits, confirm the evaluation methodology, draft theory of change, and tentative agenda for field work. Provide guidance to the national evaluator to prepare initial draft of output analysis and review technical inputs prepared by national evaluator, prior to field mission.	Draft theory of change and Evaluation framework to submit to the Evaluation Manager for clearance. Guidance to the national evaluator to prepare output analysis and technical reports	5 days	Home based
3. Briefing with the UNIDO Independent Evaluation Division, project managers and other key stakeholders at UNIDO HQ (included is preparation of presentation).	Detailed evaluation schedule with tentative mission agenda (incl. list of stakeholders to interview and site visits); mission planning; Division of evaluation tasks with the National Consultant.	2 day	Through skype
4. Conduct field mission to Pakistan in 2018[35].	Conduct meetings with relevant project stakeholders, beneficiaries, the GEF Operational Focal Point (OFP), etc. for the collection of data and clarifications; Agreement with the National Consultant on the structure and content of the evaluation report and the distribution of writing tasks; Evaluation presentation of the evaluation's	14 days	Pakistan (Islamab ad and Lahore)

[35] The exact mission dates will be decided in agreement with the Consultant, UNIDO HQ, and the country counterparts.

MAIN DUTIES	Concrete/ Measurable Outputs to be achieved	Working Days	Location
	preliminary findings, conclusions and recommendations to stakeholders in the country, including the GEF OFP, at the end of the mission.		
5. Present overall findings and recommendations to the stakeholders at UNIDO HQ	After field mission(s): Presentation slides, feedback from stakeholders obtained and discussed.	2 day	Vienna, Austria
6. Prepare the evaluation report, with inputs from the National Consultant, according to the TOR; Coordinate the inputs from the National Consultant and combine with her/his own inputs into the draft evaluation report. Share the evaluation report with UNIDO HQ and national stakeholders for feedback and comments.	Draft evaluation report.	10 day	Home-based
7. Revise the draft project evaluation report based on comments from UNIDO Independent Evaluation Division and stakeholders and edit the language and form of the final version according to UNIDO standards.	Final evaluation report.	3 day	Home-based
	TOTAL	42 days	

Tentative Mission schedule

Field mission to Pakistan to meet with key stakeholders, beneficiaries, the GEF Operational Focal Point and PMU in Islamabad and Lahore	10 – 23 February 2019
Mission to UNIDO Headquarters in Vienna	6-7 of March 2019

REQUIRED COMPETENCIES

Core values:
1. Integrity
2. Professionalism
3. Respect for diversity

Core competencies:
1. Results orientation and accountability

Managerial competencies (as applicable):
1. Strategy and direction
2. Managing people and performance
3. Judgement and decision making
4. Conflict resolution

2. Planning and organizing
3. Communication and trust
4. Team orientation
5. Client orientation
6. Organizational development and innovation

MINIMUM ORGANIZATIONAL REQUIREMENTS

Education:

Advanced degree in environment, energy, engineering, development studies or related areas.

Technical and functional experience:

Minimum of 15 years' experience in evaluation of development projects and programmes

Good working knowledge in environmental management and renewable energy technologies and/or energy production from biomass

Knowledge about GEF operational programs and strategies and about relevant GEF policies such as those on project life cycle, M&E, incremental costs, and fiduciary standards

Experience in the evaluation of GEF projects and knowledge of UNIDO activities an asset

Knowledge about multilateral technical cooperation and the UN, international development priorities and frameworks

Working experience in developing countries

Languages:

Fluency in written and spoken English is required.

All reports and related documents must be in English and presented in electronic format.

Absence of conflict of interest:

According to UNIDO rules, the consultant must not have been involved in the design and/or implementation, supervision and coordination of and/or have benefited from the programme/project (or theme) under evaluation. The consultant will be requested to sign a declaration that none of the above situations exists and that the consultants will not seek assignments with the manager/s in charge of the project before the completion of her/his contract with the UNIDO Independent Evaluation Division.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
TERMS OF REFERENCE FOR PERSONNEL UNDER INDIVIDUAL SERVICE AGREEMENT (ISA)

Title:	National evaluation consultant
Main Duty Station and Location:	Home-based
Mission/s to:	Travel to potential sites within Pakistan
Start of Contract:	1st January 2018
End of Contract:	31st March 2019
Number of Working Days:	32 days spread over the above mentioned period

ORGANIZATIONAL CONTEXT
The UNIDO Independent Evaluation Division (ODG/EIO/IED) is responsible for the independent evaluation function of UNIDO. It supports learning, continuous improvement and accountability, and provides factual information about result and practices that feed into the programmatic and strategic decision-making processes. Independent evaluations provide evidence-based information that is credible, reliable and useful, enabling the timely incorporation of findings, recommendations and lessons learned into the decision-making processes at organization-wide, programme and project level. ODG/EIO/IED is guided by the UNIDO Evaluation Policy, which is aligned to the norms and standards for evaluation in the UN system.

PROJECT CONTEXT
The national evaluation consultant will evaluate the projects according to the terms of reference (TOR) under the leadership of the team leader (international evaluation consultant). S/he will perform the following tasks:

MAIN DUTIES	Concrete/measurable outputs to be achieved	Expected duration	Location
Desk review Review and analyze project documentation and relevant country background information; in cooperation with the team leader, determine key data to collect in the field and prepare key instruments in English (questionnaires, logic models); If need be, recommend adjustments to the evaluation framework and Theory of Change in order to ensure their understanding in the local context.	Evaluation questions, questionnaires/interview guide, logic models adjusted to ensure understanding in the national context; A stakeholder mapping, in coordination with the project team.	4 days	Home-based

MAIN DUTIES	Concrete/measurable outputs to be achieved	Expected duration	Location
Carry out preliminary analysis of pertaining technical issues determined with the Team Leader. In close coordination with the project staff team verify the extent of achievement of project outputs prior to field visits. Develop a brief analysis of key contextual conditions relevant to the project	Report addressing technical issues and question previously identified with the Team leader Tables that present extent of achievement of project outputs Brief analysis of conditions relevant to the project	6 days	Home-based
Coordinate the evaluation mission agenda, ensuring and setting up the required meetings with project partners and government counterparts, and organize and lead site visits, in close cooperation with project staff in the field.	Detailed evaluation schedule. List of stakeholders to interview during the field missions.	2 days	Home-based
Coordinate and conduct the field mission with the team leader in cooperation with the Project Management Unit, where required; Consult with the Team Leader on the structure and content of the evaluation report and the distribution of writing tasks. Conduct the translation for the Team Leader, when needed.	Presentations of the evaluation's initial findings, draft conclusions and recommendations to stakeholders in the country at the end of the mission. Agreement with the Team Leader on the structure and content of the evaluation report and the distribution of writing tasks.	12 days (including travel days)	In Pakistan
Follow up with stakeholders regarding additional information promised during interviews Prepare inputs to help fill in information and analysis gaps (mostly related to technical issues) and to prepare of tables to be included in the evaluation report as agreed with the Team Leader. Revise the draft project evaluation report based on comments from UNIDO Independent Evaluation Division and stakeholders and proof read the final version.	Part of draft evaluation report prepared.	8 days	Home-based
TOTAL		32 days	

REQUIRED COMPETENCIES

Core values:
1. Integrity
2. Professionalism
3. Respect for diversity

Core competencies:
1. Results orientation and accountability
2. Planning and organizing
3. Communication and trust
4. Team orientation
5. Client orientation
6. Organizational development and innovation

Managerial competencies (as applicable):
1. Strategy and direction
2. Managing people and performance
3. Judgement and decision making
4. Conflict resolution

MINIMUM ORGANIZATIONAL REQUIREMENTS

Education: Advanced university degree in environmental science, engineering or other relevant discipline like developmental studies with a specialization in industrial energy efficiency and/or renewable energies.

Technical and functional experience:
Excellent knowledge and competency in the field of renewable energy and/or energy production from biomass.
Evaluation experience at the international level involving technical cooperation in developing countries.
Exposure to the needs, conditions and problems in developing countries.
Familiarity with the institutional context of the project is desirable.

Languages: Fluency in written and spoken English and Urdu is required.

Absence of conflict of interest:
According to UNIDO rules, the consultant must not have been involved in the design and/or implementation, supervision and coordination of and/or have benefited from the programme/project (or theme) under evaluation. The consultant will be requested to sign a declaration that none of the above situations exists and that the consultants will not seek assignments with the manager/s in charge of the project before the completion of her/his contract with the UNIDO Independent Evaluation Division.

Annex 4- Outline of an in-depth project evaluation report

Executive summary (maximum 5 pages)
Evaluation purpose and methodology
Key findings
Conclusions and recommendations
Project ratings
Tabular overview of key findings – conclusions – recommendations

Introduction
Evaluation objectives and scope
Overview of the Project Context
Overview of the Project
Theory of Change
Evaluation Methodology
Limitations of the Evaluation

Project's contribution to Development Results - Effectiveness and Impact
Project's achieved results and overall effectiveness
Progress towards impact
Behavioural change
Economically competitive - Advancing economic competitiveness
Environmentally sound – Safeguarding environment
Socially inclusive – Creating shared prosperity
Broader adoption
Mainstreaming
Replication
Scaling-up

Project's quality and performance
Design
Relevance
Efficiency
Sustainability
Gender mainstreaming

Performance of Partners
UNIDO
National counterparts
Donor

Factors facilitating or limiting the achievement of results
Monitoring & evaluation
Results-Based Management
Other factors
Overarching assessment and rating table

Conclusions, recommendations and lessons learned
Conclusions
Recommendations

Lessons learned
Good practices

Annexes (to be put online separately later)
Evaluation Terms of Reference
Evaluation framework
List of documentation reviewed
List of stakeholders consulted
Project logframe/Theory of Change
Primary data collection instruments: evaluation survey/questionnaire
Statistical data from evaluation survey/questionnaire analysis

Annex 5: Checklist on evaluation report quality

Project Title:
UNIDO ID:
Evaluation team:
Quality review done by: Date:

Report quality criteria	UNIDO IEV assessment notes	Rating
Was the report well-structured and properly written? (Clear language, correct grammar, clear and logical structure)		
Was the evaluation objective clearly stated and the methodology appropriately defined?		
Did the report present an assessment of relevant outcomes and achievement of project objectives?		
Was the report consistent with the ToR and was the evidence complete and convincing?		
Did the report present a sound assessment of sustainability of outcomes or did it explain why this is not (yet) possible? (Including assessment of assumptions, risks and impact drivers)		
Did the evidence presented support the lessons and recommendations? Are these directly based on findings?		
Did the report include the actual project costs (total, per activity, per source)?		
Did the report include an assessment of the quality of both the M&E plan at entry and the system used during the implementation? Was the M&E sufficiently budgeted for during preparation and properly funded during implementation?		
Quality of the lessons: were lessons readily applicable in other contexts? Did they suggest prescriptive action?		
Quality of the recommendations: did recommendations specify the actions necessary to correct existing conditions or improve operations ('who?' 'what?' 'where?' 'when?'). Can these be immediately implemented with current resources?		
Are the main cross-cutting issues, such as gender, human rights and environment, appropriately covered?		
Was the report delivered in a timely manner? (Observance of deadlines)		

<u>Rating system for quality of evaluation reports</u>

A rating scale of 1-6 is used for each criterion: Highly satisfactory = 6, Satisfactory = 5, Moderately satisfactory = 4, Moderately unsatisfactory = 3, Unsatisfactory = 2, Highly unsatisfactory = 1, and unable to assess = 0.

Annex 6: Guidance on integrating gender in evaluations of UNIDO projects and Projects

Introduction

Gender equality is internationally recognized as a goal of development and is fundamental to sustainable growth and poverty reduction. The UNIDO Policy on gender equality and the empowerment of women and its addendum, issued respectively in April 2009 and May 2010 (UNIDO/DGB(M).110 and UNIDO/DGB(M).110/Add.1), provides the overall guidelines for establishing a gender mainstreaming strategy and action plans to guide the process of addressing gender issues in the Organization's industrial development interventions.

According to the UNIDO Policy on gender equality and the empowerment of women:

Gender equality refers to the equal rights, responsibilities and opportunities of women and men and girls and boys. Equality does not suggest that women and men become 'the same' but that women's and men's rights, responsibilities and opportunities do not depend on whether they are born male or female. Gender equality implies that the interests, needs and priorities of both women and men are taken into consideration, recognizing the diversity of different groups of women and men. It is therefore not a 'women's issues.' On the contrary, it concerns and should fully engage both men and women and is a precondition for, and an indicator of sustainable people-centered development.

Empowerment of women signifies women gaining power and control over their own lives. It involves awareness-raising, building of self-confidence, expansion of choices, increased access to and control over resources and actions to transform the structures and institutions which reinforce and perpetuate gender discriminations and inequality.

Gender parity signifies equal numbers of men and women at all levels of an institution or organization, particularly at senior and decision-making levels.

The UNIDO projects/projects can be divided into two categories: 1) those where promotion of gender equality is one of the key aspects of the project/project; and 2) those where there is limited or no attempted integration of gender. Evaluation managers/evaluators should select relevant questions depending on the type of interventions.

Gender responsive evaluation questions

The questions below will help evaluation managers/evaluators to mainstream gender issues in their evaluations.

B.1. Design

Is the project/project in line with the UNIDO and national policies on gender equality and the empowerment of women?

Were gender issues identified at the design stage?

Did the project/project design adequately consider the gender dimensions in its interventions? If so, how?

Were adequate resources (e.g., funds, staff time, methodology, experts) allocated to address gender concerns?

To what extent were the needs and priorities of women, girls, boys and men reflected in the design?
Was a gender analysis included in a baseline study or needs assessment (if any)?
If the project/project is people-centered, were target beneficiaries clearly identified and disaggregated by sex, age, race, ethnicity and socio-economic group?
If the project/project promotes gender equality and/or women's empowerment, was gender equality reflected in its objective/s? To what extent are output/outcome indicators gender disaggregated?

B.2. Implementation management
Did project monitoring and self-evaluation collect and analyse gender disaggregated data?
Were decisions and recommendations based on the analyses? If so, how?
Were gender concerns reflected in the criteria to select beneficiaries? If so, how?
How gender-balanced was the composition of the project management team, the Steering Committee, experts and consultants and the beneficiaries?
If the project/project promotes gender equality and/or women's empowerment, did the project/project monitor, assess and report on its gender related objective/s?

B.3. Results
Have women and men benefited equally from the project's interventions? Do the results affect women and men differently? If so, why and how? How are the results likely to affect gender relations (e.g., division of labour, decision making authority)?
In the case of a project/project with gender related objective/s, to what extent has the project/project achieved the objective/s? To what extent has the project/project reduced gender disparities and enhanced women's empowerment?

ANNEX B. LIST OF DOCUMENTATION REVIEWED

Project Implementation Documents

0.1 Pro Doc

0.2-2013- 2014 PIR report
0.3-2014-2015 PIR report
0.4-2015-2016 PIR report
0.5-2016-2017 PIR report
0.6-2017-2018 PIR report
0.8-Mid-term Review Report of UNIDO Biomass Energy Project in Pakistan - Feb 2018
0.9-Final Minutes of 1st PSC Biomass - Sept 2013
1.0-Final Minutes of 2nd PSC Biomass - Jan 2015
1.1-Final Minutes of 3rd PSC Biomass - July 2016
1.2-Final Minutes of 4th PSC Biomass - Sept 2018
1.3-Workplan Component 1-2015
1.4-Workplan Component 2-2015
1.5-Workplan Component 3-2015
1.6-Workplan Component 4-2015
1.7-Workplan-2016
1.8-Workplan-2017
1.9-WorkPlan-2018

Project Design Documents

2009 08 27 PPG revised_0
2009 08 27 Revised PIF
2010 02 07 Project Design TORs for Sub-contract
2010 02 11 STAP Review
2010 07 21 Winrock - UNIDO PPG Minutes of Meeting
2010 08 10 PPG Initial Meeting with Winrock - Meeting Minutes
2010 08 10 Winrock Presentation to UNIDO Pakistan Office
2010 10 20 Bioenergy-Gasifier Project Design Presentation 1 - Van den Akker
2010 10 20 Biomass Gasification for Power Generation - MUH
2010 10 20 Biomass progress report summary
2010 10 20 Gasification Technology Presentation - Muhammad Ahmad GEF Coordinator
2010 10 20 Gasifiers Workshop Report w Project Concept Note as Annex
2010 11 27 Draft Prefeasibility Studies for SMEs
2010 12 04 Biomass PPG progress report summary
2011 02 08 Progress Report June-Dec 2010
2012 03 02 CEO Endorsement (GEF Project Document
2012 03 27 Pro Doc – Final

Other Project Documents

2015 01 21 Sapphire Finishing Mills - Bio-Mass Supply Chain Study - Green Solutions
2017 12 15 Upfront Generation Tariff for Biomass Power Projects - NEPRA-UGTBPP
2019 02 15 USPCASE-NUST First Progress Report
2019 07 31 Key Assessment of Biomass Market 2nd Progress Report - NUST for UNIDO
2019 10 15 Replication and Investment Strategy - 3rd Progress Report v2 - NUST for UNIDO

Component 1

1.1.1 Amir Rice Mills - Final Feasibility 1.05MW vs 3MW in TOR - Jan 2015
1.1.2 KDC Boards - Final Feasibility 1MW - Jan 2015
1.1.3 Sapphire Finishing Mills - 1st Progress Report - Dec 2017
1.1.4 Sapphire Finishing Mills 5.5MW BCT Contract for USD100k from UNIDO- July 2017
1.1.5 KDC Boards - Final Feasibility for 50 KW - Sept 2018
1.1.6 Financial Model BGT 50KW - 13 Feb 2019
1.1.7 Financial Model BGT 100KW - 13 Feb 2019
1.1.8 Signed Contract for USD40K from UNIDO for Tanawai Solutions for 25 KW CHP BGT Plant - 17 Feb 2019
1.1.9 TOR for RFP 25KW BGT Plant - 13 Feb 2019
1.1.10 Sapphire Finishing Mills Completion Certificate and Commissioning Data – 25 May 2019
1.1.11 Tawanai 25kW Pilot Plant Installation - Second Progress Report for UNIDO – 17 June 2019
1.1.12 Tawanai 25kW Pilot Plant Installation - Third Progress Report for UNIDO – 10 November 2019

Component 2

2.1.1 - Report on 2-day international conference on BGT - Islamabad - July 2016
2.1.2 - Biomass Communication archive
2.2.1 - CONTRACT No. 3000066256 NUST - Dec 2018
2.2.2 - TORs for Contract No 3000066256 NUST - Oct 2018

Component 3

3.1.1 - BIOMASS MANAGEMENT & PRICING FOR POWER GENERATION - DESL Delhi - May 2017
3.1.2 - POLICY ON BIOMASS ENERGY TECHNOLOGY - DESL Delhi - May 2017
3.2.1 - MINIMUM QUALITY STANDARDS FOR BIOMASS GASIFICATION PLANTS - DESL Delhi - May 2017
3.2.2 - Notice of meeting to be held - Pakistan Standards - Sept 2018
3.2.3 - Summary of PSQCA 1st TC Review Meeting for Gasification Standards - Pakistan Standards - Sept 2018

Component 4

4.1.1 - Report on one-day training workshop 1 on BGT (Engineers, Consultants etc.)
4.1.2 - Report on one-day training workshop 2 on BGT(Engineers, Consultants etc.)
4.1.3 - Report on one-day training workshop 1 for technical staff of BGT product and service providers (non-engineers)
4.1.4 - Reports on one-day training workshop 2 for technical staff of BGT product and service providers (non-engineers)
4.1.5 - Matchmaking Agreements Companies
4.2.1 - Assessment of Capacity of market players in BGT (Report)
4.2.2 - Workshop on Assessment of capacity of market players
4.2.3- Training of Research Institutions Workshop Report (NUST Islamabad) - Oct 2016
4.2.4 - FINAL Report -Capacity Building and Strengthening of Biomass Technology Support System

4.2.5 - Matchmaking Agreements universities - July 2016
4.2.6 - University Elective Course Energy from Biomass-Thermochemical Processes
4.2.7 - Inclusion of Elective Course in NUST
4.2.8 - MS-BS Course Inclusion at UMT Lahore
4.2.9 - UMT Biomass Course Working Paper
4.2.10 - Elective Course for TEVTA (DAE-BTECH Chemical)
4.2.11 - Inclusion of Course in TEVTA
4.2.12 - CONTRACT No. 3000021635 NUST
4.2.13 - TORs for Contract No. 3000021635 NUST
4.3.1 - The training manual for SMEs for installation, maintenance and operation of biomass gasification systems
4.3.2 - The training manual URDU for SMEs for installation, maintenance and operation of biomass gasification systems
4.3.3 - Report on the training workshop rural electrification projects

Secondary-Public Information - Articles – Data Gathered by TE Team

- 2013 09 23 UNIDO promotes biomass gasification in Pakistan | The Express Tribune
- 2013 09 27 "Biomass Energy- Fuelling Our Future in Pakistan" | The News Tribe
- APL - All Power Labs - Wikipedia 30 Sept 2019
- APL Powertainer 150kW Packaged BGT in 20ft Container - Not Yet Available - Under Development since 2012 - USD2M+ Grant Assistance
- APL PP10-20 -10kw & 20kw GEK Power Pallet - ALL Power Labs – 2012
- APL PP30 Developing Markets Promotion Price List USD51,413 — 2019
- APL PP30 Packaged OEM 22-24 kW CHP Ready Genset Data Sheet - 10 Aug 2019
- APL PP30 Warranty, Sales Guarantee, and Expected Component Lives
- APL PP30 Warranty, Sales Guarantee, and Expected Component Lives
- APL PP30 Wood Chip Fuel+Gasifier+CHP+ Maintenance Basic Considerations
- Biomass Atlas for Pakistan - April 2016 - WB funded for AEDB
- BGT - Biomass Gasification - Still Promising - A 30 Year Global Overview - Kirkels & Verbong, Renewable and Sustainable Energy 15 (2011) 471-481, Elsevier - 2011
- BGT - Biomass Gasifiers - Problems, Bottlenecks, Disadvantages- Energy Alternatives India - EAI India
- BGT – China Biomass Gasification Potential - Wu et al - in Bioresource Technology 83 (2002) 65–7020 (Elsevier)
- BGT Biomass Gasification and Pyrolysis - Roddy & Manson-Whitton - in Comprehensive Renewable Energy, ScienceDirect 2012
- Socio-Environmental Impact | Intech - Wu et al - 2018
- BGT in India - Current status of biomass gasification in India - Installed Capacity for Thermal and Power- Energy Applications
- Crude Oil (Brent) Average Price by Year Chart 1990-2017 - EIA
- Crude Oil (USA) Production Since 1983 -2019-09-13-macrotrends
- Crude Oil (WTI) 20-Year Historical Price Chart w Inflation Adjustment | MacroTrends
- Crude Oil (WTI) 70-year Inflation Adjusted Price Chart -2019-09-13-macrotrends
- Crude Oil Prices (Brent + WTI) and Gold Price for 15 Years - EW81 - SEF - NZ
- Crude-oil-prices-10-year-daily-chart-2019-03-21-macrotrends
- Diesel Engine Generators Life Expectancy - How Long Do They Last? - Worldwide Power Products (USA)
- Fluidyne (NZ) Gasification - Archive - Since 1976

- Froling (Austria) fixed bed (woodchip fuelled) gasifier CHP 50 - 85% efficiency in CHP mode
- Husk Power Systems (HPS) Bihar - India - 60-70 units of 32 kW standard BGTs running on Rice Husks | JSTOR Daily
- IEA-Bioenergy-Task33-Thermal-Gassification-Biomass-Waste - August 2019
- Micro-grids for Rural Electrification-A critical review of best practices based on seven case studies - UNEP - 2014
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ANNEX C. LIST OF STAKEHOLDERS CONSULTED

UNIDO HQ Project Team

UNIDO Pakistan Project Office

Alternate Energy Development Board (AEDB)

USPCASE NUST (US Pakistan Centre for Advanced Studies in Energy – National University of Science and Technology)

KDC Boards

SMEDA (SME Development Authority)

Sapphire Finishing Mills

Tawanai Solutions

University of Agriculture Faisalabad

USPCASE - UET Peshawar

Dr David Natusch, gasification expert and former Director of the New Zealand Liquid Fuels Trust Board (LFTB)

Steve Goldthorpe, gasification expert who worked for decades for British Coal

ANNEX D. PROJECT LOGICAL FRAMEWORK

See Annex 1: Project Logical Framework in Annex A